THE SODIUM METABOLISM OF TWO PRE-SCHOOL CHILDREN

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THE SODIUM METABOLISM
OF TWO PRE-SCHOOL CHILDREN

By

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Submitted in partial fulfillment
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TABLE OF CONTENTS

INDEX TO TABLES

INDEX TO GRAPHS

INTRODUCTION

Literature records very few experiments on sodium balance and none at all under the conditions of the present study. In most of the reports dealing with sodium balance, the subjects were infants whose diet consisted chiefly of milk, or hospitalized adults whose kidney function was impaired.

This paper presents a balance study of sodium on two pre-school boys. It is a portion of a larger experiment covering a period of forty-eight days and including calories, nitrogen and other minerals. The purpose of this study was to determine the sodium balance of pre-school children on a quantitative basis, to measure the effect of a high and low protein diet on the sodium metabolism in pre-school children, to observe the variations in excretion when the intake varied, to compare the sodium metabolism with that of chlorine, and finally to compare the utilization of sodium by the two subjects.

EXPERIMENTAL PROCEDURE

Subjects

The subjects used for this study were two boys D and B aged four years and nine months and four years and seven months respectively. During the experimental period both boys lived under the supervision of trained persons, in an apartment in the Home Economics Building. Their environmental conditions - meals, toilet habits, sleep, outdoor exercise and other activities were constantly supervised and carefully regulated. They attended the college nursery school and, therefore, were not denied the normal companionship of other children. Observations made of their behavior during the study indicated they were mentally normal but not superior children. Physical and medical examinations showed them to be in good physical condition at the time of the study although there was some indication of their having had infantile rickets. The children had lived nearly all their lives in an orphanage where their food habits had been carefully controlled and where their diet was thought to have been adequate for normal nutrition.

Table I shows the height and weight of the two boys at the beginning and at the end of the experiment as compared with the Woodbury height-weight standards for children under six years of age. It indicates that the children were of average size.

TABLE I

PHYSICAL MEASUREMENTS OF CHILDREN
AT BEGINNING AND END OF EXPERIMENT

Subject	Age	Height	Weight	*Variations from average weight
	mo.	cm.	kg.	per cent
D	57	108.4	17.2	-2.6
D	59	109.7	17.5	-3.1
B	55	109.7	18.6	+2.5
B	57	111.0	19.1	+2.4

The experiment covered forty-eight days during which time the boys had, first, a medium protein diet providing 3 grams of protein per kilogram of body weight for 12 preliminary and 21 collection days, and second, a high protein diet supplying 4 grams of protein per kilogram of body weight for the following 15 days. Calculations showed that both the medium and high protein diets met all the physiological needs of the children according to our present standards. Subject D received 4½ grams of codliver oil** and B, 5 grams daily.

Diet

Tables II and III give the composition of the medium and high protein diets as calculated from standard tables. Skim milk was added and the amount of beef and eggs were increased to raise the protein content of the second diet. The variations

* Woodbury, R. M., Heights and Weights of Children under Six Years of Age, U. S. Department of Labor, Children's Bureau #87 Table XXXI page 76.

**Prepared by E. L. Patch and Company, Boston, Massachusetts.

TABLE II

COMPOSITION OF THE MEDIUM PROTEIN DIET*

Food	Weight	Protein	Calories	Sodium	Chlorine	Calcium	Magnesium	Potassium	Phosphorous	Sulphur	Iron	Residue Acid	Residue Base
	gms.	gms.		gms.	gms.	gms.	gms.	gms.	gms.	gms.	gms.	cc n/10	cc n/10
Whole Milk	720	23.76	496.8	0.3672	0.7632	0.8640	0.0864	1.0296	0.6696	0.2448	0.001728		129.6
Egg	45	6.03	66.6	0.0644	0.0477	0.0302	0.0050	0.0630	0.0810	0.0878	0.001350	49.9	
Raw beef	45	9.59	70.2	0.0405	0.0365	0.0054	0.0113	0.1625	0.1035	0.1098	0.001080	51.7	
Whole wheat bread	72	6.98	177.1	0.2837	0.4370	0.0360	0.0360	0.1498	0.1260	0.0864	0.001152	52.6	
Uncooked farina	18	2.00	65.2	0.0117	0.0137	0.0081	0.0045	0.0216	0.0761	0.0279	0.000900	17.3	
Cooked potato	63	1.39	52.3	0.0132	0.0239	0.0088	0.0176	0.2703	0.0365	0.0189	0.000819		37.8
Strained tomatoes	90	1.73	37.9	0.0135	0.0495	0.0180	0.0090	0.2790	0.0334	0.0126	0.001710		50.4
" carrots	72	0.42	16.3	0.0727	0.0259	0.0212	0.0151	0.2066	0.0126	0.0158	0.000792		77.8
" prunes	90	0.89	62.5	0.0621	0.0153	0.0219	0.0495	0.9270	0.0353	0.0333	0.003800	156.0	
" applesauce	90	0.18	141.3	0.0099	0.0045	0.0063	0.0072	0.1143	0.0108	0.0054	0.000270		40.5
Lettuce	14	0.17	2.7	0.0038	0.0104	0.0060	0.0024	0.0475	0.0059	0.0020	0.000098		10.4
Strained orange juice	180		77.4	0.0144	0.0054	0.0522	0.0198	0.3276	0.0288	0.0162	0.000360		81.0
Sugar	18		72.0										
Butter	18	0.18	138.4	0.1418	0.2182	0.0027	0.0002	0.0025	0.0031	0.0018	0.000036		
Cod liver oil	4.5		40.5										
Total	1539.5	53.32	1518.98	1.0989	1.6512	1.0808	0.2640	3.6013	1.2226	0.6627	0.014095	327.5	427.5

* Table represents quantities given to D. Subject B weighed approximately 0.1 more than D and therefore was provided with 1.1 times the amounts given.

Percentage composition calculated from the following sources: Blatherwick, W.R., Studies of Urinary Acidity. II.The Increased Acidity Produced by eating Prunes and Cranberries J.B.C. 57, pages 815-818, 1923 Rose, Mary S., Handbook for Dietitics, 3rd Edition, M.A McMillan 1929.

Storms, Lillian B., Analytical Data Included in pamphlet "Baby's Vegetables" - Gerber Products Company, Fremont, Michigan.

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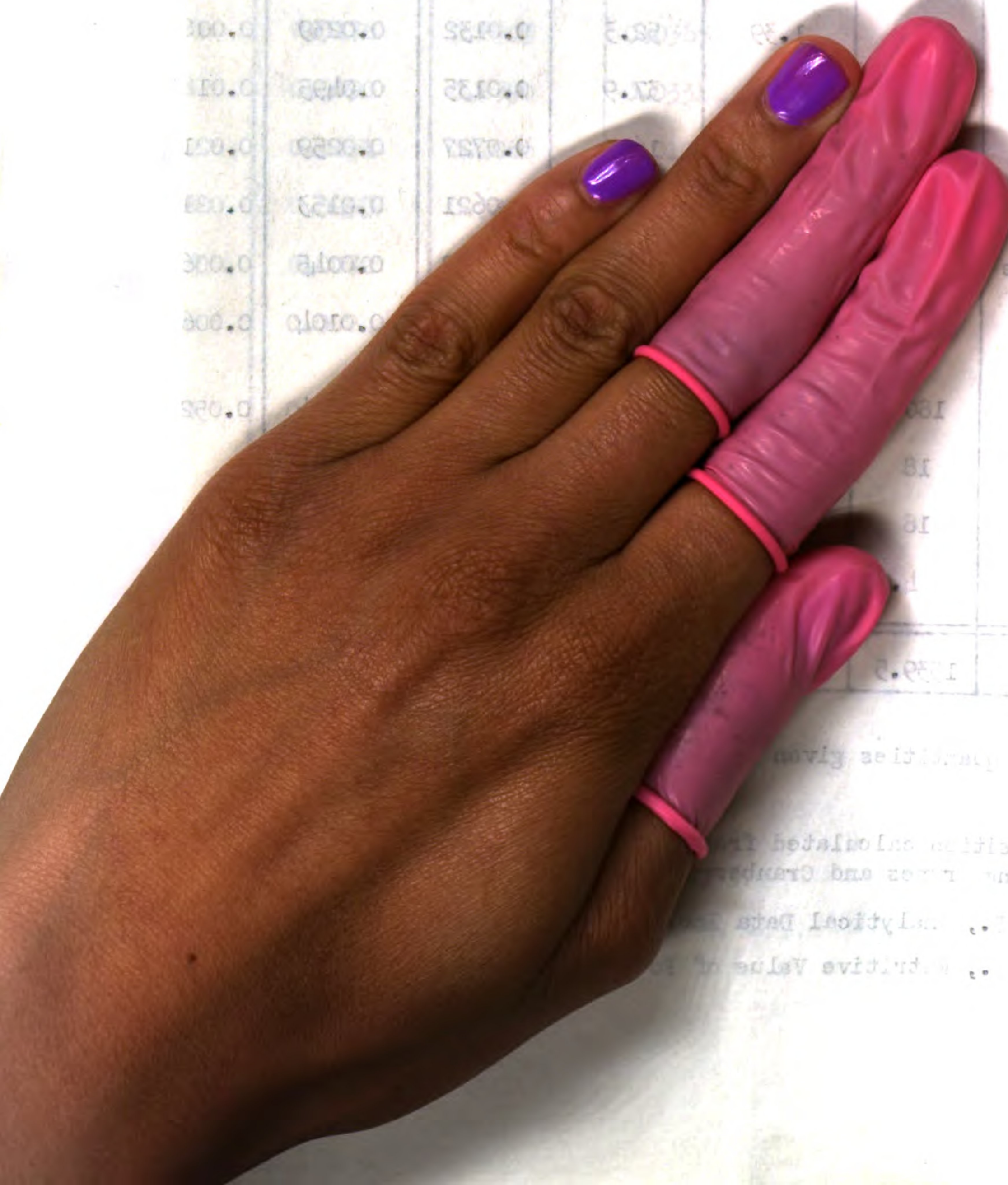

TABLE III

COMPOSITION OF THE HIGH PROTEIN DIET*

Food	Weight	Protein	Calories	Sodium	Chlorine	Calcium	Magnesium	Potassium	Phosphorous	Sulphur	Iron	Residue Acid	Residue Base
	gms.	gms.		gms.	gms.	gms.	gms.	gms.	gms.	gms.	gms.	cc n/10	cc n/10
Whole milk	425	14.03	293.3	0.2168	0.4505	0.5100	0.0510	0.6078	0.3953	0.1445	0.001020		76.5
Skim milk	425	14.45	157.2	0.2210	0.4675	0.5185	0.0510	0.6333	0.4080	0.1488	0.001063		76.5
Egg	90	12.06	133.2	0.1287	0.0954	0.0603	0.0099	0.1260	0.1620	0.1755	0.002700	99.9	
Raw beef	90	19.17	140.4	0.0810	0.0729	0.0108	0.0225	0.3249	0.2070	0.2196	0.002160	103.5	
Whole wheat bread	60	5.82	147.6	0.2364	0.3642	0.0300	0.0300	0.1248	0.1050	0.0720	0.000960	43.8	
Uncooked farina	18	2.00	65.2	0.0117	0.0137	0.0081	0.0045	0.0216	0.0761	0.0279	0.000900	17.3	
Cooked potato	50	1.10	41.5	0.0105	0.0190	0.0070	0.0140	0.2145	0.0290	0.0150	0.000650		30.0
Strained tomatoes	100	1.92	42.1	0.0150	0.0550	0.0200	0.0100	0.3100	0.0371	0.0140	0.001900		56.0
" carrots	70	0.41	15.8	0.0707	0.0252	0.0206	0.0147	0.2009	0.0123	0.0154	0.000770		75.6
" prunes	90	0.89	62.5	0.0621	0.0153	0.0219	0.0495	0.9270	0.0353	0.0333	0.003800	156.0	
" applesauce	90	0.18	141.3	0.0099	0.0045	0.0063	0.0072	0.1143	0.0108	0.0054	0.000270		40.5
Lettuce	14	0.17	2.7	0.0038	0.0104	0.0060	0.0024	0.0475	0.0059	0.0020	0.000098		10.4
Orange juice	200		86.0	0.0160	0.0060	0.0580	0.0220	0.3640	0.0320	0.0180	0.000400		90.0
Sugar	10		40.0										
Butter	20	0.20	153.8	0.1576	0.2424	0.0030	0.0002	0.0028	0.0034	0.0020	0.000040		
Cod liver oil	4.5		40.5										
Total	1756.5	72.40	1563.24	1.2412	1.8420	1.2805	0.2889	4.0194	1.5192	0.8934	0.016731	421.5	455.5

* Same as medium protein diet.

in the quantities of the other foods were very slight. These tables also indicate that the mineral content and the acid/base residue of the two diets were relatively constant. On both diets the children drank a measured amount of distilled water daily.

The investigators made careful plans to eliminate as many errors as possible in the feeding of the diets. They purchased in advance canned and dried foods sufficient to last for the entire experiment. They obtained perishable foods in quantities large enough to last for a three day period. The helpers removed the fat and grisle from the meat and ground the lean portion, beat all eggs thoroughly, cooked and mashed the potatoes and pureed the vegetables and fruit. They then mixed together thoroughly the quantity necessary for a three day period until it formed a homogenous mass. Next they weighed all the necessary portions for a three day period into individual utensils. The children consumed the portions directly from these utensils in which they were first cooked. In order to be sure of quantitative consumption the helper supervising the meal wiped each dish out with a small portion of the days allotment of bread, which the children ate and then rinsed the dishes with some of the measured distilled water. This was added to some other food which the child had not yet eaten.

Two identical portions of the homogenous mixture were weighed at the same time for analysis. They were placed in enamel bowls, partly dried over a steam bath and then placed in a constant temperature oven at 60 degrees Centigrade until they reached a constant weight. They were then ground several times and put through a fine mesh sieve. If some of the material was too hard to pass through the sieve, this was mortared, sifted and added to the other portion. From 15 to 20 grams samples of the food were weighed in duplicate. These samples were ashed in platinum dishes, at a dull red heat, dissolved in 5 - 10% H Cl and made up to a volume of 100 cc for later analysis.

Specimens

Care was taken to collect the excreta as quantitatively as possible. The children were trained to follow a definite schedule for collection and thereby prevent the loss of urine. If there was an unavoidable accident the specimen for the entire day was discarded and the results for the other two days of the period were averaged. Decomposition was limited by keeping the samples in an ice box at all times. After the 24 hour specimens had been measured and the specific gravity taken they were made up to a definite volume with distilled water. Duplicate and triplicate determinations of sodium were made on daily specimens of the fresh urine.

In an attempt to collect daily excretion of feces quantitatively, carmine and charcoal were fed on alternate days as markers. Since the amount excreted daily was small, it was difficult to separate the samples accurately. After collection, the fecal specimens were dried at a low temperature, mortated and sieved in the same manner as the food. They were ashed at a temperature below red heat, dissolved in H Cl and made up to a volume of 100 cc.

CHEMICAL METHODS

Review of Literature

There are five general methods for the quantitative determination of sodium, the platinc-chloride, the pyroantimonate, the perchlorate, the caesium bismuth nitrite and uranyl acetate methods. (3, 4, 6, 7, 8, 9, 10, 11, 13, 15, 16, 19, 20, 25a, 25b, 26, 27, 28, 29, 32, 33, 35, 39). Various workers have adapted these methods to either volumetric, colorimetric or gravimetric procedures. A brief discussion of the methods follows.

In the platinic-chloride method the sodium and potassium are weighed together as sulphates and the potassium is determined as a chloro-platinate (32). Thus the sodium is subject to the greater error because it is determined by difference. In the pyroantimonate method, sodium is precipitated with potassium pyroantimonate solution and titrated with sodium thiosulphate using potassium iodide as an indicator (32). Peters and Van Slyke state that this "method offers the only micro-titration method for sodium." They say further that, "it is capable of giving good results, but is susceptible to error from slight changes in technique, and the potassium pyroantimonate used as a reagent, obtained from dealers, has often been unsatisfactory." (32). The perchlorate method has not been adapted for use with biological materials (39). According to McCance and Shipp the precipitation of sodium as caesium bismuth nitrate presents many technical difficulties, the chief of which is that the precipitate must be kept in a cold room twenty-four hours (28). The preceeding methods were not used to determine sodium in this study, either because previous investigators reported that they presented technical difficulties or they had not been adapted to use with biological material.

A number of workers have reported that the uranyl acetate method was satisfactory for use with biological material. The basis of this method is that sodium forms quantitatively a triple salt with a saturated solution of uranium and either magnesium or zinc acetate. This triple salt is very slightly soluable in 95% alcohol, ether or glacial acetic acid. The high molecular weight of the salt makes it possible to determine very small amounts of sodium. The precipitate may be weighed or adapted to colorimetric or volumetric analysis. (3, 4, 6, 7, 8, 9, 10, 13, 15, 19, 25a, 25b, 26, 28, 35).

The history of the method indicates that the earlier workers used magnesium acetate to form the triple salt while the later investigators used zinc acetate. In 1886, the earliest record of the uranyl acetate method, Streng used the magnesium salt to precipitate sodium (35). Although other authors as Blanchetiére, have used a magnesium reagent, Barber and Kolthoff say that his method showed errors from -6.0 to +3.0 percent, and "Crepaz reports the method too inaccurate for the gravimetric determination of sodium" (1a, 3). Caley and his associates used magnesium reagent for the determination of sodium in inorganic material (7, 9, 10, 11, 19). They applied their method to gravimetric and colorimetric procedures and found it satisfactory if the amounts of sodium determined did not fall below 0.2 milligrams (7).

There has been considerable dispute regarding the composition of the triple salt. Streng originally assigned the formula $(UO_2)_3 Mg Na (CH_3 COO)_9 \cdot 9 H_2O$, which Blanchetière later confirmed. Milholic, however, believed that it contained only six molecules of water. More recently Barber and Kolthoff have studied the composition of the salt. They precipitated the sodium with zinc rather than magnesium and obtained better results (1a). They agreed with Milholic and gave the formula $(UO_2)_3 Zn Na (CH_3COO)_9 \cdot 6 H_2O$ to their product. The ratio of the weight of sodium to that of the triple salt is, therefore, 0.01495:1 (35).

Barber and Kolthoff also studied extensively the influence of various ions on the determination of sodium by this method. They found that ammonium, calcium, barium and magnesium do not interfere, that caesium and rubidium do not influence the results if present in quantities as small as 0.1 grams or less, that lithium, strontium and organic acids interfere, that potassium introduced an error if present in as large amounts as 50 milligrams per 1 cc, that phosphates and arsenates interfere and, therefore, must be removed by a magnesia mixture.

Butler and Tuthill modified the method of Barber and Kolthoff and applied it to the quantitative determination of sodium in urine. Their results were satisfactory with samples containing as little as 1.5 milligrams of sodium (6). Salit adapted the above method to a colorimetric procedure for use in determining sodium in biological material. He obtained excellent results which showed an error of not more than 2 - 3% with samples containing as low as 0.05 milligrams of sodium (35).

Chemical Method Used

Both the Butler and Tuthill and Salit modifications were tried in this laboratory. Preliminary checks were made on known solutions of sodium salts, on urine and on samples of the same specimen of urine plus a known quantity of chemically pure sodium salt.

In general, the Salit procedure was as follows: 2 cc of the sample was placed in a centrifuge tube. The same quantity of a standard sodium chloride solution, containing approximately the same amount of sodium was placed in another centrifuge tube. To these was added 6 cc of the uranyl zinc acetate reagent. Successive 0.3 cc portions of absolute alcohol were added to each tube and the contents stirred. When precipitation was complete the tubes were centrifuged for 10 minutes. The supernatant fluid was decanted and the tube allowed to drain on filter paper. The precipitate was washed with glacial acetic acid saturated with uranyl zinc acetate which had been freshly filtered. The precipitate was transferred to a 50 cc volumetric flask by rinsing with distilled water and was then made up to volume. An aliquot sample was removed (the size of the portion depending upon the amount of sodium present) and 0.5 cc of a 20% potassium ferrocyanide solution was added. The samples were then read in the colorimeter (35). To determine the accuracy of this procedure the sodium was recovered on thirty-four samples of a known sodium chloride solution and on twenty-five samples of a standard sodium sulphate solution. As shown in Table IV, there was a wide variation in the per cent recovery, the averages being 97.63% and 91.16% for the sodium chloride and the sodium sulphate solutions. The unsatisfactory results obtained with the Salit modification may be explained in part by the fact that the colorimetric procedure is subject to variations due to the difficulty some workers have in matching color values. Also the work was done in extremely hot weather when the laboratory temperature frequently exceeded 100 degrees Fahrenheit and elevations of temperature affect the soluability of the uranium salt.

Table IV indicates that more consistent results were obtained with the Butler and Tuthill gravimetric method. At first an attempt was made to dry the precipitated sodium uranium zinc acetate to constant weight. This gave as unsatisfactory results as the Salit method. Since Butler and Tuthill had stated that it was sufficient to dry the precipitate and the filter containing it in as dissicator over calcium chloride for ½ hour before weighing, this procedure was followed and the recovery of known salt was considerably more constant. Fourteen determinations were

TABLE IV

PERCENT RECOVERY ON KNOWN SOLUTIONS OF A SODIUM SALT

USING TWO METHODS

Method	Salt	Concentration Salt Solution**	Urine	Determinations	Range of recovery	Average recovery
		cc	cc	no.	per cent	per cent
Salit	Na Cl	2	0	34	80.71-125.00	97.63
(Colorimetric)	$Na_2\ So_4$	2	0	25	75.76- 98.35	91.16
Butler and	Na Cl*	2	0	14	94.06-100.93	98.22
Tuthill	Na Cl	2	0	14	99.05-102.31	100.21
(Gravimetric)	$Na_2\ So_4$*	2	0	2	94.12- 99.97	97.25
	$Na_2\ So_4$	2	0	11	97.89-100.35	99.19
	Na Cl	1	1	5	96.10-100.15	98.49
	Na Cl	2	1	5	98.68-100.10	99.38
	Na Cl	3	1	5	98.83-100.16	99.52

* Dried in oven to constant weight.

** Same standard solution of Na Cl and $Na_2\ So_4$ used for both methods.

made using the latter method on 2 cc samples of standard sodium chloride solution and eleven on 2 cc portions of a known sodium sulphate solution. The percentage recovery of sodium averaged 100.21% and 99.19% respectively. To further check the accuracy of the method five determinations each were made on dilutions of 1 cc of urine plus 1, 2, and 3 cc of the known sodium chloride solution. The average percentage recovery was in order 98.49%, 99.38% and 99.52%. These results were deemed sufficiently accurate to warrant the use of the method as outlined below.

Certain preliminary steps were necessary with each of the biological products before the general method of precipitation of the triple salt w s put into effect. For urine a 6 cc sample was pipetted into a test tube. To this was added approximately 0.2 grams of calcium hydroxide together with 1 drop of phenolthalein. (The calcium hydroxide was used to precipitate the phosphates. The urine had previously been tested and found to be free of protein, therefore, it was not necessary to remove it.) After standing 30 minutes the solution was filtered and the filtrate used for the determination of sodium. In the case of food a sample of the dried material weighing between 15 and 20 grams was dry ashed and the ash made up to a volume of 100 cc. An aliquot portion of this was removed for analysis, the size of which depended upon the original weight of the ashed sample. Exactly six, ten or twenty cc portions of the ash solution was measured into a test tube and approximately 0.2 grams of calcium hydroxide was added to precipitate the phosphate.

After 30 minutes this was filtered and the filtrate evaporated to a volume of approximately 2 cc. Some slight modifications were necessary in the method for the determination of sodium in the feces. The quantity of sodium was so small that it was necessary to add a known amount of standard sodium chloride solution to each sample. Because of a limited amount of material potassium and sodium were determined on the same sample. The potassium and sodium were precipitated as sulphates and the precipitate was transferred to a 100 cc beaker by successive washings with distilled water. This was then evaporated to dryness to remove the H Cl present. The dried material was dissolved in distilled water and approximately 0.2 grams of powdered calcium hydroxide added. After standing 30 minutes it was filtered and the filtrate evaporated to approximately 2 cc. After the preliminary steps had been taken the precipitation of the sodium as a triple salt was essentially the same. A solid rubber stopper was fitted from below into the bottom of a 30 cc porous glass filter (Jena Glass filter size 2, capacity 30 milliliter, porosity 1 G 4) that had been dried and accurately weighed. 20 cc of the uranyl zinc acetate reagent (freshly filtered) was placed in the glass filter and the sample added. This solution was stirred with a small glass rod until a precipitate appeared and several minutes thereafter. The filter was then covered with a watch glass and allowed to stand at room temperature for 1 hour. The rubber stopper was removed and the filter placed in a suction flask and suction applied. The precipitate was first washed with 95% alcohol which had been saturated with the triple salt and then with ether and finally dried in a dessicator over night. The dried precipitate was weighed and the amount of sodium in the sample determined by multiplying its weight by the factor 0.01495. Blank corrections were made on all samples. In the case of feces the sodium in the carmine and charcoal used as markers was determined and subtracted from the weight of the final precipitate. Checks within ± 2% were obtained with food and urine using samples that contained as low as 0.3 milligrams of sodium. This was considered sufficiently accurate for our purpose. Although the results on feces were less satisfactory than those on the other materials, the results were considered accurate enough for the small quantities of sodium excreted by way of the intestinal tract.

No attempt was made to determine the sodium lost in perspiration or tears. Previous workers differ as to whether the loss is sufficiently great to consider. Rominger and Meyer using infants fed on cow's milk concluded that the amount of sodium lost through the skin did not materially affect is retention. Swanson and Iob, however, stated "It is apparent from our data that no metabolic experiment involving retention of minerals can be correctly evaluated unless loss through the skin is determined " (40). To have made this determination on the present experiment would have presented great difficultie in collection of the material.

RESULTS AND DISCUSSION

Sodium Metabolism - Daily - Medium and High Protein Diets

Table V presents the daily sodium balances obtained on the two children used in this study, and Table VI data on a per kilogram basis.* They indicate that the daily amounts of sodium injested for each day during a three day period were identical due to the method of preparing the food. The amounts from period to period, however, varied considerably since a small quantity of unweighed sodium chloride was added to the food during preparation. Nevertheless, this amount was the same in the analyzed sample as in the food eaten by the children. As a result the actual number of grams received by the children daily were slightly higher than was anticipated in the calculated diets. In addition to the intake, Table V shows the daily fecal and urinary output, the retention and absorption of sodium for the two subjects on the medium and high protein diets. The tendencies evidenced by the two subjects were remarkably consistent and are, therefore, discussed together.

Although the sodium in the food varied only by three day periods, there were wide variations in the daily fecal and urinary excretion. The fecal sodium was low and there were probably errors incurred by daily collection for the samples

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* Figures for the first six days of the experiment obtained from unpublished data determined by Mrs. Merle M. Bray, Division of Home Economics, Michigan State College.

TABLE V

DAILY SODIUM BALANCES

Subject	Diet	Date	Intake	Feces	Urine	Total	Absorption		Retention	
							Total	Proportion of intake	Total	Proportion of intake
			gms.	gms.	gms.	gms.	gms.	per cent	gms.	per cent
D	Med. Prot.	2/16	1.558	0.033	1.420	1.453	1.525	97.9	0.105	6.74
		2/17	1.558	0.013	1.698	1.711	1.545	99.2	-0.153	
		2/18	1.558	0.018	1.643	1.661	1.540	98.8	-0.103	
		2/19	1.069	0.009	1.193	1.202	1.060	99.2	-0.133	
		2/20	1.069	0.031	0.802	0.833	1.038	97.1	0.236	22.08
		2/21	1.069	0.056	0.892	0.948	1.013	94.8	0.121	11.32
		2/22	1.145	0.000	1.045	1.045	1.145	100.0	0.100	8.73
		2/23	1.145	0.002	0.934	0.936	1.143	99.8	0.209	18.25
		2/24	1.145	0.000	1.092	1.092	1.145	100.0	0.053	4.63
		2/25	1.063	0.002	0.933	0.935	1.061	99.8	0.128	12.04
		2/26	1.063	0.000	0.942	0.942	1.063	100.0	0.121	11.38
		2/27	1.063	0.014	1.004	1.018	1.049	98.7	0.045	4.23
		2/28	1.159	0.015	0.932	0.947	1.144	98.7	0.212	18.29
		2/29	1.159	0.008	1.026	1.034	1.151	99.3	0.125	10.79
		3/1	1.159	0.016	1.080	1.096	1.143	98.6	0.063	5.44
		3/2	1.024	0.002	0.997	0.999	1.022	99.8	0.025	2.44
		3/3	1.024	0.000	0.862	0.862	1.024	100.0	0.162	15.82
		3/4	1.024	0.004	0.905	0.090	1.020	99.6	0.115	11.23
		3/5	1.028	0.000	1.133	1.133	1.028	100.0	-0.105	
		3/6	1.028	0.004	0.979	0.983	1.024	99.6	0.045	4.38
		3/7	1.028	0.021	0.934	0.955	1.007	98.0	0.073	7.10
	High Prot.	3/8	1.498	0.002	1.456	1.458	1.496	99.9	0.040	2.67
		3/9	1.498	0.000	1.287	1.287	1.498	100.0	0.211	14.09
		3/10	1.498	0.003	1.274	1.277	1.495	99.8	0.221	14.75
		3/11	1.104	0.000	1.121	1.121	1.104	100.0	-0.017	
		3/12	1.104	0.002	0.895	0.897	1.102	99.8	0.207	18.75
		3/13	1.104	0.000	1.177	1.177	1.104	100.0	-0.073	
		3/14	1.343	0.000	1.256	1.256	1.343	100.0	0.087	6.48
		3/15	1.343	0.001	1.201	1.202	1.342	99.9	0.141	10.50
		3/16	1.343	0.000	1.214	1.214	1.343	100.0	0.129	9.61
		3/17	1.094	0.034	1.091	1.125	1.060	96.9	-0.031	
		3/18	1.094	0.000	1.051	1.051	1.094	100.0	0.043	3.93
		3/19	1.094	0.005	1.050	1.055	1.089	99.5	0.039	3.56
		3/20	1.190	0.000	1.149	1.149	1.190	100.0	0.041	3.45
		3/21	1.190	0.009	0.972	0.981	1.181	99.2	0.209	17.56
		3/22	1.190	0.000	0.916	0.916	1.190	100.0	0.274	23.03
B	Med. Prot.	2/16	1.714	0.026	1.362	1.388	1.688	98.5	0.326	19.02
		2/17	1.714	0.025	1.478	1.503	1.689	98.5	0.211	12.31
		2/18	1.714	0.039	1.477	1.516	1.675	97.7	0.198	11.55
		2/19	1.176	0.072	1.310	1.382	1.104	93.9	-0.206	
		2/20	1.176	0.010	1.148	1.158	1.166	99.1	0.018	1.53
		2/21	1.176	0.030	1.066	1.096	1.146	97.4	0.080	6.80
		2/22	1.260	0.005	1.023	1.028	1.255	99.6	0.232	18.41
		2/23	1.260	0.020	1.157	1.177	1.240	98.4	0.083	6.59
		2/24	1.260	0.035	1.131	1.166	1.225	97.2	0.094	7.46
		2/25	1.169	0.004	0.980	0.984	1.165	99.7	0.185	15.83
		2/26	1.169	0.014	0.949	0.963	1.155	98.8	0.206	17.62
		2/27	1.169	0.011	1.018	1.029	1.158	99.1	0.140	11.98
		2/28	1.275	0.009	1.298	1.307	1.266	99.3	-0.032	
		2/29	1.275	0.012	1.237	1.249	1.263	99.1	0.026	2.04
		3/1	1.275	0.008	0.914	0.922	1.267	99.4	0.353	27.69
		3/2	1.126	0.013	1.197	1.210	1.113	98.8	-0.084	
		3/3	1.126	0.000	1.010	1.010	1.126	100.0	0.116	10.30
		3/4	1.126	0.012	0.983	0.995	1.114	98.9	0.131	11.63
		3/5	1.131	0.008	1.131	1.139	1.123	99.3	-0.008	
		3/6	1.131	0.027	1.075	1.102	1.104	97.6	0.029	2.56
		3/7	1.131	0.044	1.114	1.158	1.087	96.1	-0.027	
	High Prot.	3/8	1.648	0.014	1.261	1.275	1.634	99.2	0.373	22.63
		3/9	1.648	0.001	1.489	1.490	1.647	99.9	0.158	9.59
		3/10	1.648	0.013	1.503	1.516	1.635	99.2	0.132	8.01
		3/11	1.215	0.010	1.300	1.310	1.205	99.2	-0.095	
		3/12	1.215	0.032	1.126	1.158	1.183	97.4	0.057	4.69
		3/13	1.215	0.004	1.326	1.330	1.211	99.7	-0.115	
		3/14	1.478	0.004	1.114	1.118	1.474	99.7	0.360	24.36
		3/15	1.478	0.025	1.335	1.360	1.453	98.3	0.118	7.98
		3/16	1.478	0.002	1.609	1.611	1.476	99.9	-0.133	
		3/17	1.203	0.028	1.017	1.045	1.175	97.7	0.158	13.13
		3/18	1.203	0.025	1.348	1.373	1.178	97.9	-0.170	
		3/19	1.203	0.001	1.162	1.163	1.202	99.9	0.040	3.33
		3/20	1.309	0.000	0.964	0.964	1.309	100.0	0.345	26.36
		3/21	1.309	0.008	0.915	0.923	1.301	99.4	0.386	29.49
		3/22	1.309	0.000	1.102	1.102	1.309	100.0	0.207	15.81

TABLE VI

DAILY SODIUM BALANCES PER KILOGRAM OF BODY WEIGHT

Subject	Diet	Date	Weight	Intake	Output			Absorption	Retention
					Feces	Urine	Total		
			kg.	gms.	gms.	gms.	gms.	gms.	gms.
D	Med. Prot.	2/16	17.45	0.0893	0.0019	0.0814	0.0833	0.0874	0.0060
		2/17	17.45	0.0893	0.0007	0.0973	0.0980	0.0886	-0.0087
		2/18	17.45	0.0893	0.0010	0.0942	0.0952	0.0883	-0.0059
		2/19	17.39	0.0615	0.0005	0.0686	0.0691	0.0610	-0.0076
		2/20	17.39	0.0615	0.0018	0.0461	0.0479	0.0597	0.0136
		2/21	17.39	0.0615	0.0032	0.0513	0.0545	0.0583	0.0070
		2/22	17.41	0.0658	0.0000	0.0600	0.0600	0.0658	0.0058
		2/23	17.41	0.0658	0.0001	0.0536	0.0537	0.0657	0.0121
		2/24	17.41	0.0658	0.0000	0.0627	0.0627	0.0658	0.0031
		2/25	17.50	0.0607	0.0001	0.0533	0.0534	0.0606	0.0073
		2/26	17.50	0.0607	0.0000	0.0538	0.0538	0.0607	0.0069
		2/27	17.50	0.0607	0.0008	0.0574	0.0582	0.0599	0.0025
		2/28	17.55	0.0660	0.0009	0.0531	0.0540	0.0651	0.0120
		2/29	17.55	0.0660	0.0005	0.0585	0.0590	0.0655	0.0070
		3/1	17.55	0.0660	0.0009	0.0615	0.0624	0.0651	0.0036
		3/2	17.41	0.0588	0.0001	0.0573	0.0574	0.0587	0.0014
		3/3	17.41	0.0588	0.0000	0.0495	0.0495	0.0093	0.0588
		3/4	17.41	0.0588	0.0002	0.0520	0.0522	0.0586	0.0066
		3/5	17.45	0.0589	0.0000	0.0649	0.0649	0.0589	-0.0060
		3/6	17.45	0.0589	0.0002	0.0561	0.0563	0.0587	0.0026
		3/7	17.45	0.0589	0.0012	0.0535	0.0547	0.0577	0.0042
	High Prot.	3/8	17.45	0.0858	0.0001	0.0834	0.0835	0.0857	0.0023
		3/9	17.45	0.0858	0.0000	0.0738	0.0738	0.0858	0.0120
		3/10	17.45	0.0858	0.0002	0.0730	0.0732	0.0126	0.0856
		3/11	17.45	0.0633	0.0000	0.0642	0.0642	0.0633	-0.0009
		3/12	17.45	0.0633	0.0001	0.0513	0.0514	0.0632	0.0119
		3/13	17.45	0.0633	0.0000	0.0874	0.0674	0.0633	-0.0041
		3/14	17.41	0.0771	0.0000	0.0721	0.0721	0.0771	0.0050
		3/15	17.41	0.0771	0.0001	0.0690	0.0691	0.0770	0.0080
		3/16	17.41	0.0771	0.0000	0.0697	0.0697	0.0771	0.0074
		3/17	17.50	0.0625	0.0019	0.0623	0.0642	0.0606	-0.0017
		3/18	17.50	0.0625	0.0000	0.0601	0.0601	0.0625	0.0024
		3/19	17.50	0.0625	0.0003	0.0600	0.0603	0.0622	0.0022
		3/20	17.50	0.0680	0.0000	0.0657	0.0657	0.0680	0.0023
		3/21	17.50	0.0680	0.0005	0.0555	0.0560	0.0675	0.0120
		3/22	17.50	0.0680	0.0000	0.0523	0.0523	0.0680	0.0157
B	Med. Prot.	2/16	19.00	0.0902	0.0014	0.0717	0.0731	0.0888	0.0171
		2/17	19.00	0.0902	0.0013	0.0778	0.0791	0.0889	0.0111
		2/18	19.00	0.0902	0.0021	0.0777	0.0798	0.0881	0.0104
		2/19	19.00	0.0619	0.0038	0.0689	0.0727	0.0581	-0.0108
		2/20	19.00	0.0619	0.0005	0.0604	0.0609	0.0614	0.0010
		2/21	19.00	0.0619	0.0016	0.0561	0.0577	0.0603	0.0042
		2/22	18.98	0.0664	0.0003	0.0539	0.0542	0.0661	0.0122
		2/23	18.98	0.0664	0.0011	0.0610	0.0621	0.0653	0.0043
		2/24	18.98	0.0664	0.0018	0.0596	0.0614	0.0646	0.0050
		2/25	18.98	0.0616	0.0002	0.0516	0.0518	0.0614	0.0098
		2/26	18.98	0.0616	0.0007	0.0500	0.0507	0.0609	0.0109
		2/27	18.98	0.0616	0.0006	0.0536	0.0542	0.0610	0.0074
		2/28	19.00	0.0671	0.0005	0.0683	0.0688	0.0666	-0.0017
		2/29	19.00	0.0671	0.0006	0.0651	0.0657	0.0665	0.0014
		3/1	19.00	0.0671	0.0004	0.0481	0.0485	0.0667	0.0186
		3/2	18.98	0.0593	0.0007	0.0631	0.0638	0.0586	-0.0045
		3/3	18.98	0.0593	0.0000	0.0532	0.0532	0.0593	0.0061
		3/4	18.98	0.0593	0.0006	0.0518	0.0524	0.0587	0.0069
		3/5	19.05	0.0594	0.0004	0.0594	0.0598	0.0590	-0.0004
		3/6	19.05	0.0594	0.0014	0.0564	0.0578	0.0580	0.0016
		3/7	19.05	0.0594	0.0023	0.0585	0.0608	0.0571	0.0014
	High Prot.	3/8	18.98	0.0868	0.0007	0.0664	0.0671	0.0861	0.0197
		3/9	18.98	0.0868	0.0001	0.0785	0.0786	0.0867	0.0082
		3/10	18.98	0.0868	0.0007	0.0792	0.0799	0.0861	0.0069
		3/11	18.98	0.0640	0.0005	0.0685	0.0690	0.0635	-0.0050
		3/12	18.98	0.0640	0.0017	0.0593	0.0619	0.0623	0.0030
		3/13	18.98	0.0640	0.0002	0.0699	0.0701	0.0638	-0.0061
		3/14	19.05	0.0776	0.0002	0.0585	0.0587	0.0774	0.0189
		3/15	19.05	0.0776	0.0013	0.0701	0.0714	0.0763	0.0062
		3/16	19.05	0.0776	0.0001	0.0845	0.0846	0.0775	-0.0070
		3/17	19.09	0.0630	0.0015	0.0533	0.0548	0.0615	0.0082
		3/18	19.09	0.0630	0.0013	0.0706	0.0719	0.0617	-0.0089
		3/19	19.09	0.0630	0.0001	0.0609	0.0610	0.0629	0.0020
		3/20	19.09	0.0686	0.0000	0.0505	0.0505	0.0686	0.0181
		3/21	19.09	0.0686	0.0004	0.0479	0.0483	0.0682	0.0203
		3/22	19.09	0.0686	0.0000	0.0577	0.0577	0.0686	0.0109

were small and it was difficult to separate them sharply. A small amount of the injested sodium was excreted in the feces and the major portion was eliminated in the urine. Urinary sodium ranged from 0.802 grams to 1.698 grams daily for the two subjects. There was a small amount of fecal sodium and a high degree of absorption. The per cent of injested sodium absorbed daily by the two subjects during the entire experiment ranged from 93.9% to 100.0%. The smallest range in per cent of intake was shown on the high protein diet as indicated in Table V. In contrast to feces and urine the daily absorption of sodium closely paralled the intake. Inasmuch as retention represents the difference between absorption and urinary excretion it is obvious that the daily retention varied widely. Table V shows a number of negative balances as well as some balances when there was a relatively high retention of sodium. In sixteen cases out of twenty-four there was a slight drop in the daily amount of sodium retained following a change in the sodium intake. This drop occurred whether the dietary sodium had been increased or decreased. This would seem to indicate that there was a lag in the elimination of sodium from day to day and that the subjects never were in sodium equilibrium.

As a result of the preceeding observations statistical determinations were made in order to ascertain the relationship between intake and excretion, absorption and retention. Table VII shows a definite correlation between daily intake and urine, total excretion and absorption of sodium for the two subjects on

TABLE VII

CORRELATION OF SODIUM INTAKE WITH DAILY AND PERIOD EXCRETION, ABSORPTION AND RETENTION

Subject		No. of samples	Range gms.	Arithmetic Mean	Standard Deviation	Standard Error	Coefficient of Correlation with Intake
				Daily			
D	Intake	36	1.024-1.558	1.190	0.175	0.029	
	Feces	36	0.001-0.033	0.008	0.013	0.002	0.019
	Urine	36	0.862-1.698	1.099	0.208	0.035	0.852
	Total excretion	36	0.833-1.711	1.107	0.208	0.035	0.853
	Absorption	36	1.007-1.541	1.181	0.175	0.029	0.997
	Retention	36	-0.133-0.236	0.082	0.012	0.018	-0.022
B	Intake	36	1.126-1.714	1.309	0.193	0.032	
	Feces	36	0.001-0.072	0.016	0.015	0.003	-0.002
	Urine	36	0.914-1.609	1.184	0.185	0.031	0.664
	Total excretion	36	0.922-1.516	1.201	0.186	0.031	0.652
	Absorption	36	1.087-1.689	1.292	0.193	0.032	0.997
	Retention	36	-0.206-0.386	0.108	0.159	0.027	0.441
				Period			
D	Intake	12	1.024-1.558	1.190	0.180	0.052	
	Feces	12	0.001-0.032	0.008	0.010	0.003	0.024
	Urine	12	0.921-1.587	1.099	0.193	0.056	0.945
	Total excretion	12	0.923-1.608	1.107	0.195	0.056	0.939
	Absorption	12	1.022-1.537	1.181	0.180	0.052	0.999
	Retention	12	0.050-0.175	0.082	0.067	0.019	-0.038
B	Intake	12	1.126-1.714	1.309	0.199	0.057	1.309
	Feces	12	0.008-0.057	0.016	0.010	0.003	-0.004
	Urine	12	0.982-1.439	1.184	0.153	0.044	0.826
	Total excretion	12	0.992-1.469	1.201	0.156	0.045	0.810
	Absorption	12	1.105-1.684	1.292	0.199	0.051	0.999
	Retention	12	-0.036-0.312	0.108	0.177	0.034	0.619

the entire experiment. It shows no correlation between intake and total excretion or retention. It indicates that in all cases there was a slightly higher correlation when the comparisons were made on a period basis. On the former basis the range in values was smaller but otherwise the relationships were the same. Because the diet was constant for a three day period and it may eliminate some of the errors in fecal output of sodium, the interpretation of results which follow will be expressed in terms of the average amount of sodium for a three day period.

Sodium Metabolism by Periods - Medium Protein Diet

The sodium intake on the medium protein diet varied widely from period to period on the basis of both the total grams of sodium and the grams per kilogram of body weight as shown in Tables VIII and IX. The range in sodium intake per kilogram of body weight for subjects D and B was from 0.0588 to 0.0893 and 0.0593 to 0.0902 grams per period. This provided for a wide per cent variation from the average period intake ranging from +35.5% to -10.9%. Although the number of grams of sodium per kilogram of body weight varied per day and per period the average intake for the two subjects on the medium protein diet was similar. Subject D averaged 0.0658 grams and B, 0.0666 grams of sodium per kilogram of body weight per period.

Excretion of sodium in the feces was small. Although not as great as on a daily basis, the period excretion of sodium in the feces varied considerably. The sodium eliminated in this

TOTAL SODIUM BALANCES PER PERIOD

Subject	Diet	Period	Intake	Output			Absorption		Retention	
				Feces	Urine	Total	Total	Proportion of intake	Total	Proportion of intake
			gms.	gms.	gms.	gms.	gms.	per cent	gms.	per cent
D	Med. Prot.	1	1.558	0.021	1.587	1.608	1.537	98.7	-0.050	
		2	1.069	0.032	0.962	0.994	1.037	97.0	0.075	7.02
		3	1.145	0.001	1.024	1.025	1.144	99.9	0.120	10.48
		4	1.063	0.005	0.960	0.965	1.058	99.5	0.098	9.22
		5	1.159	0.013	1.013	1.026	1.146	98.9	0.133	11.48
		6	1.024	0.002	0.921	0.923	1.022	99.8	0.101	9.86
		7	1.028	0.008	1.015	1.023	1.020	99.2	0.005	0.49
	High Prot.	8	1.498	0.002	1.339	1.341	1.496	99.9	0.157	10.48
		9	1.104	0.001	1.064	1.065	1.103	99.9	0.039	3.53
		10	1.343	0.000	1.224	1.224	1.343	100.0	0.119	8.86
		11	1.094	0.013	1.064	1.077	1.081	98.8	0.017	1.55
		12	1.190	0.003	1.012	1.015	1.187	99.7	0.175	14.71
B	Med. Prot.	1	1.714	0.030	1.439	1.469	1.684	98.2	0.245	14.29
		2	1.176	0.037	1.175	1.212	1.139	96.9	-0.036	
		3	1.260	0.020	1.104	1.124	1.240	98.4	0.136	10.79
		4	1.169	0.010	0.982	0.992	1.159	99.1	0.177	15.14
		5	1.275	0.010	1.150	1.160	1.265	99.2	0.115	9.02
		6	1.126	0.008	1.063	1.071	1.118	99.3	0.055	4.88
		7	1.131	0.026	1.107	1.133	1.105	97.7	-0.002	
	High Prot.	8	1.648	0.009	1.418	1.427	1.639	99.5	0.221	13.41
		9	1.215	0.015	1.251	1.266	1.200	98.8	-0.051	
		10	1.478	0.010	1.353	1.363	1.468	99.3	-0.115	7.78
		11	1.203	0.018	1.176	1.194	1.185	98.5	0.009	0.75
		12	1.309	0.003	0.994	0.997	1.306	99.8	0.312	23.83

manner was only slightly more constant per kilogram of body weight than in total grams per period. As shown in Table IX the excretion of sodium in the feces of the two subjects ranged from traces to 0.019 grams per kilogram. Table X indicates that there was no correlation between the intake of sodium from the medium protein diet and the amount of sodium excreted in the feces of the two subjects.

Both children excreted a large proportion of the sodium from the medium protein diet in the urine. Subject D eliminated 90.5% and B, 92.4% of the food sodium by way of the kidneys. The period excretion of sodium in the urine ranged from 0.960 to 1.587 grams for D and 0.992 to 1.469 grams for B. Table IX indicates that there was also a wide range in urinary sodium per kilogram of body weight. Both for total and for the kilogram figures the per cent variation from the average for D and B was from +48.5% to -13.9% and +25.6% to -14.3% respectively. Averaging the three day figures for urinary elimination smoothed out some of the daily variation and the period excretion of sodium in the urine closely paralleled the intake. Graph No. 1 reveals the close relationship between the intake and the urinary sodium on both diets for the two subjects. This relationship is confirmed in Table X which indicates that the coefficient of correlation between intake and urinary sodium per kilogram of body weight was as high as 0.913 on the medium protein diet.

Practically all the sodium injested on the medium protein diet was absorbed by the children. Subject D absorbed

TABLE IX

SODIUM BALANCES PER KILOGRAM OF BODY WEIGHT PER PERIOD

Subject	Diet	Period	Weight	Intake	Output			Absorption	Retention
					Feces	Urine	Total		
			kgs.	gms.	gms.	gms.	gms.	gms.	gms.
D	Med.	1	17.45	0.0893	0.0012	0.0909	0.0921	0.0881	-0.0028
	Prot.	2	17.39	0.0615	0.0018	0.0553	0.0571	0.0597	0.0044
		3	17.41	0.0658	0.0001	0.0588	0.0589	0.0657	0.0069
		4	17.50	0.0607	0.0003	0.0549	0.0552	0.0604	0.0055
		5	17.55	0.0660	0.0007	0.0577	0.0584	0.0653	0.0076
		6	17.41	0.0588	0.0001	0.0529	0.0530	0.0587	0.0058
		7	17.45	0.0589	0.0005	0.0582	0.0587	0.0584	0.0002
	High	8	17.45	0.0858	0.0001	0.0767	0.0768	0.0857	0.0090
	Prot.	9	17.45	0.0633	0.0001	0.0610	0.0611	0.0632	0.0022
		10	17.41	0.0771	0.0000	0.0703	0.0703	0.0771	0.0068
		11	17.50	0.0625	0.0007	0.0608	0.0615	0.0618	0.0010
		12	17.50	0.0680	0.0002	0.0578	0.0580	0.0678	0.0100
B	Med.	1	19.00	0.0902	0.0016	0.0757	0.0773	0.0886	0.0129
	Prot.	2	19.00	0.0619	0.0019	0.0618	0.0637	0.0600	-0.0018
		3	18.98	0.0664	0.0011	0.0582	0.0593	0.0653	0.0071
		4	18.98	0.0616	0.0005	0.0517	0.0522	0.0094	0.0611
		5	19.00	0.0671	0.0005	0.0605	0.0610	0.0666	0.0061
		6	18.98	0.0593	0.0004	0.0560	0.0564	0.0589	0.0029
		7	19.05	0.0594	0.0014	0.0581	0.0595	0.0580	-0.0001
	High	8	18.98	0.0868	0.0005	0.0747	0.0752	0.0863	0.0116
	Prot.	9	18.98	0.0640	0.0008	0.0659	0.0667	0.0632	-0.0027
		10	19.05	0.0776	0.0005	0.0710	0.0715	0.0771	0.0061
		11	19.09	0.0630	0.0009	0.0616	0.0625	0.0621	0.0005
		12	19.09	0.0686	0.0002	0.0521	0.0523	0.0684	0.0163

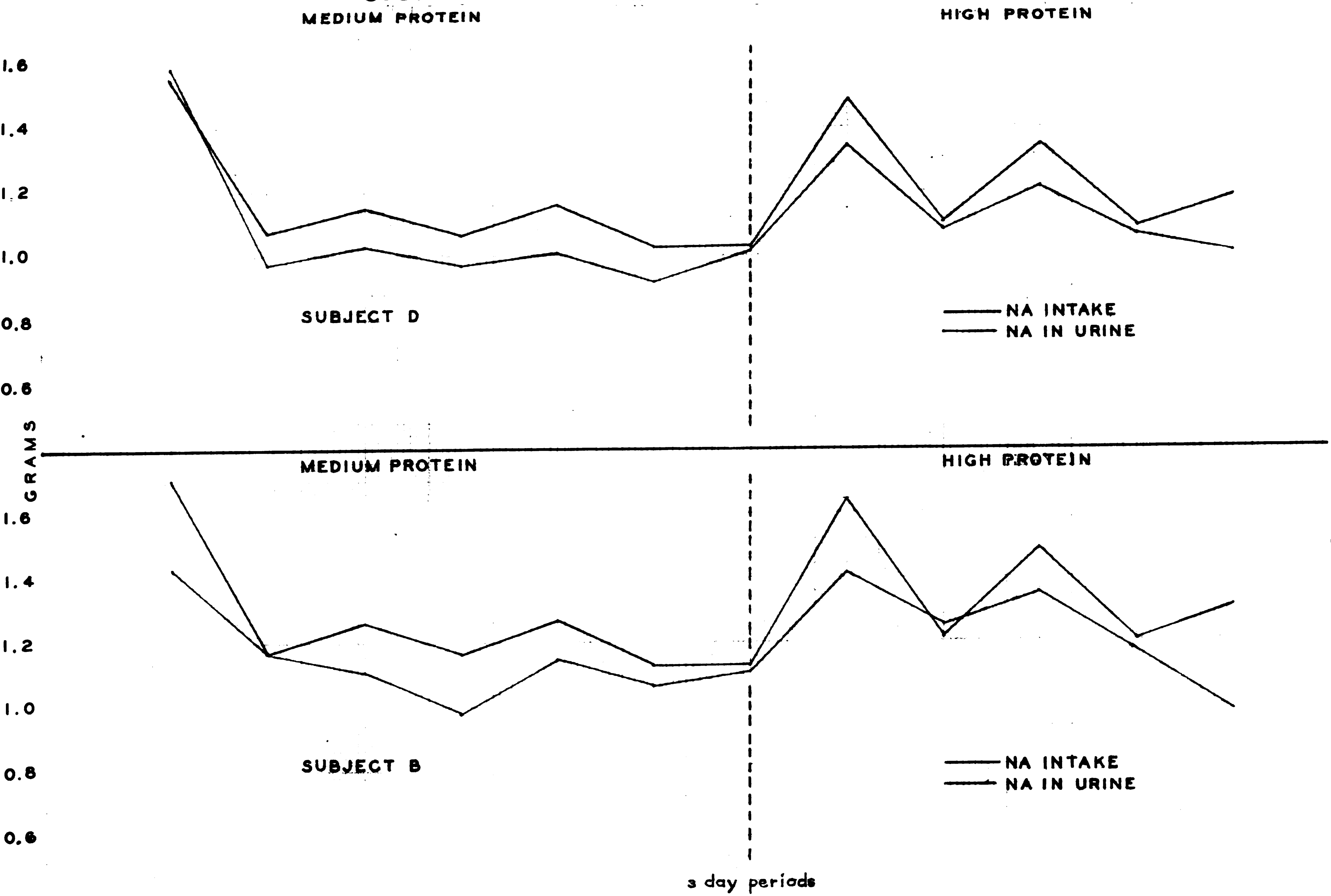
TABLE X

CORRELATION OF SODIUM INTAKE WITH PERIOD EXCRETION, ABSORPTION AND RETENTION PER KILOGRAM OF BODY WEIGHT

Medium Protein Diet	No. of samples	Range in grams per kilogram	Arithmetic Mean	Standard deviation	Standard error	Coefficient of correlation with intake
Subject D & B						
Intake	14	0.0588-0.0902	0.0662	0.010	0.003	
Feces	14	0.0001-0.0019	0.0009	0.001	0.000	0.347
Urine	14	0.0517-0.0909	0.0608	0.010	0.003	0.913
Total excretion	14	0.0522-0.0921	0.0616	0.011	0.003	0.911
Absorption	14	0.0580-0.0886	0.0653	0.010	0.003	0.998
Retention	14	0.0001-0.0129	0.0047	0.004	0.001	0.161
High Protein Diet						
Subject D & B						
Intake	10	0.0630-0.0868	0.0717	0.010	0.003	
Feces	10	0.0001-0.0009	0.0004	0.000	0.000	0.386
Urine	10	0.0521-0.0767	0.0652	0.008	0.003	0.801
Total excretion	10	0.0523-0.0768	0.0656	0.008	0.003	0.787
Absorption	10	0.0863-0.0618	0.0713	0.010	0.003	0.999
Retention	10	0.0005-0.0163	0.0061	0.006	0.002	0.558

GRAPH NO. 1

SODIUM INTAKE AND URINARY EXCRETION



an average of 98.4 and B, 98.4% of the sodium from the food. As shown in Graph No. 2, absorption closely paralleled the intake of sodium and there was therefore an appreciable variation from period to period. Tables VIII and IX show the close relationship between intake and absorption and indicate that there was a wide range in absorption per period. Table X corraborates the above findings and presents a high coeffecient of correlation between the sodium intake and absorption per kilogram of body weight on the medium protein diet. Retention of sodium was low and there was a wide variation from period to period on the medium protein diet. The sodium retained in the body by the two subjects ranged from 0.002 grams to 0.177 grams per period as shown in Table VIII. Table IX indicates that there was also a wide range in sodium per kilogram of body weight per period. Since the absorbed and urinary sodium followed the intake very closely it might be expected that the retained sodium, although small in amount, would vary with the intake also. This was not true, however, and Table X shows no correlation between intake and retention.

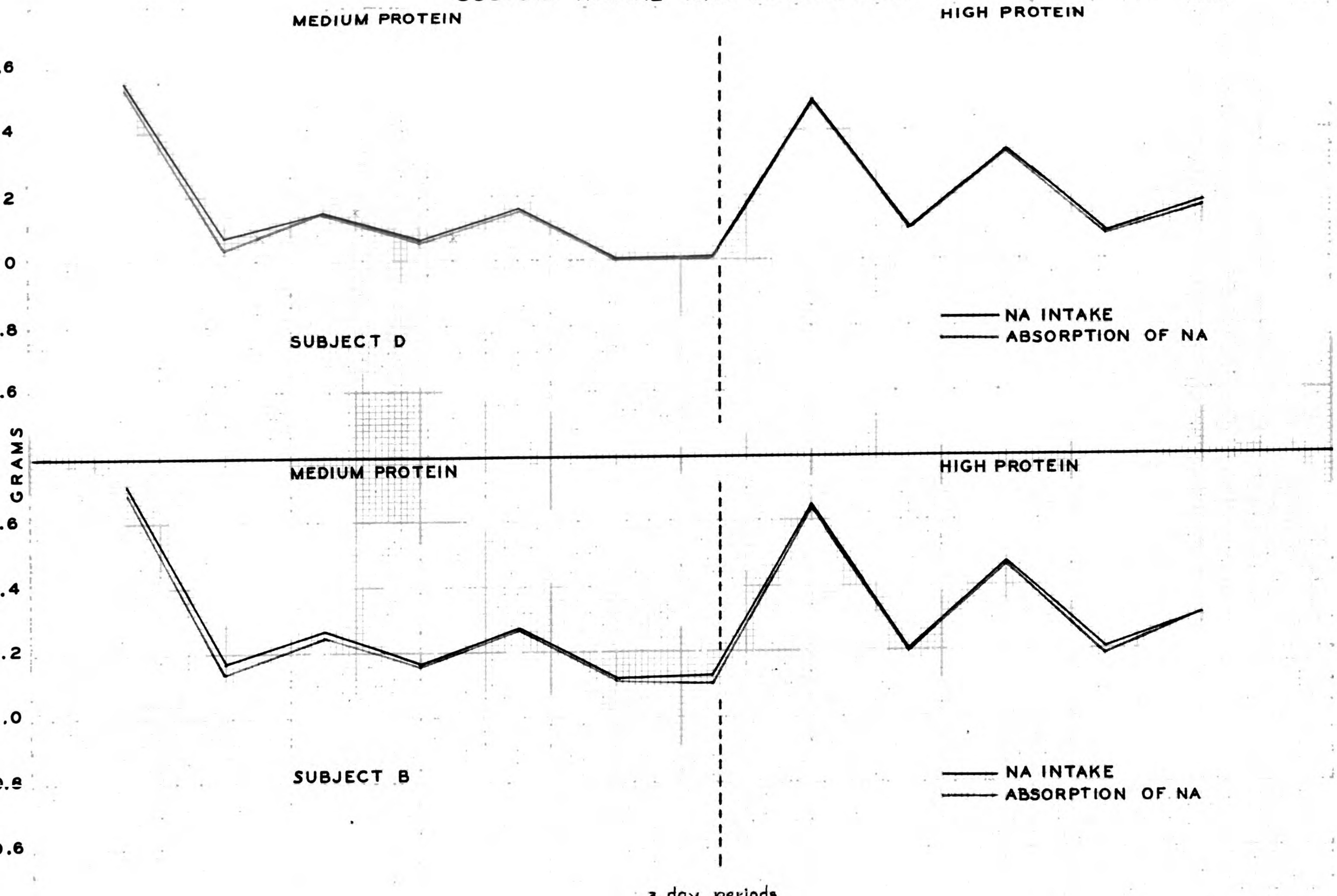
On the medium protein diet, therefore, the reactions of the two subjects were similar. Intake was paralleled by absorption and urinary excretion of sodium per period and there was no correlation between intake and either fecal excretion or retention.

<u>Sodium Metabolism by Periods</u> - <u>High Protein Diet</u>

Results obtained when the children were on the high

GRAPH NO. 2

SODIUM INTAKE AND ABSORPTION



protein diet were comparable in most respects to those on the medium protein diet. The period intake of sodium, though slightly higher than on the medium protein diet, showed a similar variation on the higher level of protein. Subject D injested from 1.094 to 1.498 grams of sodium daily and B consumed between 1.203 and 1.648 grams per period. The high protein diet also exhibited an appreciable difference in the period intake of sodium per kilogram of body weight, as shown in TableIX. The per cent variation from the average for both total and per kilogram intake was from +20.2% to -12.3% and +20.2% to 12.2% for subjects D and B respectively. In accordance with the medium protein diet, the average amount of sodium per kilogram of body weight eaten by the two subjects was similar. Subject D received an average of 0.0715 grams and B 0.0720 grams per period.

Fecal excretion of sodium was lower on the high than on the medium protein diet and there was not as great a variation between periods. Subject D excreted an average of 66.7% and B 45.0% less sodium on the high than on the medium protein diet. This was true even though the high protein diet provided 8.7% more sodium than did the medium protein. The range in fecal sodium was from 0.001 to 0.018 grams per period on the high protein level - a much smaller range than on the medium protein diet. Tables VIII and IX indicate that the amount of fecal sodium was small and the period excretion of fecal sodium was not constant either for the individual subjects or when the two were compared. Similar to the medium protein level the high protein diet did not show a correlation between intake and fecal excretion of sodium as indicated in Table X.

Sodium output in the urine on the high protein diet, like that on the medium, represented a major portion of the amount injested in the food. Period elimination varied from 1.012 to 1.339 grams for D and 0.994 to 1.418 grams for B. As shown in Table IX there was also a considerable variation in urinary output of sodium per kilogram of body weight. The variation from the average urinary excretion of sodium was from +17.5% to -11.3% and +14.5% to -19.7% respectively, for subjects D and B. Graph No. 1 demonstrates the close relationship between the injestion and urinary excretion of sodium for both subjects. As shown in Table X there was a high correlation between intake and sodium in the urine on the two diets.

Since the injestion of sodium was higher and fecal output lower on the high protein diet than on the medium the absorbed sodium was slightly higher also. The two boys absorbed between 98.8% and 100.00% of the food sodium on the higher level of protein. Tables VIII and IX indicate that the absorption and intake were similar on both diets and Graph No. 2 that on the high protein diet also, absorption of sodium closely paralleled the intake. The high coefficient of correlation between intake and absorption on the medium protein diet was simulated on the high protein as shown in Table X.

A closer relationship existed between the retention of sodium by the two children, on the high than on the medium protein diet. Variation in sodium retention ranged from 0.017 to 0.312 grams per period on the high protein diet. Table IX indicates that there was a similar wide variation on a kilogram basis. As opposed to retention on the medium protein diet, the sodium retained on the high protein showed a positive correlation with intake. There seemed to be some indication as shown in Table VIII, that as the intake increased the per- cent of sodium retained increased also. This might imply that when the sodium intake was sufficiently high the intake, absorp- tion and retention were parallel and possibly that even the high protein diet did not supply the optimun amount of sodium.

The chief difference in the sodium metabolism of the two subjects on the high protein diet from that on the medium seemed to be that the intake was slightly higher, the fecal excretion lower and, therefore, absorption was more complete.

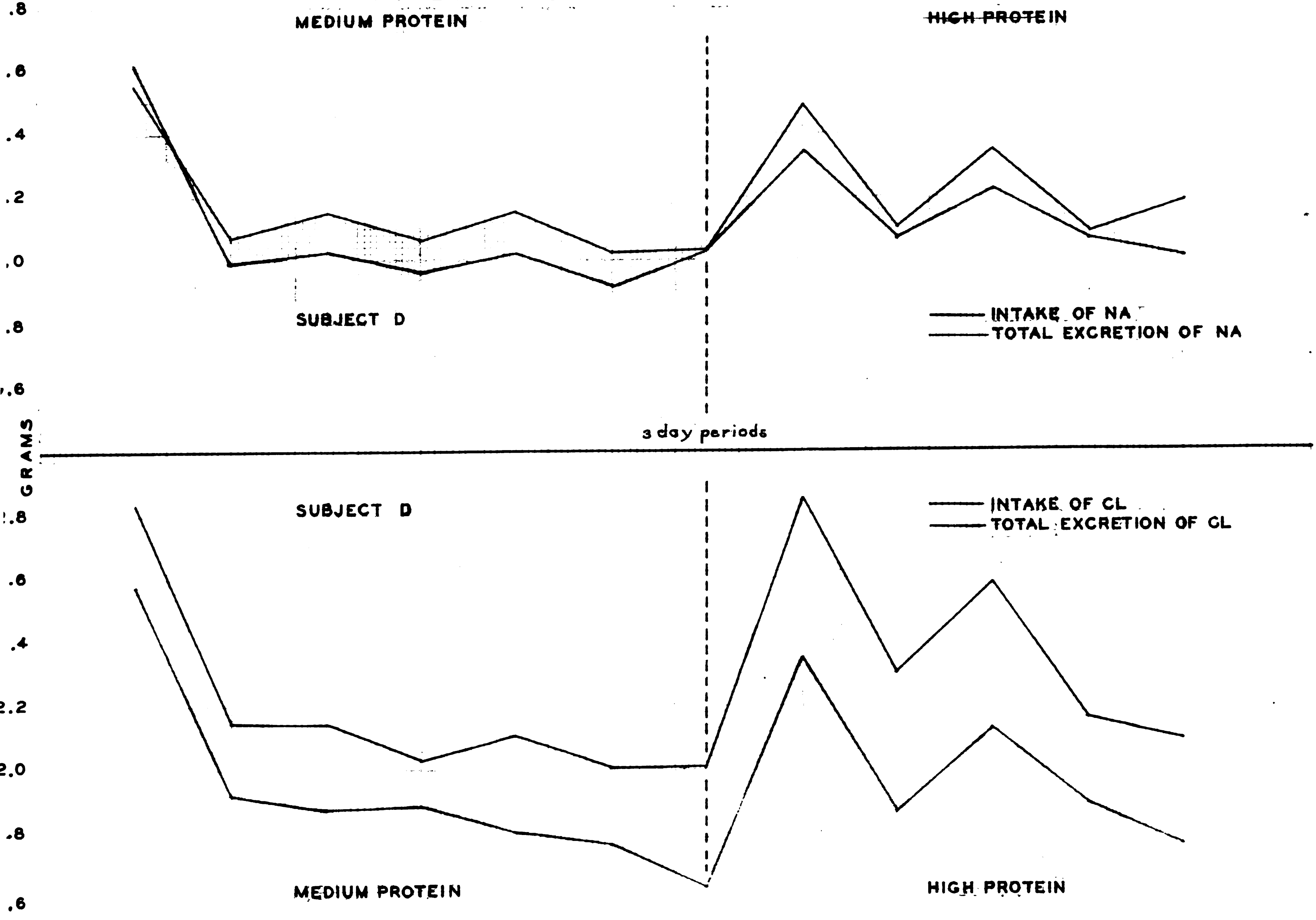
Comparison of Sodium and Chlorine Metabolism

A number of investigators have felt that there was a close relationship between sodium and chlorine metabolism (25, 31, 32, 46). Wiley, Wiley and Waller working with hospital- ized patients whose kidney function was impaired, made the following statement: "No relationship could be established be- tween the excretion of the various bases. It appears, however, that the excretion of chloride parallels the output of sodium more closely than any other base" (46).

The latter observation was confirmed with respect to the two pre-school children in this study on both the medium and high protein diets. A comparison of Graphs No. 3 and 4 indicate that the two children responded similarily with respect to sodium and

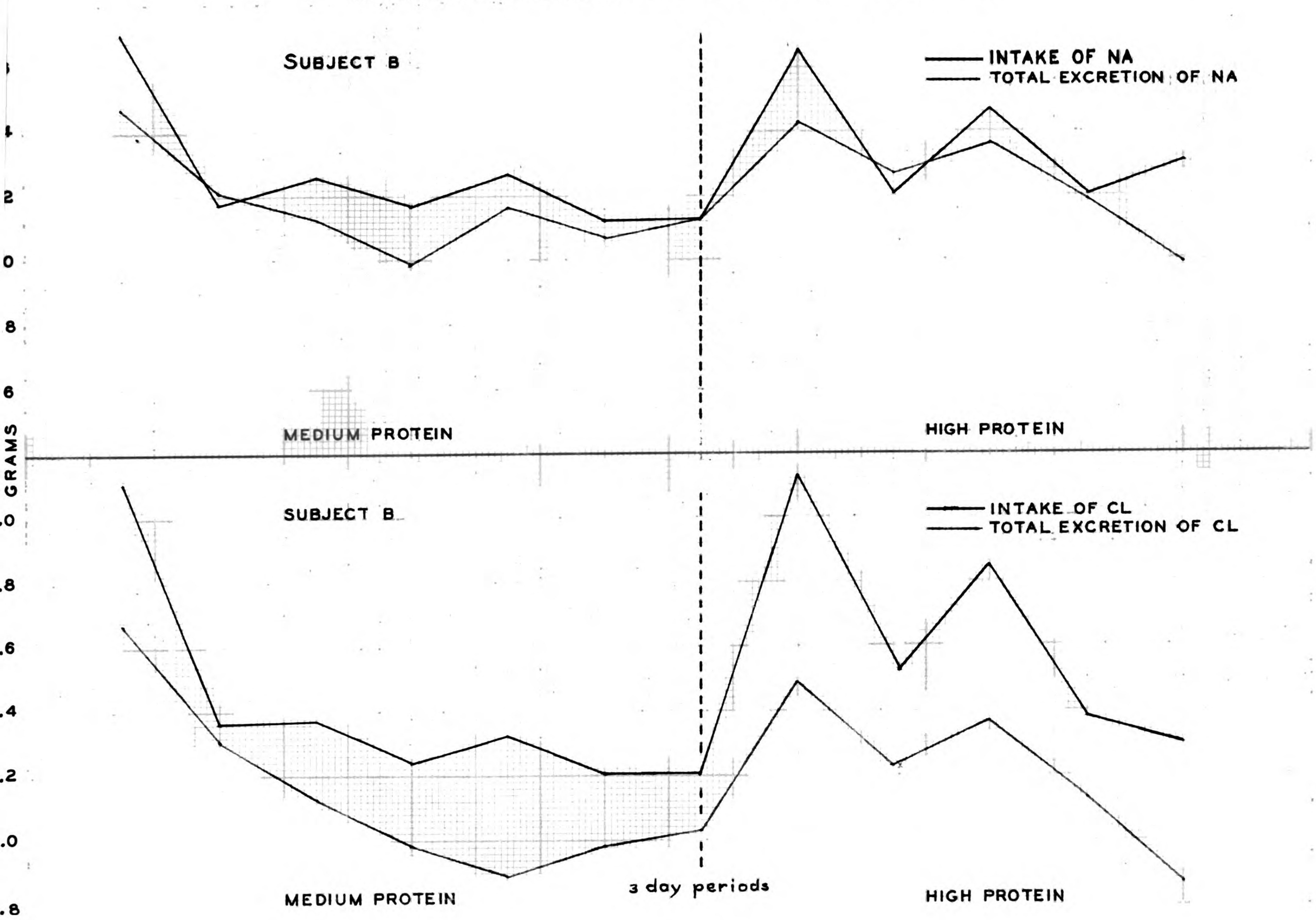
GRAPH NO. 3

INTAKE AND EXCRETION OF SODIUM AND CHLORINE



GRAPH NO. 4

INTAKE AND EXCRETION OF SODIUM AND CHLORINE



chlorine metabolism.* Very nearly all of the sodium and chlorine was absorbed. Fecal chlorine showed less variation from period to period than did the sodium in the feces. Graph No. 5 shows a close resemblance in the retention of the two bases. Judging from the above observations it would appear that under the experimental conditions of the present study the utilization of sodium and chlorine showed a marked agreement.

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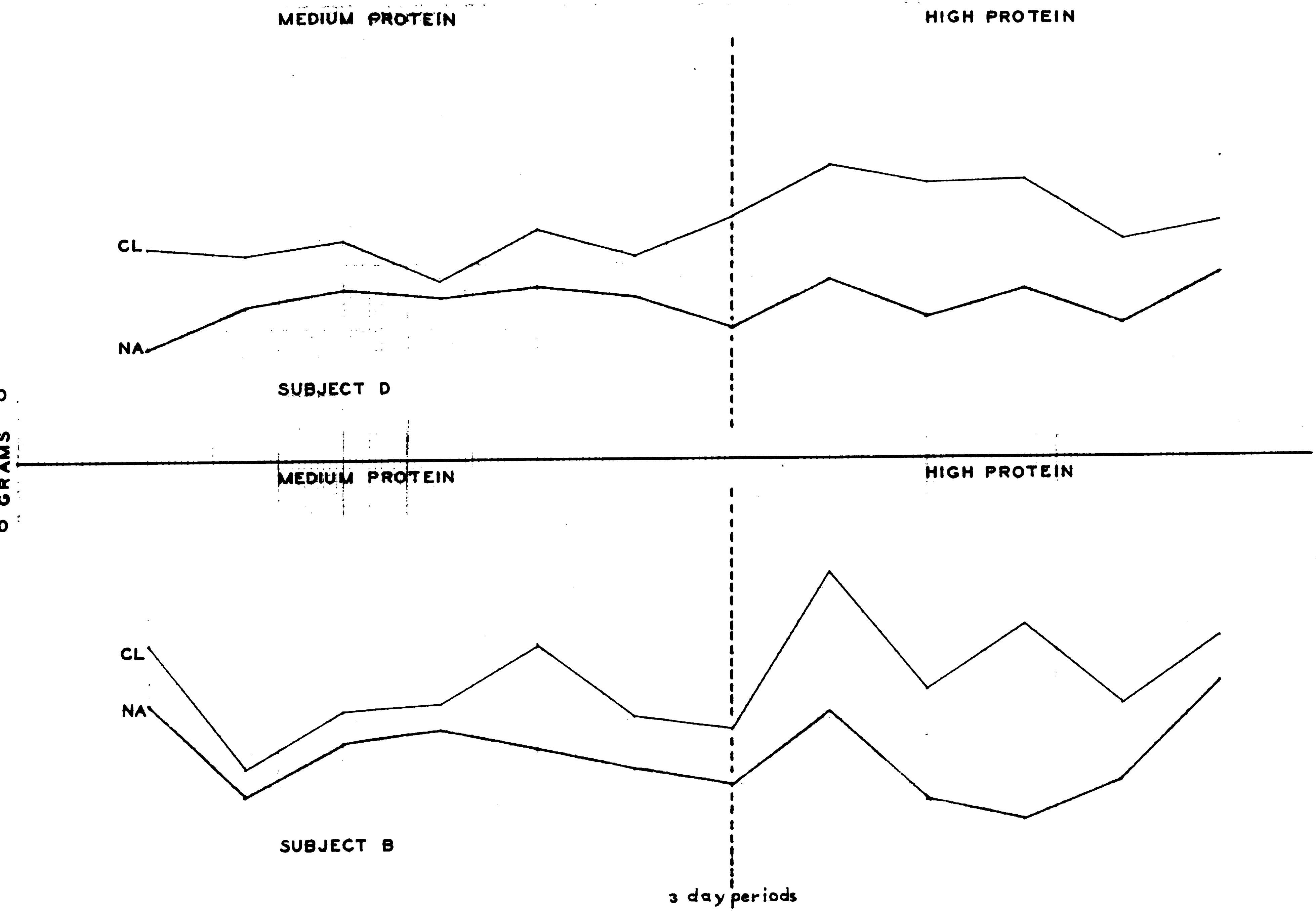
* Figures for chlorine obtained from unpublished data determined by Dr. Jean E. Hawks, Division of Home Economics, Michigan State College.

GRAPH NO. 5

RETENTION OF SODIUM AND CHLORINE



SUMMARY

1. The material presented deals with a balance study of sodium on two pre-school boys covering a period of forty-eight days and is a portion of a larger study which included calories, nitrogen and other minerals.

2. The subjects consumed, first, a medium protein diet providing 3 grams of protein per kilogram of body weight for 12 preliminary and 21 collection days; and second, a high protein diet providing 4 grams of protein per kilogram of body weight for the following 15 days.

3. Sodium intake, urinary and fecal excretion, absorption and retention were determined by analysis of daily specimens of food feces and urine.

4. Examination of the results revealed that on both the medium and high protein diets the two subjects behaved similarily.

5. Although the sodium intake varied by three day periods there were wide daily variations in the fecal and urinary sodium.

6. Daily excretion of sodium in the feces was small, absorption was very nearly complete and a major portion of the injested sodium was eliminated in the urine.

7. Both subjects showed a few negative balances.

8. In a majority of cases a change in the sodium intake, whether an increase or a decrease, was followed by a drop in the amount of sodium retained.

9. Statistical determinations revealed a higher correlation between intake and excretion, absorption and retention when the

results were considered on a three day period basis rather than on a daily. Since the injestion of sodium was the same for each three day period the results were interpreted in terms of the average amount of sodium for a three day period.

10. On the medium protein diet the sodium intake in grams varied widely from period to period; nevertheless, the average intake of sodium per kilogram of body weight was similar for the two subjects.

11. Also on the medium protein diet very nearly all of the sodium was absorbed, fecal excretion was small, retention was low and varied widely from period to period and over 90% of the injested sodium was eliminated in the urine. There was a close correlation between intake, absorption and urinary sodium but none between intake and fecal or retained sodium.

12. On the high protein level the results varied only slightly from those on the medium. The intake was somewhat higher, absorption was more nearly complete and there was a much smaller range in the fecal excretion of sodium on the high than on the medium protein diet. The urinary excretion of sodium, like on the medium protein diet, accounted for very nearly all of the injested sodium.

There was a high degree of correlation between intake, absorption and urinary sodium but none between intake and fecal excretion of sodium.

Unlike the medium protein diet there was a positive correlation between intake and retention of sodium on the high protein level.

13. Comparison was made between the sodium and chlorine metabolism of the two subjects throughout the experiment. It was noted that the two children responded similarily and there was a marked agreement between the utilization of both sodium and chlorine.

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