A STUDY OF THE
PHOSPHORUS REQUIREMENTS OF
NORMAL FOUR YEAR OLD CHILDREN

THESIS FOR THE DEGREE OF M. S.

Rena Klooster-Potts

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THESIS

Children - Nutrition

Phosphorus in the body
Total Phosphorus requirements
of — etc

Home economics

A STUDY

of the

PHOSPHORUS REQUIREMENTS

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NORMAL FOUR YEAR OLD CHILDREN

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THESIS

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THE PHOSPHORUS REQUIREMENTS of NORMAL FOUR-YEAR OLD CHILDREN

The first modern endeavor to determine the food needs of human beings took the form of dietary studies in which trained observers recorded the food eaten by individuals or groups of individuals when they instinctively followed the dictates of their own appetites. These findings were usually reduced to amounts of carbohydrate, fat and protein per person per day and were often evaluated by comparison with the types of work these individuals did. The carrying out of balance studies was the next step in determining the food needs of human beings. In balance studies the amount of a given foodstuff ingested minus the amount excreted in urine and feces gives the amount the body retains. From many such studies standards were finally established indicating in each case how much carbohydrate, fat, protein and the various minerals were needed to keep the body in a state of optimum nutrition. From these adult studies, the standards for children, as a rule, have been set more or less empirically.

In the literature we find very little experimental data on the phosphorus requirements of pre-school children. There is an abundance of material on how phosphorus is utilized by the body; as, inorganic phosphates, phospho-proteins, phospho-lipins and the phosphoric acid esters of carbohydrates. There is also a great deal of literature on the metabolism of phosphorus, especially in combination with calcium. The reason for this is that in rickets, a disease widely prevalent among both breast fed and artificially fed children, there is a lack of balance between calcium and phosphorus in the blood stream, resulting in an abnormal deposition of calcium phosphate in the bones. The emphasis has been placed upon calcium metabolism, rather than upon phosphorus metabolism, because dietary studies have revealed the fact that a large percentage of American children suffer from a deficiency of calcium in their diets. There is not usually a serious lack of phosphorus because of its close association with protein. Many studies have been made of the kind and amount of protein necessary to provide adequately for both maintenance and growth in the body of the child. Thus, it has come about, that phosphorus, because of its association with calcium and its combination with protein bearing foods, has lost its identity somewhat in the greater importance attached to a sufficient calcium supply and an adequate and complete protein ration to care for body needs.

There are but three studies available on the phosphorus needs of healthy pre-school children. In the balance study done by Sherman and Hawley (1) a series of four experiments were carried out on calcium and phosphorus retention in twelve normal children, ranging in age from three to thirteen years. The first study of the series was made to determine the calcium and phosphorus retention in relation to age. The children were on a normal mixed diet which contained 750 grams of milk per day for each child. This gave an average retention of .008 grams of phosphorus per kilogram of body weight per day. The second study was carried out with three of the twelve children as subjects to determine what daily allowance of milk would produce optimum storage of calcium in the growing child while the third and fourth experimenfs were performed to learn if the calcium of vegetables is as efficiently utilized as that of milk.

Of the group in the Sherman and Hawley study, there are three children who in either age or weight, approximate that of the children who are subjects of the present study. Their balance is given in the accompanying table which is adapted from Table 3 in the article by Sherman and Hawley.

Name	Age Yrs.	Mos.	Wt.Kg.	P.Intake	P.Output	Balance
M.O.	4	7	19.5	1.073 g	.916 g	+.157 g
A.B.	6		21.4	1.235 g	1.128 g	+.107 g
M.P.	6		19.1	.850 g	.744 g	+.106 g

Their phosphorus storage according to weight in grams per kilogram of body weight is given in the accompanying table adapted from Table 4 in the same article.

	Age			Grams per kilogram			
Name	Yr.Mo.	Wt.Kg.	Calories	Prot.	P.Intake	P.Output	Bal.
M.O.	4 7	19.5	78	2.8	.055	.047	+.008
A.B.	6	21.4	84	3.1	.058	.053	+.005
M.P.	6	19.1	78	2.6	.045	.039	+.006

These workers conclude from their observations that one gram each of calcium and phosphorus per day must be supplied to the growing child if he is to have sufficient retention for growth.

Hughina McKay of the Ohio Experiment Station (2) reports a dietary study on fifty-five normal, healthy children ranging in age from two to five years, twenty-five of whom lived in their own homes and thirty of whom lived in an orphanage. This study, based on the individual method of determining food intake was conducted for four consecutive days by workers trained in the method. These young women took records of the height, weight, activity, appetite and general condition of each child, as well as weighing and computing the value of the food each child ate in terms of protein, fat, carbohydrates and mineral content. Computed analysis of the amount of phosphorus these children were ingesting gave an average of 0.9744 grams per day for both groups with an average of 1.08554 grams for the home group and .88179 grams for the orphanage group.

Dr. Chi Che Wang and her associates (3) report a balance study on the "Minimum Requirement of Calcium and Phosphorus in Children". The ages of these eighteen children, with one exception, ranged between eight and twelve years. That one child is the only one in the group that belongs to the pre-school age and her phosphorus balance is given below as adapted from Table 2 in Dr. Wang's article. It is given in terms of phosphorus rather than as phosphorus pentoxide as originally given.

Name	Age	Wt.	P.Intake 24 hrs.	P.Intake per kg	Urine 24 hr	Feces 24 hr	Total 24 hrs.
A.J.	5	17.9	1.47	.082	.78	.596	1.37

Total Kg/24	Retention 24 hrs.	Kg/24	%
.076	.09 gms.	.005 g	6.3

These workers obtained a positive balance as long as the phosphorus ingested was as low as .034 grams per kilogram of body weight but found that there was a negative balance when the intake fell below this. Retention varied from .002 to .017 grams per kilogram of body weight. Dr. Wang and her associates conclude from their observations that an eight year old child, weighing 20 kilograms and living on a mixed diet should have a minimum of 1.58 grams of phosphorus pentoxide, or .68 grams of phosphorus daily.

Because of this lack of extensive information on the phosphorus retention of pre-school children, it was thought of value to conduct a metabolism study to learn if possible, something of their requirements for optimum retention.

PROCEDURE

In order to do a quantitative metabolism study on any of the essential factors in the diet, levels of food intake at which experimental work shall be done must first be decided. Usually there is a low level, just above maintenance, an average level, which permits of maintenance and some growth, and a high level, which may provide an excess for both maintenance and growth. Then a simple, adequate diet is planned that fulfills specifications so far as the particular foodstuff under investigation is concerned. For instance, if calcium levels were being considered, the diet planned would contain carbohydrate, fat, protein, phosphorus, iron and vitamines in amounts accepted as adequate for a child of given height, age and weight. The calcium content alone would be varied at each level in order to learn by balance studies at what level best retention was obtained. Of course, these variations in level influence in amount the other factors also. Including a large amount of milk to supply a high level of calcium while keeping the total calorie content constant, might result in a diet low in iron. This deficieny would then have to be made up by adding a source of iron sufficient to make the diet adequate in this respect. The diet to be used must be palatable and attractive and lend itself to variations to suit each level of intake. The problem is simpler if the same basic diet is used at each level. After the diet is planned, the p eriod of feeding follows with its attendant collection of excreta. Composite samples of the food eaten by the subjects are also preserved so that a chemical analysis may be performed. The results of this analysis give the actual value of the diet, and may be used for comparison with the calculated amounts. The excreta are analyzed to determine how much of the substance ingested was excreted. The difference between intake and output represents the amount retained by the body. Finally, when results from the various levels are determined, conclusions may be drawn concerning the level which supplies the optimum retention for maintenance and growth.

TABLE 1.

Subj.	Exp.	Sex	Age	Height (inches) sit	Height (inches) stand	Weight Kg.	Weight Var. from Normal ≠ Acc. to Height	Weight Var. from Normal ≠ Acc. to Age	Exp.	Caloric Intake Total 72 hr.	Caloric Intake Total 24 hr.	Caloric Intake Total Kg/24 hr.
J.B.	I	♂	4 yr 1 mo	24½	43.0	19.5	+4.6%	+15.4%	I	4785	1595	82
	II		4 yr 2 mo			19.8		16.2%	II	5115	1705	86
	III		4 yr 4 mo	24¾	43¼	20.2	+5.9%	15.8%	III	4869	1623	80
B.L.	I	♂	4 yr 4 mo	24½	43	19.3	+3.6%	+11.9%	I	4737	1579	82
	II		4 yr 5 mo			20.8		+18.3%	II	5115	1705	82
	III		4 yr 7 mo	24⅝	44¼	20.5	+1.5%	+15.1%	III	4953	1651	80
E.J.	I	♀	4 yr 8 mo	23½	41½	20.7	+16.4%	+15.9%	I	4797	1599	77
	II		4 yr 9 mo			21.4		+17.8%	II	5160	1720	80
	III		4 yr 11 mo	25.0	43.0	[illegible]	+16.2%	+18.5%	III	5169	1723	77

≠ Baldwin Wood Tables - American Child Health Association

≠ Holt Tales Tables - Sc. Nut. in Infancy and Childhood
McLean and Tales

This phosphorus balance study was carried out in conjunction with a protein-calorie study reported in another paper, hence the levels, low, medium and high, were more or less arbitrarily set, since phosphorus is so closely associated with protein in food. As the protein levels chosen were 2, 3, and 4 grams of protein per kilogram of body weight, the phosphorus content more or less automatically fell into the levels of approximately .96 grams, 1.34 grams and 1.51 grams of phosphorus daily per child.

Three healthy nursery school children of about the same age and size were selected for the study. They were two boys and a girl between four and five years of age. Their heights, weights, ages and caloric intake for each period are given in Table 1. Their meals for each level were carefully computed (4) and then prepared and served in a room especially set aside for the purpose. Between meals, the children attended the nursery school. A s usual, where excellent co-operation on the part of those in charge prevented any loss of excreta or any added intake of food throughout the three experimental periods. At night, the mothers took charge of their children, being equally careful to guard against added intake of food and loss of excreta.

TABLE 2.

DAILY MENUS

	Exp. I Approx. 2 gms. Pro/Kg	Exp. II	Exp. III
Breakfast	Orange Juice Farina Cream Sugar Buttered Toast Milk	Orange Juice Cream Wheat Milk for Cereal Sugar Buttered Toast Milk	Orange Juice Cream Wheat Milk for Cereal Sugar Buttered Toast Milk
10:30	Orange Juice Cod Liver Oil	Orange Juice Cod Liver Oil	Orange Juice Cod Liver Oil
Lunch	Lettuce Sandwiches Buttered Potatoes Scrambled Eggs Milk Peaches	Lettuce Sandwiches Buttered Potatoes Scrambled Eggs Milk Peaches	Lettuce and Cottage Cheese Sandwiches Potato } Potatoes baked with Meat } meat loaf Tomato Juice Milk Peaches
3:00 P.M.	Milk	Milk	Milk Peanut Butter Sandwiches
Supper	Creamed Carrots Thickened Tomato Juice Liver Extract Baked Custard	Buttered Carrots Tomato Juice Spinach Puree Milk Baked Custard	Buttered Carrots Scrambled Eggs Spinach Milk Baked Custard

On each level, there was a three-day preliminary period in which the children received the weighed diet, but no excreta was gathered. This was done in order to permit the children to get into the balance for that particular period so that there might be no "lag" from their previous diet reflected in the collection period. Urine and feces were collected for the last three days. Charcoal was used as a marker for the feces. This was given in capsule form before breakfast on the morning collection was begun, and again, at the close of the last meal.

On the last three days of each period, duplicate samples of the food the children ate were preserved for analysis. The purified substances such as sugar, cornstarch and filtered butter which were used in the dietary were not included in the samples for analysis for obvious reasons.

The menus for the three periods appear in Table 2. On the low-protein-low-phosphorus level, liver extract was used to bring to the accepted standard an otherwise low iron content. Whole wheat farina was used also, because of its increased amount of iron, but it was found that tiny particles of bran still in suspension in the feces after sulphuric acid digestion, interfered with the ease of analysis, so cream of wheat was substituted in the succeeding experimental periods.

During the second and third periods, when the protein and phosphorus content of the diets was higher, strained spinach was used instead of liver extract to bring the iron content up to normal. This proved to be a rather more desirable substitution because the children were accustomed to eating spinach and when served on their plates with potato and carrots, or potato and scrambled egg, their meal presented an attractive appearance, and the spinach was eaten quite automatically.

On the high level, half skimmed milk and half whole milk was used in order not to exceed a fat content of 35% in the diet. Finely ground beef from which the connective tissue was removed, cottage cheese and peanut butter were used to increase the protein and phosphorus content of this dietary. The children's individual variations in requirement during each period were provided by extra egg white and sugar.

The meals were varied within themselves. Sometimes the potatoes were creamed and the carrots buttered, and vice versa. Sometimes the tomato juice and liver extract were served in combination as a thickened hot soup, and at other times it was made into a cold drink,

TABLE 3.

PHOSPHORUS EXCRETION AND BALANCE FOR EACH PERIOD

Subj.	Wt.	Age	Phosphorus Intake			Phosphorus Output					Retention			
	Kg		gms 72 hr	gms 24 hr	gms Kg 24 hr	Urine gms 72 hr	Feces gms 72 hr	Total gms 72 hr	Total gms 24 hr	Total gms Kg 24 hr	gms 72 hr	gms 24 hr	gms Kg 24 hr	% Intake 24 hr
1st Period														
J.B.	19.5	4 yrs 1 mo	2.966	.988	.050	1.32	1.128	2.448	.816	.041	.517	.172	.008	17
B.L.	19.3	4 yrs 4 mo	2.966	.988	.051	1.539	.958	2.497	.832	.043	.468	.156	.008	15
E.J.	20.7	4 yrs 8 mo	2.970	.990	.047	1.687	1.148	2.835	.945	.045	.135	.045	.002	4.5
2nd Period														
J.B.	19.8	4 yrs 2 mo	3.713	1.237	.063	1.510	1.128	2.639	.879	.044	1.073	.357	.018	28
B.L.	20.8	4 yrs 5 mo	3.713	1.237	.060	1.629	1.176	2.805	.935	.045	.907	.302	.014	24
E.J.	21.4	4 yrs 9 mo	3.722	1.240	.058	1.834	1.262	3.089	1.029	.048	.633	.211	.010	17
3rd Period														
J.B.	20.2	4 yrs 4 mo	4.346	1.448	.071	1.812	1.206	3.018	1.006	.049	1.328	.442	.021	30
B.L.	20.5	4 yrs 7 mo	4.351	1.450	.070	1.834	1.262	3.096	1.032	.050	1.255	.418	.020	28
E.J.	22.2	4 yrs 11 mo	4.359	1.453	.065	1.925	1.332	3.257	1.085	.049	1.101	.367	.016	25

and the cornstarch used elsewhere in the diet. Occasionally the custard was baked and again it was cooked with some of the day's peaches cut into it, or the custard was made into "pink ice cream" which was always a welcome change. Weighed portions remained the same throughout each period. The s ame basic menu was used in all three experimental periods, but with variations to make possible increased protein and phosphorus.

Specific gravity, creatinine (5) and total acidity (6) determinations were made on the urine each day and the remainder made up into acid urine for further analysis. The feces were digested slowly for several days with ten percent sulphuric acid, heated over a low flame and then made up to volume for analysis. Phosphorus determinations were made on these by the Briggs' modification of the Bell-Doisy method. A ll analyses were done in triplicate. (7) Results of the fecal and urinary analyses for the three children for the three periods, appear in Table 3.

The duplicate samples of food taken for analysis were weighed, dried, weighed again, and then finely ground in a food grinder. To further insure a well mixed sample, a portion for each analysis was ground to

TABLE 4.

RESULTS OF ANALYSIS OF DAILY DIET

	Experiment I				Experiment II				Experiment III			
	1st Day	2nd Day	3rd Day	Ave. for 1 day	1st Day	2nd Day	3rd Day	Ave. for 1 day	1st Day	2nd Day	3rd Day	Ave. for 1 day
Wt. of Fresh Food	Gms. 1250	1250	1250	1250	1555	1555	1555	1555	1617	1617	1617	1617
% P Av. 6 Samples	.0784	.0803	.0787	.0791	.0791	.0804	.0794	.0796	.0899	.0898	.0893	.0896
Gms. P. per day	.9800	1.0037	.9837	.9887	1.2300	1.2502	1.2268	1.2377	1.4536	1.4520	1.4439	1.4488
Gms. P. 3 days				2.9661				3.7131				4.3464

TABLE 5.

COMPARISON OF CALCULATED AND ANALYSIS FIGURES

Exp.	Weight Portein		Calories		Weight Phosphorus	
I	gms. Calc.	gms. Anal.	Calc.	Anal.	gms. Calc.	gms. Anal.
J.B.	38	41.5	1608	1659	.9672	.9887
B.L.	38	41.5	1585	1643	.9672	.9887
E.J.	40	44.8	1605	1651	.9693	.9903
II						
J.B.	57.4	52.2	1605	1622	1.3435	1.2377
B.L.	57.4	52.2	1605	1622	1.3435	1.2377
E.J.	60	60.8	1620	1635	1.3477	1.2408
III						
J.B.	80.6	75.4	1623	1661	1.5118	1.4488
B.L.	82.4	78.8	1651	1668	1.5139	1.4504
E.J.	85.5	84.4	1723	1679	1.5174	1.4531

J. B. E. J. B. L.

powder in a mortar. This food was ashed at low heat, made into solution and analyzed for phosphorus by the same method used for urine and feces. Separate analyses were made of egg white, liver extract and cottage cheese. No figures for phosphorus analysis of liver extract or cottage cheese were obtainable from other sources. Results of the analysis of the three diets are found in Table 4 while a comparison of the figures for the calculated and analyzed amounts for each period appears in Table 5. Results of the analysis of egg white, liver extract and cottage cheese are given in Table 6.

DISCUSSION

The three children who were subjects in this balance study were all from business or professional homes. They had a background of good nutrition and health habits, so they were all three above height and weight for their age group. They were growing rapidly as will be seen by a comparison of their heights and weights at the beginning of the first experimental period with those at the beginning of the third period, three months later. (Table 1.) While B.L.'s basal requirement was the lowest during the first period, he

TABLE 6.

ANALYSIS OF SEPARATE FOOD SAMPLE

	Grams P. in 1 gram of Food
Liver Extract *	.0000407
Egg White	Period 1. - .000107 Period 2. - .000104 Period 3. - .000109
Cottage Cheese	.00033

* Grams Phosphorus in Extract from 1 gram Liver

TABLE 7.

RESULTS OF CALCULATION OF DAILY DIET (Rose Handbook)

	Experiment I	Experiment II	Experiment III
1. Total Wt. of fresh food	1250 grams	1555 grams	1617 grams
Minimum Individual Need			
Amt. of Protein	38.17 grams	57.44 grams	80.58 grams
Amt. of Fat	39.50	46.77	44.09
Amt. of Carbohydrate	155.19	142.29	143.29
Amt. of Phosphorus	.9672	1.3435	1.5118
Calories in Minimum Need	957.98	1219.85	1292.29
2. Additions to Minimum Need			
Sugar	35 grams	50 grams	40 grams
Butter	42 grams	12	14
Cod Liver Oil	5 grams	5	5
Corn Starch	16 grams	8	0
Extra Calories	627	385	331
Total Calories in Minimum portion	1584.58	1604.85	1623.29
Individual Additions			
J.B.	4 grams sugar extra Protein 38 grams Calories 1601	No extras Protein 57.44 grams Calories 1605	No extras Protein 80.58 Calories 1623
B.L.	No extras above minimum need Protein 38 grams Calories 1585	No extras above minimum need Protein 57.44 grams Calories 1605	15 gms. egg white extra 5 gms. sugar extra Protein 82.44 grams Calories 1651
E.J.	15 gms. egg white extra 2 gms. sugar extra Protein 40 grams Calories 1605	30 g. egg white extra Protein 60 grams Calories 1620	40 g. egg white extra 20 g. sugar extra Protein 85.5 grams Calories 1723

grew so rapidly, that during the second and third periods, J.B. who did not grow quite so rapidly represents the lowest basal need of the three children. He was a sturdy, healthy boy of very even disposition. B.L., on the other hand, was tall and more slender. He was active and of a nervous temperament with an appetite that needed more coaxing than the other two because his attention was more easily diverted to other things. E.J., the oldest child of the group, a girl, was probably the most active of the three. She is not of a nervous temperament, has a record of almost no illnesses and has seldom appeared tired after a day's hard play.

An attractive, adequate dietary was planned to meet the needs of the child with the lowest basal requirement. To this was added sugar, cornstarch, butter and cod liver oil to make up sufficient calories for the day's activities. The larger children's individual variations were met with added sugar or egg white. Just what these additions and variations were, are indicated in sections 2 and 3 of Table 7.

Comparatively little difficulty was experienced in getting the children to eat, in spite of the fact that at the high level, amounts seemed greater than they were in the habit of eating. Their meals were eaten at a nursery school table which was covered with a bright oilcloth cover. This added color and incidentally facilitated picking up any crumbs that might otherwise be lost. Pretty dishes were used and these helped to make the project lose some of its otherwise experimental atmosphere for the children. Their initials pencilled on the dishes with red wax pencil, seemed to please their budding sense of ownership for they never failed to look for them, nor to miss them if they failed to appear. Those who were conducting the study, ate with the children, using the same menu. When eating became a bit tedious for the children, a story sometimes helped to save the situation. Friendly competition in finishing the meal in order to get out to play contributed its bit also. In justice to the children themselves, it must be said that it was very much a point of honor with them not to do anything that, in their words, would "spoil the 'speriment".

Nevertheless, close supervision is required night and day throughout all experimental periods in order to be sure of accurate results. In addition to careful weighing and measuring of all foods, there is the necessity of seeing that nothing is lost, that each child eats all of his allotted portion, and that no additional foods are eaten. Likes and dislikes play a part in the ease with which this is accomplished. Appetites are not always alike. The excreta must be collected with no loss if the results are to be acceptable. To be sure that there has been no added food intake and no loss of excreta, one is dependent on the co-operation of the child, his mother, his instructors and any other care-takers he may have during the course of the experimental period. In spite of the watchful care of all concerned and the fact that the children wanted to make the work a success, one child in a moment of thoughtlessness did lose a sample of urine. That day's urine was discarded and the urine analysis for the day computed from an average of the other two days.

Besides the problem of seeing that there are no flaw's in the technic and execution of the experiment one must be prepared to meet and deal with the slight physical difficulties such as colds, infections or digestive disturbances which sometimes develop so easily. J.B. and B.L. both had colds during the preliminary part of the first period but they were given an abundance of fluids and kept away from the other children in the nursery school so that by the time the collection period began, they were well. During the collection period of the second experiment, B.L. had a slight cold, and J.B. contracted a severe cold, which, however, did not keep him from completing the period.

During this period, also, there was a disturbing amount of constipation in spite of the fact that strained spinach had replaced the liver extract of the previous period. These three children were all trained in regular habits of elimination and deviation from that program had a bad psychic effect as well as perhaps an undesirable physical one if there can be said to be an relationship between the colds and the constipation of this period. It was found necessary to relieve B.L.'s discomfort by an enema during the preliminary period of this second experiment. E.J. in taking what may have been too strenuous exercises soon after supper in order to bring about a bowel movement, lost her supper entirely. Fortunately these incidents occurred before the collection period began. The difficulty was anticipated during the third period when a higher protein and phosphorus level was to be fed, by giving the children mineral oil on the first two mornings of the preliminary period. This gave most satisfactory results so that no difficulty was experienced during the remainder of the period.

When results are gathered in such a study, one finds with certain expected returns, certain unexpected deviations from what is considered normal. The analysis for phosphorus in the food of the first period was higher than the figures given by Rose. With a calculated average per day of .9672 grams of phosphorus, our analysis gave an average content of .9887 grams of phosphorus per day. During the second and third periods, on the contrary, our analysis for phosphorus ran lower than the calculated amount. As against a calculated 1.3435 grams of phosphorus per day in the food of the second period our analysis gave 1.2377 grams per day, and during the third period, calculated figures gave a phosphorus content of 1.5118 grams per day while our analysis gave only 1.4488 grams per day. This is disconcerting until it is remembered that the published figures

TABLE 8.

SUMMARY OF PHOSPHORUS BALANCE FOR EACH CHILD

Subj.	Period	Phosphorus Intake			Phosphorus Output			Retention			
		gms 72 hr	gms 24 hr	gms Kg.24 hr	gms 72 hr	gms 24 hr	gms Kg.24 hr	gms 72 hr	gms 24 hr	gms Kg.24 hr	%
J.B.	I	2.9661	.9887	.050	2.4484	.8161	.041	.5177	.1726	.008	17
	II	3.7131	1.2377	.063	2.6395	.8798	.044	1.0736	.3578	.018	28
	III	4.3464	1.4488	.071	3.0182	1.0060	.049	1.3282	.4427	.021	30
B.L.	I	2.9661	.9887	.051	2.4978	.8326	.043	.4683	.1561	.008	15
	II	3.7131	1.2377	.060	2.8053	.9351	.045	.9078	.3026	.014	24
	III	4.3512	1.4504	.070	3.0962	1.0320	.050	1.2550	.4183	.020	28
E.J.	I	2.9709	.9903	.047	2.8359	.9453	.045	.1350	.0450	.002	45
	II	3.7224	1.2408	.058	3.0890	1.0296	.048	.6334	.2111	.010	17
	III	4.3593	1.4531	.065	3.2575	1.0858	.049	1.1018	.3673	.016	25

are the average of many analyses. It is of interest to note that the analysis of egg white showed a somewhat lower content of phosphorus, also than published figures indicate. Rose gives a phosphorus content of .00014 grams per gram of egg white. Our analyses showed an average phosphorus content of .000107, .000104, and .000109 respectively for the three periods. This accounts in part at least, for the discrepancy between calculated phosphorus content and the analyzed phosphorus content of the diets of the last two periods. While in the diet of the first period, there were only thirty grams of egg white used, in the second period, there were sixty grams used, and in the third period, seventy grams.

It will be observed from a study of Table 8, that there are variations in the rate of phosphorus metabolism in the three children. They are alike in that the urinary phosphorus in every case is greater than the fecal phosphorus, a fact observed with one exception by Dr. Wang and her associates (3) in their balance study on older children. The children also show an increasing retention as well as an increasing total excretion of phosphorus with each increase in food phosphorus. J.B. and B.L. show a more constant increase in retention and excretion for each period and a more economical use of phosphorus at the low level than did E.J. However, B.L. shows an interesting variation in the fecal phosphorus. For the first period, it was materially lower than that of either of the other two children and lower also comparatively than his own excretion at the succeeding levels. Bloom (8) finds increased fecal excretion of calcium and phosphorus in diets high in spinach and Ascham (9) reports high fecal excretion of calcium and phosphorus in the presence of cellulose flour and agar in the diet. If the converse of this is true, that diets low in fibre encourage greater retention of these elements, B.L.'s comparatively low fecal phosphorus excretion might be explained providing it was true also of the other periods and the other children as well. But, inasmuch as the diet in this respect was controlled and the experimental period passed off uneventfully, except for the sluggish elimination and the colds, there is no explanation to offer for this except to consider it a chance variation in output and a further corroboration of the findings of Sherman and Hawley who found "large variations among the individual children" (1). They also found that the storage of phosphorus in their children averaged .008 grams per kilogram of body weight and that at the age of 3 - 8 years, the storage of phosphorus was about .01 grams per kilo of body weight per day, continuing at nearly this rate throughout the following years of rapid growth and development. Our results at the low level in Table 8 bear an interesting similarity to the findings of Sherman and Hawley and to those of Dr. Wang in the tables adapted from theirs in the early part of this paper.

E.J. who had a weight of 20.7 kilograms at the beginning of the first experimental period and a weight of 22.2 kilograms three months later, at the beginning of the third period was comparatively the least economical of her phosphorus intake at all levels although percentage retention increases with each level. She is a very active child and has been described as "bursting at the seams" with energy. Blatherwick, Bell and Hill (10) corroborate the findings of Embden and Grafe that activity increases urinary phosphorus excretion. Highly active children excrete more phosphorus in the urine than do phlegmatic children. One child may run faster or play harder than another child. His results will differ from those of the quieter child of approximately the same age and weight. Activity in children is hard to control. Since increased muscular activity increases phosphorus excretion, probably her increased amount of metabolizing body cells and increased activity account for her greater excretion of phosphorus. The food of the first period with an analyzed phosphorus value of .9887 grams per day gave her but .002 grams of phosphorus storage per kilogram of body weight. It would seem evident from these findings that low levels of phosphorus intake are not safe for optimum development particularly of superactive children.

A further study of Table 8 reveals the fact that at the medium level with a phosphorus intake of 1.2 grams per day, there was a retention of .018 grams per kilogram for J.B., .014 grams per kilogram for B.L. and .010 grams per kilogram for B.J. This level of phosphorus intake evidently provides a margin for retention which is entirely safe for the average normal, healthy child. There is no particular reason why the child's retention and growth need to be crowded inasmuch as he has 18 - 21 years in which to attain physical maturity and physical and mental maturity need to keep pace with each other.

Maximum retention however, was obtained at the high level of phosphorus intake. With an analyzed phosphorus intake of 1.4 grams per day, retention rose to .021 grams per kilogram for J.B., .020 grams per kilogram for B.L. and .016 grams per kilogram for E.J. From the standpoint of retention per kilogram alone, a high intake of phosphorus would seem to be recommended for active, normal children. There are deterrents to that conclusion, however. A daily phosphorus intake of 1.4 grams might be accompanied by a protein content of about four grams per kilogram of body weight. We found this amount of protein most difficult of the three levels to feed. Apparently such a large proportion of protein, cutting down as it does the amount of fresh fruits and vegetables used, palls on the appetite of children. This large proportion of protein would also give the kidneys a maximum amount of work to do throughout the growing years and while it is not entirely proved that a high protein content in the diet over a long period of time injures the kidneys, we know it does cause an enlargement of the kidneys which is an end result of doubtful desirability.

In addition there is the economic phase of the question. Protein foods are always our most expensive foods. If good retention and growth can be secured on three grams of protein and 1.2 grams of phosphorus daily, it would appear to be poor economic judgment to increase costs for the average householder by advising higher levels of protein and phosphorus intake. In practical support of the theory that very high levels of protein and phosphorus intake are not needed by the growing child, we recall that the children who were subjects of this study were all well above the average for their age and none of them was accustomed to more than three grams of protein per kilogram.

Only for the superactive child would higher levels of phosphorus intake seem to be indicated. While in general, phosphorus excretion parallels somewhat nitrogen excretion, they may be independent of each other entirely as observed by Bodansky (11) Sumner (12) Bronson (13) and Blatherwick, Bell and Hill (10). The last named authors believe that the rate of phosphorus excretion is influenced largely by carbohydrate metabolism. The formation of hexose phosphate is a stage in the metabolism of glucose and these workers found on giving insulin to normal individuals that there was a marked decrease in phosphorus both in the blood and urine during the accompanying hypoglycemia. So in periods of increased muscular activity an increased amount of glucose is used, the oxidation of which results in phosphorus being liberated, carried to the blood and excreted in the urine as phosphate. It would be of interest to conduct phosphorus balance studies on children using a given dietary and varying the amount of exercise taken by the children to learn to just what extent muscular activity influences phosphorus excretion.

Meanwhile, since superactive children seem to be less provident of their phosphorus intake, higher levels of food phosphorus might be attained by using whole grains and breads rather than the refined type, since whole grains contain a large percentage of phosphorus. In so doing, the protein content of the diet would not be materially raised while inaddition to the increased phosphorus content in the whole grain cereals there is an increased iron content as well as a value accruing from the ingestion of bulk forming foods which aid in maintaining regular elimination.

CONCLUSION

1. That the discrepancy between calculated and analyzed figures for food phosphorus in all three experimental periods may be accounted for on the basis of averages.

2. The standard of 1 gram of phosphorus per day per child is conservative and allows no great margin for retention in average, active, healthy children.

3. A medium level of phosphorus intake (1.2 grams daily) probably provides a sufficient margin for retention in average, active, healthy children.

4. Children who are growing rapidly and are particularly active probably require a high phosphorus intake rather than an average one because of the greater amount of phosphorus used in the oxidation of glucose.

5. For children on a high phosphorus intake, care must be taken to see that some of the phosphorus is obtained from whole grains rather than permitting the diet to be too high in protein through out the long years of the growing period. The reasons for this are:

   a. Long continued high protein feeding is of doubtful physiological value.

b. Difficulty of feeding a continued high protein diet.

c. Expensive for the average householder.

6. Studies controlling the activity of children need to be carried out to determine if possible how greatly activity influences the excretion of phosphorus.

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