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THE URINARY PHOSPHORUS
EXCRETION OF PRESCHOOL
CHILDREN AS INFLUENCED BY
INCREASING DIETARY CALORIES

Thesis for the Degree of M. S.
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THE URINARY PHOSPHORUS EXCRETION OF PRESCHOOL CHILDREN
AS INFLUENCED BY INCREASING DIETARY CALORIES

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I. INTRODUCTION

Many studies of phosphorus metabolism in both children and in adults have been conducted to determine the various factors affecting the body's use of the mineral. These factors are age, which influences growth of bone and tissue; sex; diet variations in minerals, protein, calories, or vitamins; hormones; the acid-base balance; and the general health of the individual, past as well as at the time of the study. The effects which the various factors have are not definitely known, since sufficient studies are lacking in number and in detail.

To add to the available information on the subject the investigators in the present study determined the phosphorus metabolism as it is affected by a constant diet and by the addition of calories to the diet in the form of either filtered butter fat, cornstarch, or sugar. The study reports: first, the daily variation in urinary phosphorus excretion on a normal constant diet and on the same diet containing additional calories in the forms as mentioned above; second, the relationship between phosphorus intake and urinary phosphorus excretion; and third, the individual variations between children in their use of phosphorus.

II. REVIEW OF LITERATURE

A survey of the literature reveals that there have been relatively few studies of phosphorus metabolism of preschool children. These studies give some information concerning phosphorus utilization and various factors influencing its use.

One of the earliest of these studies (Table I) was that which Sherman and Hawley (17) reported in 1922. The purposes of their experiments were to determine the relation of age to calcium and phosphorus storage, and to find the nature and amount of calcium and phosphorus required to support optimal retention of these elements in the normal growing child. The authors conducted four series of experiments on twelve apparently normal Italian children ranging in age from 3 to 13 years. Four of the children were of preschool age. The authors made collections over two or three periods of three days each with one preliminary day for adjustment. To determine the rate of calcium and phosphorus storage in children of different ages, the subjects received a fixed diet containing 750 grams of milk, equivalent to 1.12 gm. of phosphorus per child per day. The retention of phosphorus varied from 0.09 to 0.53 gms., the amount increasing with the age and size of each child. The average phosphorus retention for the preschool group was 0.008 gms. per kg. of body weight.

The authors determined the daily allowance of phosphorus which would cause optimal retention by giving three of the children, 3, 5, and 12 years of age a fixed diet to which they added milk at five different levels from 250 to 1500 gms. The results seemed to indicate that optimal retention of phosphorus occurred when the diet contained either 750 or 1000 gms. of milk. The retentions for the preschool child on all of these diets varied from 0.008 to 0.020 gm. of phosphorus per kg. of body weight. It was only when the amount of milk was as low as 250 gms. that they obtained a retention of 0.008 gm. When the milk in the diet varied from 500 to 1000 gm. the range in retention values was small varying from 0.013 to 0.020 gms. per kg. of body weight.

Table I. Summary of Urine Phosphorus Metabolism of Preschool Children as Reported by other Authors.

Author	Date	Children		Intake		Urine Output		Per cent of Intake	Remarks
		Age	No.	Total	per kilo	Total	per kilo		
Sherman and Hawley	1922	4-5	2	gm. 1.041	gm. 0.063	gm. 0.513	gm. 0.031	49.21	750 gm. milk and fixed diet
		4-5	2	0.691	0.036	0.293	0.015	41.67	250 gm. milk and fixed diet
		4-5	2	0.926	0.048	0.398	0.021	43.75	500 gm. milk and fixed diet
		4-5	1	1.167	0.065	0.541	0.030	46.15	750 gm. milk and fixed diet
		4-5	1	1.342	0.075	0.725	0.040	53.33	1000 gm. milk and fixed diet
		4-5	2	1.694	0.087	0.705	0.036	41.38	1500 gm. milk and fixed diet
		5-6	2	1.072	0.051	0.591	0.028	54.90	375 gm. milk and vegetables
		5-6	1	0.826	0.047	0.516	0.029	61.70	375 gm. milk and vegetables
Willard and Blunt	1927	3-4	2	1.020	0.063	0.420	0.026	41.27	Evaporated milk
		3-4	2	0.960	0.060	0.450	0.028	46.67	Pasteurized milk
Burton	1930	3-5	4	1.420	0.084	0.550	0.032	38.10	Wheat cereal
		3-5	4	1.700	0.099	0.440	0.029	29.29	Oatmeal
Wang and Assoc.	1930	5	1	0.510	0.030	0.380	0.021	70.00	Mixed diet
		5	1	1.500	0.084	0.780	0.043	51.19	Mixed diet
		4	1	0.640	0.050	0.450	0.036	72.00	Mixed diet
		4	1	0.990	0.072	0.640	0.046	63.89	Mixed diet

Table I. Summary of Urine Phosphorus Metabolism
(cont'd) of Preschool Children as Reported by
other Authors.

Author	Date	Children		Intake		Urine Output		Per cent of Intake	Remarks
		Age	No.	Total	per kilo	Total	per kilo		
				gm.	gm.	gm.	gm.		
Potts	1931	4-5	3	0.990	0.050	0.505	0.026	52.00	Low protein
		4-5	3	1.244	0.061	0.550	0.027	44.26	Medium protein
		4-5	3	1.455	0.070	0.726	0.035	50.00	Medium protein
Kilpa- trick	1932	4-5	2	1.337	0.074	0.753	0.042	56.76	Medium protein
		4-5	2	1.658	0.091	0.932	0.052	57.14	High protein
Daniels and Assoc.	1934	3-6	11	1.013	0.065	0.505	0.032	49.23	475 cc milk & cod liver oil
		3-6	10	1.055	0.065	0.543	0.033	50.77	475 cc milk & cod liver oil & viosterol
		3-6	3	1.169	0.070	0.524	0.032	45.71	475 cc milk
		3-6	10	1.295	0.079	0.656	0.040	50.63	950 cc milk & cod liver oil
		3-6	8	1.325	0.079	0.693	0.041	51.90	950 cc milk & cod liver oil & viosterol
		3-6	4	1.423	0.079	0.684	0.038	48.10	950 cc milk
Hubbell and Koehne	1934	7-11	17		0.054		0.026	48.15	low sugar
		7-11	2		0.051		0.023	45.10	6% increase in calorie value with sugar
		7-11	6		0.049		0.023	46.94	16-18% increase in calories with sugar
Porter- Levin	1934	2-6	3	0.963	0.053	0.493	0.027	50.94	constant mixed diet

To study the difference in availability of phosphorus, Sherman and Hawley 1922 (17) fed a diet containing 375 gms. of milk and sufficient vegetables to make the phosphorus content equivalent to that of the diet containing 750 gms. of milk. The results were so variable that no conclusions could be drawn concerning the phosphorus utilization.

As a result of these experiments Sherman and Hawley 1922 (17) recommended a quart of milk daily for all children. In reviewing their figures it is noted that the greatest retention for the preschool child occurred when its diet contained 750 gm. of milk and that there was little difference when the diet contained either 500 or 1000 gm. Thus with small children less than a quart of milk might be advisable. It must also be remembered that Sherman and Hawley 1922 (17) gave no cod liver oil, so that the calcium and phosphorus retentions might be quite different from those found in later work.

Some years later, Daniels and her associates 1934 (6) studied the calcium and phosphorus metabolism in two girls and eight boys between 3 and 5 years of age. They sought to find the influence which variations in the amount of milk ingested (1 pt. and 1 qt. respectively) had on the retentions of the children. Each group received comparable amounts of cod liver oil. The average amount of phosphorus retained during the periods in which they gave a pint of milk was higher than the phosphorus retentions during the period when they gave 1 quart of milk, even though the ingestions were somewhat lower. They also found wide variations in the amount of calcium and phosphorus retained by different children of approximately the same ages and of the same children under varying conditions of diet.

Daniels and her associates concluded that the results studied from

the standpoint of averages were not in line with the theory that all children needed a quart of milk per day. The marked differences in the children under varying conditions appeared to be due to the physiologic condition of the child at the time of the study and to his potentialities for growth. A year later Daniels and her associates 1935 (7) verified the results of their first study. Thus they concluded that less than a quart of milk is optimal for calcium and phosphorus storage if the diet is supplemented with these minerals from other sources.

Willard and Blunt 1927 (19) fed four children, two of whom were of preschool age, a normal fixed diet to which they added, commercially pasteurized milk, and then, evaporated milk. They compared the results for phosphorus retention on the two experiments, over a period of 13 and 12 days respectively. This included a three day preliminary period and a three day collection period, there was, however, only one day between the two studies.

With an average phosphorus intake of 1.02 gms. on the evaporated milk diet the retentions averaged 0.015 gms. per kg. of body weight. While with an average intake of 0.96 gms. of phosphorus on the pasteurized milk, the average phosphorus retention was 0.008 gm. per kg. of body weight. Thus, their results indicated that better retention of phosphorus occurred with evaporated milk than with pasteurized milk.

With four normal preschool boys as subjects Burton 1930 (5) studied the assimilation of phosphorus. The normal diets fed contained 1.42 and 1.70 gm. of phosphorus per day and large amounts of cereal. She fed wheat in one period and oatmeal in another. On both diets, the retentions per kilogram of body weight were considerably higher than figures reported by Sherman and Hawley 1922 (17), Willard and Blunt 1927 (19), or Daniels

and her associates 1934 (6). Burton stated that the difference might be partially explained by the facts that the phosphorus intake was high and that these children received ultra violet irradiation which might have increased the phosphorus retention.

In a study of 18 undernourished children, Wang, Kern and Koucher (13) found that 0.069 gm. of phosphorus was the minimum requirement of an 8 year old child weighing 20 kg. and living on a mixed diet. The phosphorus intakes varied from 0.019 to 0.089 gms. per kg. of body weight. When the intakes were above 0.035 gm. a positive balance always occurred, and when below this amount the balance was negative.

Potts 1931 (15) studied the phosphorus requirement of normal 4 year old children as affected by low, medium and high levels of intake. The phosphorus intake was 0.990, 1.244, and 1.455 gms. per day respectively. She found that the retention per kg. of body weight was 0.005, 0.014, and 0.015 gms. on the three protein levels, respectively. She concluded that the standard of 1 gm. of phosphorus per day per child was conservative, but allowed no great margin for retention in the average, active healthy child, and that the medium level of phosphorus intake (1.2 gm. daily) probably provided a sufficient margin for retention.

Another study on normal preschool children, Kilpatrick (12) reported in 1932. The children on medium and high protein diets with phosphorus intakes of 1.337 and 1.658 gms. respectively had retentions of 0.006 and 0.005 gms. per kg. of body weight. The daily retention and absorption of phosphorus varied considerably in the two subjects on both diets. Although the average grams retained were practically the same, one child retained 13% of the absorbed phosphorus, while the other stored only 10%. The child who retained 13 per cent of the absorbed phosphorus

excreted only 58 per cent of the total phosphorus through the urine, while the other child excreted 63 per cent. There were definitely individual differences from period to period but the total phosphorus excretion of the two children in the urine and feces averaged the same, 0.068 gm. per kg. of body weight. Although the amount of variation in absorption and retention was larger on the high protein diet, the percentage variations from the averages were practically the same on both diets. There was no significant difference between the two diets in phosphorus retention and absorption.

Porter-Levin 1934 (14) reported normal levels of phosphorus storage for three children from 2 to 6 years of age. On a constant mixed diet, furnishing approximately one gram each of calcium and phosphorus per day, the children stored an average of 0.008 gm. of phosphorus per kg. of body weight. Nevertheless, the retentions of phosphorus in each series of successive balances showed wide variations from period to period.

With the sugar intake as the only variable factor, Hubbell and Koehne 1934 (11) reported the phosphorus metabolism for 17 children between the ages of 7 and 11 years. On a low sugar diet, they found the retention of phosphorus was 0.007 gm. per kg. of body weight over twenty-three 7-day periods. When they modified the diet only by the inclusion of sugar to give a 6 per cent increase in caloric value, there was no change in phosphorus retention which could be attributed to the added sugar. When they increased the sugar content to give a caloric value 16 to 19 per cent higher, there was a tendency toward an increased retention of phosphorus.

The majority of the authors mentioned above found over 50 per cent

of the intake phosphorus excreted in the urine. Nevertheless, Table I shows that there was considerable variation in the per cent of phosphorus intake excreted in the urine, varying from 29.29 to 72.00. The greatest number being between 45.00 and 55.00 per cent with an intake between 0.065 and 0.075 gms. per kg. of body weight. This indicates that there is the individual variation factor.

There seems to be a relation between the amount of phosphorus intake and the per cent excreted as reported by several workers. Wang and her associates 1930 (18) found that 70 and 72 per cent of the phosphorus was excreted when the intake was 0.030 and 0.050 grams per kilogram of body weight. With a phosphorus intake of 0.084 gms. of the urinary phosphorus excretion was 51.19 per cent. There is the same trend in Burton's work 1930 (5) with cereals. When the intake was 0.084 and 0.099 gms. per kg. of body weight the urinary excretion was 38.10 and 29.29 per cent of the intake respectively. Similarly Sherman and Hawley's 1922 (17) data indicated the same results. When the children were on a diet containing 375 gms. of milk and supplemented by vegetables the phosphorus excretion in the urine was high, 61.70 per cent with an intake of 0.047 gms. of phosphorus per kg. of body weight. Then when the phosphorus intake increased to 0.051 gms. per kg. of body weight the urinary phosphorus was 54.90 per cent of the intake. Thus there is a definite tendency that when intakes are low the urinary excretion will be high and as the intake increases the percentage of phosphorus excreted in the urine decreases.

Another point which must be considered in phosphorus utilization and excretion is the bulk in the diet. Ascham 1930 (1) in work with animals found that bulk reduced urinary phosphorus excretion and

influenced the excretion in the feces. The animals fed a constant fixed amount of food substances, received varying proportions of cellulose, flour, and agar as roughage. This factor probably influenced the urinary excretions which Burton 1930 (5) reported, Table (I) and affected the results on phosphorus retention and excretion of the pre-school children whom Sherman and Hawley 1922 (17) fed diets containing 375 gms. of milk supplemented with vegetables.

Another study brings forward the fact that availability of the minerals may have a place in utilization and retention. Bloom 1930 (3) conducted an animal experiment by feeding spinach, ashed, raw and cooked as supplements to a constant diet. The results seem to show that the low retentions were not due to any unsuitableness in the ash itself, nor to the cellulose as such, but to some characteristic of the spinach calcium and phosphorus such as their state of combination, which lowered the availability. Thus the availability or the combination of the minerals in the food substances may have been a factor in cereal utilization and excretion in the work Burton 1930 (5) did and in the work of Sherman and Hawley 1922 (17) when they fed the small amount of milk with vegetable supplement Table I. Therefore, availability is a factor which affects phosphorus utilization.

The physiological condition of the child and his adjustment to a certain diet are other points that may be important in explaining the work of some of the authors. As Willard and Blunt 1927 (19) mentioned, some of the children were very undernourished, when started on the experiment. It is possible that a longer adjustment period at the beginning of their study might have shown a closer relationship between the two kinds of milk.

The use of cod liver oil or irradiation as sources of vitamin D may be other influencing factors. Almost all of the authors just mentioned gave vitamin D either as cod liver oil or through ultra violet irradiation. Sherman and Hawley 1922 (17) as previously mentioned did not give either one.

Apparently, there are several obvious factors which may influence the utilization and excretion of phosphorus. To summarize they are: individual variations in children; the amount of phosphorus intake; bulk content in the diet; availability of the mineral; the length of the adjustment period; and vitamin D either as cod liver oil, concentrates, or irradiation. There may be many more conditions which also influence the utilization and excretion of phosphorus. Therefore, more work in this field is necessary.

III. PROCEDURE OF PRESENT STUDY

This report is a portion of a long time metabolism study on children of preschool age and extended from August 24 to December 14, 1937. The study consisted of five parts. The first, from August 24 to September 2, was a nine day preliminary period for adjustment. The second started on September 2 and consisted of nine 3-day collection periods for the basal or control diet. The third, which had filtered butterfat added to the basic diet to increase the calories 20 per cent contained twenty-seven days (nine 3-day collection periods). The fourth, containing a cornstarch supplement equal in caloric value to the butter fat, followed immediately for twenty-four days (eight 3-day collection periods). The fifth included a carbohydrate supplement in the form of cane sugar and lasted for 24 days (eight 3-day collection periods).

The children used as subjects were 2 boys, C and E and one girl, A, who were 47, 50, and 57 months of age respectively. The children were from an orphanage where they had lived more or less under a definite regime since their birth. Their diets prior to the experiment were probably adequate.

The children had a medical physical examination just previous to the study and were apparently in good physical condition at the time. Table II is a record of the children's average height and weight at the beginning of the study with their percentage variation from the standards of Baldwin-Wood, Height, Weight, and Age Tables (2), and the standards of the Iowa Child Welfare Research station. (20)

Table II. Comparison of Height and Weight of Subjects with Standard Tables at Beginning of Study.

Subject	Age	Observed Weight	Weight		Observed Height	Height	
			Variations from Standards			Variations from Standards	
			Baldwin-Wood	Iowa Research Station		Baldwin-Wood	Iowa Research Station
	mo.	kg.	%	%	cm.	%	%
C	47	14.94	-2.54	-12.2	103.5	+7.55	+0.8
E	50	17.38	+10.00	- 0.2	105.5	+7.77	+1.2
A	57	17.17	+8.06	- 2.5	101.1	-1.84	-5.8

In the comparison of children's weights and heights there is considerable variation noted as to the standard used. The more recent standards as those set up by the Iowa Child Welfare Research station

indicate that the normal child is taller and heavier in weight than the standards set by Baldwin-Wood.

C was a tall slender child and gave many indications of previous undernourishment. He was -2.54 and -12.2 per cent from normal according to the respective weight standards, but was +7.55 and +0.8 per cent above normal in height at the beginning of the experiment.

E, according to weight standards, was +10.00 and -0.2 per cent from normal respectively. In height, he was +7.77 and +1.20 per cent above normal. He was of good physique and very sturdily built.

The little girl, A, was "short and stocky" and varied from normal in weight +8.06 and -2.5 per cent with the two standards mentioned. In height, she was -1.84 and -5.8 per cent below normal.

Throughout the study, the children lived as normal children, but under constant supervision, in a Home Management House on the campus. The routine observed was regular in regard to meals, toilet, hours of sleep and afternoon rest. The procedure for the daily determination of height, weight, and rectal temperature of each child was as uniform as possible. The children played out of doors several hours each day except when weather conditions prevented.

During the entire study the subjects received a constant normal diet, to which calories were added, differing only in the variables as mentioned above. The diets as shown in Table III furnished the children with an adequate supply of all the known dietary essentials. They received 1.173 and 1.256 gm. of calcium and phosphorus daily, approximately 3 gms. of protein and 90 calories per kg. of body weight. To secure similar intakes of food for each individual child, body weight determined the amount for consumption. Thus per kilogram of

Table III. Calculated Diet Analysis on Basis of a 15 Kilogram Child.

No.	Food Added	Food	Wt. of food	Factor	Carbo- hydrate	Protein	Fat	Calories	Calcium	Phos- phorus
	None	Whole milk	800		gm. 40.0	gm. 26.4	gm. 32.0	552	gm. 0.960	gm. 0.744
		Ralstons	20		14.4	2.8	0.4	73	0.008	0.080
		Orange juice	200		21.6			86	0.058	0.032
		Beef, lean	40			8.5	3.2	62	0.005	0.092
		Peaches	150		16.2	1.1	0.2	71	0.024	0.036
		Apple sauce	150		55.8	0.3	1.2	236	0.011	0.018
		Celery	20		0.7	0.2		4	0.016	0.007
		Gerbers strained string beans	100		4.8	1.3		24	0.026	0.012
		Gerbers strained tomatoes	100		9.9	2.4	0.1	60	0.010	0.022
		Potatoes	80		14.7	1.8	0.1	66	0.011	0.046
		Butter	20			0.2	17.0	154	0.003	0.003
		Sugar	20		20.0			80	0.002	
		Bread	60		29.8	5.8	0.5	148	0.012	0.092
		Eggs	40			5.4	4.2	59	0.027	0.072
		Total			227.9	56.02	58.9	1675	1.173	1.256

Table IV. Calculated Portion Received by Each Child
During the Four Parts of the Study.

No.	Food Added	Child	Food	Wt. of food	Factor	Carbo- hydrate	Protein	Fat	Calories	Calcium	Phos- phorus
				gm.		gm.	gm.	gm.		gm.	gm.
I	None	C E A	Food as listed on table III.		.84 1.00 .95	191.4 227.9 216.5	47.2 56.2 53.4	49.5 58.9 56.0	1407 1675 1591	0.985 1.173 1.114	1.055 1.256 1.193
II	40 gm. Butter fat	C E A			1.00 .82 .95 .95	227.9 186.9 216.5 216.5	56.6 46.4 53.8 53.8	92.9 76.2 88.3 88.3	1982 1626 1833 1833	1.179 0.967 1.120 1.120	1.263 1.036 1.200 1.200
III	90 gm. Corn starch	C E A			1.00 .82 .95 .95	308.9 253.3 293.5 293.5	56.2 46.1 53.4 53.4	58.9 48.3 56.0 56.0	1999 1639 1899 1899	1.173 0.962 1.114 1.114	1.256 1.030 1.193 1.193
IV	90 gm. Sugar	C E A			1.00 .89 1.04 1.06	317.9 282.9 330.6 337.0	56.2 50.0 58.5 59.6	58.9 52.4 61.2 62.4	2035 1811 2116 2157	1.180 1.050 1.227 1.251	1.256 1.118 1.306 1.331

body weight each child received approximately equal amounts of all the constituents of the diet (Table IV). In addition, each child received daily one capsule of Parke, Davis & Co., Haliver Oil (Natola) equivalent to 9400 U.S.P. x 1 units of Vitamin A and 940 U.S.P. x 1 units of vitamin D (natural).

For calculating the composition of the diet, the tables from Rose "Handbook for Dietetics" (16) and Bridges "Food and Beverage Analysis" (4) were used. The phosphorus content of the calculated diet increased very slightly during the butterfat supplement to 1.263 gm. but remained the same as the constant diet, 1.256 gm., during the carbohydrate supplements.

The three children C, E, and A received 84.00, 100.00, and 95.00 per cent, respectively (Table IV) of the calculated constant diet. As the children gained in weight the proportion of the constant diet for each child varied with each change in diet, and they received 82, 95, and 95 per cent respectively, for the food periods of butterfat and cornstarch additions. During the period having additional sugar the amounts received were 89, 104, and 106 per cent.

All food which the children received was accurately weighed on a torsion balance having a sensitivity of 0.1 gm. To insure a representative sample all food was either ground or sieved and mixed thoroughly before weighing. Green beans and tomato puree were used. Sufficient food for a three day period was prepared at one time and the daily supplies weighed and stored in the refrigerator. The food was cooked and served in the same dishes so there would be no loss by transferring. All food was eaten, the dishes scraped, and rinsed with distilled water which was later consumed. The children received distilled water

exclusively in controlled amounts.

Duplicate samples of food equivalent to the diet of C were saved for analysis. The food was weighed into previously weighed glass dishes, later dried in a warming oven and placed in an electric Freas oven at 60° C where it was kept until it had reached a constant weight. The sample was then ground finely, sieved through a #50 copper wire mesh and stored in glass bottles.

All excreta were collected and preserved for analysis. The urine was collected in 24 hour samples, its volume, specific gravity, and creatinine content were determined daily. Any significant drop in the daily creatinine output was interpreted as a loss of urine for the 24 hour and such samples were discarded.

The phosphorus determinations were made by the uranium titration method as outlined by Peters and Van Slyke (13). The principle of the procedure is as follows: An uranium salt in a hot phosphate solution at a pH not below 5 will precipitate out as an uranyl phosphate $\text{Ur}_2\text{O}_3(\text{PO}_4)_2$. Cochineal as the indicator will change from the red in an acid solution to the green of the uranium--cochineal compound which forms when an excess of uranium solution is added.

Five gram samples of food were dry ashed at 400° C. The ash was taken up with 0.05 N Hcl, neutralized, then made slightly acid. It was diluted before adding the acetate buffer and before titrating the hot solution with uranium acetate.

The total urinary phosphorus was determined by taking 25 cc of urine made up to 50 cc, heating and titrating with uranium acetate. All determinations were made in triplicate.

The accuracy of the method was tested for both urine and dried

foods by recovering known amounts of phosphorus; Table V shows the range of recovery for the various tests made. It was found that in working with known phosphorus solutions that 5 mgs. of phosphorus in the sample was too small to give accurate results. The most accurate range was between 15 and 40 mg. per sample. The average recovery of these was 99.02 per cent.

The urine tests gave best results when 20 to 30 cc samples were used. When using samples of that size and adding 50 mg. of phosphorus the best recovery was at 25 cc of urine. The average recovery was 100.18 per cent.

The food determinations varied to a greater extent than known phosphorus or urine samples. The range of recovery being between 96.34 and 100.27 per cent with an average of 98.35 per cent. The percentage recovery was low on several of the determinations which indicated a possible loss, but all determinations were within 2 per cent of the average.

There are many more chances for error in weighing, ashing, and transferring of food samples. The addition of a definite amount of phosphorus solution to a food of known analyzed phosphorus content did not lower the percentage recovery indicating that the food contained no substance which inhibited the phosphorus determination.

Table V. Tests to Determine Accuracy of Phosphorus Method.

Material used	Number of determination	Sample (size)	Additional phosphorus	Phosphorus Analyzed values			Percentage Recovery	
				calculated	range	average	range	average
				mg.	mg.	mg.	%	%
K H ₂ P O ₄	2	21.9432 mg.		5	4.7583--4.7583	4.7583	95.17--95.17	95.17
K H ₂ P O ₄	2	43.8864 mg.		10	9.7932--9.7932	9.7932	97.93--97.93	97.93
K H ₂ P O ₄	2	65.8296 mg.		15	14.7544-14.7913	14.7729	98.36--98.61	98.49
K H ₂ P O ₄	3	175.5456 mg.		40	40.2183-40.3260	40.2903	100.55-100.82	100.73
K H ₂ P O ₄	4	219.4320 mg.		50	50.1650-50.3494	50.2341	100.33-100.70	100.47
average								99.02
Urine	2	15 cc.			9.0269--8.7588	8.8929		
	3	20 cc.			11.6188-11.6545	11.6307		
	3	25 cc.			14.5145-14.7469	14.6396		
	3	30 cc.			17.6069-17.6069	17.6069		
average per cc.						.5861		
Urine	3	20 cc.	50	61.7220	61.4006-61.7224	61.5675	99.35-100.00	99.69
	3	25 cc.	50	64.6525	64.5109-64.7969	64.6718	99.72-100.28	100.03
	3	30 cc.	50	67.5830	68.1038-68.1574	68.1276	100.28-101.15	100.82
average								100.18
Food	10	5 gm.			18.5006-19.4838	19.1228		
Food	9	5 gm.	5	24.1228	23.8453-24.2385	24.0856	96.34-100.27	98.35

RESULTS AND DISCUSSION

The data obtained in this study give information on the variation in food composition. Table VI gives the analyzed values for phosphorus for each sample (A and B) as well as the calculated values. This is shown through the variation in duplicate samples in the period to period and the analyzed values as compared to the calculated.

The analyzed values for samples A and B in the constant diet (nine 3-day collection periods) ranged from 1.0243 to 1.1751 grams of phosphorus. Likewise, during the remainder of the study when additions of filtered butterfat, cornstarch, or cane sugar supplemented the original diet similar variations occurred. The least variation, 0.9910 to 1.1003 was found during the periods when cornstarch supplemented the diet. However, these variations agree with those reported by Hawks, Dye and Fray, 1937 (10) showing that considerable range in mineral content may occur between diets which are supposedly identical in composition.

The difference between the duplicate samples is expressed in the percentage one sample varied from the other in Table VII. The entire study shows a range from 0.21 to 8.93 percent, with an average of 2.42 percent. This is comparable to the results of Hawks, Dye and Fray 1937 (10), reported in their statistical analysis of the reliability of metabolism technique. Since the values for duplicate diets usually vary in the same direction from the mean for the entire food period, and show a period to period variation, the average analysis of the two samples is, in most cases, a better representative of the composition of the food which the children actually received than either of the separate analysis.

Table VI. Phosphorus Content of the Diets.

Period	Constant Diet Sample			Period	Constant Diet + Filtered Butterfat Sample			Period	Constant Diet + Cornstarch Sample			Period	Constant Diet + Sugar Sample		
	A	B	Average		A	B	Average		A	B	Average		A	B	Average
Calculated Value*	gm.	gm.	gm.		gm.	gm.	gm.		gm.	gm.	gm.		gm.	gm.	gm.
			1.055				1.036				1.030				1.118
1	1.1158	1.1181	1.1170	10	1.1139	1.0778	1.0959	19	1.0922	1.0973	1.0951	27	1.0988	1.1555	1.1272
2	1.1595	1.1751	1.1647	11	1.1177	1.1038	1.1107	20	0.9920	1.0281	1.0100	28	1.0558	1.0881	1.0720
3	1.1112	1.0970	1.1041	12	1.1387	1.1326	1.1357	21	1.0808	1.0256	1.0532	29	1.0988	1.1112	1.1050
4	1.1225	1.0837	1.1031	13	1.0984	1.1080	1.1032	22	1.0037	1.0184	1.0110	30	1.1201	1.1434	1.1318
5	1.0496	1.0601	1.0548	14	1.0730	1.1123	1.0926	23	1.0326		1.0326	31	1.1540	1.1454	1.1497
6	1.0985	1.0763	1.0874	15	1.0504	1.1534	1.1019	24	1.0626	0.9869	1.0248	32	1.0958	1.1038	1.0998
7	1.0420	1.0398	1.0409	16	1.0397	1.0172	1.0285	25	1.0308	0.9910	1.0109	33	1.1936	1.1715	1.1825
8	1.0446	1.0718	1.0582	17	1.0504	1.0913	1.0631	26	1.0444	1.1008	1.0726	34	1.0650	1.0873	1.0706
9	1.0243	1.0329	1.0286	18	1.0601	1.0445	1.0523								
Av.			1.0843				1.0871				1.0388				1.1173

*Computed from tables of food composition (See Table III)

1000 • 100

A hand wearing a pink nitrile glove is pointing to a table of calculated values. The table has columns labeled 'A', 'B', 'C', 'D', and 'E'. The values in the table are as follows:

	A	B	C	D	E
1	1.113	1.113	1.113	1.113	1.113
2	1.133	1.133	1.133	1.133	1.133
3	1.113	1.113	1.113	1.113	1.113
4	1.133	1.133	1.133	1.133	1.133
5	1.043	1.043	1.043	1.043	1.043
6	1.033	1.033	1.033	1.033	1.033
7	1.043	1.043	1.043	1.043	1.043
8	1.043	1.043	1.043	1.043	1.043

*Computed from table

There was considerable variation in the average of duplicate determinations from the mean of all determinations. The average for each part as shown in Table VII may be considered the mean average. The range in percentage variation of each analysis from that mean was 0.06 to 8.37 percent, with an average for the entire study of 2.71 percent, column 2, Table VII.

Diet calculations from standard tables of food composition give only approximate values. This is due to a number of factors, such as variety of the product, degree of freshness, the type of soil, climatic conditions, the season, and the year in which it is grown. The factors will apply to the present results for food composition. Also, unavoidable slight errors in weighing and chemical method of analysis will influence results.

The average phosphorus content of the constant diet as analyzed was 1.0843 grams. This was very close to the calculated figure for this part of the study, 1.055 grams. There is a similar variation from the calculated figure in the other three parts as shown in Table VI. The least variation, when comparing the average for the four parts of the study with the calculated, occurred when sugar supplemented the diet.

Therefore, in the third column of Table VII is shown the percentage variation of the analyzed values from the calculated. The range is from 0.10 to 11.37 percent with an average of 3.48 percent. Although the precautions in technique as suggested by Hawks and her associates in 1937 (10), were carefully followed, slight variations in the composition of food were encountered.

Thus the total amount of phosphorus intake per child was not the same, but changed from period to period as the mineral composition of

Table VII. Variability in Composition of Duplicate Diet.*

Period	Differences Between Duplicate Diets		Variation of Period Average From Mean Of Each Part of Study		Variation of Period Average From Calculated Values	
	Range	Average	Range	Average	Range	Average
I Constant	% 0.21 - 3.46	% 1.44	% 0.06 - 8.37	% 3.17	% 0.47 - 11.37	% 3.62
II Fat	0.54 - 8.93	2.86	0.59 - 6.10	2.40	0.39 - 11.29	5.19
III Sugar	0.46 - 7.12	3.33	0.54 - 5.97	2.52	0.10 - 6.89	2.39
IV Starch	0.67 - 4.91	2.04	0.55 - 6.83	2.73	0.18 - 6.80	2.72
Average		2.42		2.71		3.48

$$* \% \text{ Variation between Duplicate Diets} = \frac{\text{Sample 1} - \text{Sample 2}}{\text{Sample 1}} \times 100$$

$$\% \text{ Variation of Period Average from Mean of Each Part of Study} = \frac{\text{Mean} - \text{Period Average}}{\text{Mean}} \times 100$$

$$\% \text{ Variation of Period Average from Calculated Values} = \frac{\text{Calculated Values} - \text{Period Average}}{\text{Calculated Values}} \times 100$$

the food varied. Another point is that the total amount of phosphorus intake per child was based upon the size of the child. Tables VIII, X, XII, XIV show the amounts of phosphorus each child received throughout the study. To measure and compare each child's utilization of food, it was necessary to establish a basic amount for intake and this was done on a per kilogram basis. The phosphorus intake per kilogram of body weight for each child was approximately equal and thus the intakes and excretions are discussed on a per kilogram basis. Each section of the study will be discussed separately.

Constant Diet

After nine days preliminary feeding on the constant diet, the experimental observations were started. During the twenty-seven days on the constant diet, analyses were made of the phosphorus intake and excretion, and Table VIII shows the total intake and excretion for each child.

Even though the diet was as constant in composition as could be obtained under the conditions of the study, analyses showed a variation in phosphorus content. The range in values for C. was from 1.0236 to 1.1647 grams. Similar range occurred in the diets of the other children.

The amount of phosphorus excreted by the children showed a period to period variation. The excretion values for C. ranged from 0.4767 to 0.5641 grams of phosphorus per day or 0.0319 to 0.0373 grams per kilogram of body weight. The phosphorus excreted did not correlate with the phosphorus intake either in amount or percent excreted (44.60 to 54.06%), but the variation in diet or excretion was relatively small. E. had a total phosphorus excretion which ranged from 0.5439 to 0.6054 grams or

Table VIII. Daily Phosphorus Intake and Urinary Excretion on Constant Diet.*

Period	Subject C					Subject E					Subject A				
	Total Phosphorus Intake	Total Urinary P Excretion	Intake P/kg	Urinary P per kg	% Urinary P of Intake Excreted	Total Phosphorus Intake	Total Urinary P Excretion	Intake P/kg	Urinary P per kg	% Urinary P of Intake Excreted	Total Phosphorus Intake	Total Urinary P Excretion	Intake P/kg	Urinary P per kg	% Urinary P of Intake Excreted
	GM.	gm.	gm.	gm.		gm.	gm.	gm.	gm.		gm.	gm.	gm.	gm.	
1	1.1170	0.5310	0.0748	0.0355	47.54	1.3297	0.5958	0.0765	0.0343	44.80	1.2633	0.4686	0.0736	0.0273	37.09
2	1.1647	0.5415	0.0780	0.0362	46.49	1.3865	0.5854	0.0798	0.0337	42.22	1.3172	0.5019	0.0767	0.0292	38.10
3	1.1041	0.5248	0.0739	0.0351	47.56	1.3144	0.5994	0.0756	0.0345	45.60	1.2487	0.5681	0.0727	0.0331	45.49
4	1.1031	0.5641	0.0738	0.0378	51.23	1.3132	0.6054	0.0753	0.0347	46.10	1.2475	0.5641	0.0720	0.0325	45.21
5	1.0548	0.5422	0.0706	0.0363	51.40	1.2558	0.5863	0.0720	0.0336	46.69	1.1930	0.5494	0.0688	0.0317	46.05
6	1.0874	0.4850	0.0727	0.0324	44.60	1.2945	0.5489	0.0741	0.0314	42.41	1.2298	0.4767	0.0708	0.0275	38.76
7	1.0409	0.4934	0.0696	0.0330	47.40	1.2392	0.5946	0.0709	0.0340	47.99	1.1772	0.4955	0.0678	0.0285	42.09
8	1.0582	0.4767	0.0707	0.0319	45.04	1.2598	0.5675	0.0721	0.0325	45.04	1.1968	0.5432	0.0689	0.0313	45.39
9	1.0286	0.5560	0.0688	0.0372	54.06	1.2245	0.6042	0.0700	0.0345	49.34	1.1633	0.4910	0.0663	0.0280	42.20
Average 1-9	1.0843	0.5240	0.0725	0.0351	48.37	1.2908	0.5875	0.0740	0.0337	45.58	1.2263	0.5176	0.0708	0.0299	42.26
5-9	1.0540	0.5107	0.0705	0.0342	48.50	1.2548	0.5803	0.0718	0.0332	46.29	1.1920	0.5112	0.0685	0.0294	42.90

*Each figure given is 1/3 of the total amount for a 3-day period, thus making a daily average for the period.

Date		Time		Location		Remarks	
1	1.11.70	0.00.10	0.00.10	0.00.10	0.00.10	0.00.10	0.00.10
2	1.12.70	0.00.10	0.00.10	0.00.10	0.00.10	0.00.10	0.00.10
3	1.10.71	0.00.10	0.00.10	0.00.10	0.00.10	0.00.10	0.00.10
4	1.10.71	0.00.10	0.00.10	0.00.10	0.00.10	0.00.10	0.00.10
5	1.00.70	0.00.10	0.00.10	0.00.10	0.00.10	0.00.10	0.00.10
6	1.00.70	0.00.10	0.00.10	0.00.10	0.00.10	0.00.10	0.00.10
7	1.00.70	0.00.10	0.00.10	0.00.10	0.00.10	0.00.10	0.00.10
8	1.00.70	0.00.10	0.00.10	0.00.10	0.00.10	0.00.10	0.00.10
9	1.00.70	0.00.10	0.00.10	0.00.10	0.00.10	0.00.10	0.00.10
1-3	1.00.70	0.00.10	0.00.10	0.00.10	0.00.10	0.00.10	0.00.10
2-3	1.00.70	0.00.10	0.00.10	0.00.10	0.00.10	0.00.10	0.00.10

Each time given is 1

0.0314 to 0.0347 grams per kilogram of body weight. The percent urinary phosphorus of intake excreted ranged from 42.22 to 49.34 percent. Again, there was no relation between intake and excretion. A. had an excretion of 0.4636 to 0.5631 grams or 0.0273 to 0.0331 grams per kilogram of body weight. The percent of intake phosphorus in the urine ranged from 37.09 to 46.05. There is no definite pattern that high values for urinary output always accompanied or followed high intake figures, nor that low values for intake and output always occurred on the same or following days.

The figures indicate that the children apparently did not utilize phosphorus in the same manner. The average figures of intake are similar for all the children, but individual variation is evident when excretion and percent excreted are considered. There is, apparently, no definite scheme indicated as to the way and the amount of phosphorus excreted. C. excreted more phosphorus in the urine than the other two children. He was tall and slender with indications of previous undernourishment, and was not gaining in weight as rapidly as the other children. A. excreted less than either of the two boys.

From the gains in weight made during this part of the study, Table IX, it would seem probable that A. and E. were receiving calories in excess of their need. While C. was a little slower to make a gain in weight, since he made only a 0.02 kilogram gain in comparison to 0.19 and 0.40 kilograms made by E. and A. respectively. The average daily gain for children of this age is 0.005 kilograms daily (20).

There may have been some water loss due to perspiration, as the temperature was exceptionally high during the latter part of August and the first part of September. Since the children received a large supply

TABLE IX
COMPARISON OF HEIGHT AND WEIGHT OF SUBJECTS AT END OF
CONSTANT DIET WITH STANDARDS OF BALDWIN-WOOD

Part I	Age	Observed Weight Value	Percentage Variation From normal	Observed Height	Percentage Variation From normal	Average Gain in Weight	Average Gain in Height
	mo.	kg.	%	cm.	%	kg.	cm.
C.	48	14.96	-3.17	104.0	+7.75	0.02	0.50
E.	51	17.57	+10.02	105.6	+6.75	0.19	0.10
A.	58	17.57	+8.86	101.5	+2.98	0.40	0.40

of water, it should not have enough to influence their gains in weight.

It is interesting to observe that the child who showed the least increase in weight C. (0.02 kg.), also excreted the most phosphorus (48.37%), while A. who gained the most weight (0.40 kg.) excreted the least amount of phosphorus (42.90%). E. who gained about one half as much as A. (0.19 kg.) excreted phosphorus midway between the two children (46.29%). Evidently the growth needs of the children increased the phosphorus needs.

Butter Fat Diet

Immediately following the constant diet, sufficient filtered butter-fat was added to the constant diet to make a 20 percent increase in calories. Table X shows the total intake and excretion for each child.

The total intake per child varied from period to period but remained fairly constant as in the preceding part of the study. C.'s intake ranged from 1.0285 to 1.1357 grams. The range for E. and A. was 1.1915

Table X. Daily Phosphorus Intake and Urinary Excretion
on Diet Supplemented with Butter Fat.

Subject C						Subject E					Subject A				
Period	Total Phosphorus Intake	Total Urinary P Excretion	Intake P/kg	Urinary P per kg	% Urinary P of Intake Excreted	Total Phosphorus Intake	Total Urinary P Excretion	Intake P/kg	Urinary P per kg	% Urinary P of Intake Excreted	Total Phosphorus Intake	Total Urinary P Excretion	Intake P/kg	Urinary P per kg	% Urinary P of Intake Excreted
	gm.	gm.	gm.	gm.		gm.	gm.	gm.	gm.		gm.	gm.	gm.	gm.	
10	1.0959	0.5053	0.0733	0.0338	46.10	1.2696	0.4477	0.0720	0.0254	35.27	1.2696	0.4165	0.0723	0.0237	32.81
11	1.1107	0.5208	0.0735	0.0345	46.88	1.2868	0.4542	0.0723	0.0255	35.29	1.2868	0.5351	0.0719	0.0299	41.58
12	1.1357	0.5394	0.0748	0.0355	47.50	1.3157	0.4606	0.0736	0.0258	35.00	1.3157	0.5310	0.0730	0.0295	40.36
13	1.1032	0.5088	0.0721	0.0332	46.11	1.2781	0.4961	0.0710	0.0275	38.81	1.2781	0.5446	0.0707	0.0301	42.60
14	1.0926	0.5017	0.0708	0.0325	45.91	1.2659	0.5239	0.0698	0.0289	41.39	1.2659	0.5534	0.0688	0.0301	43.72
15	1.1019	0.5386	0.0708	0.0346	48.88	1.2766	0.5313	0.0699	0.0291	41.62	1.2766	0.5479	0.0690	0.0296	42.92
16	1.0285	0.5486	0.0661	0.0353	53.26	1.1915	0.4796	0.0650	0.0262	40.25	1.1915	0.5309	0.0640	0.0285	44.55
17	1.0631	0.5970	0.0677	0.0380	56.62	1.2316	0.5735	0.0668	0.0311	46.57	1.2316	0.6228	0.0657	0.0332	50.57
18	1.0523	0.5660	0.0665	0.0358	53.79	1.2191	0.4856	0.0658	0.0262	39.82	1.2191	0.5899	0.0648	0.0314	48.40
Average 10-18	1.0871	0.5363	0.0706	0.0348	49.45	1.2594	0.4947	0.0696	0.0273	39.34	1.2594	0.5413	0.0689	0.0295	43.06
14-18	1.0677	0.5504	0.0684	0.0352	51.69	1.2369	0.5188	0.0675	0.0283	41.93	1.2369	0.5690	0.0663	0.0306	46.03

A hand wearing pink gloves is pointing to a table of data. The table has several columns and rows of numbers. The hand is pointing to the first row of the table.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100

to 1.3157 grams respectively. They received the same amount of food during this time. The total average intake remained fairly constant. The average phosphorus intake per kilogram is slightly lower in the second part of the study. This decrease can be explained by the fact that the diet remained constant during the period and the children all gained in weight.

The phosphorus excreted in the urine is irregular: C. excreted from 0.5017 to 0.5970 grams per day or 0.0325 to 0.0380 grams per kilogram of body weight; E.'s excretion ranged in values from 0.4477 to 0.5735 grams or 0.0254 to 0.0311 grams per kilogram of body weight; A.'s excretion was from 0.4165 to 0.6228 grams or 0.0237 to 0.0332 grams per kilogram of body weight. Again there is no relation between intake and excretion.

C. excreted more phosphorus in the urine than the other two children (average 49.45 percent). E. made a considerable drop in the percentage excreted (39.34%). However, A. shows more variation in the amount excreted than the other two children (32.81 to 50.57%, average 43.06%). The percentage of phosphorus intake excreted in the urine in the tenth period shows a decided drop. The change in diet may partially explain this. If the last five period averages are considered, allowing the first four for adjustment to the diet, there is relatively small variation from the averages for the percent excreted on the constant diet.

All three children made gains in weight (as expected) during this part with additional calories in the form of filtered butterfat, Table XI. All the children were above average in weight, and made greater gains than when on the constant diet.

The growth in height is the same as the growth on the constant diet, except for A., who shows a slight increase. The weight growth is more

irregular. Again, it is true the child making the least gain in weight, C., (0.94 kg.) excreted the most phosphorus in the urine (49.45%). E. who made more nearly the same gain in weight (1.03 kg.) as A. (1.31 kg.) excreted the least amount of phosphorus (39.34%). Evidently E. is requiring a greater amount of phosphorus for growth. There is not much difference in the percentage of phosphorus excreted by E. and A.

Table XI. Comparison of Height and Weight of Subjects at End of the Butterfat Diet with Standards of Baldwin-Wood.

Part II	Age	Observed Weight Value	Percentage Variation From Normal	Observed Height	Percentage Variation From Normal	Average Gain in Weight	Average Gain in Height
	mo.	kg.	%	cm.	%	kg.	cm.
C	49	15.90	+1.86	104.5	+8.03	0.94	0.5
E	52	18.60	+15.17	105.7	+4.89	1.03	0.1
A	59	18.88	+15.76	102.0	-6.83	1.31	0.5

Cornstarch Diet

In part three of the study, sufficient cornstarch to increase the calories of the constant diet twenty percent was used in place of the butterfat. The phosphorus intake per kilogram of body weight was slightly lower than in part two, but approximately the same for each child. There was very little variation in the phosphorus content of the diet from periods 19 to 26, inclusive, Table XII. E. and A. received the same amount of food, but the amount per kilogram of body weight varied, because A. was

Table XII. Daily Phosphorus Intake and Urinary Excretion
on Diet Supplemented with Cornstarch.

Subject C						Subject E					Subject A				
Period	Total Phosphorus Intake	Total Urinary P Excretion	Intake P/kg	Urinary P per kg	% Urinary P of Intake Excreted	Total Phosphorus Intake	Total Urinary P Excretion	Intake P/kg	Urinary P per kg	% Urinary P of Intake Excreted	Total Phosphorus Intake	Total Urinary P Excretion	Intake P/kg	Urinary P per kg	% Urinary P of Intake Excreted
	gm.	gm.	gm.	gm.		gm.	gm.	gm.	gm.		gm.	gm.	gm.	gm.	
19	1.0951	0.5410	0.0686	0.0339	49.41	1.2688	0.4891	0.0680	0.0262	38.54	1.2688	0.6125	0.0670	0.0323	48.27
20	1.0100	0.5315	0.0629	0.0331	52.60	1.1702	0.5017	0.0625	0.0268	42.88	1.1702	0.5709	0.0612	0.0299	48.78
21	1.0532	0.5601	0.0650	0.0346	53.26	1.2202	0.4631	0.0647	0.0246	37.96	1.2202	0.5897	0.0634	0.0306	48.33
22	1.0110	0.5363	0.0620	0.0329	53.04	1.1713	0.5065	0.0617	0.0267	43.24	1.1713	0.6240	0.0603	0.0321	53.27
23	1.0326	0.5691	0.0632	0.0348	55.12	1.1963	0.5017	0.0627	0.0263	41.94	1.1963	0.5625	0.0612	0.0288	47.02
24	1.0248	0.5787	0.0620	0.0350	56.48	1.1872	0.5167	0.0618	0.0269	43.53	1.1872	0.5982	0.0602	0.0303	50.39
25	1.0109	0.5077	0.0612	0.0307	50.21	1.1712	0.5327	0.0608	0.0276	45.48	1.1712	0.6328	0.0594	0.0321	54.03
26	1.0726	0.5522	0.0649	0.0334	51.49	1.2427	0.5327	0.0645	0.0276	42.86	1.2427	0.5744	0.0629	0.0291	46.22
Average 19-26	1.0388	0.5471	0.0637	0.0335	52.70	1.2035	0.5055	0.0633	0.0266	42.05	1.2035	0.5956	0.0619	0.0307	49.54
22-26	1.0304	0.5488	0.0626	0.0334	53.27	1.1937	0.5180	0.0623	0.0270	43.41	1.1937	0.5984	0.0608	0.0305	50.19

Period	Total Phosphorus Intake	Urinary Excretion	Total Phosphorus Intake	Urinary Excretion
19	1.0381	0.5410	0.012388	0.012388
20	1.0100	0.5315	0.011702	0.011702
21	1.0322	0.5601	0.012202	0.012202
22	1.0322	0.5322	0.012202	0.012202
23	1.0322	0.5322	0.012202	0.012202
24	1.0322	0.5322	0.012202	0.012202
25	1.0322	0.5322	0.012202	0.012202
26	1.0322	0.5322	0.012202	0.012202
Average	1.0388		0.012388	
19-26	1.0304		0.012388	



heavier than E.

C. excreted a slightly larger amount of phosphorus in the urine, ranging from 0.5077 to 0.5787 grams per day or 0.0307 to 0.0350 grams per kilogram of body weight. This averaged 0.0335 grams which was approximately the same as when butterfat supplemented the diet. E. and A. both excreted more phosphorus in the urine as shown in Table XII.

All three children showed a higher percent excreted in the urine, due to the slightly lowered ingestion. The average percent excreted by C., E., and A. was 52.70, 42.05, and 49.54 percent respectively. This tendency to excrete a higher percent of phosphorus on a lowered intake was observed by Wang (18), Burton (5), and Sherman (18). Allowing a nine day preliminary period, the percentage of phosphorus excreted in the urine during this part was slightly higher. The phosphorus excreted in the urine remained approximately the same, but due to a slightly lowered intake as compared to part one and two, the percentage was higher.

Table XIII. Comparison of Height and Weight of Subjects at End of the Cornstarch Diet with Standards of Baldwin-Wood.

Part III	Age	Observed Weight Value	Percentage Variation From Normal	Observed Height	Percentage Variation From Normal	Average Gain in Weight	Average Gain in Height
	mo.	kg.	%	cm.	%	kg.	cm.
C	50	16.60	+5.20	105.0	+7.71	0.70	0.5
E	53	19.32	+17.59	106.9	+4.46	0.72	1.2
A	60	19.87	+19.99	102.7	-9.28	0.99	0.7

The increases in weight during the cornstarch diet are greater than they were during the constant diet, but still not as high as they were when butterfat supplemented the diet. C. and E. made approximately the same gain during this period, while A. made a considerably greater gain. It is possible, since E. and C. were more active than A. that they were using a greater portion of their intake of calories to satisfy their needs for activity.

E. made the greatest gain in height with 1.2 cm. while C. continued to gain 0.5 cm. regularly as he had in the other two parts. A. has made an increase of 0.7 cm. which is greater than she made when on either the constant diet or when the diet was supplemented with butterfat. When comparing the growth made during this part with the percentage of phosphorus excreted, the child C. (0.70 kg.) making the least growth excreted the greatest percent of phosphorus in the urine (52.70%). E. who made only a slightly greater gain (0.72 kg.) in weight but the greatest in height (1.2 cm.) excreted the least percentage of phosphorus in the urine (42.05%). He is evidently making better use of the phosphorus which he takes into his body. A. made the greatest gain in weight (0.99 kg.) but the percent (49.54%) she excreted was more nearly the same as C.'s.

Sugar Diet

Sufficient sugar was added to the constant diet to increase the calories twenty percent as in the previous parts of this study. There is a slight increase in the total phosphorus intake, Table XIV, for each child. Total phosphorus intake for C. ranged from 1.0706 to 1.1825 grams or 0.0621 to 0.0688 grams per kilogram of body weight. E.'s total intake of phosphorus was from 1.2510 to 1.3818 grams per day or 0.0622 to 0.0688

Table XIV. Daily Phosphorus Intake and Urinary Excretion
on Diet Supplemented with Sugar.

Subject C						Subject E					Subject A				
Period	Total Phosphorus Intake	Total Urinary P Excretion	Intake P/kg	Urinary P per kg	% Urinary P of Intake Excreted	Total Phosphorus Intake	Total Urinary P Excretion	Intake P/kg	Urinary P per kg	% Urinary P of Intake Excreted	Total Phosphorus Intake	Total Urinary P Excretion	Intake P/kg	Urinary P per kg	% Urinary P of Intake Excreted
	gm.	gm.	gm.	gm.		gm.	gm.	gm.	gm.		gm.	gm.	gm.	gm.	
27	1.1272	0.5346	0.0677	0.0321	47.43	1.3172	0.5398	0.0680	0.0279	40.97	1.3425	0.5377	0.0672	0.0269	40.05
28	1.0720	0.5382	0.0638	0.0320	45.91	1.2526	0.5498	0.0643	0.0282	43.89	1.2767	0.6006	0.0632	0.0297	47.05
29	1.1050	0.5427	0.0657	0.0323	49.11	1.2912	0.5557	0.0658	0.0283	43.04	1.3160	0.5989	0.0647	0.0295	45.52
30	1.1318	0.6039	0.0667	0.0356	53.37	1.3225	0.5460	0.0668	0.0276	41.29	1.3479	0.7033	0.0657	0.0343	52.80
31	1.1497	0.5553	0.0674	0.0326	48.30	1.3435	0.6264	0.0678	0.0316	46.62	1.3693	0.7043	0.0664	0.0342	51.16
32	1.0998	0.5270	0.0642	0.0308	47.91	1.2852	0.6352	0.0642	0.0317	49.42	1.3099	0.7090	0.0630	0.0341	54.14
33	1.1825	0.6006	0.0688	0.0349	50.79	1.3818	0.6149	0.0688	0.0306	44.50	1.4084	0.6943	0.0673	0.0332	49.29
34	1.0706	0.5966	0.0621	0.0346	55.72	1.2510	0.5534	0.0622	0.0275	44.27	1.2750	0.6990	0.0606	0.0332	54.82
Average 27-34	1.1173	0.5624	0.0658	0.0331	49.82	1.3056	0.5777	0.0660	0.0292	44.25	1.3307	0.6559	0.0648	0.0319	49.28
30-34	1.1269	0.5767	0.0659	0.0337	51.22	1.3168	0.5952	0.0659	0.0298	45.22	1.3421	0.7020	0.0646	0.0338	52.32



grams per kilogram of body weight. A. had a greater total intake than the other two due to her weight. Her total intake ranged from 1.2750 to 1.4084 grams per day or 0.0606 to 0.0673 grams per kilogram of body weight. The phosphorus per kilogram of body weight is approximately the same for all three children, but A. is slightly lower.

The total phosphorus excreted in the urine by C. ranged from 0.5270 to 0.6039 grams or 0.0308 to 0.0356 grams per kilogram of body weight. E.'s excretion ranged in values from 0.5398 to 0.6352 grams per day or 0.0279 to 0.0317 grams per kilogram of body weight. A.'s excretion was from 0.5377 to 0.7090 grams per day or 0.0269 to 0.0343 grams per kilogram of body weight. The high or low phosphorus excretions do not accompany or follow the high or low intakes of phosphorus by the children.

There is only a small difference in the percentage excreted in the urine by C., E., and A. in this part of the study, 49.82, 44.25, and 49.28% respectively. If the last five periods are considered, the percentage is slightly higher. The first three periods might be considered as an adjustment period to the new diet.

The two boys, C. and E., made similar gains in weight during the sugar supplement, Table XV, while A. made an excessive gain. The activity factor should possibly be considered for A. was not as active as the two boys.

The growth in height was the same for C. (0.5 cm.) as in the other three parts of the study. E. made only a small gain in height (0.1 cm.) while A. made 0.9 cm. which was the greatest gain that she had made.

The comparison of the growth made and the percentage excreted in the urine is interesting, for C. making 0.63 kg. gain in weight only excreted 49.82%, which is approximately the same as excreted by A. (49.28%), but

Table XV. Comparison of Height and Weight of Subjects at End of the Sugar Diet with Standards of Baldwin-Wood.

Part IV	Age	Observed Weight Value	Percentage Variation From Normal	Observed Height	Percentage Variation From Normal	Average Gain in Weight	Average Gain Height
	mo.	kg.	%	cm.	%	kg.	cm.
C	51	17.23	+7.89	105.5	+7.23	0.63	0.5
E	54	20.13	+20.90	107.0	+2.57	0.81	0.1
A	61	21.03	+25.78	103.6	-10.62	1.16	0.9

she made 1.16 kg. gain in weight. C. is undoubtedly retaining more phosphorus than he had previously. He developed and appeared in much better health than at the beginning of the study. E., as in the previous parts, has the smallest percent excreted in the urine. It is more nearly the same as the other children.

Table XVI. Comparison of Height and Weight of Subjects With Standards of Iowa Research Station.

Subject	Age	Observed Weight Values	Percentage Variation From Normal	Observed Height Values	Percentage Variation From Normal
	mo.	kg.	%	cm.	%
C	51	17.23	-1.1	105.5	+1.2
E	54	20.13	+12.5	107.0	+0.9
A	61	21.03	+17.2	103.6	-5.0

Again, it is interesting to notice the comparison of the standards of Baldwin-Wood with the more recent figures of the Iowa Research station. Iowa's standards are considerably higher than Baldwin-Wood. Using the standards of Iowa, C. is within a ± 10 percent of the standard with E. only slightly above for their weights. For heights they are all within the ± 10 percent of the standard. The standards of the present day would indicate that the normal child has a better physique than in the past.

GENERAL DISCUSSION

Thus far, the data has been discussed in four sections; the constant diet, the diet as changed by the addition of calories in the forms of butterfat, cornstarch and sugar. To consider the whole experiment, Graph I was prepared to show the period variations in phosphorus intake and excretion for each child. The graph shows the milligrams of phosphorus intake and excretion per kilogram of body weight so that it can be compared.

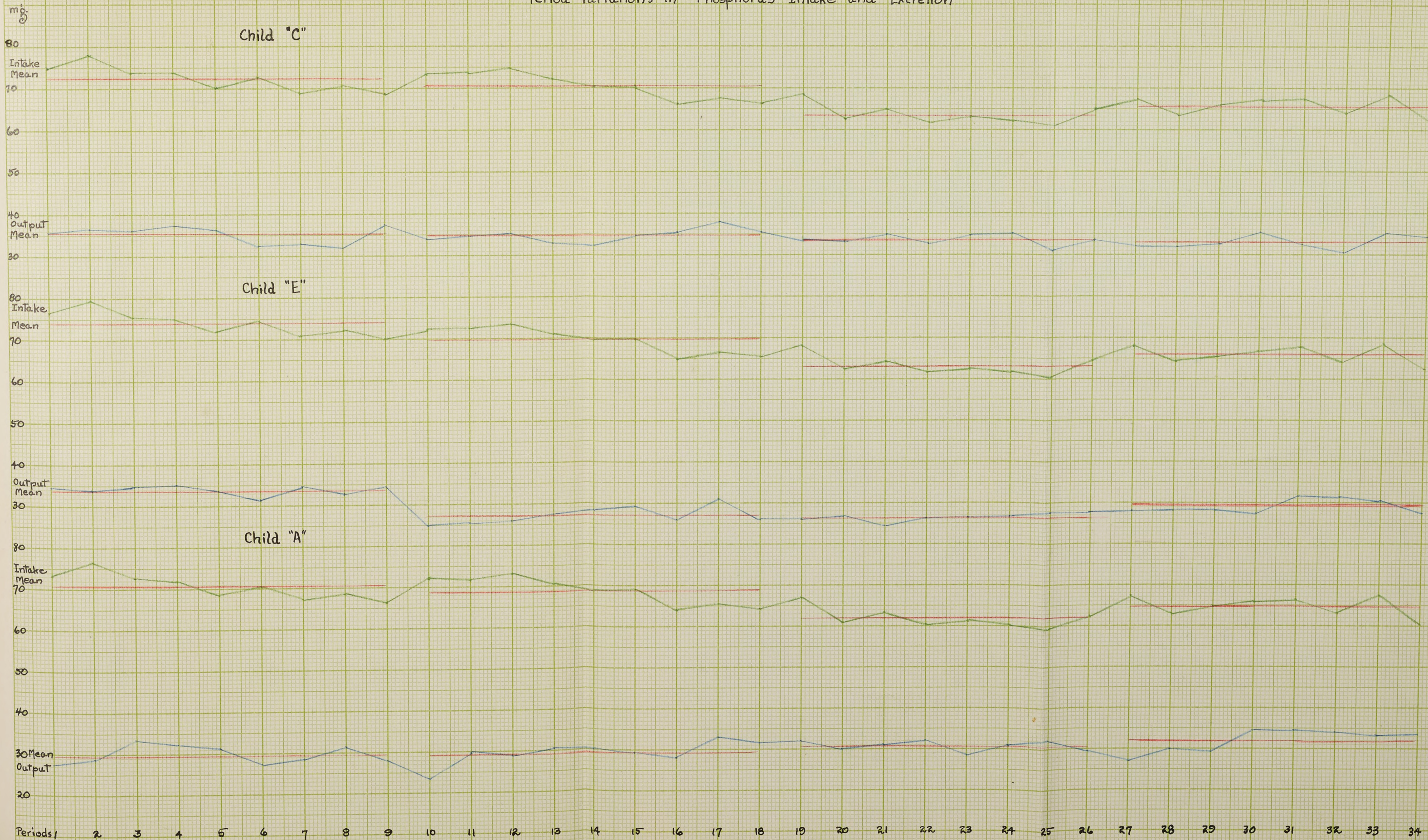
Through the entire study, the intake for each child shows a slight decline and then a rise during the last part when sugar supplemented the diet. C. excreted almost a constant amount of phosphorus, with a slight drop during the last part. E. had a different picture, as he made a definite drop in urinary phosphorus excretion during the second part when butterfat supplemented the diet and this excretion remained low throughout the study. A. showed a consistent increase in the phosphorus output as well as a gradual increase in the percentage of phosphorus eliminated. It would appear that during the cornstarch supplement there was a lowered intake of phosphorus but the same approximate amounts excreted.

The relationship of urinary phosphorus to intake was determined statistically by finding the correlation coefficient between the urinary phosphorus output and phosphorus intake. The statistical formula used was:

$$r_{yx} = \frac{\text{eddy} - \frac{\text{edx} \cdot \text{edy}}{n}}{\sqrt{\left[\text{ed}^2\text{x} - \frac{(\text{edx})^2}{n} \right] \left[\text{ed}^2\text{y} - \frac{(\text{edy})^2}{n} \right]}}$$

Graph I.

Period Variations in Phosphorus Intake and Excretion





This means that at 0.0 there is no relationship of one factor to the other, and as r_{yx} approaches ± 1.0 the relationship becomes significant as expressed and calculated by Fisher (8). These data show no significant difference from zero in any of the four parts of the study. The r_{yx} being +0.306, -0.095, +0.125, and -0.016 respectively for the constant diet, and when supplemented with filtered butterfat, cornstarch, or sugar.

Modifications of the diet seem to have altered the relation between phosphorus elimination and gain in weight (Table XVII). C. has made the lowest gain in weight and also excreted the highest amount of phosphorus per kilogram of body weight in all parts of the study except the last one when an adjustment of three periods is allowed. He is slightly under that of A. when a similar adjustment period is allowed. C. had a continuous gain in weight but was not consistent. He made his greatest gain in weight during the butterfat supplement as did the other two children.

A. made the most rapid gains in weight and was considerably above the average standards for her age. While on the constant diet, she made the greatest gain in weight with the lowest percentage of phosphorus excreted. The percent of phosphorus excreted continued to increase during the next two parts, but was only slightly lower during the last part if no adjustment period is allowed. This increase in the urinary phosphorus output may indicate that she received a higher ingestion of phosphorus due to the fact that she was overweight.

The gain in weight for E. was in between the other two children. He made the greatest gains during the butterfat and sugar supplements. The percentage of phosphorus eliminated dropped decidedly during the

Table XVII. Gains in Weight and Percentage of Phosphorus Excreted in the Urine.

Child	Periods	Constant		Butterfat Supplement		Periods		Cornstarch Supplement		Periods		Sugar Supplement	
		Gain in Weight	% Phos-phorus Excreted	Gain in Weight	% Phos-phorus Excreted			Gain in Weight	% Phos-phorus Excreted			Gain in Weight	% Phos-phorus Excreted
C	1-9	kg. 0.02	% 43.37	kg. 0.94	% 49.45	10-18		kg. 0.70	% 52.70	27-34		kg. 0.63	% 49.82
	5-9		48.50		51.69	14-18			53.27	30-34			51.22
E	1-9	0.19	45.58	1.03	39.34	10-18		0.72	42.05	27-34		0.81	44.25
	5-9		46.29		41.93	14-18			43.41	30-34			45.22
A	1-9	0.40	42.26	1.31	43.06	10-18		0.99	49.54	27-34		1.16	43.28
	5-9		42.90		46.03	14-18			50.19	30-34			52.32

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butterfat supplement, then raised to approximately the same amount during the starch and sugar supplements to what it was during the constant diet.

The data just presented follows rather closely the work of others. The amounts of phosphorus excreted in the urine when similar intakes are ingested, compare very closely with the results of Sherman and Hawley 1922 (17), Willard and Blunt 1927 (19), and Daniels and her associates in 1934 (6). The percentage of phosphorus excreted in the urine is also similar to that of the workers mentioned above.

SUMMARY

The data is from a long time study on metabolism of normal preschool children. The three children, C., E., and A., were 47, 50, and 57 months of age respectively at the beginning of the study.

These children were fed approximately the same amounts of phosphorus per kilogram of body weight for 34 consecutive three day periods. This diet was constant for 9 three day periods, then a supplement of filtered butterfat was added so as to increase the caloric intake twenty percent. This diet continued for the next 9 three day periods when a cornstarch supplement replaced the butterfat, and increased the calories twenty percent more than on constant diet. This diet was continued for 8 three day periods, when sugar replaced the cornstarch supplement in increasing the calories of the constant diet twenty percent.

The phosphorus intake shows during the study a slight decline during the butterfat and cornstarch supplements, being the lowest during the cornstarch supplement. Then a slight rise occurs during the sugar supplement.

All the children gained in weight with the greatest gain in weight during the period when butterfat supplements the diet.

There is definite indication that as the children gained in weight there was a greater percent of urinary phosphorus excreted.

The gain in height was fairly consistent for the three children with the exception of E., who made an excessive growth in height during the part when cornstarch supplemented the diet. During this part he

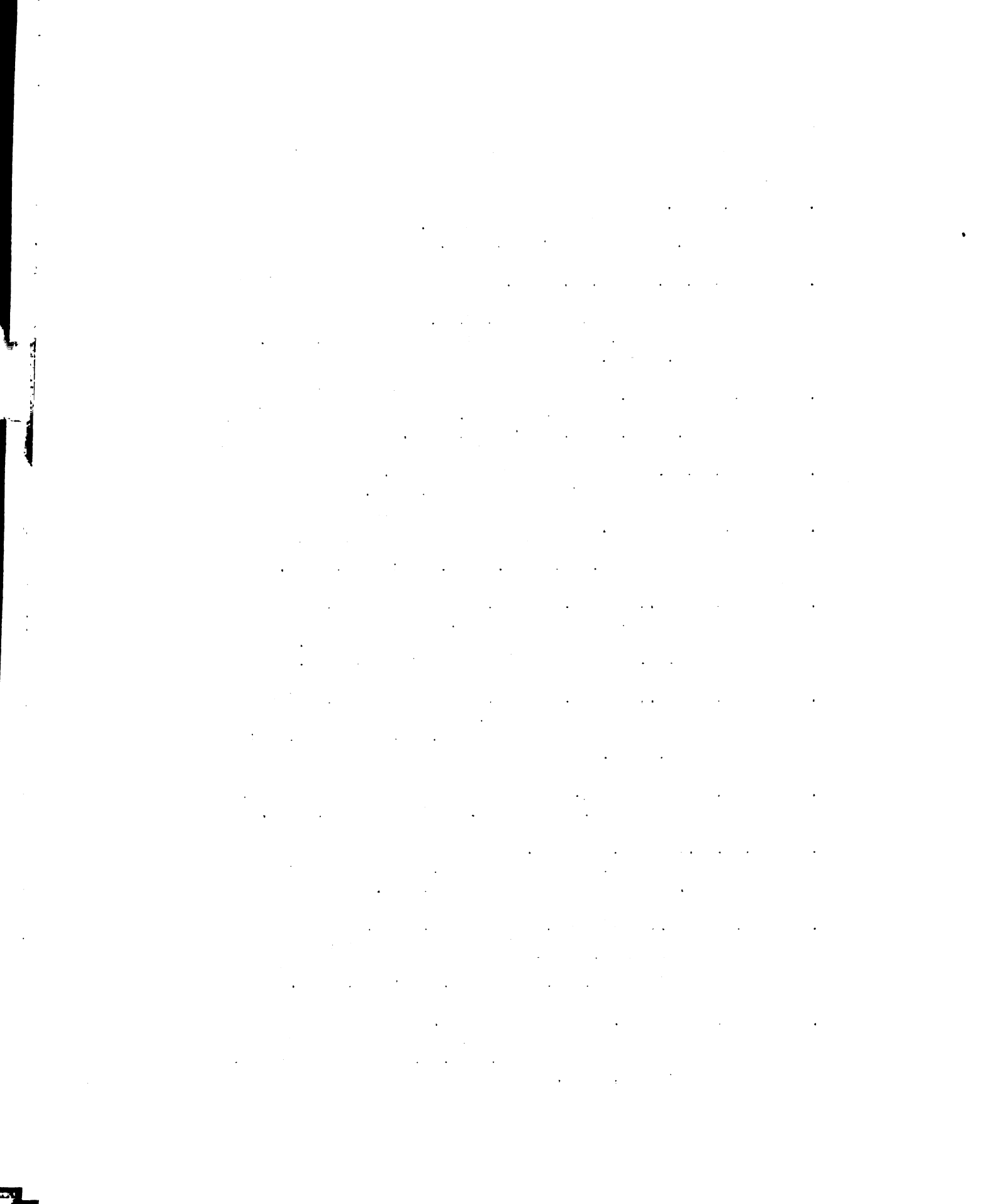
did not gain so much in weight and the percent of phosphorus excreted in the urine was lower than the other children.

The constancy of the urinary phosphorus excretion is quite striking even though there is an apparent lowered intake during the corn-starch supplement.

From the data secured in this study it would seem that the diet variations made no change in the utilization of phosphorus.

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