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Possible interrelationships between thiamine intake and ascorbic acid value of the plasma ...

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POSSIBLE INTERRELATIONSHIPS BETWEEN THIAMINE INTAKE AND ASCORBIC ACID VALUE OF THE PLASMA

by

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INTRODUCTION AND CITATION OF LITERATURE

Before modern methods of detecting mild or subclinical deficiency diseases were developed, the status of the individual with regard to vitamin C adequacy was determined by the presence or absence of mild or gross symptoms of scurvy. As early as 1772 Lind reported that the presence of petechiae was the most constant symptom to occur in individuals with scurvy. Another frequent early sign of vitamin C deficiency was that of mild bleeding or swelling of the gums. These gross signs of vitamin C shortage were preceded only by a short period of five to eight days characterized by weakness and lassitude. The early appreciation of the antiscorbutic properties of fresh vegetables and citrus fruits led to the appraisal of the diet as an indirect means of diagnosing suspected cases of vitamin C deficiency. Thus manifestations of symptoms of scurvy associated with an apparent low intake of foods possessing antiscorbutic properties served as the early means of judging vitamin C status.

In recent years it has been appreciated that deficiency diseases have reached an advanced state when they can be diagnosed by tissue changes which can be recognized grossly. Less severe tissue changes may not be apparent and yet the individual may be suffering from prolonged vitamin C shortages.

The isolation and synthesis of ascorbic acid and the development of practical methods of assaying for this nutrient have acted as a great stimulus to the study of methods of measuring vitamin C status. At present the adequacy of vitamin C in human nutrition is determined by one or more

of several measurements. These include determination of the resistance of the capillaries to pressure, measurement of the excretion of ascorbic acid in the urine when the subject is on an average mixed diet or following administration of large doses of ascorbic acid, and the analysis of the fasting blood ascorbic acid level.

Capillary fragility is determined either by the positive pressure technic of Göthlin (1933), or the negative pressure technic of Dalldorf (1933). This method was first used by Göthlin who measured the capillary resistance at varying levels of vitamin C intake, in an attempt to determine the human requirement of the vitamin. While it was first thought that this method might be practical for detecting mild cases of vitamin C inadequacy, it has been pointed out in later papers by Göthlin (1937) that the test may serve only as a method of detecting a rather severe degree of vitamin C undernutrition. Göthlin found that when the capillary resistance fell, indicating definite vitamin C shortage, plasma ascorbic acid values ranged from 0.1 to 0.14 milligrams percent. These values are considerably below the accepted minimum normal values for ascorbic acid concentration of blood as revealed by more recent studies.

Other investigators have found no correlation between values for capillary fragility and plasma concentrations of ascorbic acid (Farmer, Abt, and Epstein, 1936; Hawley and Stevens, 1936). According to Sloan (1938) the capillary resistance test in the majority of cases gives dependable information concerning the presence or absence of vitamin C depletion but does not indicate the degree of depletion. He points out that the test also gives falsely negative results in the presence of severe anemia. Rhinehart

and Greenberg (1942) state that capillary fragility is not specific for vitamin C depletion and is of little value as an index of vitamin C status. Thus the method of determining capillary resistance as a means of detecting early or mild avitaminosis C must be ruled out, and has been widely replaced by the direct chemical tests which determine the ascorbic acid concentration in blood and in urine.

During the years 1937 and 1938 several reports have appeared in the literature suggesting an intradermal test for detecting vitamin C deficiency (Rotter, 1937; Portnoy and Wilkerson, 1938a). This method in brief consists of injecting a small quantity of the dye 2:6 dichlorophenolindophenol beneath the surface of the skin and noting the speed of decolorization which occurs. The method has likewise been discarded as a means of detecting mild vitamin C deficiency.

The quantity of ascorbic acid excreted in the urine during the twenty-four hour period has been used extensively as a method of measuring the state of vitamin C nutrition. The excretion of vitamin C in the urine appears to be dependent upon the relative degree of saturation of the tissues and the immediate intake of ascorbic acid. In general, at intakes of vitamin C designated as low or deficient, the urinary excretion of ascorbic acid is low, increasing with increased intakes of the vitamin. Objections have been raised, however, to the use of the twenty-four hour excretion of vitamin C as a diagnostic test, because of the wide individual variation observed in the amount of ascorbic acid excreted at relatively constant levels of intake (Fincke and Lundquist, 1942; Todhunter and Fatzer, 1940). Moreover, temporary variations in the dietary intake cause corresponding fluctuations in

the amount of the vitamin excreted. Hence a single low value may not be an indication of a deficiency state. In those cases, however, when a single value of ascorbic acid is determined for the twenty-four hour period, it is assumed that the subject has been receiving a generous intake of vitamin C if the amount of ascorbic acid excreted ranges from 20 to 50 milligrams per day, while excretions below 15 milligrams are considered suggestive of a deficiency (Youmans, 1941).

It is now fairly well recognized that a more sensitive estimation of the vitamin C nutrition can be obtained by the use of a test dose, or saturation period, than by determining the resting level of vitamin C excretion alone. This method consists of determining the daily excretion of ascorbic acid during a period in which large doses of ascorbic acid are given to completely saturate the tissues. In normal subjects a considerable portion of such a dose is excreted in the urine within twenty-four hours. In the deficient subject much of the dose may be retained in the tissues and little or none appears in the urine.

Numerous procedures have been described in the literature for determining the degree of saturation of the tissues. It is difficult to evaluate these findings due to variations in the size of doses fed, the number of days the dose is to be administered, the method of administration, and the time interval used to recover the major portion of the ingested ascorbic acid. A dosage of 700 milligrams of crystalline ascorbic acid per 10 stone of body weight (140 pounds) has been recommended by Harris and associates (1936) and has been used frequently by other investigators. However, doses as low as 100 milligrams and as high as 1000 milligrams

have been reported. When the ascorbic acid is taken by mouth, as is commonly the case, the excretion of 50 percent or more of the entire test dose within twenty-four hours is considered to indicate tissue saturation (Smith 1938). As has been pointed out by Shaffer (1944) the excretion of ascorbic acid following a test dose varies with the route of administration. A test dose administered orally reaches a peak of excretion within three to six hours due to the time required for absorption. Ascorbic acid administered intravenously is followed by an immediate rise in plasma concentration and maximum excretion occurs in less than two hours. Subcutaneous injection is preferred to intravenous administration by van Eekelen and Heinemann (1938) since intravenous administration raises the concentration in the blood so suddenly that a transitory overflow into the urine results before the tissues become saturated. Lilienfeld et al. (1936) consider intramuscular injections of the vitamin as satisfactory as oral dosages and superior to the intravenous route, in that absorption is slower and the height of the increase in blood plasma is sustained longer.

Urinary tolerance tests have been used by Portnoy and Wilkerson (1938b), Ralli and associates (1938), and Wright and coworkers (1937). This procedure consists of administering a massive dose of ascorbic acid parenterally and observing the urinary excretion which occurs within the following three to five hours. Goldsmith and Ellinger (1939) state that in normal subjects ascorbic acid excretion begins to increase within one hour after the administration of the test dose, and reaches a peak between the first and sixth hours. The individual with depleted vitamin C stores exhibits only a slight rise or shows no rise at all following a test dose. Since approximately 80 percent

of the total twenty-four hour excretion occurs within the first six hours, it is unnecessary to follow the excretion period longer. The urinary tolerance test, because of its convenient six hour collection period, has been used widely by clinicians as a means of diagnosing vitamin C depletion.

A further advancement has occurred in the evaluation of vitamin C status with the development of methods for the determination of vitamin C in blood and plasma. While it is generally accepted that fasting blood levels of ascorbic acid parallel the intake of the vitamin, there is less agreement as to what value of fasting blood ascorbic acid indicates depletion. Abt et al. (1936) have reported that healthy individuals receiving an adequate intake of vitamin C will exhibit a plasma level of 0.7 milligrams percent or above. Values below 0.7 milligrams percent are considered subnormal or at least suboptimal. Kajdi, Light and Kajdi (1939) state that on an adequate intake of ascorbic acid, fasting values of the plasma range from 0.7 to 0.9 milligrams percent, and that levels between 0.5 and 0.15 milligrams percent indicate suboptimal stores. Symptoms of scurvy are reported to occur at levels below 0.15 milligrams percent. Goldsmith and Ellinger (1939) designate the normal range of blood plasma as being between 0.45 and 1.98 milligrams percent. A plasma value of at least 0.8 milligrams of ascorbic acid per 100 milliliters of plasma has been used widely as a criterion of normal stores of vitamin C. The determination of the fasting level has been considered the simplest and most direct exploratory method for detecting subclinical deficiency of the vitamin. Van Eekelen and associates (1937) have shown that with an ascorbic acid content of the blood of approximately 0.4 milligrams percent, a total of 2 grams of ascorbic acid

is required in adults before saturation is reached, as compared with only 1 gram for an initial blood value of 0.8 milligrams percent. These workers conclude that the degree of vitamin C saturation of a subject can be estimated by a single blood determination rather than the tedious urinary excretion test. The standards used by Van Eekelen and associates agree with those suggested by Farmer, Abt and Epstein (1936), a blood value of 0.0 to 0.4 milligrams percent denoting depletion, from 0.4 to 0.8 milligrams percent indicating moderate stores of vitamin C, and all values above 1.2 milligrams percent indicative of an excellent state of saturation.

Tolerance tests based on the rise in plasma ascorbic acid following a standard orally administered test dose have been developed as a means of determining the degree of tissue depletion existing at an obviously low fasting level. Kajdi, Light and Kajdi state that in measuring or estimating vitamin C nutrition, the customary plasma vitamin C determination is not an adequate criterion. These investigators point out that plasma level of ascorbic acid is regulated by the intake, the rate of withdrawal from or deposition into the stores, the rate of excretion and the rate of utilization. A low plasma level of ascorbic acid therefore may be due to ingestion of inadequate amounts of vitamin, low stores, or increased destruction or utilization. If inadequate ingestion or increased destruction is of short duration, then the storage may not be greatly interfered with, although the plasma level is low. In such a case the increase in the plasma vitamin C following the administration of a test dose may be normal or even above normal. Hence a combination of the initial plasma level and the increase four hours following a test dose is considered to give a more

reliable picture of the storage of vitamin C in the tissues. Kajdi and associates have developed a test for vitamin C storage which they refer to as the "vitamin C index". The index is the product of the initial value of the plasma and the increase in plasma vitamin C four hours after injection of the test dose. Thus small rise in the concentration of the plasma ascorbic acid denotes severe tissue depletion, whereas a marked increase indicates a state of saturation. Other workers have expressed a similar criticism of the use of the fasting plasma level as the sole criterion of degree of saturation. Greenberg et al. (1936) state that the reduced plasma ascorbic acid is merely a measure of the immediate nutritive or metabolic level relative to vitamin C and is dependent on recent dietary habits to a large degree. Consequently, although it is an index of the vitamin C nutrition at the time of the test, a single low level does not imply tissue injury or scurvy. Conversely a good or high level of ascorbic acid in the plasma would not always indicate that a deficiency had not operated to produce tissue injury in the immediate past. These workers conclude that a more accurate index of vitamin C status in any given case can be made by means of serial determinations following administration of known vitamin C supplements.

Oral and intravenous tolerance tests, involving simultaneous determinations of the blood and urine at frequent intervals following the administration of a single massive dose of ascorbic acid orally or intravenously, have been suggested by Portnoy and Wilkerson (1938b) as furnishing the most reliable information concerning the state of vitamin C nutrition.

Numerous reports have appeared in which either blood or urine analyses

have been used to determine the state of vitamin C nutrition, since in normal subjects there appears to be a direct relationship between the blood level and the level of excretion at given intakes of the vitamin.

The criterion most frequently used as indicative of a satisfactory state of vitamin C nutrition has been a fasting plasma level of 0.7 milligrams percent or above and the excretion of 50 percent or more of a test dose of ascorbic acid. These criteria have been based on the usual performance of a normal individual who can be expected to maintain a fasting plasma level at or above this concentration on adequate intakes of vitamin C and who will excrete 50 percent of a test dose when the tissues are in a state of saturation.

In studying the vitamin C status of various groups of individuals, it has been observed that occasionally subjects failed to reach the expected fasting blood ascorbic acid level, even though the intake of ascorbic acid was high. Stotz et al. (1942), in studying ascorbic acid storage of senile patients, observed two individuals showing low plasma levels and tolerance curves indicating a deficiency in spite of seemingly adequate intakes of vitamin C furnished from their hospital diet. These patients displayed the expected saturation curves only after receiving supplementary doses of 300 milligrams of ascorbic acid daily for a period of two weeks. The fact that normal excretion curves were obtained after two weeks of high vitamin C ingestion has been interpreted by Stotz and his coworkers to mean that absorption of vitamin C was normal in these cases. Bessey and White (1942) in studying the ascorbic acid requirements of children, observed a small number of individuals whose blood plasma levels remained definitely low in

spite of a regular intake of ascorbic acid which was considered adequate for the average child. All children included in this study were considered to be in normal health. Bessey and White suggest that the low levels may be characteristic of certain individuals and that in previous studies they have also encountered an occasional subject exhibiting low plasma levels of ascorbic acid which were not explainable by their previous vitamin C intake.

In the nutrition laboratory of Iowa State College, routine examinations of plasma ascorbic acid levels of prospective subjects for a study of vitamin C metabolism during periods of controlled exercise led to an extended observation of one subject whose initial fasting level of ascorbic acid varied from 0.21 to 0.46 milligrams percent. A quantitative check of the self selected diet of this individual revealed an approximate intake of 112 milligrams of ascorbic acid daily. Administration of a test dose of 500 milligrams of ascorbic acid resulted in a urinary excretion of 53 percent of the test dose. Continued study of this same subject revealed that the plasma concentration of ascorbic acid did not increase following the administration of 500 milligrams daily for 4 successive days. Judging from the findings of other workers it would appear that the tissues of this subject were saturated with ascorbic acid but that the plasma ascorbic acid level remained within a deficient or suboptimal range.

In an attempt to determine whether other factors of the diet may have influenced the plasma level of ascorbic acid, a check was made of the customary eating habits of the subject. The diet was found to be adequate in all the usual nutrients when checked against the recommended amounts proposed

by the National Research Council with the possible exception of thiamine. The calculated thiamine intake of the diet was approximately 0.95 milligrams per day as compared with the figure of 1.5 milligrams as suggested by the National Research Council. Inquiry into the previous dietary habits of this subject indicated that the diet had been constantly limited to avoid gain in weight and that the thiamine intake of the diet was apt to have been low for quite some period of time. During a second experimental period at which time one milligram of thiamine as thiamine hydrochloride was added to the diet for a period of two weeks, it was observed that the plasma ascorbic acid values increased to within levels considered indicative of normal ascorbic acid stores.

A search of the literature relative to possible interrelationships between thiamine and ascorbic acid has revealed little experimental evidence of a positive nature. Sure and coworkers (1939) have studied the influence of avitaminoses on the oxidation-reduction mechanisms of the animal organism by studying the ascorbic acid content of various tissues of rats during various deficiency diseases. The above workers report considerable reduction of ascorbic acid in certain tissues of rats during thiamine and riboflavin deficiency. More recently it has been demonstrated that ascorbic acid will prevent or cure certain secondary manifestations of thiamine deficiency in dogs (Govier and Greig, 1943). These studies, although demonstrated with species which synthesize vitamin C, suggest an interrelationship between thiamine and ascorbic acid which may have significance in human nutrition.

The observations of Sealock and Silberstein (1939, 1940) and Levine, Marples and Gordon (1941) concerning the requirement of ascorbic acid for

normal metabolism of phenylalanine and tyrosine may also be of importance here. According to the above workers, in the absence of sufficient ascorbic acid, incomplete metabolism of aromatic amino acids occurs. In such instances alpha keto acids are excreted in abnormal quantities. Since thiamine functions in the removal of pyruvic acid derivatives from the blood, the possibility exists that a shortage of thiamine influences the requirement for ascorbic acid depending upon the height of aromatic amino acids ingested.

In view of these possibilities and the results obtained in the earlier study from this laboratory which suggested that thiamine intake influences the plasma ascorbic acid concentration, further investigation of a possible interrelationship between these two vitamins has been indicated. The present study, therefore, was undertaken to determine whether the thiamine intake of the diet plays a measurable part in the regulation of the ascorbic acid level of the plasma.

EXPERIMENTAL PROCEDURE

Subjects

Healthy college women of senior or graduate level were selected. It was believed that advanced students would show greater interest in the study and cooperate more fully than students of a lower classification. Data regarding age, height, and weight of the subjects are recorded in Table 1.

Table 1. Age, height, and weight of subjects

Subject	Age	Height	Weight
		inches	pounds
J.B.	24	64.5	123
A.C.	23	62.5	125
B.C.	24	64.0	143
P.M.	20	64.5	128
K.M.	20	64.0	122
G.O.	19	65.0	125

Routine college entrance examinations and health records of the subjects indicated that they were physically normal.

The purpose and procedure of the experiment was explained to each prospective subject at the outset and the necessity for complete cooperation throughout the study was emphasized.

During the experiment, subjects continued the ordinary routine of classwork and participation in extracurricular functions. They were asked to keep a record of any unusual activity. The use of aspirin or similar drugs was not permitted.

Diet

All food was served at the college hospital in order to insure accuracy of dietary records. Due to conditions prevailing at the time of the study it was impossible to offer a special diet during the experiment and the diet served to the regular hospital staff was used. Food for the subjects was weighed on a Chattilon scale which could be read to an accuracy of one gram. Records were kept of the dietary intake of each subject. The nutritive value of the diets was calculated by a short method of analysis recommended by Donelson and Leichsenring (1942). This method consists of grouping foods previously reported to contain approximately the same quantity of a given nutrient and allowing one value to serve as typical of the group.

Originally it was planned to allow subjects to select unrestricted amounts of food throughout the study according to their individual appetites. Subjects J.B., A.C., and B.C. were studied on this basis. However, calculation of vitamin C intake of these subjects showed a wide variation from day to day; thus it seemed advisable to control the quantity of vitamin C rich foods in future subjects. Accordingly, the vitamin C intake for subjects P.M., K.N., and G.O. was limited to a calculated range of 70 to 90 milligrams of ascorbic acid daily. This intake of ascorbic acid was chosen

because it approximates the recommended allowance for vitamin C as set up by the Food and Nutrition Board of the National Research Council (1945).

Experimental Periods

The general plan of procedure throughout the study included the following periods:

1. An initial period varying from seven to fourteen days was studied during which all subjects received a known quantity of the regular college hospital diet, the quantities of foods consumed depending on the individual's appetite. Subjects J.B., A.C., and B.C. were maintained on this initial period for seven days while P.M., K.M., and G.O. were continued on the hospital diet for fourteen days. Fasting plasma levels and urinary excretion of ascorbic acid were determined on alternate days throughout this period.

2. A saturation period of three to four days followed during which the subjects received a supplement of 500 milligrams of crystalline ascorbic acid daily in evenly divided doses given at breakfast and at lunch. Plasma ascorbic acid values and urinary output of ascorbic acid were checked daily during this period to determine the extent of tissue saturation maintained on the previous intake of vitamin C.

3. A final period varying from seven to fourteen days followed the saturation period. Those subjects maintained on period 1 for seven days were likewise continued for seven days following the saturation test. Plasma and urine were analyzed daily until the excretion of ascorbic acid fell to that of the initial period. Determinations were then made on alternate days.

4. Each subject was then given a supplement of one milligram of thiamine hydrochloride[1] daily and the periods described above were repeated on this higher level of thiamine intake.

Collection of Urine

Twenty-four hour urine specimens were collected directly into wide-

[1] Merck and Company, Inc., Rahway, N. J.

mouthed brown bottles containing an acid preservative. The preservative used consisted of 100 milliliters of 5 N sulfuric acid, 100 milliliters of one percent metaphosphoric acid and 2 milliliters of 8-hydroxy quinoline (1.45 grams in 100 milliliters of alcohol). Subjects were instructed to keep the urine samples tightly stoppered between collections. Sample bottles were held at room temperature. After the completion of the twenty-four hour collection, samples were brought to the laboratory immediately and analyses were made within four hours of this time.

Determination of Ascorbic Acid in Urine

The ascorbic acid content of the urine samples was determined by the method of Evelyn et al. (1938) with corrections for turbidity and color as suggested by Bessey (1938). This method involves the use of a photoelectric colorimeter in measuring the amount of 2:6 dichlorophenol indophenol decolorized when a measured quantity of urine reacts with an excess of the dye. The use of 2:6 dichlorophenol indophenol to determine ascorbic acid is based on the fact that the dye is quantitatively and rapidly reduced to a colorless compound by ascorbic acid in acid solution (Bessey, 1938).

A stock solution of dye was prepared every two weeks by dissolving 100 milligrams of sodium 2:6 dichlorobenzenone indophenol[1] in 200 milliliters of Sorenson's phosphate buffer solution having a pH of 7. This buffer was prepared by combining 38.9 parts of a molar solution of potassium dihydrogen phosphate (9.08 grams per liter of solution) and

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[1] Eastman Kodak Co., Rochester, N. Y.

61.1 parts of a molar solution of sodium monohydrogen phosphate (23.887 grams per liter of solution). The dye was refrigerated in a brown glass bottle when not in use. The stock solution of dye was diluted 1:10 with freshly redistilled water immediately preceeding urine determinations.

The original optical density of the dye solution was measured by adding 5 milliliters of dye by means of a rapid delivery pipette to a one milliliter aliquot of a solution containing the quantity of preservative present in a similar aliquot of urine. The readings were made in a Klett Summerson colorimeter after the galvanometer had been adjusted to zero when checked against a tube containing distilled water. Readings were taken at 10, 15, 20, 30, 40, 50, and 60 seconds. These values were termed blank readings. Next, the same quantity of dye was added to a one milliliter aliquot of urine and readings taken at the intervals noted above. A correction for color and turbidity in the urine was made by completely reducing the excess dye with a few crystals of ascorbic acid, and subtracting the decolorized readings from each of the original readings. The reducing value of the urine was calculated by subtracting the corrected urine readings from the corresponding blank readings. These values were plotted against time and the curve extrapolated by a smooth free hand curve to intersect the axis of ordinates to determine the reducing value of ascorbic acid. The concentration of ascorbic acid in the sample was calculated by multiplying this extrapolated value by the calibration constant for the colorimeter determined by measurements of solutions of pure ascorbic acid.

A typical reaction velocity curve obtained by this method is shown in Figure 1.

Form E-5

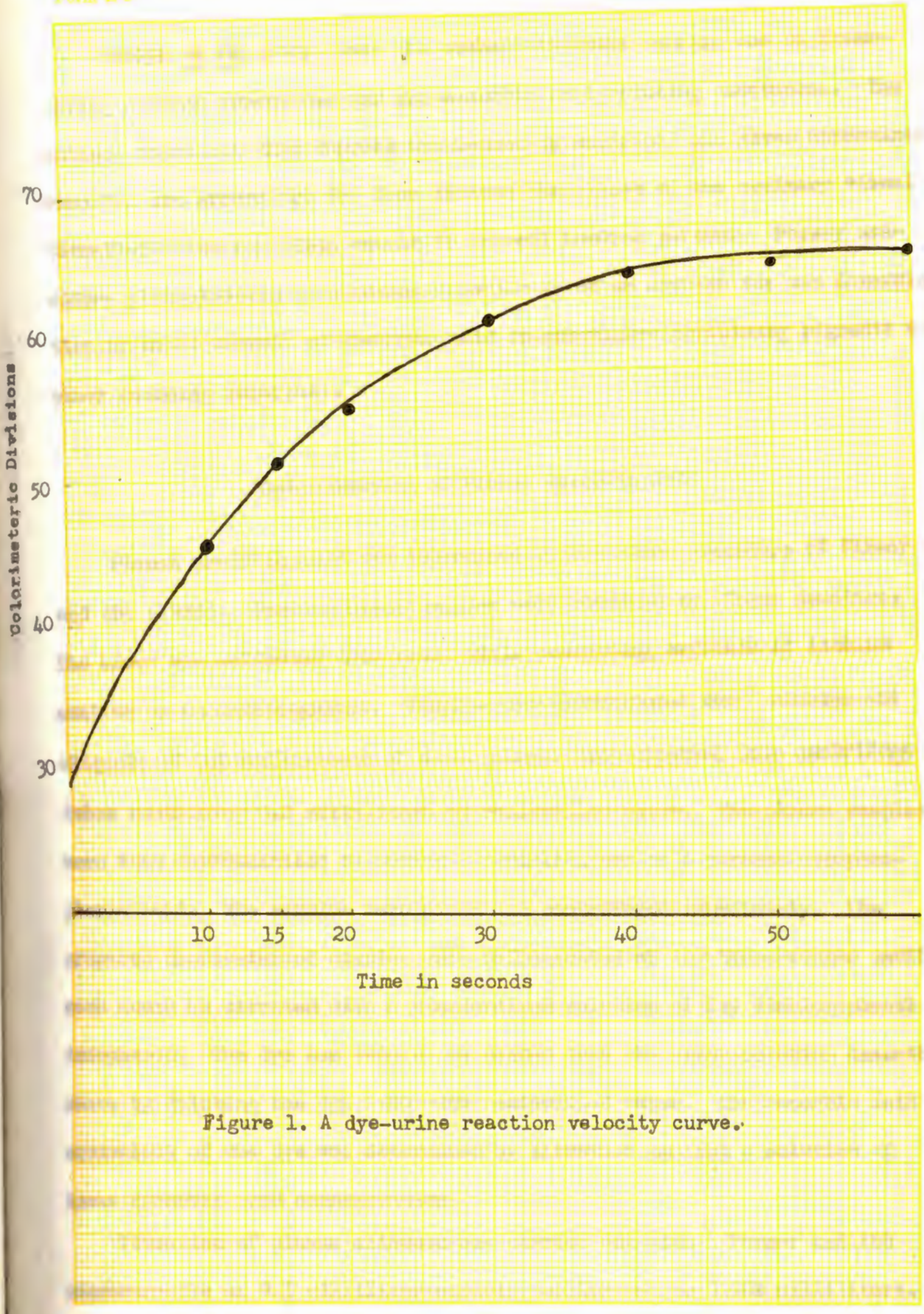

Figure 1. A dye-urine reaction velocity curve.

Evelyn et al. state that the method eliminates errors due to interfering colored substances and non-ascorbic acid reducing substances. The authors point out that whereas the method is empirical and gives approximate results, the errors are far less serious than those of the ordinary visual titration which may often amount to several hundred percent. Bessey considers photoelectric measurement superior to other methods for the determination of small amounts of ascorbic acid in substances containing pigments and other reducing materials.

Determination of Plasma Ascorbic Acid

Plasma ascorbic acid was determined by the micro procedure of Farmer and Abt (1936). Fasting blood samples were obtained by finger puncture. The blood was collected into small vials containing crystals of lithium oxalate as an anticoagulant. Samples were centrifuged for 5 minutes and aliquots of 0.2 milliliters of clear plasma were pipetted into centrifuge tubes containing 0.2 milliliters of redistilled water. The plasma samples were then deproteinized by adding 0.4 milliliters of 5 percent metaphosphoric acid. The samples were mixed and centrifuged immediately. The prepared deproteinized samples were refrigerated at low temperatures until each could be titrated with a standardized solution of 2:6 dichlorophenol indophenol. The dye was made up as needed from the stock solution described above by diluting the dye 1:20 with redistilled water. The ascorbic acid equivalent of the dye was determined by titration against a solution of known ascorbic acid concentration.

Titration of plasma aliquots was carried out with a Farmer and Abt microburrette of 0.1 milliliter capacity calibrated to 0.002 milliliters.

The pipette was read to the nearest 0.001 milliliter. A blank was determined with each aliquot of plasma by titrating 0.2 milliliters of 2.5 percent metaphosphoric acid to the first permanent pink. The 0.2 milliliter aliquot of plasma was titrated to the same end point. The reduced ascorbic acid content of the plasma was calculated according to the following formula:

> Milligrams of ascorbic acid = milliliters of dye for plasma aliquot - blank titration x dye equivalent x dilution factor.

Three individual determinations were made from two separate samples of plasma and the average value obtained from the six titrations was used as the fasting plasma ascorbic acid concentration.

RESULTS AND DISCUSSION

Dietary Intake of Thiamine and Ascorbic Acid

All menus served to the subjects during the experiment are recorded in Table I (APPENDIX). The calculated average daily intake and the range of intake for both thiamine and ascorbic acid have been summarized in Table 2. At no time did the estimated consumption of ascorbic acid fall below that of 70 milligrams suggested by the National Research Council as desirable for normal adult women. During several days the level of ascorbic acid ingestion was very high especially for subjects J.B., A.C., and B.C. who were studied first and who were not restricted in any way as to the quantity of ascorbic acid foods eaten. Thiamine intake, however, during the first period of the experiment did not meet the value suggested by the National Research Council as desirable for adult women of moderate activity. The quantity of thiamine estimated to be present in the hospital diet served all six subjects during the first period of the experiment averaged about one milligram per day as compared with the 1.6 milligrams proposed by the National Research Council. While the thiamine intake of the diets during the first period did not approach the figure quoted by the National Research Council as one desirable for women showing moderate activity, it exceeded the value of 0.8 milligrams per 2500 calories given by Lane and associates (1942) as typical of the intake of three-fourths of the American population.

During the period of high thiamine intake, an increased intake in dietary sources of thiamine occurred in all subjects due to the inclusion in the diet

Table 2. Calculated dietary intake of ascorbic acid and thiamine

Subject	Estimated Average Daily Intake of Ascorbic Acid	Range of Estimated Ascorbic Acid Intake	Estimated Average Daily Intake of Thiamine	Range of Estimated Thiamine Intake
	Mgs.	Mgs.	Mgs.	Mgs.
Hospital Diet				
J.B.	125	78-185	1.12	0.83-1.35
A.C.	140	85-190	1.01	0.79-1.28
B.C.	149	75-185	1.00	0.88-1.36
P.M.	80	75- 85	0.96	0.81-1.25
K.N.	80	75- 85	1.05	0.90-1.26
G.O.	80	75- 85	0.98	0.79-1.30
Hospital Diet Plus 1 Milligram Thiamine				
J.B.	139	95-180	2.20	1.92-2.43
A.C.	136	88-195	2.26	1.86-2.45
B.C.	150	75-190	2.29	1.80-2.56
P.M.	80	70- 90	2.22	1.85-2.49
K.N.	80	70- 90	2.32	1.82-2.46
G.O.	80	70- 90	2.25	1.90-2.39

of whole grain or enriched breads. Moreover, an unexpected increase in total consumption of foods was observed. Three to five hundred additional calories were consumed regularly during this period. The addition of the one milligram supplement of thiamine hydrochloride brought the thiamine level of the diet to approximately 2.25 milligrams daily. Occasional higher levels of thiamine intake resulted when the menu included pork, liver or peas which are rich sources of the vitamin.

Urinary Excretion of Ascorbic Acid

Tables 5 through 8 give complete data on each subject including the calculated dietary intake of ascorbic acid and thiamine, the urinary excretion of ascorbic acid and the plasma concentration of ascorbic acid. A wide fluctuation in daily urinary excretion of ascorbic acid was observed in subjects J.B., A.C., and B.C. These data are given in Table 9. When one considers the variation in ascorbic acid intake of these subjects, this fluctuation is to be expected. A smaller day to day fluctuation in urinary ascorbic acid was observed for subjects P.M., K.M., and G.O., who were on a relatively fixed ascorbic acid intake. The extent of the fluctuation in ascorbic acid excretion observed in these subjects agrees with the findings of other investigators including Todhunter and Robbins (1940), Storvick and Hauck (1942) and Roberts and Roberts (1942). Todhunter and Robbins have questioned the reliability of urinary excretion as a criterion of vitamin C status because of the variable results obtained with subjects consuming the same basal diet and receiving the same supplements of crystalline ascorbic acid. Storvick and Hauck have pointed out that although daily fluctuations in ascorbic acid

Table 3. The influence of varying the level of thiamine of the diet on the urinary excretion and plasma concentration of ascorbic acid of subject J.B.

Date	Estimated Intake Ascorbic Acid	Estimated Intake Thiamine	Urinary Excretion Ascorbic Acid 24-hours	Plasma Concentration Ascorbic Acid
	Mgs.	Mgs.	Mgs.	Mgs. Percent
Initial Period				
6-26-44	95	1.01	70.9	0.80
6-28-44	128	0.98	55.9	0.83
6-30-44	150	0.95	52.9	0.85
Saturation Period (500 milligrams of ascorbic acid given for four days)				
7- 1-44	605	0.89	372.9	0.94
7- 2-44	615	0.85	651.9	0.96
7- 3-44	620	0.87	551.6	0.93
7- 4-44	680	0.96	451.4	0.93
Post-Saturation Period				
7- 5-44	158	1.04	129.5	0.87
7- 7-44	125	0.85	36.6	0.79
7- 9-44	100	1.21	25.8	0.80
7-11-44	85	1.01	30.0	0.82

Table 3. The influence of varying the level of thiamine of the diet on the urinary excretion and plasma concentration of ascorbic acid of subject J.B. (Continued)

Date	Estimated Intake Ascorbic Acid	Estimated Intake Thiamine	Urinary Excretion Ascorbic Acid 24-hours	Plasma Concentration Ascorbic Acid
	Mgs.	Mgs.	Mgs.	Mgs. Percent
Initial Period with Thiamine Supplementation				
7-11-44	165	1.98	88.5	0.82
7-13-44	150	2.25	67.0	0.89
7-14-44	90	2.15	28.0	0.90
7-15-44	160	2.06	62.5	0.84
Saturation Period (500 milligrams of ascorbic acid given for four days)				
7-17-44	625	1.96	446.9	0.92
7-18-44	675	1.90	702.0	1.18
7-19-44	620	1.97	353.8	1.01
Post-Saturation Period				
7-20-44	95	1.95	159.5	1.00
7-21-44	165	2.21	85.6	0.92
7-23-44	159	2.18	39.3	0.93
7-25-44	150	1.92	65.7	0.93
7-29-44	143	2.13	50.2	0.91

Table 4. The influence of varying the level of thiamine of the diet on the urinary excretion and plasma concentration of ascorbic acid of subject A.C.

Date	Estimated Intake Ascorbic Acid	Estimated Intake Thiamine	Urinary Excretion Ascorbic Acid 24-hours	Plasma Concentration Ascorbic Acid
	Mgs.	Mgs.	Mgs.	Mgs. Percent
Initial Period				
4-26-44	165	0.84	83.2	0.76
4-28-44	129	1.35	23.8	0.74
4-30-44	161	1.48	53.2	0.39
5- 3-44	139	1.04	28.6	0.46
Saturation Period (500 milligrams of ascorbic acid given for four days)				
5- 5-44	665	1.06	417.3	0.54
5- 6-44	670	1.00	497.5	0.56
5- 7-44	682	0.79	702.4	0.56
5- 8-44	617	0.81	523.2	0.54
Post-Saturation				
5- 9-44	96	0.88	152.1	0.54
5-10-44	159	0.79	82.4	0.49
5-12-44	129	0.94	42.1	0.49
5-14-44	113	0.89	35.4	0.50

Table 4. The influence of varying the level of thiamine of the diet on the urinary excretion and plasma concentration of ascorbic acid of subject A.C. (Continued)

Date	Estimated Intake Ascorbic Acid	Estimated Intake Thiamine	Urinary Excretion Ascorbic Acid 24-hours	Plasma Concentration Ascorbic Acid
	Mgs.	Mgs.	Mgs.	Mgs. Percent
Initial Period with Thiamine Supplementation				
6-24-44	126	2.06	42.0	0.55
6-26-44	102	2.09	60.9	0.73
6-28-44	135	2.15	94.5	0.87
Saturation Period (500 milligrams of ascorbic acid given for four days)				
6-29-44	592	2.27	347.2	1.05
6-30-44	603	1.85	328.8	1.05
7- 1-44	589	1.93	469.3	0.99
7- 2-44	620	1.99	663.4	0.93
Post-Saturation Period				
7- 3-44	112	1.95	148.8	0.94
7- 4-44	109	1.87	38.7	0.90
7- 7-44	163	2.28	30.4	0.87
7- 9-44	159	2.49	32.4	0.88

Table 5. The influence of varying the level of thiamine of the diet on the urinary excretion and plasma concentration of ascorbic acid of subject B.C.

Date	Estimated Intake Ascorbic Acid	Estimated Intake Thiamine	Urinary Excretion Ascorbic Acid 24-hours	Plasma Concentration Ascorbic Acid
	Mgs.	Mgs.	Mgs.	Mgs. Percent
Initial Period				
6-28-44	95	0.90	25.2	0.63
6-30-44	115	1.21	65.9	0.59
7- 3-44	95	1.36	56.3	0.84
Saturation Period (500 milligrams of ascorbic acid given for four days)				
7- 4-44	655	0.96	328.3	0.87
7- 5-44	665	0.85	375.1	0.95
7- 6-44	625	0.87	385.6	0.98
7- 7-44	695	0.93	449.5	0.91
Post-Saturation Period				
7- 8-44	95	0.88	91.8	0.82
7-10-44	89	1.01	75.7	0.72
7-12-44	98	1.03	69.3	0.75
7-14-44	83	0.97	45.5	0.70

Table 5. The influence of varying the level of thiamine of the diet on the urinary excretion and plasma concentration of ascorbic acid of subject B.C. (Continued)

Date	Estimated Intake Ascorbic Acid	Estimated Intake Thiamine	Urinary Excretion Ascorbic Acid 24-hours	Plasma Concentration Ascorbic Acid
	Mgs.	Mgs.	Mgs.	Mgs. Percent
Initial Period with Thiamine Supplementation				
7-15-44	150	1.79	41.4	0.81
7-16-44	95	1.98	46.5	0.69
7-17-44	160	1.69	62.8	0.88
7-18-44	75	1.75	24.5	0.87
Saturation Period (500 milligrams of ascorbic acid given for four days)				
7-19-44	625	2.20	242.1	1.01
7-20-44	603	2.31	386.4	0.97
7-21-44	595	2.26	403.9	0.91
Post-Saturation Period				
7-22-44	125	2.15	199.6	0.87
7-23-44	165	1.98	104.7	0.87
7-25-44	179	1.96	66.4	0.85
7-27-44	150	2.40	50.5	0.83
7-29-44	146	2.25	39.3	0.86

Table 6. The influence of varying the level of thiamine of the diet on the urinary excretion and plasma concentration of ascorbic acid of subject P.M.

Date	Estimated Intake Ascorbic Acid	Estimated Intake Thiamine	Urinary Excretion Ascorbic Acid 24-hours	Plasma Concentration Ascorbic Acid
	Mgs.	Mgs.	Mgs.	Mgs. Percent
Initial Period				
10-18-44	75	1.01	32.5	0.73
10-20-44	75	0.96	15.6	0.75
10-23-44	80	0.85	25.8	0.75
10-25-44	85	0.97	12.3	0.76
10-27-44	75	1.06	39.1	0.71
10-30-44	80	1.23	29.9	0.68
Saturation Period (500 milligrams of ascorbic acid given for four days)				
10-31-44	580	1.25	185.7	0.79
11- 1-44	585	1.07	295.8	0.82
11- 2-44	575	1.23	328.9	0.85
11- 3-44	585	1.13	406.5	0.82
Post-Saturation Period				
11- 4-44	90	1.17	118.7	0.81
11- 5-44	85	0.96	75.8	0.80
11- 8-44	70	0.82	28.5	0.79
11-10-44	85	0.85	25.6	0.79
11-13-44	90	0.96	30.9	0.74
11-15-44	80	0.95	33.3	0.71
11-17-44	75	0.91	31.7	0.73

Table 6. The influence of varying the level of thiamine of the diet on the urinary excretion and plasma concentration of ascorbic acid of subject P.M. (Continued)

Date	Estimated Intake Ascorbic Acid	Estimated Intake Thiamine	Urinary Excretion Ascorbic Acid 24-hours	Plasma Concentration Ascorbic Acid
	Mgs.	Mgs.	Mgs.	Mgs. Percent
Initial Period with Thiamine Supplementation				
11-20-44	80	2.15	25.5	0.75
11-22-44	85	2.59	30.6	0.79
11-24-44	85	1.90	42.8	0.79
11-27-44	90	1.86	18.7	0.82
11-29-44	75	2.25	20.3	0.85
12- 1-44	75	2.03	30.2	0.89
Saturation Period (500 milligrams of ascorbic acid given for four days)				
12- 4-44	575	1.97	298.6	0.89
12- 5-44	580	1.89	345.7	0.92
12- 6-44	575	2.05	425.5	0.89
12- 7-44	585	2.16	429.2	0.87
Post-Saturation Period				
12- 8-44	80	2.25	290.9	0.87
12- 9-44	75	2.39	71.5	0.84
12-11-44	70	1.78	33.9	0.86
12-13-44	75	1.98	24.6	0.85
12-15-44	80	2.09	26.8	0.83
12-17-44	85	2.35	30.7	0.83

Table 7. The influence of varying the level of thiamine of the diet on the urinary excretion and plasma concentration of ascorbic acid of subject K.N.

Date	Estimated Intake Ascorbic Acid	Estimated Intake Thiamine	Urinary Excretion Ascorbic Acid 24-hours	Plasma Concentration Ascorbic Acid
	Mgs.	Mgs.	Mgs.	Mgs. Percent
Initial Period				
10-18-44	75	1.05	18.4	0.64
10-20-44	75	0.96	22.3	0.69
10-23-44	80	1.23	26.6	0.63
10-25-44	85	1.12	31.3	0.71
10-27-44	75	0.90	24.7	0.68
10-30-44	80	0.99	29.9	0.68
Saturation Period (500 milligrams of ascorbic acid given for four days)				
10-31-44	580	0.95	295.8	0.75
11- 1-44	585	1.12	352.9	0.71
11- 2-44	575	1.00	355.6	0.70
11- 3-44	585	1.03	420.2	0.72
Post-Saturation Period				
11- 4-44	90	0.97	216.3	0.66
11- 5-44	85	0.91	72.1	0.63
11- 8-44	70	0.93	38.9	0.62
11-10-44	85	0.98	25.4	0.62
11-13-44	90	1.01	39.6	0.65
11-15-44	80	0.93	27.3	0.69
11-17-44	75	0.96	29.5	0.65

Table 7. The influence of varying the level of thiamine of the diet on the urinary excretion and plasma concentration of ascorbic acid of subject K.H. (Continued)

Date	Estimated Intake Ascorbic Acid	Estimated Intake Thiamine	Urinary Excretion Ascorbic Acid 24-hours	Plasma Concentration Ascorbic Acid
	Mgs.	Mgs.	Mgs.	Mgs. Percent
Initial Period with Thiamine Supplementation				
11-20-44	80	1.96	15.4	0.65
11-22-44	85	2.12	12.6	0.63
11-24-44	85	2.03	18.9	0.69
11-27-44	90	2.14	20.3	0.72
11-29-44	75	2.23	22.5	0.75
12- 1-44	75	2.41	25.7	0.79
Saturation Period (500 milligrams of ascorbic acid given for four days)				
12- 4-44	575	1.96	320.8	0.80
12- 5-44	580	1.86	369.5	0.79
12- 6-44	575	1.95	386.6	0.77
12- 7-44	585	2.39	418.5	0.73
Post-Saturation Period				
12- 8-44	80	2.26	116.4	0.76
12- 9-44	75	2.42	45.3	0.74
12-11-44	70	2.09	31.2	0.74
12-13-44	75	2.31	29.6	0.73
12-15-44	80	2.26	25.7	0.71
12-17-44	85	1.98	20.9	0.71

Table 8. The influence of varying the level of thiamine of the diet on the urinary excretion and plasma concentration of ascorbic acid of subject G.O.

Date	Estimated Intake Ascorbic Acid	Estimated Intake Thiamine	Urinary Excretion Ascorbic Acid 24-hours	Plasma Concentration Ascorbic Acid
	Mgs.	Mgs.	Mgs.	Mgs. Percent
Initial Period				
10-18-44	75	1.09	26.9	0.49
10-20-44	75	0.79	24.3	0.46
10-23-44	30	0.82	18.7	0.42
10-25-44	85	0.88	19.5	0.39
10-27-44	75	1.01	20.6	0.41
10-30-44	80	0.92	29.3	0.36
Saturation Period (500 milligrams of ascorbic acid given for four days)				
10-31-44	580	0.90	296.5	0.39
11- 1-44	585	1.06	299.7	0.42
11- 2-44	575	1.04	320.5	0.39
11- 3-44	585	1.09	345.7	0.37
Post-Saturation Period				
11- 4-44	90	0.80	169.5	0.32
11- 5-44	85	0.83	96.5	0.32
11- 8-44	70	1.05	35.4	0.33
11-10-44	85	1.15	28.7	0.35
11-13-44	90	1.34	26.7	0.31
11-15-44	80	0.92	25.4	0.33
11-17-44	75	0.98	23.1	0.37

Table 8. The influence of varying the level of thiamine of the diet on the urinary excretion and plasma concentration of ascorbic acid of subject G.O. (Continued)

Date	Estimated Intake Ascorbic Acid	Estimated Intake Thiamine	Urinary Excretion Ascorbic Acid 24-hours	Plasma Concentration Ascorbic Acid
	Mgs.	Mgs.	Mgs.	Mgs. Percent
Initial Period with Thiamine Supplementation				
11-20-44	80	2.26	29.5	0.39
11-22-44	85	2.35	32.6	0.42
11-24-44	85	2.90	26.7	0.42
11-27-44	90	2.94	18.9	0.56
11-29-44	75	2.35	33.5	0.69
12- 1-44	75	2.05	39.1	0.83
Saturation Period (500 milligrams of ascorbic acid given for four days)				
12- 4-44	575	2.96	325.5	0.96
12- 5-44	580	2.84	380.6	0.97
12- 6-44	575	2.09	425.3	0.99
12- 7-44	585	2.25	460.1	0.97
12- 8-44	80	2.37	186.2	0.95
12- 9-44	75	2.41	52.9	0.93
Post-Saturation Period				
12-11-44	70	2.90	31.4	0.93
12-13-44	75	2.94	28.3	0.94
12-15-44	80	2.35	18.7	0.95
12-17-44	85	2.46	20.6	0.91

Table 9. Range of intake and excretion of ascorbic acid for six subjects receiving two levels of dietary thiamine

Subjects	Hospital Diet		Hospital Diet Plus 1 Milligram Thiamine	
	Range of Ascorbic Acid Intake	Range of Ascorbic Acid Excretion	Range of Ascorbic Acid Intake	Range of Ascorbic Acid Excretion
	Mgs.	Mgs.	Mgs.	Mgs.
J.B.	78-185	26-71	95-180	27-86
A.C.	85-190	17-82	88-195	30-95
B.C.	75-185	23-86	75-190	25-66
K.N.	76- 85	12-39	70- 90	20-45
P.M.	75- 85	18-39	70- 90	12-31
G.O.	75- 85	19-35	70- 90	19-39

excretion occur, in general lower urinary values are observed on lower intakes of the vitamin. Average excretion values over a period of time on a given level of intake will ordinarily show this trend. The relation of the average calculated dietary intake of ascorbic acid to the average daily excretion is shown in Table 10. The values are arranged according to increasing intakes of ascorbic acid. It is apparent that the higher levels of intake resulted in a greater excretion of the vitamin. There is no marked variation in the excretion values for subjects on comparable levels of intake. There appears to be little difference in the pattern of excretion of ascorbic acid on the two levels of thiamine intake.

The urinary excretion values obtained in this study are comparable to values reported by other investigators for individuals receiving an adequate diet.

Harris and coworkers (1936) reported that a daily excretion of 20 to 30 milligrams of ascorbic acid indicated adequate stores of vitamin C while an excretion of less than 13 milligrams per day indicated a depletion of vitamin C. Abbassy et al. (1935) reported that adults receiving a diet adequate in vitamin C excrete 20 to 40 milligrams per day. Van Eekelen (1936) states that daily excretion of 40 milligrams of ascorbic acid indicates a liberal intake of the vitamin and a state of tissue saturation in the individual.

According to these standards, the average excretion values of subjects J.B., A.C., and B.C. reflect a liberal intake of ascorbic acid, while those of subjects P.M., K.N., and G.O indicate a moderate intake and normal stores of the vitamin. The excretion values appear to present an accurate picture of the vitamin C intake since the average calculated intake for subjects J.B., A.C., and B.C. was 125 milligrams or above which would be considered liberal.

Table 10. The relation of the average calculated ascorbic acid intake to the average daily excretion of ascorbic acid.

Subject	Average Calculated Intake of Ascorbic Acid	Average Urinary Excretion of Ascorbic Acid
	Mgs.	Mgs.
Hospital Diet		
G.O.	80	24.5
P.M.	80	27.0
K.N.	80	30.0
J.B.	125	45.5
A.C.	140	41.0
B.C.	149	51.0
Hospital Diet Supplemented with 1 Milligram Thiamine		
K.N.	80	24.5
G.O.	80	27.5
P.M.	80	28.5
A.C.	136	50.0
J.B.	139	44.5
B.C.	150	50.0

Eighty milligrams of ascorbic acid was estimated as the average intake for subjects P.M., K.M., and G.O., a value which meets the recommended allowances suggested by the National Research Council.

Therefore, on the basis of urinary excretion, it would appear that all of the subjects were in a satisfactory state of vitamin C nutrition.

The response to the 500 milligram test doses of ascorbic acid gives further evidence of apparently adequate stores of ascorbic acid in the subjects studied. In Table 11 the urinary response of the subjects to the successive doses of 500 milligrams of ascorbic acid is recorded. If excretion of 50 percent of the added ascorbic acid within twenty-four hours is taken as a criterion of tissue saturation, subjects P.M. and B.C. were the only subjects who showed a slight deficit in vitamin C stores. Since these two subjects met the requirements for saturation on the second day of ascorbic acid supplementation, there does not appear to have been any significant deficit of ascorbic acid in the tissues.

Subjects A.C., K.M., and G.O. excreted more than 50 percent of the test dose on the first day of the saturation period and progressively greater amounts thereafter. Apparently there was a lag in the excretion of the test dose in the case of J.B. who excreted more than the ingested amount of ascorbic acid following the second test dose in both saturation periods. A.C. also showed a lag in excretion of ascorbic acid on two separate occasions.

After the final test dose of ascorbic acid, from two to three days were required before the excretion level of the subjects returned to the previous basal level. Even after this period, the levels of excretion were slightly higher than those observed previous to supplementation with crystalline ascorbic acid.

Table 11. Record of the percent of ascorbic acid excreted in the urine following four days of supplementation with 500 milligrams of ascorbic acid.

Subject	1st day Percent	2nd day Percent	3rd day Percent	4th day Percent
Hospital Diet				
J.B.	63	106	98	78
A.C.	75	91	103	96
B.C.	54	63	66	78
P.M.	52	54	61	76
K.N.	54	65	66	79
G.O.	55	55	62	65
Hospital Diet Plus 1 Milligram Thiamine				
J.B.	80	104	81	*
A.C.	56	53	81	107
B.C.	43	72	75	*
P.M.	54	64	77	80
K.N.	60	70	73	80
G.O.	59	70	79	86

* Subjects J.B. and B.C. were given saturation doses for three days only.

Thus the response to the test doses of ascorbic acid indicated that the subjects were receiving adequate amounts of ascorbic acid. There was no marked difference in the urinary excretion of ascorbic acid during the two levels of thiamine intake.

Plasma Ascorbic Acid Values

Average plasma ascorbic acid concentrations for all subjects throughout the entire study are summarized in Table 12. In view of the adequate stores of ascorbic acid predicted by the urinary excretion values, the levels of plasma ascorbic acid found appear somewhat low. Average values during the initial period of study ranged from 0.43 milligrams percent to 0.83 milligrams percent. Normal individuals receiving an adequate intake of ascorbic acid have been observed by others to maintain a plasma ascorbic acid level of 0.7 milligrams percent or above. According to Greenberg et al. (1936) fasting ascorbic acid levels below 0.7 milligrams percent are suboptimal, levels ranging from 0.7 to 0.9 milligrams percent are adequate, and optimal values are reported to lie above 0.9 milligrams percent. Levels below 0.5 milligrams percent have been considered to indicate severe tissue depletion. If plasma ascorbic acid values are used as the criteria for evaluating the vitamin C status of the present subjects, it would appear that subjects J.B. and P.M. have adequate stores of the vitamin during the initial period of the study. Subjects B.C. and K.N. showed a slight depletion, while subjects A.C. and G.O. fell within a range considered to indicate severe depletion. When it is recalled that subject A.C. received more than 100 milligrams of ascorbic acid daily throughout the study and G. O. received

Table 12. Average plasma ascorbic acid levels

Period	Subjects					
	J.B.	B.C.	P.M.	K.N.	A.C.	C.O.
Initial period	0.83	0.69	0.73	0.67	0.59	0.42
Saturation period (500 mg. of ascorbic acid given daily)	0.94	0.93	0.82	0.72	0.55	0.39
Post-saturation period	0.83	0.75	0.77	0.65	0.51	0.33
Initial period with thiamine supplementation	0.86	0.81	0.82	0.71	0.72	0.55
Saturation period (500 mg. of ascorbic acid given daily)	1.04	0.96	0.89	0.77	1.01	0.97
Post-saturation period	0.94	0.86	0.85	0.73	0.85	0.94

an average of 80 milligrams per day, it must be concluded that the suboptimal levels of plasma ascorbic acid observed in these two women cannot be attributed to low intakes of vitamin C. Furthermore, the response of subjects A.C. and G.O. to the high intakes of ascorbic acid during the saturation period was unexpected. Whereas all other subjects showed a measurable rise in plasma ascorbic acid during the saturation period, the plasma levels of A.C. and G.O. were decreased slightly. In fact, a gradual decline in the plasma ascorbic acid levels had been noted in these subjects throughout the first period on the hospital diet. The plasma ascorbic acid concentrations of subjects J.B., B. C., P.M., and K.M. remained relatively constant previous to the saturation period, showed a moderate rise at this time, and gradually returned to the previous levels following the saturation period. It would appear, therefore, from the plasma ascorbic acid values, that four of the subjects observed in this study followed the usual trend for normal individuals receiving liberal intakes of ascorbic acid and further supplemented with saturation doses of ascorbic acid. Two subjects failed to maintain high ascorbic acid concentrations even on intakes above 500 milligrams per day.

During the period of increased thiamin intake, subjects A.C. and G.O. showed a marked rise in plasma ascorbic acid concentration. In Table 13 an attempt has been made to show the differences in response of subjects during periods of low and high thiamin ingestion. The average plasma ascorbic acid levels maintained by each subject during the saturation periods on the two levels of thiamine intake are compared, and the increase which occurred during thiamine supplementation is recorded.

Table 13. Average plasma ascorbic acid levels during the saturation periods.

Subject	Plasma Ascorbic Acid Concentration		Increase in Plasma Ascorbic Acid Concentration
	Hospital Diet	Hospital Diet Plus 1 mg. Thiamine	
B.C.	0.93	0.96	0.03
K.N.	0.72	0.77	0.05
P.M.	0.82	0.89	0.07
J.B.	0.94	1.04	0.10
A.C.	0.55	1.01	0.46
G.O.	0.39	0.97	0.58

It is apparent that there was some increase in the plasma ascorbic acid levels of each subject during the period of thiamine supplementation. However, the slight increases observed for subjects B.C., K.N., P.M., and J.B., could not be interpreted as significant improvements in vitamin C status. On the other hand, the plasma ascorbic acid levels of subjects A.C. and G.O. were increased by 84 and 149 percent respectively when the thiamine ingestion was high. Thus it would appear that an intake of approximately 2.25 milligrams of thiamine produced a measurable improvement in the levels of plasma ascorbic acid maintained in these subjects. The concentration of ascorbic acid in the plasma of subjects A.C. and G.O. increased progressively following the improvement in thiamine intake, reaching a maximum during the saturation period and remaining within the normal range in the subsequent period.

Data concerning the thiamine stores of these subjects would have been very worthwhile in the interpretation of these findings.

Limited data obtained during the present study appear to indicate that a high thiamine ingestion may improve the level of plasma ascorbic acid maintained by individuals who show low plasma ascorbic acid levels which do not respond to liberal ascorbic acid ingestion.

SUGGESTIONS FOR FURTHER INVESTIGATION OF THE PROBLEM

The observation that two of six college women ingesting diets estimated to provide from 80 to 125 milligrams of ascorbic acid daily showed low plasma ascorbic acid values introduces several interesting questions for further study.

First, how frequently do low plasma ascorbic acid values exist among the college student group? If the presence of low ascorbic acid values can be used as an index of vitamin C nutrition, is there evidence that an appreciable number of students show signs of inadequate vitamin C stores?

Second, the question may be raised that individuals showing low plasma ascorbic acid concentration on their self-chosen diets might respond to increased ascorbic acid intakes if ingestion were continued over a longer period of time than was used in the study just reported. Also, since the length of the saturation period followed in this study varied from three to four days, the possibility remains that the subjects did not have sufficient time to become entirely saturated with ascorbic acid. A longer saturation period therefore, would seem advisable in a continued investigation of this problem.

Third, will additional subjects showing low plasma ascorbic acid values which do not respond to high ascorbic acid intake always respond to thiamine therapy? While the present study strongly points to thiamine as the factor influencing the ascorbic acid level of the plasma, it would be preferable in future work on this problem to study the subjects on diets of constant composition and of known thiamine and ascorbic acid content. In the present

study, variations in protein intake as well as in calorie content were allowed; both are factors which are recognized as influencing the total requirement of the adult. If additional subjects respond to thiamine therapy by showing an increase in suboptimal levels of plasma ascorbic acid to a value of 0.7 milligrams percent or above, what level of thiamine must be ingested to produce this effect? In the present study high thiamine intakes ranging from 2 to 2.25 milligrams per day have been used. These amounts are considered unnecessary for women of moderate activity judging by the values recommended by the National Research Council. Estimations of the average thiamine consumption of American families, also, indicate that thiamine ingestion is very much lower than this figure. Is a beneficial effect therefore producible in subjects receiving less than this amount of thiamine?

A fourth question which arises, is that concerned with the state of thiamine nutrition of subjects showing an interrelationship between thiamine intake and ascorbic acid levels. An investigation of the thiamine stores of such individuals would seem necessary and a careful determination of all signs of thiamine deficiency noted. In addition, very little information is available at the present time as to the length of response produced by high thiamine intakes. In the study just reported plasma ascorbic acid values were not continued for an extended period of time after thiamine supplementation.

In general continued investigations of this problem involve confirmation of the present findings on several additional subjects, and a study of plasma ascorbic acid values over a wider range of thiamine and ascorbic acid intakes.

SUMMARY AND CONCLUSIONS

Six college women considered in good health have been studied during several experimental periods to determine a possible relationship between the thiamine intake of the diet and the level of ascorbic acid of the plasma. During an initial period ranging from seven to fourteen days in length, three of the subjects consumed a diet which was calculated to contain an average of 80 milligrams of ascorbic acid per day. Three subjects received a diet estimated to contain an average of from 125 to 150 milligrams of ascorbic acid daily. The intake of thiamine during this period was approximately one milligram per day. Urinary excretion values for ascorbic acid fluctuated somewhat with the dietary level of ascorbic acid, but in general the excretion of ascorbic acid paralleled the intake and indicated that all six subjects were receiving adequate amounts of vitamin C.

A saturation period of four days followed during which time the subjects received 500 milligrams of crystalline ascorbic acid in addition to their regular diet. Urinary excretion values of ascorbic acid following the saturation doses indicated again that the tissues were well saturated with ascorbic acid. Plasma values for ascorbic acid for the six subjects varied considerably. At the beginning of the experiment two of the six subjects showed plasma values indicating suboptimal or deficient stores of vitamin C. During the saturation period and the high ingestion of vitamin C four subjects showed an increase in plasma ascorbic acid values. Following the saturation period the level of ascorbic acid in the plasma dropped slightly but remained in the range considered to indicate normal stores

of vitamin C. The two subjects who showed suboptimal levels of ascorbic at the beginning of the study failed to respond to the saturation period and the blood values remained within the suboptimal range.

Upon the addition of one milligram of thiamine to the regular diet it was observed that all subjects showed a level of ascorbic acid in the plasma considered to indicate adequate stores of vitamin C. Seemingly two subjects responded to thiamine therapy in that they showed a rise in ascorbic acid value not previously observed in spite of high ascorbic acid feeding. The percent of ascorbic acid excreted by the six subjects during the administration of thiamine was much like that observed during the lower thiamine ingestion.

No explanation is given for the observation that two of six subjects studied showed plasma ascorbic acid values considered to indicate suboptimal storage of vitamin C when the diet contained liberal amounts of vitamin C and that these two subjects responded by an increase in plasma ascorbic acid upon the addition of 1 milligram of thiamine to comprise a total thiamine intake of approximately 2.25 milligrams daily.

Suggestions have been made as to further plans in the continuation of this problem.

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APPENDIX

Table I. Hospital menus served to subjects throughout the experiment.

Date	Breakfast	Lunch	Dinner
4-26-44	Stewed prunes Bread Butter Milk	Vegetable soup Cheese sandwich Radishes Fruit cup (fresh) Plain cookies Milk	Baked fish Steamed potatoes Stewed tomatoes Cole slaw Bread Butter Fresh pineapple Milk
4-27-44	Rhubarb Bread Butter Milk	Roast Beef Gravy Tomato salad Celery Bread Plain cookies Milk	Chop suey (beef) Steamed potatoes Vegetable salad Whole orange Milk Bread Butter Milk
4-28-44	Grapefruit juice Oatmeal Bread Butter Milk	Omelet Fresh peas Bran muffin Jam Butter Milk	Liver Boiled potato Green beans Vegetable salad Jello Butter Bread Milk
4-29-44	Grapefruit Bread Butter Milk	Creamed ham Toast Lettuce Oranges Milk	Roast beef Steamed potatoes Gravy Cauliflower Rhubarb Jello Butter Bread Milk

Table I. (Continued)

Date	Breakfast	Lunch	Dinner
4-30-44	Grapefruit juice Cornflakes Milk	Clam chowder Lettuce Bread Pineapple Plain cookies Milk	Roast pork Green beans Steamed potatoes Gravy Tomato salad Rutabaga (raw) Rolls Ice cream
5-1-44	Sliced oranges Cornflakes Milk	Omelet Mixed vegetable salad Cornbread Maple syrup Milk	Meatloaf Steamed potatoes Rutabaga Tomato salad Butter Bread Pineapple Milk
5-2-44	Stewed prunes Rolls Butter Milk	Roast beef Potato salad Tomatoes (fresh) Gingerbread Milk	Vegetable beef Stew Jello salad Oranges Angel cake Bread Milk
5-3-44	Grapefruit Grape nuts flakes Milk	Vegetable soup Cheese sandwiches Apricot preserves Milk	Roast beef Steamed potato Green beans Mixed vegetable salad Biscuits Butter Milk Ice cream
5-4-44	Stewed prunes Bread Butter Milk	Devilled eggs Tomatoes Clam chowder Potato salad Rolls Butter Milk	Roast beef Steamed potato Creamed carrots Gravy Lemon pie Milk

Table I. (Continued)

Date	Breakfast	Lunch	Dinner
5-5-44	Grapefruit Bread Milk Mi	Salmon salad sandwiches Creamed asparagus soup Fresh fruit cup Milk	Meat loaf Green beans Steamed potato Mixed vegetable salad Spice cake Bread Butter Milk
5-6-44	Orange juice Rolls Butter Milk	Vegetable stew Apple and celery salad Biscuits Milk Rice pudding	Lamb chops Baked potato Cauliflower Cream sauce Fruit cup Bread Butter Milk
5-7-44	Apple sauce Bread Butter Milk	Roast beef Tomatoes Cottage cheese Bread Butter Milk Pumpkin pie	Roast beef Potato Gravy Corn Fruit salad Milk
5-8-44	Stewed prunes Bread Butter Milk	Creamed vegetable soup Roast beef sandwiches Custard Milk	Liver Steamed potatoes Creamed onions Tomatoes (fresh) Rhubarb Bread Butter Milk
5-9-44	Grapefruit Bread Butter Milk	Baked beans Onions Cottage cheese Celery Nut bread Butter Pineapple Milk	Tongue Steamed potatoes Cabbage Tomato sauce Onions (creamed) Bread Butter Cookies Milk

Table I (Continued)

Date	Breakfast	Lunch	Dinner
5-10-44	Grapefruit juice Bread (w.w.) Butter Milk	Omelet Cornbread Karo syrup Tomato salad Butter Milk	Hamburger bun Onions Vegetable soup Fruit salad Ice cream Milk
5-11-44	Grapefruit Bread Butter Milk	Mixed vegetable salad Corn (escalloped) Bacon Bread Rhubarb pie Milk	Pork (lean) Potatoes Gravy Peas Celery Cream cheese Spice cake Bread Butter Milk
5-12-44	Prunes Bread Butter Milk	Fish Potato Tomato Cabbage (raw) Pineapple Bread Butter Milk	Vegetable soup Radishes Cheese Mayonaise Pineapple orange Lettuce Cookie Bread Butter Milk
5-13-44	Stewed apples Bread Butter Milk	Egg Salmon Asparagus soup Pineapple Bread Milk	Meat loaf Potato Apple and celery salad Gravy Jello Bread Butter Milk
6-20-44	Oatmeal Toast Oranges Butter Milk	Meat loaf Potato Mixed vegetable salad Jello Butter Milk	Roast pork Potato Celery and lettuce Tomato Bread pudding Milk

Table I. (Continued)

Date	Breakfast	Lunch	Dinner
6-21-44	Orange juice Oatmeal Bread Butter Milk	Fried egg plant Green beans Tomatoes Lettuce Cottage cheese Cornbread Fruit cup Butter Milk	Roast pork Potato Carrots Mayonaise Lettuce Cauliflower Cheese sauce Ice cream Butter Milk
6-22-44	Grapefruit Bread Butter Milk	Ham Tomato sauce Lima beans Bran muffin Rhubarb shortcake Cream Butter Milk	Pork Onions Potato Apples (spiced) Apricots Bread Butter Milk
6-23-44	Rhubarb Oatmeal Cream Bread Butter Cocoa	Fish cake Cheese sauce Green beans Tomato Lettuce Mayonaise Chocolate pudding Bread Butter Milk	Fish Cheese sauce Escalloped potatoes Cabbage Lettuce Mayonaise Spice cake Whipped cream Bread Butter Milk
6-24-44	Grapefruit Cinnamon roll Bread Butter Milk	Cabbage slaw Pork Gravy Pineapple Bread Milk	Liver Potatoes Carrots Lemon pie Bread Butter Milk

Table I. (Continued)

Date	Breakfast	Lunch	Dinner
6-25-44	Grapefruit Bread Butter Milk	Ham Lettuce Egg Mayonaise Oranges Bread Butter Milk	Beef Potatoes Gravy Cauliflower Rhubarb gelatin Lettuce pineapple Ice cream Butter Milk
6-26-44	Cereal Grapefruit juice Bread Butter Milk	Lettuce Tomato Fruit Butter Milk	Lettuce Cole slaw Hamburger Buns Cake Ice cream Milk
6-27-44	Grapefruit Bread Butter Milk	Stewed tomatoes Scrambled eggs Cornbread Gelatin Peaches Sponge cake Butter Milk	Roast beef Steamed potatoes Cauliflower Mixed vegetable salad Pineapple tapioca Butter Milk
6-28-44	Grapefruit juice Bread Butter Milk	Fresh fruit salad Cheese Peanut butter Jam Lettuce Cinnamon roll Butter Chocolate milk	Ham Apple (spiced) Potato Peas Gravy Lettuce Rolls Ice cream Milk

Table I. (Continued)

Date	Breakfast	Lunch	Dinner
6-29-44	Grapefruit Bread Butter Milk	Meat Lettuce Tomatoes Cucumber Chicken broth Cookie Bread Butter Milk	Frankfurters Potatoes Cabbage Lettuce Grapefruit Gingerbread Whipped cream milk
6-30-44	Grapefruit Jelly Egg Bread Butter Milk	Macaroni and cheese Carrots Cabbage Fruit cup Tea ring Butter Milk	Potato Beets Parsley Cabbage Egg Tomato Mayonaise Rolls Cake Butter Milk
7-1-44	Sliced oranges Toast Jam Butter Milk	Eggplant Ham Beet tops Cream sauce Bread pudding Chocolate sauce Toast Butter Milk	Steak Potato Green beans Mixed vegetable salad Stewed tomatoes Cherry pie Milk
7-2-44	Orange juice Bread Butter Milk	Meat loaf Potato chips Tomato salad Bread Butter Milk	Beef Gravy Vegetable salad Cauliflower Cream sauce Potatoes Fruit juice Ginger ale Ice cream Cherry sauce Butter Milk

Table I. (Continued)

Date	Breakfast	Lunch	Dinner
7-3-44	Orange juice Bread Butter Milk	Vegetable soup Cheese sandwich Cherries Lettuce Butter Milk	Pork roast Potatoes Peas Green pepper Lettuce Mayonaise Cranberry relish Jelly roll Butter Milk
7-4-44	Orange juice Bread Butter Milk	Chicken cream sauce Biscuit Lettuce Plums Peas Nut pie Milk	Ham salad sandwich Tomatoes Grapefruit Sliced oranges Bread Butter Milk
7-5-44	Sliced oranges Bread Jam Butter Milk	Eggs Bacon Tomato Lettuce Blitz Torte Milk	Beef Potato Carrots Tomato Lettuce Peaches Butter Milk
7-6-44	Orange juice Bread Butter Milk	Beef Gravy Lettuce Fruit French dressing Bread Butter Milk	Spagetti Meat balls Cranberry sauce Lettuce Chocolate pudding Bread Butter Milk
7-7-44	Sliced oranges Cornflakes Bread Butter Milk	Potatoes with Cheese Sliced tomatoes Gingerbread Whipped cream Milk	Baked fish Tartar sauce Green beans Fruit salad Rolls Butter Milk

Table I. (Continued)

Date	Breakfast	Lunch	Dinner
7-8-44	Sliced oranges Grape nuts flakes Butter Bread Milk	Cheese waffles Syrup Butter Fruit salad Rolls Butter Milk	Liver Steamed potatoes Beets Apple pie Bread Butter Milk
7-9-44	Grapefruit Corn flakes Bread Butter Milk	Boston baked beans Bran muffins Frozen fruit salad Butter Milk	Tongue Tomato sauce Boiled potatoes Mixed vegetable salad Prune pudding Bread Butter Milk
7-10-44	Sliced bananas Corn flakes Bread Butter Milk	Vegetable soup Ham salad sandwiches Jello salad Milk	Swiss steak Baked potato Carrots Gravy Bread Tapioca Milk
7-11-44	Grapefruit juice Corn flakes Bread Butter Milk	Sliced ham Fried potatoes Banana nut salad Ice cream Bread Butter Milk	Scrambled eggs Bread Butter Banana cake Milk
7-12-44	Stewed apricots Cream of wheat Bread Butter Milk	Meat loaf Tomato salad Celery Bread Butter Cookies Milk	Roast pork Baked potatoes Celery and peas Apple sauce Rolls Butter Peaches Ice cream Milk

Table I. (Continued)

Date	Breakfast	Lunch	Dinner
7-13-44	Sliced oranges Oatmeal Bread Butter Milk	Vegetable soup Ham sandwich Frozen fruit salad Rolls Butter Milk	Weiners Baked potato Corn Bread Butter Milk
7-14-44	Sliced oranges Oatmeal Bread Butter Milk	Navy bean soup Cheese sandwich Fresh peaches Milk	Baked fish Steamed potatoes Tomato salad Bread Butter Gingerbread Apple sauce Milk
7-15-44	Grapefruit juice Oatmeal Bread Milk	Roast beef Potato salad Raw carrots Rolls Butter Custard Gingerbread Milk	Hamburger Buns Beets Tomato salad Milk
7-16-44	Grapefruit Wheaties Bread Butter Milk	Egg salad sandwich Apple sauce Plums Milk	Roast beef Steamed potatoes Peas Lettuce Rolls Butter Ice cream Chocolate sauce Milk
7-17-44	Stewed prunes Rolls Butter Milk	Scrambled eggs Tomato salad Fruit cup Bread Butter Milk	Roast beef Gravy Potatoes Carrots and peas Bread Butter Milk

Table I. (Continued)

Date	Breakfast	Lunch	Dinner
7-18-44	Grapefruit Oatmeal Bread Butter Milk	Roast beef sandwich Gravy Fruit jelle salad Milk	Roast pork Potatoes Asparagus Raw celery and carrots Bread Butter Devil's food cake Milk
7-19-44	Apple sauce Bread Butter Milk	Scrambled eggs Tomato salad Cheese biscuits Butter Prune pudding Milk	Beef stew Noodles Green beans Tomato salad Bread Butter Ice cream Milk
7-20-44	Sliced oranges Bread Butter Milk	Fruit salad Cornbread Butter Custard Milk	Liver Baked potato Beets Apple sauce Bread Butter Spice cake Milk
7-21-44	Grapefruit Bread Butter Milk	Creamed eggs Toast Stewed tomato Cantelope Milk	Baked fish Potatoes Peas Orange salad Bread Butter Plain cake Milk
7-22-44	Cantelope Bread Butter Milk	Beef hash Buttered carrots Pickle relish Fruit cup Bread Butter Milk	Spanish rice Buttered cauliflower Vegetable salad Apricot cake Bread Butter Milk

Table I. (Continued)

Date	Breakfast	Lunch	Dinner
7-23-44	Cantelope Bread Butter Milk	Potato salad Raw carrots Lunch meats Apple sauce Cookies Milk	Roast beef Apple sauce Potatoes Peas Fruit cup Cookies Milk
10-5-44	Grapefruit juice Corn flakes Bread Butter Milk	Bacon Eggs Vegetable salad Bread Butter Banana tapioca Milk	Broiled ham Sweet potato Cauliflower Tomato and lettuce Brown betty Milk
10-6-44	Fresh pears Corn flakes Bread Butter Milk	Asparagus on toast Cheese sauce Cole slaw Plain cake Milk	Baked fish Baked potato Butter Broccoli Fruit salad Bread Butter Milk
10-7-44	Grapefruit Scrambled eggs Bread Butter Marmalade Milk	Pea soup Peanut butter sandwiches Jam Stewed pears Milk	Swiss steak Boiled potatoes Gravy Cauliflower Lettuce Bread Butter Stewed plums Milk
10-8-44	Grapefruit Cream of wheat Bread Butter Milk	Spiced ham sandwiches Fresh pears Doughnuts Milk	Roast pork Sweet potatoes Carrots Lettuce Bread Butter Ice cream Milk

Table I. (Continued)

Date	Breakfast	Lunch	Dinner
10-9-44	Sliced oranges Puffed wheat Bread Butter Milk	Cream of pea soup Cottage cheese Apricots Bread Butter Milk	Roast beef Steamed potatoes Gravy Scalloped tomatoes Carrot and raisin salad Bread Butter Brownies Milk
10-10-44	Grapefruit Cream of wheat Bread Butter Milk	Baked beans Celery Cabbage Chocolate pudding Cream Bread Butter Milk	Liver Baked squash Boiled onions Steamed potatoes Lettuce salad Bread Butter Plain cake Milk
10-11-44	Grapefruit juice Cream of wheat Bread Butter Milk	Pork stew with noodles Baked apple Lettuce Bread Butter Milk	Smoked sausage Green beans Steamed potatoes Cole slaw Bread Butter Bread pudding Lemon sauce Milk
10-12-44	Grapefruit juice Corn flakes Bread Butter Jam Milk	Chili Lettuce salad Bread Butter Cookies Milk	Stewed chicken Rice Peas Vegetable salad Bread Butter Ice cream Butter scotch sauce Milk

Table I. (Continued)

Date	Breakfast	Lunch	Dinner
10-13-44	Fresh pears Cream of wheat Bread Butter Jam Milk	Egg outlet Fruit salad with cottage cheese Bread Butter Milk	Baked salmon Corn Lettuce salad Lemon pie Bread Butter Milk
10-14-44	Sliced oranges Corn flakes Bread Butter Milk	Weiner sandwich Potato salad Fresh pears Milk	Meat loaf Mashed potatoes Creamed celery Orange salad Bread Butter Rice pudding Milk
10-15-44	Stewed plums Cream of wheat Bread Butter Jelly Milk	Meat loaf Potato salad Plums Bread Butter Milk	Roast lamb Creamed potatoes Peas Lettuce salad Bread Butter Ice Cream Milk
10-16-44	Stewed plums Cream of wheat Bread Butter Jam Milk	Creamed eggs Toast Apple sauce Bread Butter Milk	Stuffed beef heart Egg plant Lettuce salad Sliced oranges Plain cake Lemon sauce Milk
10-17-44	Grapefruit juice Scrambled egg Bread Butter Jam Milk	Mixed vegetable salad Bake potato Plain cookies Bread Butter Milk	Baked ham Sweet potatoes Green beans Celery Cabbage Bread Butter Cranberry tarts Milk

Table I. (Continued)

Date	Breakfast	Lunch	Dinner
10-18-44	Grapefruit juice Puffed wheat Bread Butter Milk	Tomato soup Bran muffins Boiled egg Macaroni salad Grapes Milk	Tongue Raisin sauce Steamed potatoes Baked squash Cole slaw Bread Butter Ice cream Milk
10-19-44	Orange juice Cream of wheat Bread Butter Milk	Cheese souffle Lettuce salad Fruit cup Muffins Milk	Chicken pie Egg plant Waldorf salad Brownies Milk
10-20-44	Sliced oranges Poached egg Bread Butter Milk	Bean loaf Celery Cabbage Apple crisp Milk	Baked fish Dressing Steamed potatoes Stewed tomatoes Orange salad Chocolate cake Milk
10-21-44	Grapefruit Corn flakes Bread Butter Milk	Bean soup Crackers Fruit salad Chocolate cookies Milk	Beef steak Steamed potatoes Cabbage Gravy Lettuce Bread Butter Grapes Milk
10-22-44	Stewed prunes Oatmeal Bread Butter Milk	Cheese sandwich Tomato juice Celery Carrots Rice pudding Milk	Baked ham Sweet potatoes Spinach Apple salad Bread Butter Ice cream Milk

Table I. (Continued)

Date	Breakfast	Lunch	Dinner
10-23-44	Stewed prunes Corn flakes Bread Butter Milk	Tomato juice Minced ham sandwiches Carrot and raisin salad Butterscotch pudding Milk	Liver Onions Gravy Steamed potatoes Lima beans and corn Cole slaw Bread Butter Milk
10-24-44	Stewed prunes Puffed wheat Bread Butter Milk	Bean soup Macaroni salad Celery Carrots Bread Butter Milk	Roast veal Baked potato Steamed rutabaga Mixed vegetable salad Bread Butter Baked apple Milk
10-25-44	Sliced oranges Corn flakes Bread Butter	Macaroni and cheese Grapefruit salad Milk	Stewed chicken Egg plant Creamed cheese and prune salad Bread Butter Milk
10-26-44	Grapefruit Cream of wheat Bread Butter Milk	Kidney bean and egg salad Raw carrots Bread Butter Apple dumpling Milk	Beef stew Potatoes Carrots Stewed tomato Bread Butter Canned peaches Milk
10-27-44	Grapefruit Bread Butter Milk	Creamed eggs Toast Beets salad Bread Butter Milk	Fish cakes Steamed potatoes Cabbage Lettuce salad Bread Butter Ice cream Milk

Table I. (Continued)

Date	Breakfast	Lunch	Dinner
10-28-44	Grapefruit Corn flakes Bread Butter Milk	Hamburger Bun Raw onion Sliced tomato Apple Milk	Roast beef Gravy Steamed potatoes Brussel sprouts Bread Butter Peach tapioca Milk
10-29-44	Sliced oranges Oatmeal Bread Butter Milk	Potato salad Boiled egg Butter Bread Cranberry whip Milk	Roast lamb Boiled potatoes Creamed onions Grapefruit salad Ice cream Milk
10-30-44	Grapefruit juice Sliced bananas Corn flakes Bread Butter Milk	Hash Dumpling Red cabbage salad Chocolate pudding Cream Milk	Pork chops Baked potatoes Stewed tomato Banana and peanut butter salad Cranberry salad Bread Butter Milk
10-31-44	Sliced oranges Puffed wheat Bread Butter Milk	Bacon Baked squash Banana and orange salad Bread Butter Ginger cookies Milk	Smoked sausage Baked potato Scalloped apples Carrot and raisin salad Bread Butter Pumpkin pie Whipped cream Milk

Table I. (Continued)

Date	Breakfast	Lunch	Dinner
11-1-44	Sliced oranges Corn flakes Bread Butter Milk	Mushroom soup Bran muffin Butter Raw carrots Celery Radishes Baked pear Milk	Meat pie Parsnips Pear salad Jello Milk
11-2-44	Sliced oranges Corn flakes Bread Butter Milk	Boston baked beans Red cabbage salad Brown bread Butter Grapes	Roast beef Potatoes Green beans Lettuce Bread Butter Milk
11-3-44	Steamed prunes Corn flakes Bread Butter Milk	Oyster stew Fruit salad Biscuits Brownies Milk	Baked fish Creamed potatoes Peas Cream cheese Celery Radishes Ice cream Milk
11-4-44	Stewed prunes Bread Butter Milk	Vegetable soup Lunch meat Fresh tomato salad Scalloped apples Bread Butter Milk	Liver Sweet potatoes Scalloped apples Grapefruit and apple salad Bread Butter Ice cream Milk
11-5-44	Grapefruit Corn flakes Bread Butter Milk	Fish chowder Nut bread Carrots Celery Fruit cup Milk	Stewed chicken Potatoes Brussel sprouts Raw carrots Celery and radishes Cottage cheese Ice cream Milk

Table I. (Continued)

Date	Breakfast	Lunch	Dinner
11-6-44	Grapefruit Corn flakes Bread Butter Milk	Barley soup Hash Beets Banana salad Bread Butter Vanilla pudding Milk	Breaded pork chop Steamed potatoes Creamed celery Pear and cottage cheese salad Bread pudding Milk
11-7-44	Grapefruit Corn flakes Bread Butter Milk	Omelet Peas, corn and celery Orange salad Milk	Stuffed veal Potatoes Beets Tomato salad Apple Milk
11-8-44	Orange juice Grape nuts flakes Bread Butter Milk	Vegetable beef stew Pear salad Rolls Butter Jelly roll Milk	Fried chicken Gravy Red cabbage Peas Cauliflower Biscuit Apple Milk
11-9-44	Sliced oranges Puffed wheat Bread Butter Milk	Oyster stew Coffee cake Orange and grape salad Milk	Baked ham Sweet potatoes Lima beans Prunes and cottage cheese salad Coffee cake Butter Milk
11-10-44	Grapefruit Puffed wheat Bread Butter Milk	Cheese sandwich Cole slaw Baked apple Milk	Baked fish Potato cakes Green beans Lettuce salad Bread Butter Ice cream Milk

Table I. (Continued)

Date	Breakfast	Lunch	Dinner
11-11-44	Grapefruit Grape nuts flakes Bread Butter Milk	Beef stew Dumpling Cottage cheese salad Grapes Milk	Hamburger Bun Raw carrots Celery Graham crackers Chocolate sauce Milk
11-12-44	Apricots Grape nuts flakes Bread Butter Milk	Baked beans Raw carrots Celery Bread Butter Cranberry whip Milk	Fruit juice Baked ham Steamed potatoes Cranberry salad Bread Butter Milk
11-13-44	Grapefruit juice Corn flakes Bread Butter Milk	Beef and potato cake Carrots Lettuce salad Rolls Butter Milk	Liver Steamed potatoes Parsnips Gravy Pear salad Bread Butter Brownies Milk
11-14-44	Orange juice Corn flakes Bread Butter Milk	Spagetti Cranberry salad Boston cream pie Milk	Roast beef Mashed potatoes Green beans Carrots Lettuce salad Bread Butter Baked pears Milk
11-15-44	Grapefruit juice Grape nuts flakes Bread Butter Milk	Creamed eggs Toast Cole slaw Oatmeal cookies Milk	smoked sausage Steamed potatoes Peas Bread Butter Cranberries Milk

Table I. (Continued)

Date	Breakfast	Lunch	Dinner
11-16-44	Tangerine Oatmeal Bread Butter Milk	Vegetable soup Apricot and cabbage Cheese salad Biscuits Butter Gingerbread Milk	Stuffed hearts Beets Lettuce salad Radishes Bread Butter Chocolate pie Milk
11-17-44	Orange juice Bread Butter Milk	Tuna fish and egg salad Tomatoes Bread Butter Cranberry upside down cake Milk	Baked fish Corn Stewed tomatoes Lettuce salad Biscuits Butter Ice cream Milk
11-18-44	Grapefruit juice Puffed wheat Bread Butter Milk	Meat loaf Creamed carrots and celery Potatoes Beet salad Bread Butter Chocolate pudding Milk	Hamburger French fried potatoes Romaine Bread Butter Ice cream Milk
11-19-44	Grapefruit Grape nuts flakes Bread Butter Jam Milk	Spagetti Tomato sauce Bread Butter Pear salad Gingerbread Milk	Roast lamb Gravy Mashed potatoes Broccolli Cranberry and orange salad Bread Butter Ice Cream Milk

Table I. (Continued)

Date	Breakfast	Lunch	Dinner
11-20-44	Sliced oranges Corn flakes Bread Butter Milk	Lamb stew Potatoes Carrots Cranberry sauce Bread Butter Brownies Milk	Roast veal Baked potato Baked squash Lettuce salad Bread Butter Apple crisp Milk
11-21-44	Grapefruit Oatmeal Bread Butter Milk	Bacon Escalloped corn Carrot and raisin salad Lettuce Bread Butter Spice cake Milk	Lamb Noodles and gravy Broccoli Apple and cranberry salad Bread Butter Cherry pie Milk
11-22-44	Sliced oranges Oatmeal Bread Butter Milk	Omelet Corn, green beans and peas Lettuce salad Bread Butter Apple dumpling Milk	Smoked sausage Potato cake Beets Peaches with cottage cheese salad Bread Butter Jelly roll Milk
11-23-44	Grapefruit juice Sausage Pancakes Butter Maple syrup Milk	Turkey sandwich Lettuce salad Apple Milk	Roast turkey Dressing Cranberry sauce Gravy Sweet potato Mashed white potato Green beans Lettuce salad Raw carrot, radishes and olives Rolls Butter Mincemeat pie Milk

Table I. (Continued)

Date	Breakfast	Lunch	Dinner
11-24-44	Grapefruit Grape nuts flakes Bread Butter Milk	Cream of tomato soup Crackers Orange salad Apple crisp Milk	Baked fish Peas and corn Sweet potato Apple and celery salad Rolls Butter Mincemeat pit Milk
11-25-44	Grapefruit Cream of wheat Bread Butter Jam Milk	Weiner sandwich Raw carrots Celery and radishes Plain cookies Milk	Roast turkey Dressing Gravy Creamed potatoes Cranberry sauce Lettuce salad Rolls Butter Oatmeal cookies Milk
11-26-44	Orange juice Corn flakes Bread Butter Milk	Scrambled eggs Bread Butter Jam Milk	Swiss steak Baked potatoes Broccoli Lettuce salad Bread Butter Ice Cream Milk
11-27-44	Sliced oranges Bran flakes Bread Butter Milk	Roast lamb sandwich Gravy Steamed potato Carrot and raisin salad Bread Butter Milk	Pork cutlet Sweet potatoes Cranberries Bread Butter Brownies Milk

Table I. (Continued)

Date	Breakfast	Lunch	Dinner
11-28-44	Sliced oranges Cream of wheat Bread Butter Jam Milk	Spanish rice Orange and cranberry salad Bread pudding with cream Milk	Roast beef Gravy Steamed potato Baked squash Cabbage and apple salad Bread Butter Mincemeat pie Milk
11-29-44	Grapefruit Bran flakes Bread Butter Milk	Vegetable soup Cottage cheese salad Coffee cake Butter Pears Milk	Baked ham Sweet potatoes Cabbage Fruit salad Rolls Butter Spice cake Milk
11-30-44	Sliced oranges Cream of wheat Bread Butter Milk	Beef stew Dumplings Lettuce salad Doughnuts Milk	Tongue Raisin sauce Carrots Creamed onion Steamed potatoes Celery Bread Butter Butterscotch pudding Milk
12-1-44	Sliced oranges Bread Butter Milk	Omelet Lettuce salad Cranberry sauce Bread Butter Vanilla pudding Milk	Baked fish Baked potato Brussel sprouts Lettuce Cottage cheese Bread Butter Ice cream Milk

Table I. (Continued)

Date	Breakfast	Lunch	Dinner
12-2-44	Grapefruit Cream of wheat Bread Butter Milk	Tomato soup Hamburger Bun Raw carrot Celery Peanut butter cookies Milk	Meat pie (beef) Stewed tomatoes Lettuce salad Cranberry sauce Milk
12-3-44	Grapefruit Corn flakes Bread Butter Milk	Scrambled eggs Raw carrots celery Radishes Nut bread Butter Jello Milk	Lamb chops Steamed potato Peas Apple, celery and nut salad Bread Butter Ice cream Milk
12-4-44	Grapefruit juice Bran flakes Bread Butter Milk	Tomato soup Ham and egg omelet Peas and corn Pear salad Bread Butter Plain cake Milk	Roast beef Potato cake Carrots Lettuce Bread Butter Lemon pie Milk
12-5-44	Grapefruit Bran flakes Bread Butter Milk	Bacon Scalloped corn Apple and celery salad Rolls Butter Sliced bananas Milk	Liver Onions Steamed potatoes Wax beans Cole slaw Rolls Butter Chocolate cake Milk
12-6-44	Orange juice Bran flakes Bread Butter Milk	Spagetti Tomato sauce Lettuce salad Bread Butter Milk	Pork cutlet Potato Cabbage Lettuce salad Bread Butter Cranberry shortcake Milk

Table I. (Continued)

Date	Breakfast	Lunch	Dinner
12-7-44	Grapefruit juice Bran flakes Bread Butter Milk	Chili Crackers Carrots Celery Radishes Bread Butter Milk	Roast beef Steamed potatoes Asparagus Cranberry gelatin salad Bread Butter Baked pears Milk
12-8-44	Sliced oranges Bran flakes Bread Butter Milk	Tuna fish and egg salad Fruit Rolls Butter Butterscotch squares Milk	Fried oysters Baked potatoes Stewed tomatoes Lettuce salad Bread Butter Milk
12-9-44	Tangerines Corn flakes Bread Butter Milk	Roast beef Steamed potatoes Orange salad Bread Butter Baked Apple Milk	Tongue Raisin sauce Carrots Celery Cabbage Bread Butter Spice cake Milk
12-10-44	Tangerines Bran flakes Bread Butter Milk	Peanut butter sandwich Jam Apple Milk	Swiss steak Mashed potatoes Cauliflower Orange and grapefruit salad Bread Butter Ice cream Milk
12-11-44	Oranges Corn flakes Bread Butter Milk	Meat pie (beef) Lettuce salad Plain cookies Milk	Smoked sausage Baked potato Cauliflower greens Fruit salad Bread Butter Banana cream pie Milk

Table I. (Continued)

Date	Breakfast	Lunch	Dinner
12-12-44	Grapefruit Corn flakes Bread Butter Milk	Hamburger Bun Onion Tomato salad Apple Milk	Roast beef Baked potato Brussel sprout Gravy Orange salad Bread Butter Tapioca Milk
12-13-44	Orange juice Oatmeal Bread Butter Milk	Boiled eggs Potato salad Bread Butter Milk	Roast lamb Steamed potatoes Creamed onions Lettuce salad Bread Butter Ice cream Milk
12-14-44	Orange juice Corn flakes Bread Butter Milk	Lamb stew Dumplings Cole slaw Chocolate pudding Milk	Pork chop Baked potato Gravy Stewed tomato Lettuce salad Bread Butter Cranberry whip Milk
12-15-44	Sliced oranges Puffed wheat Bread Butter Milk	Sausage Baked squash Lettuce salad Bread Butter Milk	Smoked sausage Scalloped potatoes Carrot and raisin salad Bread Butter Pumpkin pie Milk

Table I. (Continued)

Date	Breakfast	Lunch	Dinner
12-16-44	Grapefruit Corn flakes Bread Butter Milk	Mushroom soup Crackers Raw carrots Celery Baked pear Milk	Meat pie (beef) Parsnips Lettuce salad Pear salad Cookies Milk
12-17-44	Orange juice Bran flakes Bread Butter Milk	Baked beans Cole slaw Bread Butter Baked pears Milk	Roast beef Gravy Mashed potatoes Green beans Lettuce salad Bread Butter Cookies Milk