THE CALORIE BALANCES OF PRE-SCHOOL CHILDREN AS AFFECTED BY A CONSTANT DIET AND BY AN INCREASE IN THE PROTEIN CONTENT OF THE DIET

Thesis for the Degree of M. S.

Jeanne Martin Voorhees

1936

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THESIS

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THE FOUR CHILDREN

From left to right: J.H., V.B., E.C. and C.[illegible].

THE FOUR CHILDREN

From left to right: J.H., V.B., E.C. and C.B.

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THE CALORIE BALANCES OF PRE-SCHOOL CHILDREN AS AFFECTED BY A CONSTANT DIET AND BY AN INCREASE IN THE PROTEIN CONTENT OF THE DIET

INTRODUCTION

Since the caloric requirements of pre-school children have interested investigators for many years, children have served as subjects for numerous dietary studies. The early German investigators, as well as the later scientists, actually analyzed the food for calories in a few of these studies, but in the majority of the cases they calculated the values from food composition tables. The investigators did not analyze the excreta in these dietary studies; thus they did not measure the calories available for the various bodily processes. Nevertheless, these results have in a large degree furnished the basis for determining the caloric requirements of pre-school children.

Although information concerning the caloric balances of pre-school children is meager, a few studies have been made both in Germany and in this country. The majority of the subjects were greatly under-nourished or very much overweight; therefore these studies did not give results for normal children as compared with the standards of today.

Even if there are a few results for normal children, they do not fully determine all the factors which affect the caloric utilization.

The main object of the present study was to investigate some of the factors which influence the caloric utilization of pre-school children. The study determined, first, the influence of a constant diet having a fixed caloric intake on the calorie utilization, second, the effect of an increase in the protein content of the diet, and, third, the variation in the reaction of individual children.

REVIEW OF THE LITERATURE

Early German workers did the first studies of caloric requirements and they prepared standards for children of all ages. The value of these results lies in their historic interest rather than in their information. There are several reasons for this. The technique was inaccurate, chiefly because scientific methods of analysis had not yet been perfected. There was a small variety of implements to work with, and those that were available were not as carefully calibrated as those used today. Thus the chemical technique did not give as correct results as that now available, although it was probably excellent for that time. Then, too, the data obtained was limited. In many instances the periods were short and the entire experiment extended over an insufficient number of days to show the total range in fluctuations. Often the number of subjects observed was not large enough for comparisons or for definite conclusions to be made. According to the present height-weight-age standards many of these subjects were under-nourished, although some were overweight, and the majority of them were typical institution children.

Table 1 presents in chronological order, along with other data, the data on caloric intakes (as quoted by Holt and Fales (18)) which a number of the early German authors reported. In 1881 Uffelmann, one of these workers, reported a study on his own four boys. The eldest and the youngest were slightly under-weight, while the other two were very much below standard. Their caloric intake ranged from 88 calories per kilogram of body weight at one year of age to 68 at five years. Hasse calculated the caloric intake of six girls from 2 to 11 years of age, four being of the preschool age. Two were underweight children; of these a two-year-old consumed 120 calories per kilo, and a five-year-old 90 calories. On the other hand the other two were three-year-old overweight girls and they used 77 and 81 calories per kilo. Of the early results, Camerer's standards are most widely quoted. He obtained his results from the food consumption of his own children and grand-children, practically

Table 1

Caloric Intakes of Preschool Children as

Reported in the Literature

	Av. for Boys	Age of boys - years					Av. for Girls	Age of girls - years				
		2	3	4	5	6		2	3	4	5	6
	cal/kg	cal/kg	cal/kg	cal/kg	cal/kg	cal/kg	cal/kg	cal/kg	cal/kg	cal/kg	cal/kg	cal/kg
Uffelmann		80	73	71	68							
Hasse								102	77&81		90	
Camerer		80	78	75	84	77		80	78	75	70	67
Herbst		90		87								
Steffen*		99	105	125	114	103						
Locke*		94		82								
Gillett		90	83	79	77	75		93	83	79	73	71
Lusk - boys												
Quiet		97	90	88	79	78						
Active		129	117	116	105	105						
Very active		193	177	175	158	158						
Holt & Fales		93	88	84	87	80		94	87	82	78	76
Tigerstedt*					73-114							
Goodhue*	85											
Messenger			71.5	77.0					72.2	79.2	59.3	
Jones				91.7	96.6				81.5	77		
Winters												
Amer	77.60						72.54					
Negro	80.16						72.49					
Mexican	71.14						66.75					
Sherman*		80-90	80-90	80-90	80-90	70-80						
Bray	82		74*	81*	77*		75					

*Boys and Girls averaged together.

all of whom were underweight. For boys he allowed 89 calories per kilogram of body weight at one year of age and decreased the value to 75 calories at four years. After the age of five the per kilogram allowance for both sexes rapidly and steadily decreased until at ages over 15 it was only a little over the basal requirements as determined later by Benedict and Talbot. Baginsky reported data from several children who were convalescent from various diseases. With but one exception the children were very much undernourished. Thus, the values were for the most part high per kilogram of body weight. Of the six children whom Herbst observed only two boys aged two and four were of pre-school age. The youngest, who was considerably overweight, consumed 90 calories per kilo, and the normal child 87. In 1899, Steffin reported values which were higher than any other scientist had advocated. He thought that children needed over 100 calories per kilo for the entire pre-school period. Later, Locke averaged the values found by Uffelmann, Hasse, Steffin, Herbst, Camerer, and other German workers and from these results compiled a table. He found that the average calorie intake for a child two years old was 94 calories per kilogram of body weight, and for a four-year-old, 82 calories.

Before the above miscellaneous material, even the standards of Locke, could be used to estimate the food needs of large groups of children it was necessary to gather it together, organize it, and compile a simple table. Therefore, Atwater (1) surveyed the dietary studies made in this and foreign countries and deduced general factors in terms of calories per man per day. The consumption of an average 70 kilogram man doing moderate work was 100 grams of protein and 3000 calories. To this amount he gave the value of 1.0 and to children he assigned fractional portions (Table 2). These he used to calculate the food needs of children.

Table 2

Atwater and Inter-Allied Standards

Child	Age	Atwater	Inter-Allied
	0-2	0.3	0.5
	2-6	0.4	0.5
	6-10	0.5	0.7
Boy	10-12	0.6	0.83
Girl	10-14	0.6	0.83
Boy	12-14	0.8	0.83
Boy	14-16	0.9	1.00
Girl	14-16	0.7	0.83
Man		1.0*	1.0*
Woman		0.8	0.83
Heavy muscular work			1.20

*This unit value of 1.0 was equal to 100 grams of protein and 3000 calories.

The New York Association for Improving Conditions of the Poor questioned whether the allowances for the food requirement of children as expressed in terms of man as a unit were adequate. Therefore Lucy Gillett studied 563 well-nourished children between the ages of two and seventeen (13). She made 223 dietary observations when the subjects ate a freely chosen diet; conducted 131 metabolism experiments and 209 respiration tests. She reported that results of the metabolism and the respiratory experiments were comparable with those of the dietary observation. She also found that it was necessary to make a distinction in the total caloric requirements for boys and girls after the third year, and, furthermore, if the Atwater Standards were used there should be a range of from 300 to 600 calories above the standard for each age to allow for individual variation. Although her work was thorough she did not have enough material for each age group to make adequate standards of her own. She did, however, report standards (Table 1) determined by averaging her own results with those of previous workers.

In 1918, after Gillett had pointed out the errors in the Atwater standard, the Inter-Allied Food Commission revised and improved the earlier standard in order to be able to estimate the food needs of the nation during the war. The Inter-Allied Standard left the calorie allowance for men the same, but increased that for women and for all children. (Table 2).

Lusk (22) took as his foundation for the calorie requirements the basal metabolic needs and estimated over and above this the hypothetical number of calories for various degrees of activity. He allowed an increase of 50 per cent for a quiet boy, 100 per cent for an active boy, and 200 per cent for a very active boy.

Although some of the above standards were suitable for estimating the food needs of large groups, none were adequate for determining the calorie intakes of small groups, because there was not enough data for children of various ages. Therefore Holt and Fales (18) obtained the dietary records of 100 children from 1 to 16 years of age who were healthy, well cared for, and normal as to digestion. They kept an exact record of the food intake of each child for four days. The study included five to twelve observations for each child up to the age of eleven, and from these they determined definite standards of total caloric intake for each year of age for both boys and girls. In calculating these standards they considered the calories needed to provide for basal requirements, growth, muscular activity and the loss in the excreta. Since they used the factors 4, 9, and 4 for estimating calories from protein, fat, and carbohydrate, which care for loss in the excreta, they allowed the metabolic waste twice. Thus, their allowance for loss in the excreta was higher than it should have been.

These various standards give an idea of the number of calories per kilogram of body weight required by children to enable them to grow into normal healthy men and women. Other work was needed, however, to make the standards for preschool children more dependable. Thus, there have been a number of other studies on children of this age (Table 1).

E. H. Starling (31) quotes Carl Tiyerstedt who reported

47 observations on children ranging in age from four to 14 years. The wide range of calories consumed was the most striking characteristic. In four observations on children in their fifth year he reported a range of from 73 to 114 calories per kilo and in five observations for the seventh year a range of from 71 to 102 (Table 1).

While at the University of Chicago, Goodhue (15) observed 31 superior children from two to six years of age. She computed the caloric content of the cooked food consumed on the basis of the raw foods used in the recipe and employed factors derived from the percentage composition tables made by Atwater and Bryant. A six-year-old boy consumed the maximum number of calories, 2761, and a three-year-old the minimum, or 1214 calories. The children had an average total intake of 1644 calories or 85 calories and 3 grams of protein for each kilogram of body weight.

Messenger (24) made a dietary study on 13 nursery school children from three to five years of age. She found it necessary to have the mother keep the records of the morning and of the night meals at home and she recorded the food intake of the mid-day meal at the nursery school. With the help of assistants she weighed the food for the noon lunch on a Chatillon balance and recorded the weights. Then each child chose his or her own plate of food. If desired the children selected extra sandwiches and milk. Either the author or an assistant weighed all uneaten food back and deducted it from the original amount served. They kept records for 24 days and divided the time into periods of six days duration and selected for each child that period most nearly average for the entire study and for this single period calculated the calories from Rose's tables. By this method the average total calorie intake for the group ranged from 1153 to 1640 calories.

In their homes, Jones (20) studied four nursery children. She weighed all food consumed and calculated the calorie content from the figures of Peterson and Hoppert for cooked vegetables and reckoned the ash of canned fruit as three-quarters that of the fresh product. The average caloric intake per kilogram ranged from 77 calories for a four-year-old girl to 96.6 calories for a five-year-old boy. The results compared favorably with the standards of various authors excluding those of Lusk which were much higher.

At a Chicago orphan asylum, White (37) observed the diets of children of a number of different nationalities. For the complete dietary study 10 healthy children from three to six years of age served as subjects for three weeks excluding all Saturdays and Sundays. She weighed or measured the food and computed the calories from Sherman and Rose's tables. Average figures for the entire study show that the group consumed 1704 calories daily which was more than any other author had reported in dietary studies. In a table, White quoted the average intake, 1285 calories, reported by

Imlay (19) in her thesis.

McClelland (23) studied 42 separate daily calorie intakes of two nursery school subjects and paid special attention to the length of time of sampling periods in order to determine a reliable period for dietary observations. She weighed all food as eaten and saved aliquot samples and analyzed them for caloric content. Then she grouped these daily intakes in all possible 3, 4, 5, and 7-day periods and in 2, 3, or 4-week intervals. Although the intake varied greatly from day to day it rarely fluctuated in the same direction on two consecutive days. The average intake of the two children was 1309 calories. Her data seemed to indicate that chance selection in a short time study may obscure the wide variations characteristic of the voluntary food intakes of children. Since the mean and the medium were nearly equal, and the number of days above and below each were about the same, the 42 day period constituted an adequate sample. The four and five-day periods were no more reliable than the three-day periods. Consecutive days gave a more uniform and consistent sample of intake than scattered days so that omission of one day in a short time study might make the results fallacious. In the seven-day periods one out of every 12 deviated more than 10 per cent from the average, but none varied more than 15 per cent. In the 14, 21, and 28-day periods all varied within five per cent from the average. Thus a dietary study should extend over an interval of not less than two weeks.

In 1931 Winters (38) reported an interesting comparison of the calorie intake of 50 American, 50 Negro and 75 Mexican children. She calculated food intakes and grouped the data according to age, sex and nationality. These groups were fairly evenly divided as to sex but age was unevenly distributed; therefore the figures are only indicative. As the child grew older the caloric intake per unit of weight decreased. She considered that an intake 10 per cent below Holt and Fale's standard was inadequate. On this basis 52 per cent of the American children, 62 per cent of the Negro and 66 per cent of the Mexican received daily an inadequate number of calories. A large percentage of the children also had the necessary food constituents other than calories in amounts too small to insure an adequate diet.

Through a period of years Bray and others (8) accumulated data on the food intake of nursery school children. The subjects, 8 boys and 12 girls, varied in age from 33 to 61 months. The authors weighed an exact duplicate of each day's diet and determined the caloric values with the oxy-calorimeter and also by calculations. The difference between the analyzed and calculated values of the composition of the diets varied greatly, from plus 35.4 to -27.3 per cent, although the coefficient of correlation between the two was fairly high, 0.841. They also found marked variations in analyzed intake, ranging from 879 to 2422 calories per day (Table 3) with an average of 1399 or 77 calories per kilogram of body weight. Table 1 shows that these average results per kilo are comparable with those reported by other workers.

Table 3

A Rearranged Portion of Bray's Table 3

Age in Months	Number of Children	Calories			
		Total		Per Kilogram	
		average	range	average	range
30-41	19	1260	879-1691	74	53-100
42-53	26	1440	1081-2422	81	58-128
54-65	15	1526	919-2215	77	54-96
	24 boys	1460		82	
	36 girls	1367		75	
	60 total	1404		78	

Although these dietary studies have given much information concerning the food consumption of children, they have not shown the number of calories of the food ingested which were utilized and those which were excreted. There are only two calorie balance studies, that of Muller (18) and that of Wang and her associates (34, 35, and 36) available for comparison with the data presented later in this experiment; therefore, the author rearranged the results for normal preschool children and made some additional calculations. Tables 4 and 5 give the results as thus organized.

Muller conducted an extensive experiment on 23 boys and 9 girls from two to six years old. He collected composite samples of food, feces, and urine for each child during

Table 4

Rearranged Portions of Wang's Tables

Total Balance

Child	Sex	Intake	Caloric Output						Absorption		Retention	
			Total		Feces		Urine					
		calories	calories	%	calories	%	calories	%	calories	%	calories	%
H.D.	M	1267	104	8.2	52	4.1	52	4.1	1215	96	1163	92
E.B.	F	1674	181	10.8	124	7.4	57	3.4	1550	93	1493	89
A.Ge	F	2192	128	5.8	80	3.6	48	2.2	2112	96	2064	94
E.S.	F	1046	87	8.3	36	3.4	51	4.9	1010	97	959	92
H.P.	F	1233	87	7.1	53	4.3	34	2.8	1180	96	1146	93
A.Ge	F	1661	112	6.7	80	4.8	32	1.9	1581	95	1549	93

Table 5

Rearranged Portions of Wang's and of Muller's Tables

Balance per Kilogram of Body Weight

Child	Sex	Age	Weight	Intake		Output			Absorption	Retention
				Protein	Calories	Total	Feces	Urine		
Wang		Years	Kilograms	Gms/kg.	Cal/kg	Cal/kg	Cal/kg	Cal/kg	Cal/kg	Cal/kg
H.D.	M	5	13.9 Normal		91.2	7.4	3.7	3.7	87.5	83.8
E.B.	F	5	15.8 5.4% under		106.0	11.5	7.9	3.6	98.1	94.5
A.Ge	F	5	17.9 Normal	4.3	122.4	7.1	4.4	2.7	118.0	115.3
E.S	F	4	13.7 11% under	4.3	76.3	6.3	2.6	3.7	73.7	70.0
H.P	F	4	16.5 Normal	1.3-2.6	74.7	5.3	3.2	2.1	71.5	69.4
A.Ge	F	5	17.1 Normal	2.2	97.2	6.6	4.7	1.9	92.5	90.6
Muller average figures					104.0	10.5	5.9	4.6	98.1	93.5

a six-day period and analyzed the three samples in a bomb calorimeter. The children consumed an average of 104 calories per kilogram of body weight. The boys used 15 calories per kilo more than the girls who were slightly less underweight than the boys. Daily, the children excreted an average of 5.9 calories per kilogram of body weight in the feces, and 4.6 in the urine. This was an average loss of from 8 to 14 per cent of the total calorie intake. For the group, the average absorption was 98.1 and the average retention 93.5 calories.

Wang and her assistants conducted many metabolic experiments which included caloric balance studies. These latter they reported in three papers on calories. Although the majority of the subjects were undernourished the controls were normal. Wang et al calculated the calorie intake from tables by Rose and determined the output in the feces and the urine in a bomb calorimeter. For the first study (34) they used subjects over 8 years of age; consequently the results were not comparable with those reported in this paper. In the second study (35), Wang planned two diets which were similar in calorie content, and which were to supply two and four grams of protein per kilogram of body weight respectively. Some children refused to eat all the food served and the analyzed nitrogen content was higher than the calculated; therefore the number of calories in the high protein diet was greater than in the low. The calorie intakes for the normal pre-school children on the medium diet were 74.7 and 97.2 calories for a four and for a five-year-old girl. They retained 69.4 and 90.6 calories respectively. On the high protein diet a different four-year-old consumed 76.3 calories and retained 70.0, while the same five-year-old girl consumed 122.4 and retained 115.3 calories. Tables 4 and 5 give the complete data for all the pre-school subjects reported.

From this study Wang et al drew several general conclusions. The low protein diet gave a higher percentage utilization of calories than the higher level. In all groups the children had a greater calorie loss in both urine and feces on the high protein diet. The increased calorie value of the urine was due to the higher content of nitrogenous substances such as urea and uric acid, and the increased calorie value of the feces to a larger amount of indigestible connective tissue and to the larger caloric intake on the high protein diet.

In a third study (36) Wang and her associates observed twelve children as they gained in weight. Results confirmed the earlier findings, that the absorption of the undernourished children was equal to that of children normal in weight and that it varied directly with the intake.

Sherman (29) believed that the standards for the food consumption of children were not suited to short time studies on small groups of children. Practically all of the early standards, including those of Locke, were determined almost entirely from data on under-nourished children. Even the later ones by Gillet and those by Holt and Hales which included some studies on normal children were greatly influenced by the results from underweight subjects. He thought it dangerous to use the standards of Atwater for estimating the dietary needs of a family including children, because of the wide individual variation in the food requirement of a man according to his occupation and his nationality. Recent dietary studies had contributed some valuable information concerning the wide range from day to day in calorie intake for normal healthy children. Therefore Sherman compiled new standards for the food consumption of normal children. To provide a safe margin he allowed a range of from 90 to 100 calories per kilogram of body weight for the child from one to two years of age, from 80 to 90 for the two to five-year-old, and from 70 to 80 for the six to nine-year-old. Rose quoted these values in her book (28).

Although some of the recent dietary studies previously reviewed seem to confirm the authenticity of Sherman's standards there are still many things to be learned about the calorie requirements of children such as the caloric utilization, and the factors which influence this utilization. The present balance study should help toward clarifying some of these problems.

PROCEDURE

In this experiment four normal pre-school children, two girls and two boys, served as subjects for two metabolic studies, one on a medium and one on a high protein diet. The experiment lasted for 55 consecutive days.

The subjects were similar in age and in physical condition. The two girls, J. H. and C. B., were both 36 months old. According to Woodbury's tables (39) they were slightly below the average weight for their height and age (Table 6), but within the normal range. It is interesting to note that, although both girls gained equally in weight, the percentage variation from the average decreased for C. B., and increased for J. H., due to the latter's slightly greater increase in height. Since the percentage variation from the theoretical weight varied more for J. H. than for C. B., her gain was more irregular. Physical examination showed that J. H. had definite signs of infantile rickets which had apparently been cured, and that she also had a somewhat lowered muscle tone. As the experiment continued, however, she improved greatly in muscle tone, in color, and in activity. Since the children both gained in weight throughout the entire interval the diets probably furnished as many calories as normal children receive.

Table 6

Height and Weight of Children Compared

With Woodbury's Tables

Period	J. H.-36 Months				C. B.-36 Months				V.B.-48 Months				E.C.-53 Months			
	Height	Weight			Height	Weight			Height	Weight			Height	Weight		
		Actual	Theo-retical	Varia-tion		Actual	Theo-retical	Varia-tion		Actual	Theo-retical	Varia-tion		Actual	Theo-retical	Varia-tion
Med. Prot.	cm	kg	kg	%	cm	kg	kg	%	cm	kg	kg	%	cm	kg	kg	%
1	37.5	13.60	14.1	-3.7	38.8	14.55	14.9	-2.4	40.5	16.97	16.1	+5.1	43.1	18.42	18.0	+2.3
2	37.5	13.64	14.1	-3.4	38.8	14.55	14.9	-2.4	40.5	17.05	16.1	+5.6				
3	37.5	13.64	14.1	-3.4	38.8	14.55	14.9	-2.4	40.5	17.05	16.1	+5.6				
4	37.5	13.64	14.1	-3.4	38.8	14.66	14.9	-1.6	40.5	17.16	16.1	+6.2				
5	37.6	13.64	14.2	-4.1	38.8	14.66	14.9	-1.6	40.6	17.12	16.2	+5.4	43.3	18.28	18.2	+0.4
6	37.6	13.64	14.2	-4.1	38.8	14.62	14.9	-1.9	40.6	17.08	16.2	+5.2	43.3	18.28	18.2	+0.4
7	37.6	13.67	14.2	-3.9	38.8	14.62	14.9	-1.9	40.6	17.05	16.2	+5.0	43.3	18.28	18.2	+0.4
High Prot.																
1	37.8	13.64	14.3	-4.8	38.9	14.66	14.9	-1.6	40.6	17.05	16.2	+5.0	43.3	18.28	18.2	+0.4
2	37.9	13.67	14.4	-5.3	38.9	14.70	14.9	-1.4	40.7	17.05	16.3	+4.4	43.3	18.28	18.2	+0.4
3	37.9	13.83	14.4	-4.1	38.9	14.77	14.9	-0.9	40.7	17.05	16.3	+4.4	43.3	18.28	18.2	+0.4
4	37.9	13.90	14.4	-3.6	38.9	14.81	14.9	-0.6	40.8	17.05	16.4	+3.8	43.3	18.28	18.2	+0.4
5	37.9	13.83	14.4	-4.1	38.9	14.77	14.9	-0.9	40.8	17.05	16.4	+3.8	43.3	18.28	18.2	+0.4
6	37.9	13.86	14.4	-3.9	39.0	14.81	15.0	-1.3	40.8	17.16	16.4	+4.4	43.3	18.28	18.2	+0.4
7	37.9	13.86	14.4	-3.9	39.0	14.85	14.9	-1.0	40.8	17.05	16.4	+3.8	43.3	18.28	18.2	+0.4
8	38.0	13.86	14.5	-4.6	39.0	14.81	14.9	-1.3	40.9	17.05	16.5	+3.2	43.3	18.28	18.2	+0.4

The other two subjects were boys; one, V. B., was 48 months old, the other, E. C., was 53 months. They were both slightly above the predicted average weight for their height and age, but again within the normal range (Table 6). During the experiment V. B. gained more in height than in weight; consequently the percentage variation from the theoretical weight decreased. The children both seemed normal, although without doubt, E. C. had had infantile rickets. On the fifth day of the medium protein diet E. C. contracted a throat infection and was not able to take his diet for three days. He recovered rapidly, ate all of his food and seemed normal. To rule out all possible effects of his illness all of his data were omitted from the first study. During the high protein study E. C. maintained a constant height and weight.

At the time of the experiment all of the subjects were healthy, normal children as revealed by physical and medical examinations. As far as could be determined their diets prior to the experiment were at least typical of the average child. None had suffered from any serious illness.

The psychological factors were as nearly normal as possible. Throughout the experiment, the children lived in an apartment in the Home Economics building under constant supervision. They observed a regular routine in regard to meals, toilet habits, play, hours of sleep and afternoon rest. Every day the children spent several hours in active outdoor exercise. The conditions were as near those of a happy home life as could be managed. J. H. finally decided the only thing lacking was a Daddy!

In determining an adequate sampling period in dietary studies McClelland (22) found that in 14-day intervals all data varied within five per cent from the average, also that individual periods of three days' duration were as reliable as those for four and five days. For calcium and phosphorus balance studies Porter-Levin (21) reported that it required from 15 to 21 consecutive days to include the whole range in retention variations. Therefore, if these are representative, the present experiment was sufficiently long to indicate general trends as well as short time variations. The experiment consisted of two studies. In the first the children received a medium protein diet which furnished approximately 85 calories and three grams of protein per kilogram of body weight. The first ten days were a preliminary and the next 21 days a collection period, further divided into seven three-day periods. Immediately following this first study the protein content of the diet was increased from three to four grams per kilogram of body weight, while the calories and all other factors were unchanged (Table 7). The second study lasted for 24 days, which were divided into eight three-day periods.

The quantities of food for each child and for both diets are given in tables 8 and 9. In order to have identical food

Table 7

Composition of Diets as Calculated from

Standard Tables

Food	Weight	Calories	Protein	Calcium	Phosphorus	Iron
Both Diets	Grams		Grams	Gram	Gram	Gram
Milk	800	552.0	26.40	0.960	0.744	0.0016
Ralston	20	72.4	2.22	0.009	0.085	0.0010
Orange juice	200	86.0		0.058	0.032	0.0004
Beef	40	62.4	8.52	0.005	0.092	0.0010
Egg	40	59.2	5.36	0.027	0.072	0.0012
Peaches	150	70.5	1.05	0.024	0.036	0.0005
Apple sauce	150	235.5	0.30	0.011	0.018	0.0005
Celery	20	3.8	0.22	0.016	0.007	0.0001
String beans	100	24.7	1.27	0.026	0.012	0.0014
Tomatoes	100	50.2	2.40	0.010	0.022	0.0014
Potatoes	80	66.4	1.76	0.011	0.046	0.0010
Bread	60	147.6	5.82	0.030	0.105	0.0010
Sugar	20	80.0				
Total-1		1510.7	55.32	1.187	1.271	0.0111
All Children						
Carmine	1/3 of 0.5	0.7				
Haliver oil	1 capsule	3.8	0.1			
Total-2		4.5	0.1			
Med. Prot. Diet						
Butter	20	153.8	0.20	0.003	0.003	
Total-3	20	153.8	0.20	0.003	0.003	
High Prot. Diet						
Butter	10	76.9	0.10	0.002	0.002	
Egg white	80	40.8	9.84	0.012	0.011	0.0010
Gelatin	10	36.7	9.14			
Total-4		154.4	19.08	0.014	0.013	0.0010
Med. Prot. Diet Totals 1 2 & 3		1669.0	55.62	1.190	1.274	0.0111
High Prot. Diet Totals 1 2 & 4		1669.6	74.50	1.201	1.284	0.0121

Table 8

Quantities of Foods for Each Child,

Medium Protein Diet

Food	J.H.	C.B.	V.B.	E.C.
	grams	grams	grams	grams
Milk	560	640	720	800
Ralston	14	16	18	20
Orange juice	140	160	180	200
Beef	28	32	36	40
Egg	28	32	36	40
Peaches	105	120	135	150
Apple sauce	105	120	135	150
Celery	14	16	18	20
String beans	70	80	90	100
Tomatoes	70	80	90	100
Potatoes	56	64	72	80
Butter	14	16	18	20
Sugar	14	16	18	20
Bread	42	48	54	60
Water	200	200	300	300
Carmine	1/3 of 0.5 gm	1/3 of 0.5 gm	1/3 of 0.5 gm	1/3 of 0.5 gm
Haliver oil	1 capsul	1 capsul	1 capsul	1 capsul

Table 9

Quantities of Food for Each Child

High Protein Diet

Food	J.H.	C.B.	V.B.	E.C.
	grams	grams	grams	grams
Milk	560	640	720	800
Ralston	14	16	18	20
Orange juice	140	160	180	200
Beef	28	32	36	40
Egg	28	32	36	40
Peaches	105	120	135	150
Apple sauce	105	120	135	150
Celery	14	16	18	20
String beans	70	80	90	100
Tomatoes	70	80	90	100
Potatoes	56	64	72	80
Butter	7	8	9	10
Sugar	14	16	18	20
Bread	42	48	54	60
Egg white	56	64	72	80
Gelatin	7	8	9	10
Water	200	200	300	300
Carmine	0.5 in 3 days	0.5 in 3 days	0.5 in 3 days	0.5 in 3 days
Haliver oil	1 capsul	1 capsul	1 capsul	1 capsul

E. C. received the diet as calculated. V. B. received 0.9, C. B. 0.8, and J. H. 0.7 of the amount given E. C.

intakes, the children received the same amount of each food per kilogram of body weight and the ratio between the quantity of each food given was the same as the ratio between the weights of the various children. For example, the weight of E. C., the largest child, was taken as unity and given a value of 1.0. Since V. B. weighed approximately 0.9 as much as E. C., C. B. 0.8 as much and J. H. 0.7 as much they were given these proportions of the diet calculated for E. C. By this method of figuring it was possible to give within experimental error 85 calories for each child per kilogram of body weight.

To show the effects of a change in protein content, the two diets were as nearly as possible identical. The majority of the foods, in both kind and amount, were the same on the two studies. The only difference was that in the high protein diet, gelatin and egg white increased the protein content and the omission of a part of the butter kept the calories at the same level. These changes also produced slight variations other than those desired. The increase in protein changed the calorie to nitrogen ratio, and the decrease in fat, the carbohydrate to fat ratio. These, however, were not radically altered. The gelatin and egg white increased the percentage of animal protein. Butter supplied more fat soluble vitamins than the egg white, but the children were probably receiving an adequate supply from other sources. The residue was the same because the cereals, fruits and vegetables remained identical for both diets. Minerals were probably slightly increased by the protein products which replaced part of the butter, and made only slight alterations in the acid-base relationships.

In order to insure uniform quality, sufficient amounts of foods to last during the entire experiment were purchased whenever possible and in all cases enough was obtained for a three-day period. Each type of food was thoroughly mixed to secure a homogeneous sample and then from this the individual portions for the children for each of the three days in the period and for the two samples for analysis were weighed on the first day of the period. The foods were prepared by the following methods: all water was distilled, milk was thoroughly mixed, the orange juice was squeezed on an electric squeezer, sieved and stirred, visible fat was removed from the beef which was then ground and mixed, Irish potatoes were boiled and put through a ricer, the eggs were broken together and beaten, and the celery was cut in small cubes and mixed. A sufficient number of the canned products for one period were opened and the contents thoroughly mixed. Gerber's pureed string beans and tomatoes were used as purchased. Peaches and apple sauce were pureed. The whole wheat bread was cut in such a way that the various samples contained approximately the same amount of crust and soft inside part. The gelatin, ralston, butter and sugar were weighed as purchased without any special preparation, except that the same pound of butter was used for all samples in one experiment. Ten grams of the total calculated amoung of sugar was in the powdered state. This was used in making a candy to contain the 0.5 grams of carmine which was given at the beginning of each period to mark the feces. One capsule of Park Davis' Haliver Oil, 250 D, was given to each child daily.

An attempt was made to reduce food losses to a minimum. Each food was weighed individually into marked dishes in which it would later be cooked and served, or, in the case of dry foods, onto the waxed paper in which it was to be wrapped. Weighed portions were never transferred from one dish to another when there was the least tendency for particles to adhere to the sides of the container. Samples were well covered with oiled paper and stored in a refrigerator until used.

The children cooperated excellently by eating all the food served. They did not object to the monotonous diet, probably because the food combinations were varied as much as possible without complicating meal preparation. After each meal the dishes were scraped with a spoon, wiped out with bread, and finally rinsed with distilled water which was added to another food that the children had to eat on that day.

Duplicate samples of food in amounts given to J. H. were saved for analysis and treated as described later in this section. Since all children received equal amounts, Haliver Oil and carmine were not added to these samples.

Duplicate samples of food, each equivalent to the amount received by J. H. (Tables 8 and 9), were weighed into enamel-ware pans. They were partially dried on a steam bath, and then placed in an oven at 60^{0} C. until they had reached a constant weight. The dried material was ground several times in a food chopper, then passed through a fine meshed sieve. If small hard pieces remained they were crushed in a mortar, then sieved. The final product was sifted several times through a larger mesh sieve to insure thorough mixing and then stored in stoppered bottles.

All excreta were carefully collected and preserved for analysis. Carmine was used to mark the feces into three-day periods. The sample for each period was saved in an enamel-ware pan and treated by the same method as the food.

Urine was collected in 24-hour specimens. After its volume and specific gravity were taken it was made up to a definite volume each day with redistilled water. Triplicate samples, each containing 15 cubic centimeters of the diluted urine were pipetted into shallow evaporating dishes which contained about 0.1 gram of salicylic acid (which is a preservative aswell as an aid to combustion). The samples were dried overnight before an electric fan and urine for the second and third days were added to the same dishes. After the entire sample was thoroughly dry, the dishes were stored in a covered box until analyzed.

The oxy-calorimeter described by Benedict (5, 6) was used in burning the samples. Before starting the analysis the machine was tested and standardized. In order to determine if there were leaks in the circuit a weight was placed on the partially filled spirometer bell and the blower started. It was assumed that the circuit was air-tight if readings taken at several minute intervals were constant when there was no temperature change.

The carbon-dioxide absorption power of the soda lime was tested by blowing the breath through the soda lime into a concentrated solution of barium-hydroxide. The absence of a milky precipitate indicated that the carbon-dioxide was all absorbed.

The area of the spirometer bell used was 20.61 square centimeters. This factor was employed in converting the millimeters of oxygen as read from the scale into cubic centimeters.

A definite procedure was used in running the oxy-calorimeter. A small amount of the substance to be burned was weighed by difference into a nickle crucible. It was then placed in the machine, number 30 iron wire was bent into shape so that it just dipped below the surface of the material, and a small amount of powdered pumice was placed at points of contact to prevent scattering and to insure ignition. After starting the blower and before the spirometer bell was finally filled the circuit was flushed out four times with small amounts of oxygen. This was done to insure an atmosphere of pure oxygen undiluted with outside air. To provide an even temperature the motor was run for 10 minutes. Then the barometer pressure, the spirometer reading and the temperature of the circuit were recorded; after this the sample was burned completely. Before final readings were taken the motor was run until equilibrium had again been established. This cooling process was sometimes hastened by wrapping clothes wrung from ice water tightly around the hot pipes. They were always removed at least five minutes before taking the final readings. This same technique was used for all substances burned for this study.

Before any determinations for the calorie balance were made, the efficiency of the machine was tested with pure sucrose from the Bureau of Standards, Washington, D. C. From 1.5 to 2.0 grams of sugar were weighed into a nickle crucible and burned as described above. The results from the combustion of 16 samples of sucrose showed a range from 769.26 to 790.79 with an average of 782.15 cubic centimeters of oxygen per gram (Table 10). This average represented 99.57 per cent of the theoretical yield; therefore there was an average error of 0.43 per cent for each determination. A correction for this error was made on every sample.

Table 10

Fluctuations in the Composition of

Various Substances Used in the Study

Material	No. Tests	Analyzed $CC.O_2/gm$	Range	Theoretical $CC.O_2/gm$	Average % of Theoretical	Cal. per gram
Sucrose	16	782.15	769.26- 790.79	785.5	99.57	3.9903
Beta naphthol	5	1788.65	1777.57-1811.83	1787.5	100.06	
Salicylic acid	12	1129.41	1110.11-1163.94	1135.6	99.45	5.2805
Carmine	3	819.15 cor.	811.44- 822.87			3.9524
Haliver oil	4	817.54 ea. corrected	761.23- 865.79			3.8343

A portion of the dried food was heated overnight at 60°C to drive off any moisture that might have been adsorbed and triplicate samples of 2.0 to 2.5 grams were weighed by difference into nickle crucibles and then burned according to the method described. In order to convert cubic centimeters of oxygen into calories the factor 4.825 (Table 11) calories per liter of oxygen, which Benedict gave for a mixed food was used.

Table 11

Factors for Changing Cubic Centimeters of Oxygen to Calories

Substance Burned	Cal. per Liter Oxygen
Food	4.825
Feces	4.970
Urine	4.680
Sucrose	5.080
Beta-naphthol	
Salicylic acid	4.650
Carmine	4.825
Haliver oil	4.690

Since Haliver Oil was not added to the food sample and was given in equal amounts to all the children it was analyzed separately and corrections made. Four determinations gave an average of 3.8 calories per capsule (Table 10) when the factor 4.69, which Benedict reported for fat was used in the calculations.

After reheating a part of the dried feces sample, triplicate samples containing about 1.5 grams each were weighed for analysis. According to the factor determined by Benedict one liter of oxygen will oxidize 4.97 calories from feces. This factor was used in this experiment.

Carmine, which was used to mark the feces, was also analyzed for calories. Table 10 shows that triplicate samples checked closely, giving an average of 3.95 calories per gram. It was assumed that one liter of oxygen would give off 4.825

calories in burning carmine, the same amount as would be given off in the combustion of a mixed food sample.

The dried urine was transferred from the evaporating dishes to nickel crucibles with redistilled water and ignited asbestos. Ivory tipped forceps and a glass medicine dropper aided in the process. The samples were again dried before an electric fan for at least 24 hours, and then placed for 12 to 14 hours in an evacuated discicator over concentrated sulphuric acid. A weighed sample of Beta naphthol which contained about 0.2 grams, and a small amount of powdered pumice were added to each sample. A sharp instrument was used to loosen the asbestos so that the above mixture could sift down. After the sample was burned correction was made for the oxygen consumed in oxydizing the salicylic acid and the Beta-naphthol (Table 10). The factor given by Benedict, 4.68 calories per liter of oxygen for urine, was used.

Before the salicylic acid and the Beta-naphthol were standardized, they were dried over concentrated sulphuric acid in a descicator. When the samples for these two substances were burned alone it was found that they scattered badly and did not burn completely; consequently ignited asbestos and pumice stone, in relatively large amounts, were carefully mixed with each sample before it was ignited. In this way oxidation was slowed up so that combustion could be complete. This difficulty was not present during ignition of urine samples because the substances were mixed in much smaller amounts, about 0.1 gram of salicylic acid and 0.2 gram Beta naphthal for each sample. The average of 12 determinations on salicylic acid was 1129.41 cubic centimeters of oxygen per gram (Table 10) or 99.45 per cent of the theoretical value., Five tests on Beta-naphthal gave an average of 1788.65 cubic centimeters per gram, or 100.06 per cent of the theoretical (Table 10). Because such small amounts of salicylic acid and Beta-naphthal were used in the urine analysis and since the determined values were so near the theoretical yield, the theoretical values were used in correcting for both the salicylic acid and the Beta-naphthal.

DISCUSSION OF RESULTS

FOOD INTAKE

In this study of the calorie balances of 4 normal pre-school children the estimated calorie value of each diet, both on the medium and on the high protein level was the same. The calculated values for the calorie intakes on the two studies varied only 1 calorie (Table 7) being 1166 and 1167 calories for J. H . respectively. As formerly stated the two diets contained the same quantity of each food except those necessary to change the protein content. Because the medium and the high protein diets were similar they are discussed together in this section.

Since the calculated calories for each period on the medium and on the high protein diet were the same, it was thought that the analyzed diet would contain the same number of calories each period, but the analysis showed fluctuations. There were even variations in the duplicate samples of food collected for each period. Chart 1 shows the fluctuations both between the duplicate samples and from period to period.

There was a significant difference between the duplicate samples for some of the periods. The least difference between the calorie content of the samples for any one period was 2 calories in period 4 of the high protein diet, and the greatest was 42 calories for period 5 of the medium protein diet. The above values represent a percentage difference of from 0.2 to 3.6 per cent between the duplicate

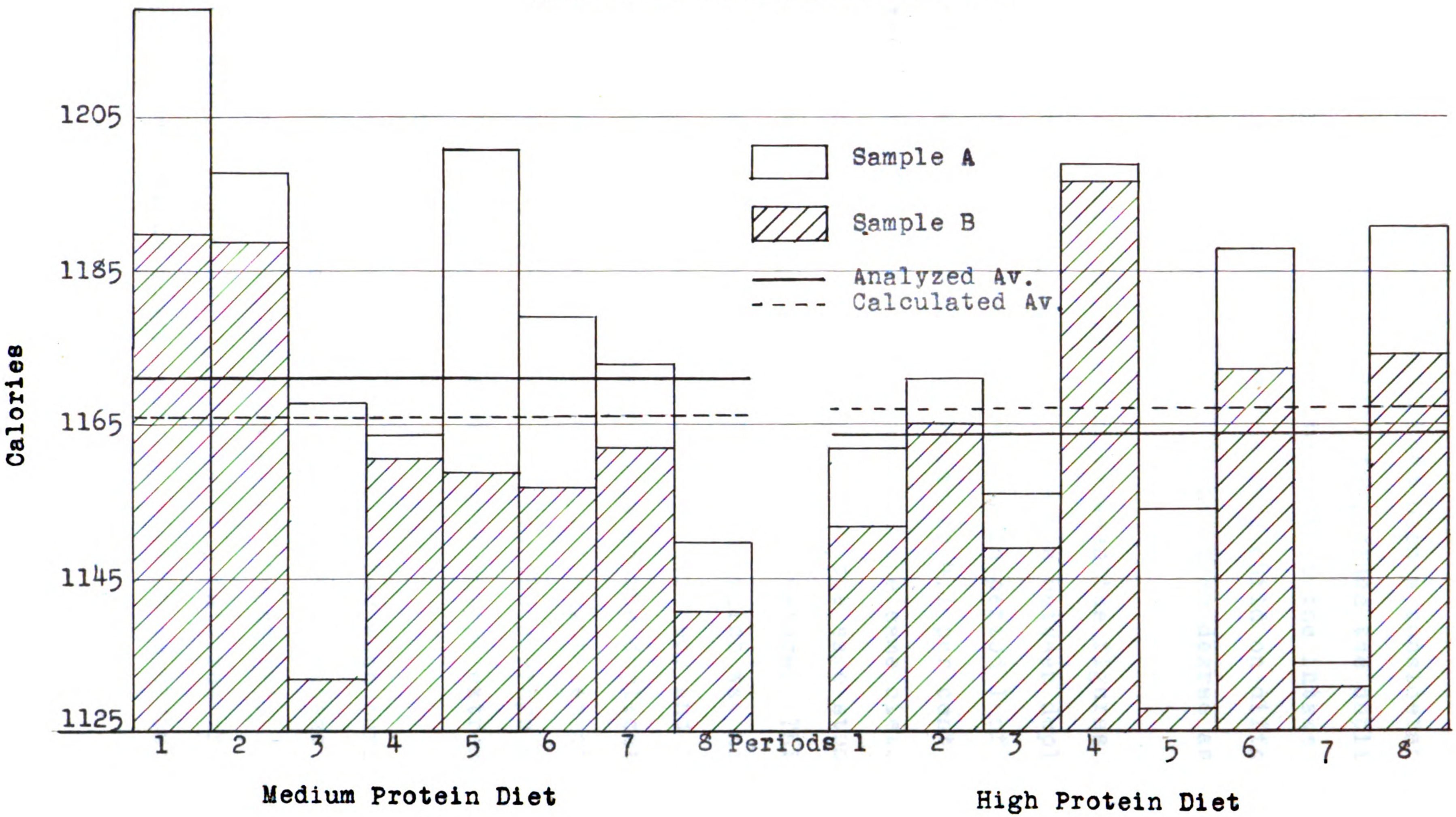
Table 12

Variations in Analyzed Calories

Sample Period	Analyzed Calories	Difference From Analyzed Averages	Per Cent	Difference From Calculated Averages	Per Cent	Average of A and B Samples	Difference From Analyzed Averages	Per Cent	Difference From Calculated Averages	Per Cent	Difference Between A & B Samples	Per Cent
	cal	cal		cal		cal	cal		cal		cal	
Medium Protein Diet												
1 A	1219	+48	+4.1	+53	+4.5	1205	+34	+2.9	+39	+3.3	29	2.4
B	1190	+19	+1.6	+24	+2.1							
2 A	1198	+27	+2.3	+32	+2.7	1193	+22	+1.9	+27	+2.3	9	0.8
B	1189	+18	+1.5	+23	+2.0							
3 A	1168	- 3	-0.3	+ 2	+0.2	1150	-21	-1.8	-16	-1.4	36	3.1
B	1132	-39	-3.3	-34	-2.9							
4 A	1164	- 7	-0.6	- 2	-0.2	1162	- 9	-0.8	- 4	-0.3	3	0.3
B	1161	-10	-0.9	- 5	-0.4							
5 A	1201	+30	+2.6	+35	+3.0	1180	+ 9	+0.8	+14	+1.2	42	3.6
B	1159	-12	-1.0	- 7	-0.6							
6 A	1179	+ 8	+0.7	+13	+1.1	1168	- 3	-0.3	+ 2	+0.2	22	1.9
B	1157	-14	-1.2	- 9	-0.8							
7 A	1173	+ 2	+0.2	+ 7	+0.6	1167	+ 4	-0.3	+ 1	+0.1	11	0.9
B	1162	- 9	-0.8	- 4	-0.3							
8 A	1150	-21	-1.8	-16	-1.4	1146	-25	-2.1	-20	-1.7	9	0.8
B	1141	-30	-2.6	-25	-2.1							
Av.	1171		1.6	1166	1.6	1171		1.4	1166	1.3		1.7
High Protein Diet												
1 A	1152	-12	1.0	-15	-1.3	1157	- 7	-0.6	-10	-0.9	10	0.9
B	1162	- 2	-0.2	- 5	-0.4							
2 A	1165	+ 1	+0.1	- 2	-0.2	1168	- 4	+0.3	+ 1	+0.1	6	0.5
B	1171	+ 7	+0.6	+ 4	+0.3							
3 A	1149	-15	-1.3	-18	-1.5	1152	-12	-1.0	-15	-1.3	7	0.6
B	1156	- 8	-0.7	-11	-0.9							
4 A	1197	+33	+2.8	+30	+2.6	1198	+34	+2.9	+31	+2.7	2	0.2
B	1199	+35	+3.0	+32	+2.7							
5 A	1128	-36	-3.1	-39	+3.3	1141	-23	-2.0	-26	-2.2	26	2.3
B	1154	-10	-0.9	-13	-1.1							
6 A	1172	+ 8	+0.7	+ 5	+0.4	1180	+16	+1.4	+13	+1.1	16	1.4
B	1188	-24	+2.1	+21	+1.8							
7 A	1131	-33	-2.8	-36	-3.1	1132	-32	-2.7	-35	-3.0	3	0.3
B	1134	-30	-2.6	-33	-2.8							
8 A	1174	+10	+0.9	+ 7	+0.6	1182	+18	+1.5	+15	+1.3	17	1.4
B	1191	+27	+2.3	+24	+2.1							
Av.	1164		1.6	1167	1.6	1164		1.5	1167	-1.6		1.0

Chart 1

Variations in Analyzed Calories



samples. These variations might have been a considerable factor in determining the results, for, since the duplicate diets varied this much, it is probable that the intake for the various children or for the same child on different days of the period would vary to the same degree as did the samples.

There was a wider fluctuation between the figures for the individual analysis than there was between duplicate analysis for the same diet. One sample in period 1 of the first study was as much as 48 calories or 4.1 per cent above the average of all the analysis on the same diet. On the other hand, another in period 3 of the same study was 39 calories or 3.3 per cent below the average. This gave a maximum total range of 7.4 per cent which was nearly as much as the percentage of the intake excreted, and twice the greatest percentage difference between the duplicate samples. Thus, it would be possible for the intakes of the subjects to vary both above and below the average and to have a difference of 7.4 per cent between the extreme high and low values.

The average of the duplicate samples for each period varied less than the individual samples. The greatest difference was 34 calories or 2.9% above the average of all the analysis for the diets and the least 3 calories or 0.3 per cent below. Since these average values were probably more nearly correct than those for individual samples they were used as the period intakes of the children.

Although the samples varied from period to period in each study the averages of all the periods for the 25 studies were similar. The medium protein diet contained an average of 1171 calories and the high protein diet, 1164 calories. Thus the average difference between the two diets was only 7 calories, a variation less than that between the majority of the duplicate samples for each period or between the average intakes per period.

It was possible to persent these fluctuations statistically. The coefficients of variation of all the data from the analyzed average was 1.79 and 1.91 for the medium and for the high protein diets. For similar diets, Hawks found coefficients of variation of 1.62 and 2.18. All of these values were near to those which Bassett (3) and his associates reported for the various mineral constituents of the diet. They believed that technical errors were great enough so that these results were probably as low as it was possible to obtain.

The fluctuations in the analyzed values caused a variation from the calculated figures. The greatest difference was 53 calories above the calculated;on the other hand in many periods the agreement between the two was very close. On the medium protein diet, the percentage variation from the calculated ranged from plus 4.5 to -2.9 percent with an average of 1.3 per cent, and on the high protein diet, from plus 3.3 to -3.1 with an average of 1.6 per cent

In the percentage variations from the calculated average for some preliminary studies, Hawks found similar ranges, namely: from plus 1.73 to -3.63 on a medium protein intake and from plus 2.84 to -2.61 per cent on a high protein diet. When the diet was freely chosen and thus not constant the differences between the analyzed and calculated values seemed to be greater. Bray et al (8) found a range of from plus 35.4 to -27.3 per cent between the 2, when the recipe method was employed. On the other hand, Donelson and her associates (12) reported that on some days there was close agreement, but on others a wide divergence between the calculated and the analyzed values. Although the fluctuations of the analyzed from the calculated diets may seem small, still they may be an important factor in determining the results.

Study Number 1

Mediam Protien Diet- Total and Percentage Intake: The data for the first study included the figures for only three children. Although E. C. apparently recovered from the infection he contracted during the second period no excreta were saved until period 5. This gave a preliminary period of only six days which was too short

Table 13

Daily Caloric Balances

Medium Protein Diet

Child Period	Intake	Caloric Output						Absorption		Retention	
		Total		Feces		Urine					
J.H.											
1	1197	91.7	7.7	57.1	4.8	34.6	2.9	1140	95.2	1106	92.4
2	1154	96.4	8.4	62.4	5.4	34.1	3.0	1092	94.6	1058	91.7
3	1166	98.8	8.5	62.8	5.4	36.0	3.1	1104	94.7	1068	91.6
4	1184	103.2	8.7	65.8	5.6	36.4	3.1	1117	94.3	1080	91.2
5	7160	104.0	9.0	66.8	5.8	37.2	3.2	1094	94.3	1056	91.0
6	1171	97.9	8.4	61.4	5.2	36.5	3.1	1110	94.8	1073	91.6
7	1149	97.8	8.5	61.4	5.3	36.5	3.2	1088	94.7	1052	91.6
Average	1169	98.5	8.5	62.7	5.4	35.9	3.1	1106	94.7	1070	91.6
C.B.											
1	1368	104.6	7.6	64.4	4.7	40.3	2.9	1303	95.2	1263	92.3
2	1318	103.6	7.9	65.4	5.0	38.2	2.9	1253	95.1	1215	92.2
3	1332	104.6	7.9	64.6	4.8	40.0	3.0	1268	95.2	1228	92.2
4	1352	110.5	8.2	65.5	4.8	45.0	3.3	1287	95.2	1242	91.9
5	1362	110.5	8.3	66.6	5.0	43.9	3.3	1259	94.9	1215	91.6
6	1338	103.4	7.7	63.1	4.7	40.3	3.0	1275	95.3	1235	92.3
7	1313	102.8	7.8	61.7	4.7	41.1	3.1	1251	95.3	1210	92.2
Average	1335	105.7	7.9	64.5	4.8	41.3	3.1	1271	95.2	1230	92.1
V.B.											
1	1538	102.7	6.7	62.5	4.1	40.3	2.6	1476	96.0	1436	93.4
2	1483	109.8	7.4	63.2	4.3	46.6	3.1	1419	95.7	1373	92.6
3											
4											
5	1491	115.2	7.7	68.2	4.6	47.0	3.2	1423	95.4	1376	92.3
6	1505	111.3	7.4	62.9	4.2	48.4	3.2	1442	95.8	1393	92.6
7	1477	105.9	7.2	62.0	4.2	43.9	3.0	1415	95.8	1371	92.8
Average	1499	109.0	7.3	63.8	4.3	45.2	3.0	1435	95.7	1390	92.7

when compared with that at the beginning of the experiment. Possibly the last period (period 7) could have been included, nevertheless, since periods 1 and 7 were not consecutive none of the data for E. C. were included in the first part of the experiment. Since V. B. discarded a feces sample between the third and fourth period of the first study all data for him on these two periods were omitted.

Chart 2

A Comparison of Totals

Calorie Outputs

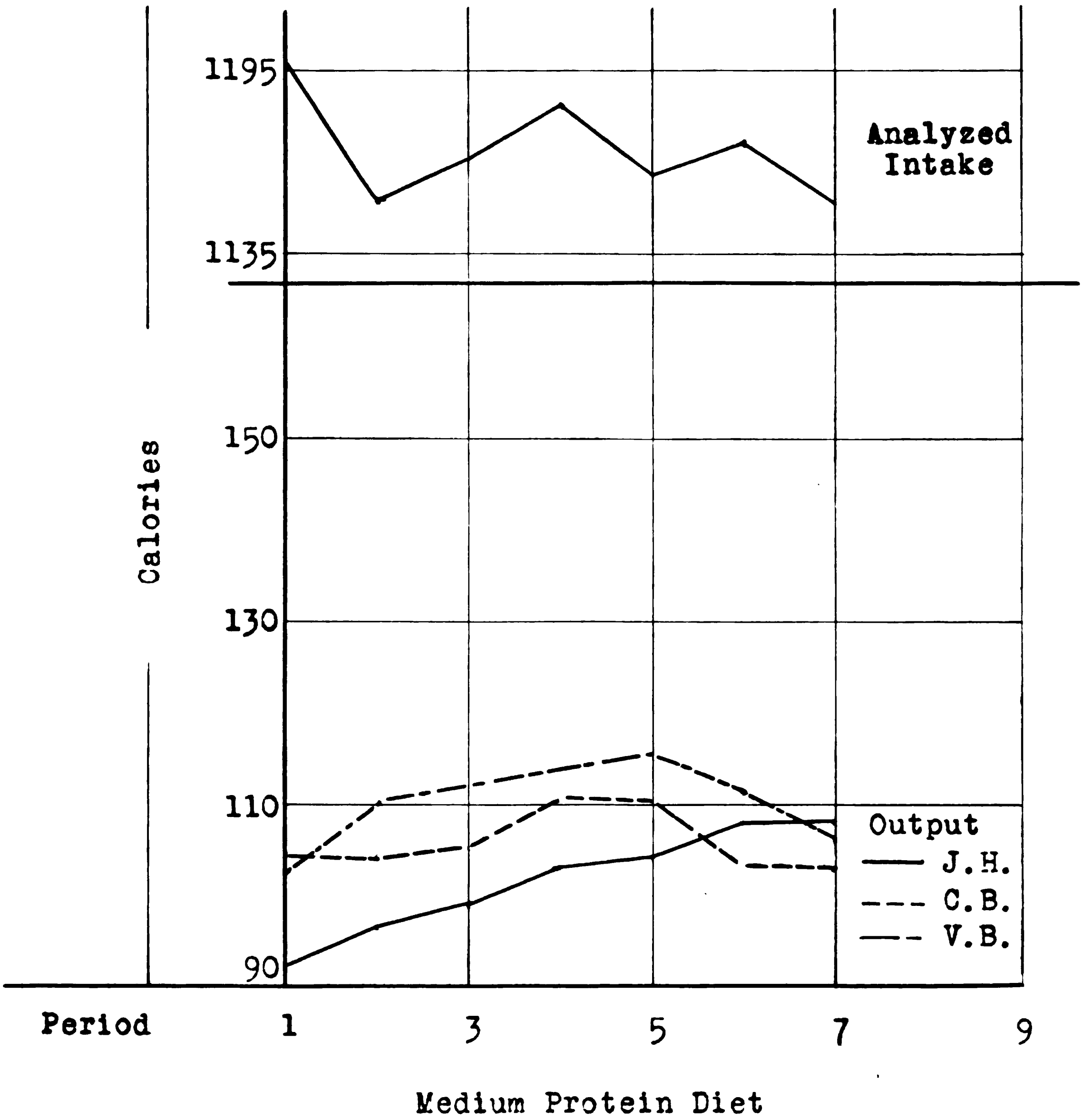


Table 13 gives the total calorie balances for the children while an the medium protein diet. As noted before, the intake valves fluctuated from period to period, and the variation was proportional for each child since all received approximately the same number of calories per kilo. In every case the highest intake was in period 1 and the lowest in period 7. The difference between these two extreme values in intake for each child increased from 48 calories for J. H. to 61 for V. B.

Average figures show that J. H. received 1169 calories per 24 hours, C. B., 1335 and V. B., 1499. These calorie intakes were probably adequate since the children gained in weight and the values were similar to those which other people found. All of the intakes, except that for J. H., fell within the range advocated in the standards of Holt and Fales (from 1300 to 1600 calories) and of Sherman (from 1200 to 1500 calories). In their respective master's thesis, Goodhue and White reported intake values higher than any of these, 1644 and 1704 calories, while Imlay found an average intake greater than that for J. H., but less than those for the other children.

Total output: The actual excretion of calories was small in proportion to the intake. The highest individual total output was only 115.2 calories for V. B. which amounted to 7.7 per cent of the intake. Nevertheless, J. H. excreted the highest percentage of intake (9.0 per cent) in period 5 .

The constancy of the total calorie output from period to period was indicated by the fact that there was only 12.5 and 12.3 calories difference between the lowest and the highest output for V. B. and J. H. respectively. The least variation was 7.7 calories for C. B.

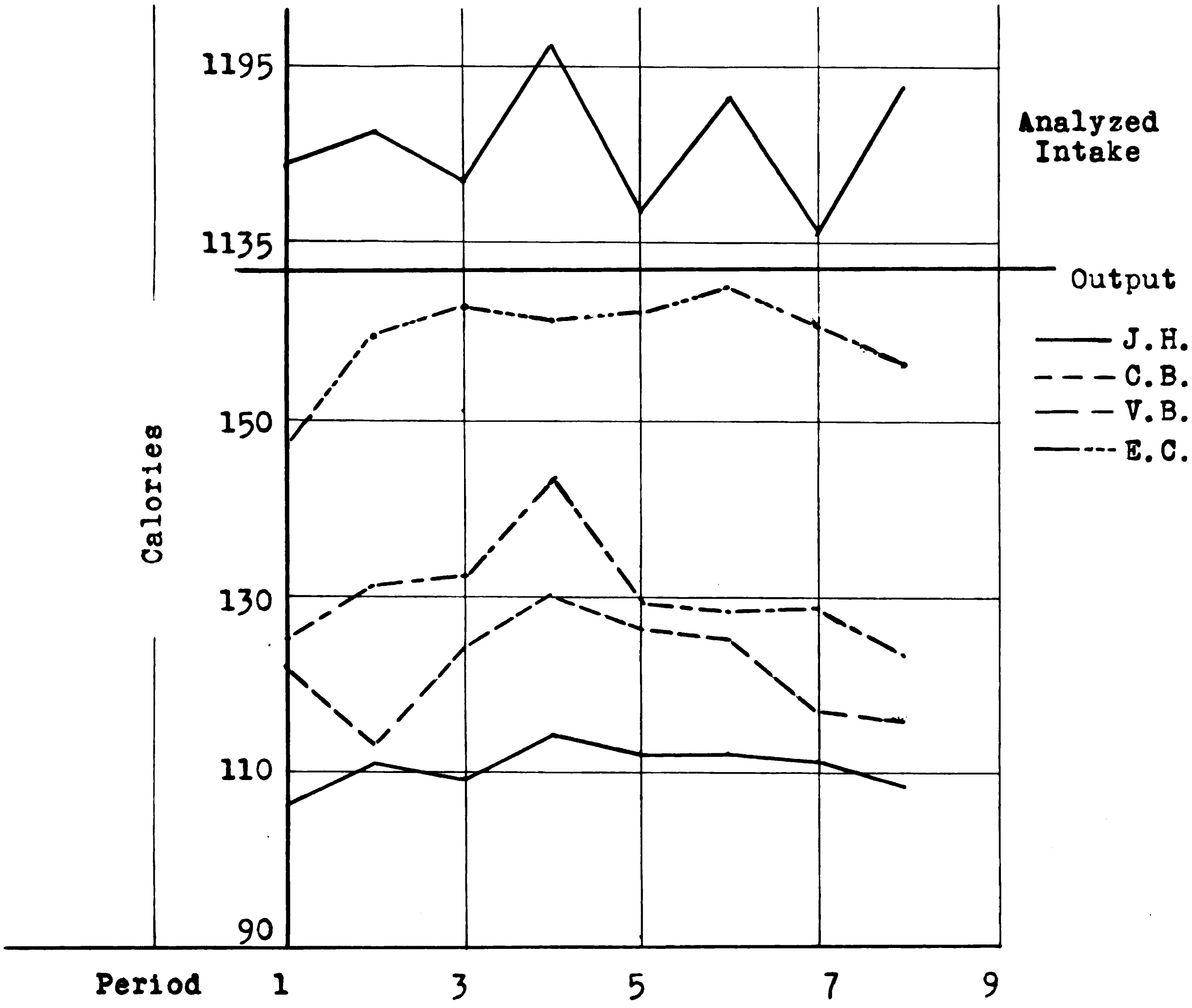
The relation of the output to the intake was shown in several different ways. Since a constant percentage of intake excreted would indicate a direct relationship between the two values, any variations would mean a lowered correlation. There were a number of discrepancies. Each child excreted the lowest percentage of the intake in period 1 when the intake was greatest. Nevertheless, the greatest excretion of total calories and the highest percentage of the intake excreted occured in period 5 which was relatively low in calorie intake. This period, however, followed the period of the second highest intake. Table 13 also indicates and chart 2 shows that the periods of high and low outputs do not always coincide. Furthermore, these variations did not always follow those in the calorie intake as shown when the output curves were compared with the curves for the intake.

The difference between the two extremes in output for any child did not increase in proportion to the size of the child as did the values for calorie intake. In

Chart 3

A Comparison of Total

Calorie Outputs



order of increasing size of the subjects these differences were 12.3, 7.7, and 12.5 calories for output, and 48, 55, and 61 calories for intake. This lack of correlation between intake and output may have been due to unavoidable errors in collection of samples or to individual differences in the reactions of the children. It may also be associated with the character of the stools which were loose for J. H. and somewhat constipated for V. B. Another factor may be that a high output may occur in the period following a high intake as a hang over. This lack of correlation showed up very well when the data were treated statistically. The results will be given later in the discussion of the values on the per kilogram basis.

Although the three children did not react in just the same way, the average total calorie output increased with the calarie intake and therefore with the size of the child. In order of increasing size the subjects excreted 98.5 calories for J. H., 105.7 for C. B., and 109.0 for V. B. Differences between these average values were less than the period variations for individuals. Nevertheless the percentage of the intake excreted decreased from 8.5 per cent for J. H. to 7.3 per cent for V. B., therefore the total output did not increase in the same proportion as the intake. The older children may have needed more calories in proportion to size than the younger ones. Bray and her associates

(8) found that the older nursery school children used the largest number of calories per kilogram of body weight. As compared with the study of Wang and her co-workers, (Table 4), the above total outputs were higher than one value and lower than another. One of their 4 year old subjects excreted 87 calories or 7.1 per cent of the intake, the other, 112 calories or 6.7 per cent of the intake. Both of these percentages were lower than any average value for the present study.

Output in feces: More than half of the total output was excreted in the feces. Generally the fecal output varied from period to period in the same proportion as the total output. The differences between the high and the low values for each child, however, were not the same as those for total output. This fluctuation was least 61.7 to 66.6 calories) for C. B., and most (57.1 to 66.8 calories) for J. H.

The average calorie output in the feces for the different children varied much less than the individual fluctuations discussed above. There was a difference of only 2 calories between the extreme outputs instead of 9.7 calories for J. H., the greatest difference between individual fecal outputs. J. H. had the lowest average output in the feces, 62.7 calories or 5.4 per cent of the intake; C. B.

had the highest, 64.5 calories, or 4.8 per cent of the intake; and V. B. had 63. 8 calories, or 4.3 per cent. This indicates that the children did not excrete the same proportion of calories in the feces and, as mentioned before, may have been due to the character of the stools.

Output in urine: Roughly estimated there were about two-thirds as many calories excreted in the urine as there were in the feces. Furthermore, individual variations were less pronounced than in either the feces or the total output. Fluctuations in the urinary output were greatest for V. B., (40.3 to 48.4 calories) and least for J. H. (34.1 to 37.2 calories). The periods of high and of low value did not seem to come in any difinite order, although there was a slight tendency for periods of higher intake to also have a higher urinary output in calories.

The average percentage of the calorie intake excreted in the urine was practically identical for the three children; 3.1 per cent for J. H. and for C. B., and 3.0 per cent for V. B. On the other hand the average values for calories excreted in the urine increased in exact proportion to the intake. This increase was from 35.9 for J. H. to 45.2 calories for V. B. Thus the number of calories excreted in the urine was in direct proportion to the intake while those excreted in the feces were practically the same for each child.

Total absorption: Total calorie absorption measures all the calories ingested in the food which pass through the walls of the alimentary tract and excludes those excreted in the feces. Since the fecal output was so small the variations did not effect the calories absorbed, and thus they seemed directly proportional to the intake. The absorption would also vary inversely with the fecal output.

The widest range in absorption values was from 1415 to 1476 calories for V. B. This gave a difference of only 61 calories between the highest and the lowest values. J. H. and C. B. had narrower ranges and therefore smaller differences between the two extreme values, 52 calories in both cases. The variation between the low and the high number of calories absorbed by each child compared favorably with similar differences between extremes in intake. V. B. had the same difference in both intake and absorption, while for J. H. it was 4 calories less in intake than in absorption, and for C. B. it was 3 calories more.

There was an increase in average total absorption for the subjects which corresponded to the higher calorie content of the diet and to the size of the child. Average figures show that J. H. absorbed 1106 calories, C. B., 1271, and V. B. 1435. This increase in absorption with the higher intakes was the same as the increase in the size of the subjects, therefore the average percentage of the total intake absorbed was about the same for C. B. and V. B., 95.2and 95.7 per cent respectively, and only slightly less, 94.7 per cent, for J. H. Wang and her associates reported (Table 4) similar values (95 and 96 per cent) for two pre-school children.

Total retention: Retention values give the number of calories used in the body and vary inversely with the total output. Again, since the output was such a small part of the intake, the slight variations did not influence the retention greatly. In retention, as in absorption and intake, V. B. had the greatest variation between the low and high value with a difference of 65 calories. This was about 10 calories difference more than that for the other two children.

From period to period the percentage of the intake retained was nearly constant for each child. This percentage retention was inversely proportional to the percentage of total excretion and the differences were directly related to the fecal variation, because the percentage of the diet excreted in the urine remained constant.

The average retention varied directly with the intake, and indirectly with the total output. It was least, 1070 calories, for J. H. and most, 1390, for V. B. On the other hand, average percentages of the intake retained varied only about one per cent; J. H. had the smallest value (91.6 per cent) and V. B. the largest (92.7 per cent). These results are comparable with those which Wang and her associates reported for two pre-school children and diets similar in protein content, but varying widely in calorie content. The children whom they reported upon retained 1146 and 1549 calories, or, in both cases, 93 per cent of the intake. Thus retention probably varies directly with the intake when the calorie consumption fluctuates, providing other constituents of the diet remain unchanged.

Study Number 1

Medium Protein Diet-Per Kilogram Basis

Intake: Since the daily calorie balances expressed in terms of calories per kilogram of body weight present the data an a comman basis, the results are more comparable for the various children. Table 14 gives the data on this basis.

There were considerable differences between the intakes of the children due to several causes. The children changed slightly in weight during the experiment. Thus the factors used in calculating the intakes were not always in the same proportion. These factors were not exactly proportional to the weights of the different children even at the beginning of the experiment as they were carried out to only one decimal. Other slight variations were due to the inability to weigh fractions of a gram of food. Therefore the children did not receive exactly the same number of calories per kilogram of body weight.

There was also an individual variation from period to period. The greatest difference between the lowest and

Table 14

Daily Calorie Balances per Kilograms of Body Weight on a Medium Protein Diet

Child Period	Weight	Intake	Output Total	Output Feces	Output Urine	Absorption	Retention
	kgs.	cal.	cal.	cal.	cal.	cal.	cal.
J.H.							
1	13.60	88.04	6.74	4.20	2.55	83.84	81.29
2	13.64	84.60	7.07	4.57	2.50	80.03	77.53
3	13.64	85.50	7.24	4.60	2.64	80.90	78.26
4	13.64	86.77	7.57	4.90	2.66	81.87	79.21
5	13.64	85.07	7.63	4.90	2.73	80.17	77.45
6	13.64	85.87	7.17	4.50	2.68	81.37	78.69
7	13.67	84.08	7.15	4.49	2.67	79.59	76.92
Average		85.70	7.22	4.59	2.63	81.11	78.48
C.B.							
1	14.55	94.01	7.19	4.42	2.77	89.59	86.82
2	14.55	90.60	7.12	4.49	2.63	86.11	83.48
3	14.55	91.57	7.19	4.44	2.75	87.13	84.38
4	14.66	92.23	7.54	4.47	3.07	87.77	84.70
5	14.66	90.42	7.54	4.54	3.00	85.88	82.89
6	14.62	91.52	7.07	4.32	2.76	87.20	84.44
7	14.62	89.81	7.03	4.22	2.81	85.59	82.77
Average		91.45	7.24	4.41	2.83	87.04	84.21
V.B.							
1	16.97	90.65	6.05	3.68	2.37	86.97	84.60
2	17.05	86.96	6.44	3.71	2.73	83.25	80.51
3							
4							
5	17.12	87.08	6.73	3.98	2.75	83.10	80.35
6	17.08	88.10	6.52	3.68	2.83	84.42	81.58
7	17.05	86.61	6.21	3.64	2.58	82.97	80.40
Average		87.88	6.39	3.74	2.65	84.14	81.49

the highest intake for any subject was 4.20 calories for C. B. The smallest individual intake was 84.08 calories for J. H. and the largest, 94.01 for C. B., thus the fluctuation was about 10 calories. All of the lowest values for calorie intake were in period 7 and the highest in period 1.

The average intakes for the children varied in the same proportion as the individual differences. J. H. consumed 85.70 calories per kilo, C. B., 91.45, and V. B., 87.88 calories, thus there was a difference of only five calories between the lowest and the highest average figure. This was probably within experimental error.

The above values were similar to those reported in food intake studies (Table 1). Of the more recent authors, Goodhue reported an average intake of 85 calories per kilo and Bray et al 82, while Jones found a higher value, 91.7 calories. Sherman allowed a range in intake from 80 to 90 calories per kilo for children from two to three years old, and from 70 to 80 for those from three to four years. In calorie balance, Wang and her associates found that average figures gave intakes of 74.7 calories per kilo for a four year old girl and 97.2 calories for a five year old. These two subjects were on a diet similar in protein content to the present study. Muller reported an average intake of 104 calories per kilo. Since the subjects in the present study gained in weight when given a diet similar in calorie content to these reported in the literature they probably received an average diet.

Total output: Even on this weight basis, there were period to period variations in the calorie output. The greatest was from 6.74 to 7.63 for J. H. and the least from 7.03 to 7.54 calories for C. B. These variations did not bear any definite relationship to fluctuations in intake. Table 15 clearly shows this lackof interdependence as the correlation for the two was only 0.04.

Table 15

Correlation Between Diet Calories and Caloric Output, Retention and Absorption

Diet	Period	Intake and Output	Intake and Absorption	Intake and Retention
Medium Protein	all	0.04	0.94	0.94
High Protein	all	0.48	0.95	0.96
Med. & High Prot.	all	0.23	0.97	0.95

In spite of the period variations the average total calorie outputs per kilogram of body weight were remarkably similar for the children. For J. H. and C. B. the values were nearly identical (7.22 and 7.24 calories) and for V. B. the figures were slightly less (6.39 calories). These variations were so small that they might have been due to experimental error. The results were slightly higher than Wang and her associates reported (5.3 and 5.0 calories) for two four year old girls, one of whom was from the underweight group (Table 5). The values were also higher than a normal 5 year old girl excreted (6.6 calories per kilo). Muller found that the average daily loss of calories was 10.5 per kilogram of body weight. This was for above any individual figure for the children in this study.

Output in feces: So few calories were excreted in the feces that the differences were very small and probably due to experimental error. The greatest difference between the highest and the lowest output in the feces was only 0.7. calories for J. H. and the smallest 0.32 for C. B. These variations were slightly less than those for total output for the same children. Period to period fluctuations did not vary with the intake.

The variation in the average number of calories excreted in the feces of the various children was also relatively small. Average figures show that J. H. exereted 4.59, C. B. 4.41, and V. B. 3.74 calories per kilo. In each case this was about two-thirds of the total number of calories excreted. These values were comparable with those Wang and her associates reported for two normal children. One four year old girl excreted, in her feces, an average of 3.2 calories per kilo when her intake was 74.7 calories, and a five year old 4.7 calories when her intake was 97.2. Another five year old whose protein intake was not given, but who consumed 106 calories per kilo excreted much more, 7.9 calories per kilo. Muller also reported a higher average figure, 5.9 calories per kilogram of body weight when his subjects consumed an average of 104 calories per kilo.

Output in urine: A smaller number of calories per kilo were excreted in the urine than in the feces. Furthermore, individual variations in the calorie output in the urine were less from period to period than those in the feces or the total output (Table 14). Fluctuation was greatest for V. B., (from 2.37 to 2.83 calories) and least for J. H. (from 2.50 to 2.73 calories). Subject J. H. also had the least variation in intake but the greatest in total output and in calories excreted in the feces.

The variationsin the average calorie excretion in the urine per kilogram of body weight were so slight that they might easily have been due to technical errors. The average excretion was greatest, 2.83 calories, for C. B. and least, 2. 63 calories for J. H.; values which are again proportional to the total intake. Since the number of calories excreted in the urine was so nearly uniform for all of the subjects the low total output for V. B. was thus due entirely to his lower excretion of calories in his feces.

Wang and her associates reported two values for urinary excretion, 1.9 and 2.1 calories per kilo, which were slightly less than any for the present study. These lower urinary outputs were not entirely due to a lower intake in relation to age, as the child who excreted 1.9 calories consumed 97.2 calories per kilo, or slightly more than any of the children on the present study. On the other hand, Muller found that his subjects excreted much more in the urine than any of these subjects, 4.6 calories per kilo when the diet furnished 104 calories per kilogram of body weight

Absorption: The number of calories excreted in the feces was so small in comparison with the number consumed that variations in absorption did not show, if they were present. Since this was true there was a very high correlation of

0.94 between the intake and the absorption per kilogram of body weight (Table 15). In every case the absorption varied inversely in proportion to the fecal output. For each of the subjects in the present study there was a difference of only about 4.0 calories between the highest and the lowest absorption value. This was about as great as the fecal output and greater than the urinary output, but about the same as the difference in intake from period to period.

For every kilogram of body weight J. H. absorbed an average of 81.11 calories, C. B. 87.04 and V. B., 84.14 or about 92, 92 and 93 per cent of the intake per kilo respectively. On a diet somewhat similar to this, Wang and her associates' subjects absorbed 71.5 and 92.5 calories which were 96 and 95 per cent of the per kilo intake. Muller reported data, which, when further calculated, gave an average absorption value of about 98 calories per kilo or 94 per cent of the intake. This variation in the number of calories absorbed may have been due to the higher levels of intake.

Retention: Since the intake was relatively constant and the total output was small the correlation (Table 15) between the intake and retention was high (0.94). This contrasts well with the correlation between the intake and the total output which was very low because of unavoidable errors and the small figures for output. Individual variations in retention per kilogram of body weight were very small and practically the same for all of the children.

Flucluations were greatest (76.92 to 81.29 calories) for J. H. and least(82.77 to 86.82 calories) for C. B. This variation was in inverse proportion to the output.

Average retenton values were quite uniform for the various children. They were lowest for J. H., 78.48 calories per kilo and highest for C. B., 84.21 calories, Thus they were proportional to the intake. Intake apparently governs the utilization of calories because the output values were such a small proportion of the intake. The large proportion of error in fecal output may make the total output seem more irregular than it really is and may hide a correlation with intake. Wang and her associates reported results that would lead to the same general conclusions. They also found that for normal children the total output was slightly higher for the child receiving the high intake than for the one on the lower calorie diet. Thus a four year old child retained 69.4 calories when on a relatively low calorie intake, and a five year old 90.6 when on a higher intake level. There were not, however, a large enough number of subjects on one level of calorie intake for comparisons.

Study Number 11

High Protein Diet-Total and Percentage

Intake:Since the preliminary period for E. C. was sufficiently long he served as a subject for the study in which the children received a high protein diet. This gave four children for comparison while ther had been only three on the first study.

Individual variations in intake from period to period were greater on the high protein diet than they had been on the medium protein level (Table 16). The maximum fluctuation in calorie intake was 94 calories for E. C. and was proportionally less, in relation to the size, for the other children.

As formenly pointed out there was very close agreement between the averages of the analyzed calories in the medium and in the high protein diets. On the second study J. H. consumed an average of 1168 calories, C. B. 1334, V. B., 1500 and E. C., 1667. These compare favorably with those reported by other authors. Since the variation was small between the two diets, any differences in utilization would be due to the change in the protein content.

Total output: The proportion of the intake excreted on the high protin diet was low, from 8.7 to 9.5 per cent. This was, however, about 1 per cent greater than that on the medium protein diet.

As in the previous study the output for each child varied from period to period. Three of the children had rather large individual fluctuations in calorie output, the fourth, J. H., had a relatively uniform excretion of calories with a difference of only 7.8 calories between the

Table 16

Table 16

Daily Caloric Balances

High Protein Diet

Child Period	Intake	Caloric Output						Absorption		Retention	
		Total		Feces		Urine					
J.H.	cal	cal	%	cal	%	cal	%	cal	%	cal	%
1	1161	106.4	9.2	62.6	5.4	43.8	3.8	1098	94.6	1055	90.9
2	1172	110.8	9.5	60.8	5.2	50.0	4.3	1111	94.8	1061	90.5
3	1156	109.2	9.4	63.1	5.5	46.1	4.0	1093	94.6	1047	90.6
4	1202	114.2	9.5	60.5	5.0	53.8	4.5	1142	95.0	1088	90.5
5	1145	112.1	9.8	63.0	5.5	49.1	4.3	1082	94.5	1033	90.2

Table 16

Daily Caloric Balances

High Protein Diet

Child Period	Intake	Caloric Output						Absorption		Retention	
		Total		Feces		Urine					
	cal	cal	%	cal	%	cal	%	cal	%	cal	%
J.H.											
1	1161	106.4	9.2	62.6	5.4	43.8	3.8	1098	94.6	1055	90.9
2	1172	110.8	9.5	60.8	5.2	50.0	4.3	1111	94.8	1061	90.5
3	1156	109.2	9.4	63.1	5.5	46.1	4.0	1093	94.6	1047	90.6
4	1202	114.2	9.5	60.5	5.0	53.8	4.5	1142	95.0	1088	90.5
5	1145	112.1	9.8	63.0	5.5	49.1	4.3	1082	94.5	1033	90.2
6	1184	111.7	9.4	64.4	5.4	47.4	4.0	1119	94.5	1072	90.5
7	1136	110.8	9.8	64.4	5.7	46.4	4.1	1072	94.4	1026	90.3
8	1186	108.1	9.1	64.4	5.4	43.8	3.7	1122	94.6	1078	90.9
Average	1168	110.4	9.5	62.9	5.4	47.6	4.1	1105	94.6	1058	90.6
C.B.											
1	1326	122.3	9.2	70.3	5.3	52.0	3.9	1256	94.7	1204	90.8
2	1334	112.6	8.4	54.6	4.1	58.0	4.3	1284	95.9	1226	91.6
3	1321	123.8	9.4	68.9	5.2	55.0	4.2	1252	94.8	1197	90.6
4	1373	129.8	9.5	74.8	5.4	55.0	4.0	1299	94.6	1244	90.6
5	1308	126.1	9.6	69.6	5.3	56.5	4.3	1238	94.6	1182	90.4
6	1352	124.6	9.2	67.9	5.0	56.7	4.2	1284	95.0	1228	90.8
7	1298	117.4	9.0	62.2	4.8	55.2	4.3	1236	95.2	1181	91.0
8	1355	116.1	8.6	61.4	4.5	54.7	4.0	1294	95.5	1239	91.4
Average	1334	121.6	9.1	66.2	5.0	55.4	4.2	1268	95.0	1213	90.9
V.B.											
1	1491	124.7	8.4	63.3	4.2	61.4	4.1	1428	95.8	1367	91.7
2	1506	131.0	8.7	69.4	4.6	61.6	4.1	1436	95.4	1375	91.3
3	1485	132.3	8.9	68.7	4.6	63.6	4.3	1417	95.4	1353	91.1
4	1545	143.2	9.3	79.2	5.1	64.1	4.1	1465	94.8	1401	90.7
5	1471	129.3	8.8	70.1	4.8	59.1	4.0	1401	95.2	1342	91.2
6	1521	128.2	8.4	67.4	4.4	60.7	4.0	1453	95.5	1393	91.6
7	1460	128.0	8.8	64.6	4.4	63.4	4.3	1395	95.5	1332	91.2
8	1524	123.2	8.1	60.8	4.0	62.5	4.1	1463	96.0	1401	91.9
Average	1500	130.0	8.7	67.9	4.5	62.1	4.1	1432	95.5	1371	91.3
E.C.											
1	1657	147.1	8.9	86.9	5.2	60.2	3.6	1570	94.7	1510	91.1
2	1673	159.4	9.5	90.7	5.4	68.7	4.1	1582	94.6	1513	90.4
3	1650	162.5	9.8	91.3	5.5	71.2	4.3	1559	94.5	1488	90.2
4	1716	161.1	9.4	95.5	5.6	65.6	3.8	1620	94.4	1555	90.6
5	1634	161.9	9.9	101.0	6.2	60.9	3.7	1533	93.8	1472	90.1
6	1689	164.6	9.7	98.3	5.8	66.3	3.9	1591	94.2	1525	90.3
7	1622	159.5	9.8	94.2	5.8	65.3	4.0	1527	94.1	1462	90.1
8	1693	155.9	9.2	90.7	5.4	65.2	3.9	1602	94.6	1537	90.8
Average	1667	159.0	9.5	93.6	5.6	65.4	3.9	1573	94.4	1508	90.5

smallest and the largest values.

There was a low correlation between intake and output as shown by chart 3. The curve for E. C. was quite different from those of the other children. It indicated a higher output, was more smooth, and reached its highest point in period 6. For the other three subjects the greatest output come in that period in which the intake was greatest, or period 4. At no time did the periods of least output and lowest intake coincide, although the latter was seldom the same on any two periods. The output curve for J. H. was nearest to being a straight line, and, therefore, more like the curves for the first study.

The relation between the intake and the output was also shown by the percentage of the intake excreted, which was more constant for J. H. (9.1 to 9.8 per cent) than for any of the other children. Fluctuations were more and practically the same for the other three children. It is interesting that the largest percentage of the intake was excreted in the period following the greates intake with but one exception; the two periods coincide for V. B. In only two instances does the period of lowest percentage of intake excreted follow that of least intake.

The children did not excrete the same average number of calories, but the percentage of total intake excreted was quite similar. The lowest average excretion was 110.4

calories for J. H. and the highest 159.0 for E. C. Although these amounts vary widely they both represent 9.5 per cent of the intake. C. B. had a total excretion of 121.6 calories or 9.1 per cent of the intake, and V. B. 130.0 calories or 8.7 per cent. For children on a high protein diet Want and her associates reported total outputs representing 5.8 and 8.3 per cent of the intake (Table 4). These values are both lower than those in the present study.

Output in feces: Individual fluctuations in the output of the feces did not vary directly with the variations in intake, because the percentage of the intake excreted in the feces was not the same for each period. The range was least (60.5 to 64.4 calories for J. H. and greatest (54.6 to 74.8 calories for C. B. In only two cases, for C. B. and V. B. did the periods of highest intake and greatest output coincide.

The average total calorie output in the feces increased slightly with the intake for the first three children; 62.9, 66.2 and 67.9 calories for each respectively, while that for E. C. was much higher, 93.6 calories. This was nearly 26 calories above the output for any of the other children, and a much greater variation than had been found on the first study. Part of the wide variation in output in the feces for E. C. was, of course, due to his larger intake, but this does not show clearly except when expressed in term of the percentage of the intake excreted. E. C. had the largest percentage of excretion in the feces, 5.6 per cent; J. H. slightly less, 5.4 per cent; C. B. 5.0 per cent; V. B. least, or 4.5 per cent. The three children who served in both studies excreted the same percentage of the intake on both levels of protein. E. C. reacted like J. H. Individual variation from period to period was greater than that between the children. Since the subjects did not excrete the same percentage of the intake, the output in the feces did not vary directly with the calorie consumption. These fluctuations are comparable with those presented for the first study except for E. C. Wang and her associates, however, reported on excretion of 80 calories with a much lower percentage of intake excreted, or only 3.6 per cent. Another value of 36 was equivalent to 3.4 percent of the intake. In both cases the percentage of intake excreted was much lower than in the present study.

Output in urine: Individual calorie outputs in the urine per period varied 11.0 calories for E. C. and less than that for the other three children. From period to period the values did not seem to hear any relationship to the intake. In only two cases, for J. H. and for V. B. did the periods of high output andhigh intake coincide, on the other hand, in no instance did the low values come at the same time.

In every case less calories were excreted in the urine than in the feces, but, due to an increase in urinary calories the difference was less marked than on the medium protein diet. The increase amounted to about a third of the number of calories excreted in the urine during the first study. The average value was 47.6 calories for J. H. and increased with the intake or size of the child so that it was 65.4 calories for E. C. According to Wang and her associates this increase was probably due to the larger amount of nitrogenous waste products such as urea and uric acid excreted by the children receiving the larger total protein intake. The fact that all of the children excreted practically the same percentage of the intake (4.1, 4.2, 4.1, and 3.9 per cent in order of their size) shows that the number of calories excreted in the urine was in direct proportion to the total mitrogen intake, and probably independent of the calorie content of the diet as shown by the uniform increase for each child in the second study. Each child showed an increase of about 1.0 per cent of the intake excreted in the urine. This was the same as the percentage increase in total excretion for the high protein diet. These conclusions are comparable with those Wang and her associates formed from the results of a somewhat similar study. One of their subjects exereted 1.9 per cent of the intake on a medium protein diet and 2.2 per cent on a high protein level. This was slightly less than the difference in percentages observed on the present experiment.

Total absorption: Absorption fluctuated inversely with the fecal output as it did in the study in which the children received a medium protein diet. The greatest period to period variation (1527 to 1620 calories) was for E. C. and the least (1236 to 1299 calories) for C. B.

Since the two diets were identical in calorie content and each child excreted approximately the same number of calories in the feces on the two studies the two average figures for absorption values for any child are very similar. The greatest difference was only 3 calories. On the high protein diet the lowest absorption value was 1105 calories or 94.6 per cent of the intake, and the highest 1573 or 94.4 per cent of the food consumed. Although the absorption increased with the larger intakes it remained relatively uniform for all the children as they absorbed the same percentage. V. B. had the highest average percentage of absorption (95.5 per cent) and also the largest absorption (96.0 per cent) for any one period. Likewise E. C., who had the lowest individual figure, had the lowest average. These results are comparable to those Wang et al reported which were 96 and 97 per cent. They are, however, slightly lower.

Total retention: The retention remained rather constant for each of the subjects, but varied with the intakes of the different children. There was a definite relationship existing between retention and intake for, without exception, the highest intake and the greatest retentian for all the children were in period 4 and the lowest in period 7. Individual fluctuation from period to period in calories retained was greatest (1462 to 1555 calories) for E. C., and relatively uniform, though less, for the other three children.

Because retention did vary directly with the intake and inversely with the total output, J. H. had the lowest average retention (1058 calories) and E. C. the highest (1503 calories) Since the calorie intake and the output in the feces for each child was practically the same on both diets, any difference in retention on the two studies would be due to the increased number of calories excreted in the urine on the high protein diet. Average values (Tables 13 and 16) show that in this study the retention values were from 12 to 19 calories less than on the other study. This difference varied directly with the size of the subject, and, therefore, with the total intake. The variation was greatest for V. B., being 91.3 per cent of the intake on the high protein diet and 92.7 per cent on the medium protein level. The lowest average percentage of retention was 90.5 per cent for E. C. Wang and her associates reported retention values, 94 and 92 per cent of the intake, slightly higher than those in this study. They found that both children retained 93 per cent of the intake in a medium protein diet.

Study Number 11

High Protein Diet-On the Per Kilogram Basis

Intake: Although the calorie intake on the high protein diet was quite constant, yet, when the values were expressed in terms of kilograms there was a variation from period to period. The greatest difference between the lowest and the highest intake was 5.32 calories for C. B. Fluctuations for the other subjects were only slightly less. In every case the children consumed the smallest number of calories per kilo in period 7 and the largest number in period 4. As in the medium protein diet, fluctuations were not the same for each of the children, and actually varied somewhat from child to child

Fluctuations in the average intakes for the various children were slightly greater than those for a single child from period to period. They were also less than could be secured in studies in which the food was freely selected. The average intakes per kilogram of body weight in order of increasing size were 84.59 calories for J. H., 90.31 for C. B., 87.93 for V. B. and 91.17 for E. C. These values compare favorably with those reorted an the first

Table 17

Daily Caloric Balances per Kilogram of Body Weight

on a High Protein Diet

Child Period	Weight	Intake	Output			Absorption	Retention
			Total	Feces	Urine		
J.H.	kgs.	cal.	cal.	cal.	cal.	cal.	cal.
1	13.64	85.11	7.80	4.59	3.21	80.52	77.31
2	13.67	85.73	8.10	4.45	3.65	81.28	77.62
3	13.83	83.60	7.90	4.56	3.33	79.04	75.71
4	13.90	86.49	8.22	4.35	3.87	82.14	78.27
5	13.83	82.78	8.10	4.56	3.55	78.22	74.68
6	13.86	85.41	8.06	4.64	3.42	80.76	77.35
7	13.86	81.99	7.99	4.64	3.35	77.34	73.99
8	13.86	85.59	7.80	4.64	3.16	80.95	77.79
Average		84.59	8.00	4.55	3.44	80.03	76.59
C.B.							
1	14.66	90.46	8.34	4.79	3.55	85.67	82.12
2	14.70	91.07	7.66	3.72	3.94	87.36	83.41
3	14.77	89.43	8.38	4.66	3.72	84.77	81.05
4	14.81	92.73	8.76	5.05	3.71	87.68	83.97
5	14.77	88.55	8.54	4.71	3.83	83.83	80.01
6	14.81	91.31	8.41	4.58	3.83	86.73	82.90
7	14.85	87.41	7.90	4.19	3.72	83.23	79.51
8	14.81	91.51	7.84	4.15	3.69	87.36	83.67
Average		90.31	8.23	4.48	3.75	85.83	82.08
V.B.							
1	17.05	87.48	7.31	3.71	3.60	83.76	80.16
2	17.05	88.31	7.68	4.07	3.61	84.24	80.62
3	17.05	87.13	7.76	4.03	3.73	83.10	79.36
4	17.05	90.59	8.40	4.64	3.76	85.95	82.19
5	17.05	86.27	7.58	4.11	3.47	82.15	78.68
6	17.16	88.63	7.47	3.93	3.54	84.70	81.16
7	17.05	85.62	7.51	3.79	3.72	81.83	78.12
8	17.05	89.39	7.23	3.56	3.66	85.83	82.17
Average		87.93	7.62	3.98	3.64	83.93	80.31
E.C.							
1	18.28	90.63	8.05	4.75	3.30	85.88	82.58
2	18.28	91.49	8.72	4.96	3.76	86.53	82.77
3	18.28	90.27	8.89	4.99	3.90	85.28	81.38
4	18.28	93.86	8.81	5.22	3.59	88.64	85.05
5	18.28	89.38	8.85	5.52	3.33	83.85	80.52
6	18.28	92.42	9.00	5.38	3.63	87.04	83.42
7	18.28	88.71	8.72	5.15	3.57	83.56	79.99
8	18.28	92.62	8.53	4.96	3.57	87.66	84.09
Average		91.17	8.70	5.12	3.58	86.06	82.48

study. There was a variation of only about one calorie between the intakes per kilogram an the two diets. These values were somewhat different from those which Wang and her associates reported from two subjects who received a diet high in protein content. The four year old consumed less calories per kilo (76.3 calories) and the five year old more (122.4 calories) than the children in the present study.

Total output: The output per kilogram of body weight varied in much the same way as did the total calorie output previously discussed. Individual fluctuations were least (7.80 to 8.22 calories) for J. H. As discussed on the basis of total calories, the periods of largest intake and greatest output per kilo correspond for J. H., C. B. and V. B. On the per kilogram basis the eriods of least intake and lowest output were also identical for J. H. and E. C. The correlation between diet calories and the total excreted was 0.48 for the entire high protein study. This was a great increase over the correlation of only 0.04 in the first part of the experiment. When the data for the two studies were treated together the correlation was 0.24.

The lowest average output, 7.62 calories, was for V. B. and the highest, 8.70 for E. C. These values were considerably higher than those reported in the first study due to the increased excretion of the nitrogenous products. In the experiment conducted by Wang and her associates,

the total calories excreted per kilo were less than the averages for this experiment, being 6.3 and 7.1 calories for the two children.

Output in feces: The individual variation in calories excreted in the feces was very slight for each child. Maximum fluctuations, from 3.72 to 5.05 calories per kilogram of body weight, were for C. B. and the least for J. H. (4.35 to 4.64 calories).

The average calorie output in the feces per kilogram of body weight was relatively uniform for the various subjects. E. C. excreted the largest number of calories (5.12 calories) and V. B. the smallest number (3.98 calories). These average values were practically the same as those excreted on the medium protein diets, there being less than 0.3 calories difference between any two values. The above results were comparable to those reported by Wang et al for two normal contrats, one four and one five years of age. Average figures show that they excreted in the feces 2.6 and 4.4 calories per kilo respectively. The difference between the intakes for these children was 46.1 calories. Muller reported a loss in the feces slightly higher (5.9 calories per kilo) than any mentioned above.

Output in urine: Although J. H. had the least variation in fecal output she had the greatest fluctuation in urinary excretion (3.16 to 3.87 calories). It is interesting that

V. B. showed an opposite condition; the greater variation being in fecal output and the least in urinary excretion (3.54 to 3.76 calories). This pairing of high and low values was probably accidental and indicated that there was no definite relationship.

The average number of calories per kilogram of body weight which were excreted in the urine were 3.44 for J. H., 3.75 for C. B., 3.64 for V. B. and 3.58 for E. C. This marked similarity in average outputs in the urine was also present on the medium protein diet. Nevertheless, there was one outstanding difference between the results obtained on the two studies: those on the high protein diet were about one-third greater than those on the medium protein level. The subjects of Wang and her associates also excreted a larger number of calories by way of the urine when the protein content of the diet was increased, but, since the calories were not the same on the two levels of protein intake, the results can only indicate a trend. One of the children who consumed 4.3 grams of protein per kilo, excreted less in the urine (2.7 calories) than the subjects on the present study, the other excreted a comparable number (3.7 calories).

Absorption: The absorption of calories per kilogram of body weight varied directly with the per kilo intake and inversely with the fecal output. These variations were slight, however, and were approximately the same for each child. E. C. showed the widest range (83.56 to 88.64 calories(and also the largest absorption for any period. There was a high correlation (Table 15) of 0.95 when data from all the subjects on the high protein diet were used. This was about the same as that on the first study, 0.94, and slightly less than that on the two studies combined (0.97).

For three periods J. H. absorbed less than 80 calories per kilo which helped to make her average the lowest (80.03 calories) for this study. E. C. had the highest average absorption (86.06 calories). Since the calorie intake and the output in the feces were so nearly equal for both diets for any one child, the absorption values in the two studies were practically identical. The greatest difference was only one calorie. These results were less than the average absorption value calculated from Muller's data (98.1 calories) and from Wang and her associates' data (118 calories). Another of the latter's subjects on a diet similar in protein content, but lower in calories, absorbed less, about 74 calories.

Retention: When retention was expressed as calories per kilogram of body weight it varied directly with the intake and inversely with the total output per kilo for each child. Although this fluctuation in retention was slight, it was least (78.12 to 82.19 calories) for V. B. and most (79.99 to 85.05 calories) for E. C. For every subject the highest intake and the greatest retention per kilo were both in period 4 and the lowest in period 7. Thus the correlation between diet calories and retention was very high (0.95). When the data for the two studies were combined the correlation was 0.97 (Table 15).

There was only a slight variation in the average retention values for the children. Both the intake and the retention in calories per kilo were less for V. B. than for C. B., although the average total calorie intake had been greater for V. B. than for C. B. (Table 16). This apparent discrepancy was due to the slightly greater calorie intake per kilo of C. B., who was not as much over the average weight as was V. B. The average retention per kilogram of body weight was least for J. H. (76.59 calories) and greatest for E. C. (82.48 calories). Since there were more calories excreted in the urine on this experiment than there were when a medium protein diet was given the retention values were lower. In every case the decrease amounted to about two calories. This decrease was proportional to the increase in nitrogen excretion, particularly that in the urine.

The data reported by Wang and her associates show that the retention values for their subjects were either somewhat lower or a great deal higher than those obtained in the present study. Due to the wide variations in the number of calories consumed per kilo by their subjects the retention values on the high and those on the low protein intake cannot be accurately compared on the per kilo basis.

Period Averages

Since diet calories in the present study were averages of two samples the average of the retention value of each of the three children on one period might be more comparable than the individual data.

The averages for intake and retention which are discussed in this section are different from any other presented in the experiment. They were computed by adding the intakes, then the retentions of the children for each period separately and dividing by the number of children. This gave the average intake and retention per period per kilogram of body weight. Table 18 and Chart 4 show the variations from the average retention per period per kilogram of body weight, and compares these with the average intake per period per kilo.

When the retention and intake curve were plotted, they were nearly identical in contour. The individual values for each child are also marked on the chart. The table gives the calorie variation of each of these figures above and below the average. The values for J. H. varied more from the average on the high protein diet than they did on the

Table 18

Variations from the Average Retention per Period

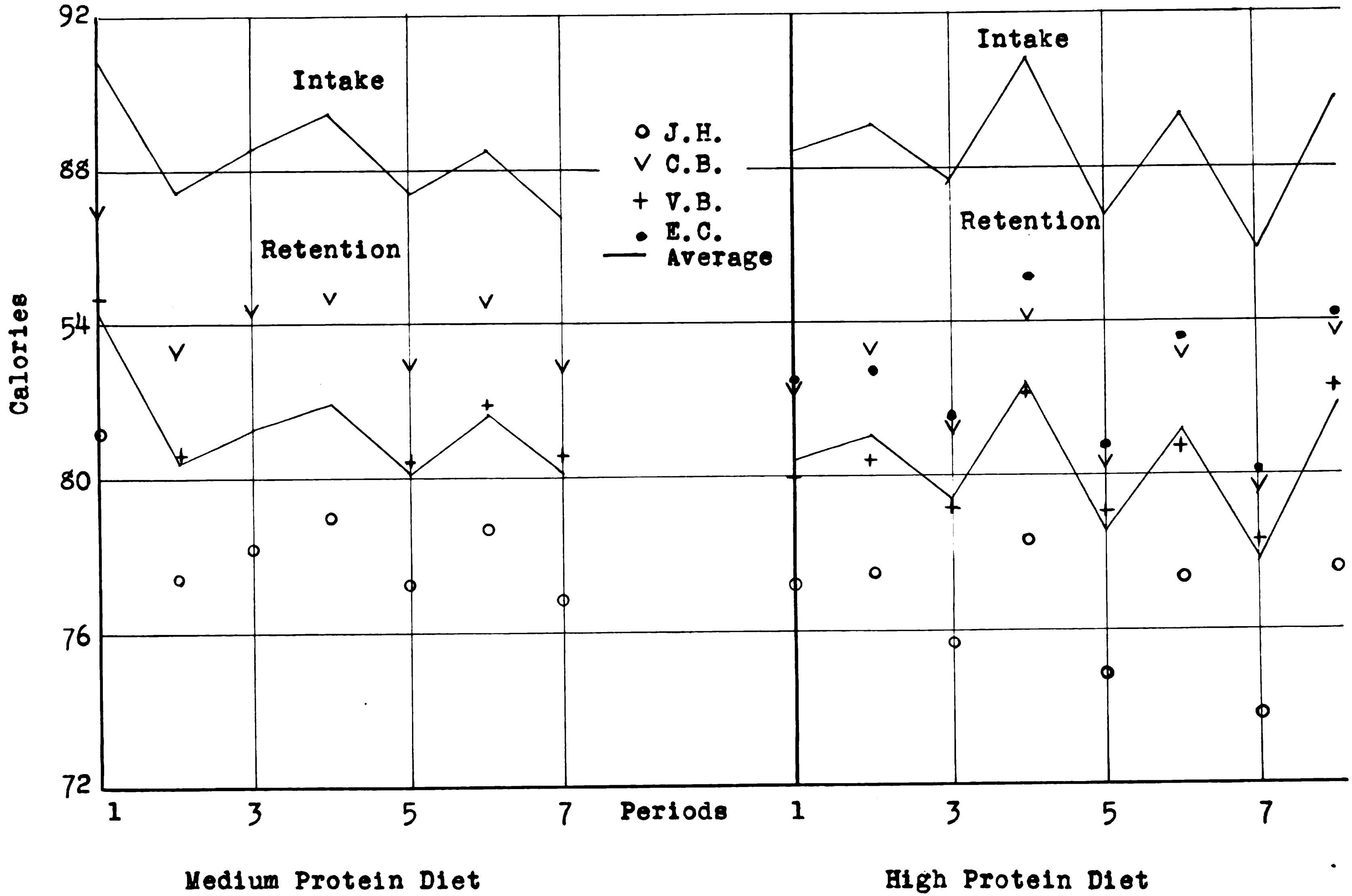
Per Kilogram of Body Weight

Period	Av. Intake per kg.	Av. Reten. per kg.	Variation from Av.			
			J.H.	C.B.	V.B.	E.C.
M.P.						
1	90.90	84.24	-2.95	+2.58	+0.36	
2	87.39	80.51	-2.98	+2.97	0.00	
3	88.54	81.32	-3.06	+3.06		
4	89.50	81.96	-2.75	+2.74		
5	87.52	80.23	-2.78	+2.66	+0.12	
6	88.50	81.57	-2.88	+2.87	+0.01	
7	86.83	80.03	-3.11	+2.74	+0.37	
H.P.						
1	88.42	80.54	-3.23	+1.58	-0.38	+2.04
2	89.15	81.11	-3.49	+2.30	-0.49	+1.66
3	87.61	79.38	-3.67	+1.67	-0.02	+2.00
4	90.92	82.37	-4.10	+1.60	-0.18	+2.68
5	86 75	78.47	-3.79	+1.54	+0.21	+2.05
6	89.44	81.21	-3.86	+1.69	-0.05	+2.21
7	85.93	77.90	-3.91	+1.61	+0.22	+2.09
8	89.78	81.93	-4.14	+1.74	+0.24	+2.16

medium protein diet, while those for C. B. varied less. The fluctuations in the data for V. B. were practically the same on the two diets, but those on the medium protein were above and those on the high protein below the average values. The values for E. C. on the high protein diet varied to about the same extent as those for C. B. on the medium protein diet. These values, of course, were proportional to the intake figures and in each case followed the average curve quite closely. Nevertheless the average for all the children per kilogram followed the average intake curve more closely.

Chart 4

Variations from the Average Retention per Period per Kilogram of Body Weight



Discussion

In the experiment the only appreciable difference between the two studies was the increase in the protein content of the diet in the second part. The average analyzed calorie content of the medium and the high protein diets were practically identical. There were, however, slight variations from period to period in the intakes for each child.

The total output did not fluctuate in proportion to the intake variations on each period. This was partially due to the fact that the feces calories remained nearly constant for each child from period to period on both diets, and constituted about two-thirds of the total output. Although the per cent of fecal output remained the same on each period, J. H., who had rather loose stools, had the highest percentage output while V. B., who had rather constipated stools, had the lowest percentage output. Therefore the calories in the feces were influenced more by the character of the stools than by the nitrogen content of the diet.

On the other hand the urinary excretion varied in proportion to the intake on each period. Furthermore, the nitrogen content of the diet affected the urine calories, as there was an increase of about one per cent in the percentage excretion in the urine, on the high protein diet. This increase was the same for all of the children.

In all cases the absorption values varied inversely with the fecal output, and the retention with the total output. Therefore, the absorption figures were relatively constant for the various children and practically the same for both diets. Although the retention values were also uniform on each diet, they were slightly less, about one per cent, on the high protein level. This decrease was due to the increased urinary excretion. All of the data seemed to indicate that the protein content of the diet had practically no influence on the calorie exchange.

Summary

1. This investigation was made to study the affects of varying the nitrogen intake on the calorie balances of four normal pre-school children.

2. The average total calorie content of the analyzed diets for both studies were identical.

3. The only significant difference between the two diets was that on the medium protein diet the subjects consumed three grams of protein per kilogram of body weight, while on the high protein intake they received four grams per kilo.

4. There was a slight variation in intake from period to period. The greatest difference between the lowest and the highest for any one child was 94 calories for E. C. on

the high protein diet.

5. On the medium protein diet average intakes ranged from 1169 to 1499 calories in total intake, or from 85.70 to 91.45 calories per kilogram of body weight. On the high protein diet average intakes ranged from 1168 to 1667 calories, in total intake, or from 84.59 to 91.17 calories per kilo.

6. There was an increase of about one per cent of the intake excreted on the second study. The least difference between the average outputs for any one child on the two studies was 11.9 calories for J. H. and the greatest 21.0 calories for V. B. Since the number of calories excreted in the feces was practically the same on both diets, this increase was due to the greater number of calories excreted, in the urine on the high protein diet. This increase was probably due almost entirely to the products of a greater protein metabolism on the second study. The total output did not vary with the intake. On the other hand the urinary excretion increased slightly with the intake.

7. In every case the absorption values varied inversely with the calorie output in the feces and thus remained relatively constant on both diets. The percentage of the intake absorbed varied from 94.7 to 95.7 per cent on the medium protein diet, and from 94.4 to 95.5 per cent on the high protein diet.

8. Since the retention values varied inversely with the total output they were slightly less on the second study. This difference was about one per cent, and due to the increase in urinary excretion. The percentage of the intake retained varied from 91.6 to 92.7 per cent on the medium protein diet and from 90.5 to 91.3 on the high protein diet.

9. Apparently the protein content of the diet did not affect the calorie balances of the children other than the increase in urinary calories on the higher protein level.

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