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Estimation of Iron Bioavailability from the Diets of an Adolescent Population

Gina C. Viglietti
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To the Graduate Council:

I am submitting herewith a thesis written by Gina C. Viglietti entitled "Estimation of Iron Bioavailability from the Diets of an Adolescent Population." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Nutrition.

Jean D. Skinner, Major Professor

We have read this thesis and recommend its acceptance:

Gail W. Disney, Jane R. Savage, Marjorie P. Penfield

Accepted for the Council:
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Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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ESTIMATION OF IRON BIOAVAILABILITY FROM THE DIETS OF AN ADOLESCENT POPULATION

A Thesis

Presented for the

Master of Science

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Gina C. Viglietti

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ABSTRACT

Estimation of dietary iron bioavailability and determination of dietary iron intake were evaluated from 24-hour food records of 224 adolescents in eastern Tennessee. Total daily iron intakes, 16.1 mg for males and 11.1 mg for females, were below the Recommended Dietary Allowances (RDA). Application of the Monsen and Balintfy model to estimate iron bioavailability showed that absorbable iron from males' diets, 1.38 mg, and from females' diets, 0.91 mg, was below recommended levels. Percentages of bioavailable iron were below the assumed 10% absorption level, a criterion used in establishing the RDA for iron. Thus, total dietary iron was inadequate for males and females as indicated by both measures.

Patterns of iron bioavailability differed among eating occasions but were similar for males and females. Although intakes of the enhancing factor, ascorbic acid, were high at breakfast, the meal was lowest in total iron, percentages of bioavailable iron, and amounts of absorbable iron compared with other meals. The nutrient density of ascorbic acid and iron of lunch meals of adolescents did not meet recommended levels, but more meat, fish, and poultry foods were consumed at lunch than at breakfast. In comparison to other meals, evening meal patterns were highest in meat, fish, and poultry; total iron; total amounts of enhancing factors; amounts of absorbable iron; and percentages of bioavailable iron. Dietary patterns of adolescent males at the evening meal approached

desirable patterns to maximize iron bioavailability. Intakes of iron and absorbable amounts of iron in adolescent females' diets were less than in males' diets and were inadequate.

Snacks, which were consumed frequently by adolescents, contributed substantial amounts of food energy but were low in total iron, absorbable iron, and bioavailable iron. The inclusion of ascorbic acid sources and animal tissue foods, enhancers of iron bioavailability, were low in snacks.

Further evaluation of dietary patterns of adolescents shows that some males and females exhibited patterns that contributed to desirable levels of absorbable iron. Ascorbic acid and meat, fish, and poultry foods were high in their diets. Mean iron intakes of adolescent males and females in this group exceeded or approached the RDA.

Adolescents whose iron intakes were inadequate may not be able to significantly improve iron adequacy through enhancement of iron absorption. They need to increase consumption of iron as well as enhancing factors. Application of the model to estimate iron bioavailability was useful in identifying patterns contributing to iron bioavailability.

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CHAPTER I

INTRODUCTION

Iron deficiency is considered to be the most common nutritional deficiency in the world, affecting 10-20% of the population (1). Factors contributing to iron deficiency include dietary inadequacy, extreme blood loss, and periods of high requirements due to accelerated growth, such as in early infancy, adolescence, and pregnancy.

An adequate intake of iron is difficult to achieve, especially during periods when requirements are high. In addition, absorption of dietary iron does not occur readily. Composition of the diet, the amount of stored iron, and the condition of the intestinal mucosa determine the quantity of iron that is absorbed. Recent evidence indicates that the total iron content of the diet is not an accurate means of expressing dietary iron adequacy (2). Determination of the bioavailability of dietary iron, which is highly dependent on certain other dietary factors, is a useful indicator of dietary iron status. Dietary factors affecting iron absorption include both enhancing and inhibiting factors.

Adolescents may be nutritionally at risk for iron because of their dietary habits. Males, who need more energy than females, generally consume food sufficient for the provision of adequate dietary iron, but females, who need less energy than males, find it difficult to meet their iron needs through food selection. In addition, adolescents frequently consume fast food meals, skip meals,

or replace meals with snacks, habits that contribute to diets of poor quality. Identification of adolescents' dietary habits leading to enhancement or inhibition of dietary iron absorption may be a useful tool in providing recommendations to improve their iron nutriture.

The purpose of this study was to describe the availability of dietary iron in adolescents' diets by comparing two methods of calculating dietary iron: total iron values calculated from tables of food composition and bioavailability of that iron calculated in relation to eating patterns. Adolescents' eating patterns were analyzed to identify patterns that were characteristic of high iron bioavailability. Dietary patterns consistent with adequate iron intakes, as indicated by the calculated amounts of absorbable iron, were described.

CHAPTER II

REVIEW OF LITERATURE

Adolescent Nutriture

Growth

Adolescence is a period of rapid growth beginning between the ages of 8-10 years and ending at the ages of 14-16 (3). This period is marked by physiological changes associated with increases in skeletal and muscle mass and blood volume. Average yearly increases in body mass for adolescent males, around 4.6 kg, are higher than for adolescent females at 4.0 kg (4). In addition to growth variability between sexes, there exists growth variability among individuals. To account for this variability, biological age rather than chronological age should be considered when assessing growth. Biological age is a function of maturity level based on the development of secondary sex characteristics. The use of a sex maturity level for adolescents is considered to be a more significant rationale in relating nutritional needs to growth than the use of chronological age but has not been effectively employed in defining nutrient recommendations for adolescents. Physical examination and identification of secondary sex characteristics are necessary in assigning a sex maturity level to an individual and thus may not be appropriate for large population studies. As of yet, limited data are available on adolescent nutrient requirements according to biological age.

Dietary Patterns

Environmental factors of family structure, peer groups, social systems, and the community have a great impact on adolescents' health status because these factors influence adolescents' behavior. Researchers have attempted to correlate adolescents' food-related behaviors with the biological, psychological, and social transitions occurring at this time (5-7). By way of food habits, some adolescents express their desire to establish an identity. Adolescents may express their desire for independence by adopting eating patterns associated with rapid loss or gain of weight; by overconsumption of fast foods, snacks, or alcohol; or by selecting unconventional meals (8).

Adolescents have been reported to frequently consume between-meal snacks and omit meals. Huenemann et al. (9) found that adolescents' food patterns ranged from regular consumption of meals and snacks to irregular patterns of great variability. The breakfast meal was one that was frequently skipped by adolescents but was an important meal for the consumption of key nutrients (9-11). The evening meal was the most frequently consumed meal and contributed significant amounts of food energy and nutrients to the diet (9,12). Thomas and Call (13) reported that about 23% of the total daily kilocaloric intake for adolescents was obtained from between-meal foods but adequacy of nutrients such as calcium, vitamin A, and iron was below the standard dietary distribution of these nutrients.

Nutrient intakes per 100 kcal for protein, riboflavin, and ascorbic acid in snack foods were above the recommended allowances (13). Hruban (14) discovered that teenagers tended to select nutritious snacks when given a variety of nutritious snacks but tended not to select nutritious snack items when provided with a combination of nutritious and less nutritious snacks. It has been recommended that nutritious snacks be provided for teenagers to encourage consumption of an adequate diet (13-15).

Americans' consumption of fast food items as either meals or snacks also has greatly increased in recent years. Evaluation of fast-food meal combinations has indicated that they are low in vitamin A, ascorbic acid, and calcium and sometimes provided less than one-third of the U. S. Recommended Daily Allowances (U. S. RDA) for iron, thiamin, niacin, and riboflavin (16). The U. S. RDA values are based on the maximum Recommended Dietary Allowances (RDA)(1968) of each nutrient and are used in food labeling (17). In a more recent study, it was shown that food combinations providing one-third of the RDA with the exception of vitamin A and calcium were chosen at most fast-food restaurants (18). Greecher and Shannon (18) suggested that consumers ultimately are responsible for selecting foods low in nutrient composition. Adolescents have been targeted as a group who are frequent consumers at fast-food eating establishments (19). Adolescents chose a fast-food restaurant more often than other types of restaurants (20). In addition, they consumed fast-food type meal combinations in some school lunches, thus placing emphasis on these types of foods (20).

Adolescents may consume adequate food energy, but the nutrient adequacy of their diets often is low because of the foods selected. Intake below two-thirds of the RDA for a nutrient traditionally has been used as a measure of dietary inadequacy for large groups of individuals. Consumption of less than two-thirds of the RDA by adolescents has been found for iron, calcium, ascorbic acid, and vitamin A (5,10,21). The RDA, used by health professionals as dietary standards, include margins of safety so that short term inadequate intakes will not result in deficiencies. However, the margins of safety are low for vitamin A, calcium, and iron, nutrients for which consumption often is below standards (22). Iron deficiency was reported to be the most prevalent nutritional deficiency among Americans and was particularly common among adolescents (3). Knowledge of the biological availability of nutrients, specifically of iron, can lead to effective application of the RDA in planning well-balanced diets (22-24).

Iron Needs

The need for an increased dietary iron intake is important during the rapid growth period of adolescence. Associated with growth is an increasing blood volume necessitating an increase of iron to maintain hemoglobin concentration. In addition, hemoglobin concentration increases about 0.5-1.0 g/dl per year during this period for males, requiring an additional increase of iron. The average adolescent male gains about 10 kg in his peak year of growth;

a total increase of about 350 mg iron in that year is required to maintain hemoglobin concentration in the increased blood volume and to increase hemoglobin concentration overall. Increases in yearly weight gain and increases in hemoglobin concentration are lower in adolescent females than in adolescent males, but the onset of menses is an additional factor contributing to the increased need for iron in females. About 280 mg iron per year is necessary to maintain a constant hemoglobin concentration in the expanding blood volume in the adolescent female (25). Normal obligatory iron losses in the adult male are 0.5-1.0 mg/day, values similar to adolescents' iron losses. Females need an additional average of 0.5 mg iron a day to cover iron losses during the menstrual period (3). Thus, adolescents should absorb adequate iron to cover daily losses and meet the demands of growth.

A 10% absorption rate of the 18 mg iron allowance for adolescents has been assumed in setting the RDA; this would result in 1.8 mg iron per day available for the body (26). Intakes of 18 mg iron and/or absorption of 1.8 mg iron would tend to promote a positive iron balance and supply sufficient iron for the demands of growth. Although inconsistencies exist as to exact requirements, it is suggested that adolescent males average a daily iron absorption of 1.6 mg. This figure decreases to 1.2 mg absorbable iron for the recommendation for adult males (4). The growth spurt in adolescent females is not as great as in adolescent males, but the onset of menses necessitates a high iron requirement. Monsen (27) recommends

daily absorption of 1.4 mg iron by menstruating females to promote iron storage of 500 mg. The RDA of 18 mg iron has included a margin of safety, so that in the event intakes are less than 18 mg, absorbable amounts could approximate the absorption recommendations.

Adequacy of Dietary Iron and Ascorbic Acid

Adolescents of both genders and from all socioeconomic levels and races have been identified as at risk for iron deficiency (3,25, 28,29). Dietary patterns low in iron compared to need are regarded as causative factors in the prevalence of iron deficiency. Dietary iron intakes less than the daily recommended allowances of 18 mg for adolescents are reported in 80% of the females and 75% of the males (30). Many adolescents consumed less than two-thirds of the RDA for iron (5,10,28,31,32). Iron intakes less than 12 mg daily were reported for 54.8% of adolescents aged 15-17 years (33). Adolescent females have consistently lower intakes than males; 74% of the females and 36% of the males surveyed had intakes less than 12 mg daily in a national survey (33). Averages for daily iron consumption among female adolescents 12-16 years of age were 9-13 mg and 10-16 mg for adolescent males in the same age group (3). For all income groups surveyed in HANES-I, the median daily iron intake for adolescents was 10.9 mg iron and the mean was 12.5 mg iron daily (34).

Achieving an intake of 18 mg iron daily is difficult by dietary means; typical American diets provide approximately 6 mg iron/

1000 kcal (23). Caloric intakes of 3000 kcal to achieve an intake of 18 mg iron may be undesirable for some individuals, especially females. Daily kilocaloric intakes vary among adolescent males and females. In the Nationwide Food Consumption Survey (NFCS) 1977-78, the mean daily kilocalorie intake for adolescent females was about 2000 kcal and about 3000 kcal for adolescent males (12). Dietary ascorbic acid intakes are of importance because the amount of ascorbic acid consumed in a meal or snack positively affects the bio-availability of dietary iron present in the same meal or snack. It has been reported previously that ascorbic acid intakes were low among adolescents, but mean daily intakes of 88 mg ascorbic acid have been reported in a sample of adolescents (5). The reported mean ascorbic acid intake for all income groups of adolescents in HANES-I was 78 mg daily, but the median was 50 mg ascorbic acid (34). Based on the RDA of 60 mg ascorbic acid, mean nutrient intakes appear to have been sufficient in adolescents' diets (26).

Sources of Iron

Dietary

Achievement of the recommended 18 mg iron allowance for adolescents may be difficult by dietary means, particularly by adolescent females who tend to have lower energy intakes than males. Diets of 1800 kilocalories containing the recommended servings of meats, legumes, vegetables, and grain products probably will provide about 10 mg iron. Meats, especially liver and other organ meats, provide

substantial amounts of iron. Beef liver contains 7.5 mg iron in a 3-oz. serving. Other types of meat and poultry are fairly good sources of iron as well. A 3-oz. serving of beef provides from 2.5 to 3.0 mg iron; chicken has less iron than beef with a 3-oz. portion containing up to 1.5 mg iron. Ham and pork products vary from 1.6 mg iron in 2 oz. of luncheon ham to 2.7 mg iron in 3 oz. of pork roast. Certain fish and shellfish are high in iron; 1 C of oyster meat contains 13.2 mg iron. Tuna is fairly low but does provide 1.6 mg iron per 3-oz. serving.

Legumes are a good source of iron and an especially important source in diets low in animal foods. Lima and northern beans contribute approximately 5-6 mg iron in a 1-C serving. Other dried peas and beans contain 3-4 mg iron per 1-C serving. Other vegetables, especially the dark green leafy vegetables, also are iron-rich foods. Greens such as collards, turnips, and spinach contain 2-3 mg iron in a 1-C serving. Vegetables also are important sources of ascorbic acid, a major enhancer of iron absorption. Dried fruits and molasses are good iron sources to supplement the diet. One cup of raisins provides 5.8 mg iron. Whole-grain products or enriched cereals and breads also are important sources of iron in the diets of Americans. One slice of white bread contains 0.6 mg iron and whole wheat bread has 0.8 mg iron per slice; bread can contribute substantially to daily iron intake when consumed several times a day (35).

Supplemental

One means of preventing iron deficiency is by direct intervention with supplementation or fortification (36,37). Supplementation involves distribution of iron as a tablet whereas iron added to food is the method of fortification. Iron fortification of food is an economical approach in preventing iron deficiency, especially among large populations. Iron fortification necessitates the selection of a suitable source of iron, an appropriate amount of iron, and a suitable iron carrier. The iron compound that is chosen should be technologically and nutritionally suitable for its use in the diet. The iron carrier also should be technologically stable and acceptable by consumers. Food vehicles currently used include cereals and their flours, successfully used in developed countries, and other foods such as sugar and salt, which have been satisfactorily employed in developing societies (36,38,39). Consumption of cereals and grain products is common in many countries and fortification of these foods with iron is favorably accepted. Wheat flour, used in the production of baked products, and breakfast-type cereals made from a variety of grains, are fortified with iron in developed countries because of the frequency of their use. Iron bioavailability needs to be considered in setting standards for iron enrichment (36,40).

Iron Metabolism

Body Iron

The essential element iron exists in the body as iron in functional forms and as iron in storage forms. The functional forms

consist of hemoglobin iron, which comprises about 70% of body iron; myoglobin iron, which is in muscle; and the tissue iron enzymes (cytochromes, catalases, and peroxidases). Myoglobin and the iron enzymes represent about 5% of body iron. The transport iron protein, transferrin, represents a small fraction of body iron. The storage forms of iron are ferritin and hemosiderin. About 25% of iron in the adult male is present in the storage form, whereas about 10% of iron in females is in this form (3).

Factors affecting iron balance include the amount and bioavailability of dietary iron, iron stores, and iron loss from the body. Dietary iron intake and its bioavailability are considered to be limiting factors in iron balance. Only a portion of dietary iron is available for absorption due to inhibiting gastrointestinal and dietary factors. Heme iron, a small fraction of dietary iron, is highly available, but nonheme iron availability is dependent on certain dietary factors. Iron stores are mobilized to produce hemoglobin and other important iron compounds when dietary iron intake is inadequate. Absorption of iron increases when iron stores are depleted. Physiological iron losses from intestinal cell desquamation are considered to be relatively fixed and have little effect on iron balance. Uterine iron loss resulting from menstruation and pregnancy and iron demands due to growth will influence iron status. The absorptive mechanism of iron is considered the regulator of iron balance (3,25,37).

Iron Absorption

Regulation of iron absorption from the duodenum is divided into three phases: (1) the intraluminal phase, (2) the mucosal phase, and (3) the corporeal phase. The intraluminal phase involves the process of digestion of food and the transformation of inorganic (nonheme) iron III (ferric) complexes to the absorbable iron II (ferrous) form. Conversion of nonheme iron III to nonheme iron II in this phase is facilitated by ascorbic acid in a meal (25). The uptake of soluble nonheme iron by the mucosa depends on the quantity of iron in the lumen. Brush border receptors then bind nonheme iron for its transfer into the mucosal cell. The number of brush border receptors increase in iron deficiency. Dietary ligands that enhance or inhibit iron absorption compete for iron with acceptor sites on the receptors. In the corporeal phase of iron transfer, nonheme iron binds to specific carriers and is transferred to plasma transferrin on the serosal side. Excess iron in the mucosa that is not transferred is taken up by apotransferrin and stored as ferritin (36).

Preparation for absorption of heme iron differs from that of nonheme iron. Heme is split from the globin fraction in the intestinal lumen and enters the mucosal cell where ionic iron is released from the porphyrin complex by the enzyme xanthine oxidase. Heme iron enters the mucosal pool also containing nonheme iron and iron from both sources is handled similarly from this point on (36).

Reliable methods for quantitating iron absorption are essential in evaluating measures used to prevent iron deficiency. Techniques have improved since radioisotopic measurements have replaced the imprecise chemical balance methods (25). The variability of iron absorption from intersubject and intrasubject measurements has made assessment difficult, but the use of large groups of individuals has produced more consistent results. Methods of evaluation have involved the feeding of biosynthetically labeled plant and animal foods to determine the rate of absorption (25,41). Early studies focused on iron absorption from single foods (42-44). Layrisse et al. (44) reported that iron is less well absorbed from vegetable foods than from animal foods, and iron from food is less well absorbed than it is from iron salts. Evidence has supported the idea that absorbed iron from various foods forms a two pool system in the gut consisting of heme iron from animal foods and nonheme iron from vegetable and animal foods (45-47). Further investigation has revealed that the process is more complex and is dependent on the interaction among different foods. Cook et al. (46) compared nonheme iron absorption of ^{55}Fe biosynthetically incorporated (intrinsic tag) and inorganic ^{59}Fe (extrinsic tag) from composite meals. Results indicated that absorption of the two tracers were identical, suggesting that nonheme iron from foods ingested in a meal forms a pool in the body in which nonheme iron availability is dependent on certain dietary factors affecting absorption. This method has been used in determining nonheme iron absorption from foods such as corn, wheat,

soybeans, black beans, and eggs (46,47). Further investigation has supported the validity of the two-pool extrinsic tracer method in measuring iron absorption from the two pools of body iron (47).

Evaluation of dietary factors influencing iron absorption has led researchers to refine techniques in measuring iron absorption from composite meals. Cook and Monsen (48) measured nonheme iron absorption from a standard meal chosen as representative of a typical American meal and from a semisynthetic meal of the same chemical composition. The semisynthetic meal provided low bioavailability of iron while high iron bioavailability was obtained from the standard meal. These results contributed to the evaluation of dietary factors enhancing and inhibiting dietary iron. Other investigators have utilized the extrinsic-tag method to measure iron absorption from freely chosen meals realistically prepared and consumed by subjects (49-51). The concepts learned from these studies are valuable in evaluating iron absorption from diets that are representative of a population or of a representative segment of the population.

Biochemical Measurement of Iron Status

Iron deficiency refers to a reduced total iron content in the body. The sequence of iron deficiency occurs in three stages: depletion of iron stores, decreased transport iron, and reduced production of the physiologically important iron-containing protein compounds: myoglobin, hemoglobin, and the iron-containing enzymes (52). Distinct

terms are used to describe these stages of iron deficiency. "Iron depletion" is the term defining a state of deficient iron stores. "Iron deficiency" (without anemia) describes the condition when there are no iron stores and there is a decrease in percent transferrin saturation, yet anemia is undetected. "Iron deficiency anemia" refers to the condition of iron depletion inadequate for hemoglobin production (3). Several laboratory tests are employed to determine which stage of iron deficiency exists. Serum ferritin is an estimate of storage iron and is about the only test capable of assessing the degree of iron depletion. Estimation of serum ferritin is a costly procedure, and there are limited data on this value in the adolescent population. Transport iron is measured by the ratio of serum iron to iron binding capacity. Hemoglobin and protoporphyrin levels are indicators of the presence of anemia and the decreased production of iron-containing compounds. Unfortunately, overlap between stages of iron deficiency and individual variability may affect the reliability of laboratory tests. Consequences of iron deficiency or anemia result in reduced oxygen uptake and decreased work output.

The general indicators used to assess anemia are concentration of hemoglobin and percentage hematocrit. Measurement of hemoglobin indicates the red blood cell concentration of this iron-containing compound. In the HANES-II population the mean hemoglobin value for males aged 15-17 years was 14.3 g/dl and 13.3 g/dl for females aged 15-17 years. Based on standards of less than 13 g/dl for males and less than 11.5 g/dl for females as low, the prevalence of low

hemoglobin values for males in the age group 15-17 years was 5.0% and 5.5% for females aged 15-17 years (53). Bailey et al. (29) classified 11% of the females and 3% of the males as anemic, defined as less than 12 g/dl hemoglobin.

Hematocrit is a measure of the percent of packed red cells in a volume of whole blood. The presence of low hematocrit levels for males in the HANES-II population aged 15-17 years was 13% and 9.3% for females aged 15-17 years, based on standards of less than 40% hematocrit for males and less than 36% hematocrit for females. The mean hematocrit was 43% for males and 39% for females (53). Greger et al. (28) reported that only 1% of adolescent girls surveyed had low hematocrit levels (less than 36%) with a mean hematocrit of 42%.

Serum iron and transferrin saturation are other measures used to evaluate the status of iron stores. About 5% of adolescent males and 3% of adolescent females surveyed in HANES-II were reported to have low serum iron. The mean transferrin saturation for adolescent males was 29% with a standard of less than 20% considered low, and the mean was 26% for females with a standard of less than 15% considered low (53). Bailey et al. (29) reported that iron status measured by transferrin saturation was inadequate for a portion of a population of low-income subjects. Transferrin saturation was low in 12% of the females and 2% of the males on a standard of less than 16%. Levels decreased in females as age increased, probably due to the onset of menses, but males' levels increased with age.

Even though the prevalence of low dietary iron intakes is greater among adolescents than is the presence of low biochemical indices, the potential for iron deficiency remains. The occurrence of iron deficiency, as a factor of time, is related to the extent of dietary iron inadequacy. Consideration of dietary patterns in regard to bioavailability of iron can assist in prevention of iron deficiency.

Iron Bioavailability

Dietary Forms of Iron

Iron exists in food as heme iron in meat, poultry, and fish, and as nonheme iron in vegetables, fruits, and grains. Meat, poultry, and fish also contain some nonheme iron. Heme iron occurs as the soluble porphyrin complex in hemoglobin and myoglobin of animal tissue. Nonheme iron exists as the inorganic iron III complex in food that is reduced to the absorbable iron II form during digestion (25). Nonheme iron constitutes the majority of dietary iron but is absorbed at a lower rate than is heme iron.

Absorption of dietary iron from plant foods is 3-8%; dietary iron absorption from animal foods is 8-16% (44,54). About 40% of the iron in animal tissue is present as heme iron, and nonheme iron accounts for the remaining 60% of animal tissue iron (55). Dietary sources of heme iron may be low in the diet because of food habits. Thus, heme iron comprises a smaller portion of total dietary iron than nonheme iron. Hallberg (56) states that heme iron comprises 10-15% of the total dietary iron, but in an earlier study it was

reported that about 6% of total iron is consumed as heme iron (48).

Factors Affecting Iron Absorption

Layrisse et al. (54) reported that an interaction that affects iron absorption occurs between animal and vegetable foods during digestion. They found that iron absorption from beef alone was significantly greater than iron absorption from beef combined with corn or black beans. However, iron from corn and black beans was absorbed better when combined with beef than when consumed alone. Absorption of heme iron is not affected by other factors in the diet, but absorption of nonheme iron is influenced by certain factors in the diet (54,57). Heme iron absorption is not influenced by dietary enhancing or inhibiting factors because of its solubility and its particular absorptive mechanism in the duodenum (58).

Nonheme iron bioavailability is enhanced by ascorbic acid (59,60) and an unidentified substance in meat, poultry, and fish that apparently is not present in milk and dairy products (55,57). Dietary factors inhibiting nonheme iron absorption are tannates (61), coffee (62), calcium phosphate (63), egg yolk (57,64), EDTA (65), bran (66), and a wide variety of soy products (67). Enhanced absorption of nonheme iron is due to the formation of soluble complexes, while the formation of insoluble large polymers and iron precipitates inhibit absorption (68).

Nonheme iron absorption enhancement by ascorbic acid is dose and time dependent. The absorption of nonheme iron increases proportionately at levels up to 1 g ascorbic acid and is greatest when

ascorbic acid is consumed simultaneously with food containing nonheme iron (58,69). Ascorbic acid maintains iron in a soluble form by acting as a reducing agent and by complexing with the ferric form of nonheme iron at the alkaline pH of the duodenum (58,70). A reduced enhancement of nonheme iron absorption by ascorbic acid has been observed when foods have been sustained at warm temperatures as occurs in restaurants and cafeterias. Ascorbate content in foods is significantly reduced within one hour of prolonged warming at 75°C thus depressing nonheme iron absorption (71). The mechanism by which animal tissue enhances absorption of nonheme iron is unknown (55). A distinction is made between sources of animal protein and animal tissue because milk and dairy products have no effect on nonheme iron absorption (55,58).

Researchers have focused on the importance of enhancing factors on nonheme iron absorption; however, a limited number of studies have involved the effect of inhibiting factors. Knowledge of the effect of inhibiting factors may be significant because their removal from the diet may improve iron status. Elucidation of the mechanisms of inhibitory action on iron absorption or ways to overcome their effect is needed. Such research is important especially for populations consuming large amounts of inhibitory substances.

Tea can reduce nonheme iron absorption from a meal by as much as 87% (61). Hallberg and Rossander (60) reported a 62% reduction in iron absorption when one cup of tea was consumed in a standard meal containing meat and vegetables. The tannins in tea form

insoluble iron-tannate complexes in the lumen, decreasing iron availability (58). Polyphenolic compounds in coffee, chemically similar to tannins in tea, also inhibit nonheme iron absorption but by a mechanism different from and with less effect than tannin inhibition. While the exact mechanism is unknown, a possible explanation for this effect is that a substance in coffee oxidizes iron to the insoluble ferric state. The inhibitory effect of coffee on iron absorption occurs in the lumen when coffee is ingested simultaneously or one hour after a meal; there is no inhibition when coffee is consumed one hour before a meal. No differences have been found between drip and instant coffee, but inhibition was dependent on the coffee strength. Coffee has been shown to reduce dietary iron absorption by 39% (58,62).

When fed simultaneously, calcium and phosphorus compounds have been shown to decrease nonheme iron absorption in animal studies, but the addition of calcium or phosphorus compounds separately to diets had no effect on nonheme iron absorption in humans (63). Iron absorption was decreased significantly in humans when both calcium chloride and potassium phosphate were added to a meal, due to the formation of an insoluble complex of iron, calcium, and phosphate (58,63). Phosphate salts and calcium phosphate perform several functions in food processing, and these are of interest with respect to their involvement in iron metabolism.

The consumption of egg inhibits absorption of other dietary nonheme iron present in the meal, and the iron in egg also is poorly

available (58). The phosphorylated protein in egg yolk, phosvitin, binds ferric ions and inhibits absorption of iron from egg and iron supplied from other foods when simultaneously ingested, but egg albumin reportedly has no effect on nonheme iron absorption (72). Rossander et al. (73) however, reported that inclusion of egg in a breakfast meal containing bread, orange juice, bacon, and coffee, did not affect the amount of iron absorbed. Thus, it has been determined that not all animal proteins enhance nonheme iron absorption (55,64,72).

Ethylenediaminetetraacetic acid (EDTA), a compound used in food processing as an antioxidant agent, is a chelator inhibiting iron absorption. It functions by maintaining the solubility of iron at a neutral pH at which iron is not available to the body. Cook and Monsen (65) demonstrated that EDTA reduces dietary iron absorption and that the effect is dependent on the total amount of EDTA and the molar ratio of EDTA to iron in the diet. In a meal containing 50 mg EDTA and 4.1 mg iron, a 2:1 molar ratio, nonheme iron absorption was reduced by 50%. However, molar ratios of EDTA to iron less than 1:1 do not reduce iron absorption and might enhance iron absorption (58). Total dietary EDTA consumption is unknown, but the average daily intake among the American population is thought to be about 50 mg (65).

Wheat bran has been associated with inhibition of nonheme iron absorption also. Iron absorption from white bread with added bran was lower than from white bread alone, despite the additional iron

content in bran (66). Possible reasons suggested include the presence of phytate, phosphate, and unhydrolysed dietary fiber (74). Phytate, a compound that binds iron and other minerals, is present in wheat bran. Monoferric phytate, the dominant fraction of iron in bran, is of high bioavailability to humans in contrast to insoluble di- or tetraferric phytate (75-77), but purified dietary sodium phytate added to meals reduced iron bioavailability (78). The inhibitory effect of bran on iron absorption is not attributed to phytate because dephytinized bran also inhibits iron absorption. Therefore, the action may be due to fiber or phosphate, which are more inhibitory than phytate, in influencing iron absorption, but the effects of both have not been clearly identified (77). It has been suggested that the inhibitory mechanism possibly is due to interactions between the fiber, phytate, and iron in the whole bran (75).

The enhancement of iron absorption by animal protein has led researchers to investigate the effect of soy proteins because soy frequently is used as a fortifying agent in various food products and also is used as an alternative to animal protein. Cook et al. (67) found that soy protein inhibited dietary iron absorption under some circumstances. Confusion exists because earlier studies indicated high iron bioavailability in meals containing soy. Reasons for the variability in iron absorption from soy containing meals is unknown as is the mechanism by which soy inhibits iron absorption. Implications with regard to iron status are indicated in areas where soy is a major dietary protein and dietary enhancing factors are low.

Soy protein is a useful source of dietary protein, therefore measures to modify its inhibitory effect on iron absorption are needed. Morck et al. (79) suggested the possibility of adding fortification forms of iron to the meal to increase total iron content. Their investigation of inclusion of dietary enhancing factors showed that beef exhibited a slight enhancing effect in overcoming soy-induced inhibition. Addition of ascorbic acid to a meal that included soy protein resulted in a partial reversal of soy-induced inhibition, but the effect was less enhancement than when ascorbic acid was added to a meal without inhibitors (79).

Estimation and Calculation of Iron Absorption

Investigations thus far have shown that the total iron content of a diet provides a rough estimate of dietary iron adequacy and that potentially absorbable iron is influenced by meal composition. Investigators have supported the need to estimate iron bioavailability in making dietary recommendations (2). A method proposed by Monsen et al. (2) to estimate the quantity of absorbable iron in a meal is based on the effect of the enhancing factors of meat, fish, poultry, and ascorbic acid on nonheme iron absorption. Inclusion of the effect of inhibitory factors on iron absorption has not been included in the method thus far. Use of the Monsen model provides a more precise value for absorbable iron than the assumed 10% iron absorption used in establishing the RDA.

Both heme and nonheme iron absorption are inversely influenced by iron stores. A level of 500 mg iron stores is used for calculation in the Monsen method because this level is considered a desired level of storage iron and is a convenient value to use in comparing iron bioavailability of various dietary patterns. The Monsen method involves calculation of the following variables in estimating the amount of absorbable dietary iron: (1) total iron (mg), (2) heme iron (mg), (3) nonheme iron (mg), (4) ascorbic acid (mg), and (5) meat, fish, and poultry (g). Summation of the amounts of the enhancers, ascorbic acid and meat, poultry, or fish consumed in a meal or snack, is the enhancing factor value. One mg of ascorbic acid has an equivalent enhancement effect as 1 g of meat, fish, or poultry. Each eating occasion is regarded as being of high, medium, or low iron bioavailability based on the amount of enhancing factors present (2). A refined model (80) for estimating iron bioavailability now exists, based on the concept that enhancing factors participate in a logarithmic relationship to nonheme iron bioavailability. To determine bioavailability, the total amounts of ascorbic acid; meat, poultry, or fish; total iron; heme iron; and nonheme iron are calculated for each meal or snack. Heme iron represents approximately 40% of the total iron of meat, poultry, and fish foods, and the remaining iron is in the nonheme form. Iron in fruits, vegetables, and grains is present as nonheme iron. Thus, bioavailability of nonheme iron is between 3 and 8%, depending on the amount of enhancing factors present; the reference individual

with 500 mg iron stores will absorb 3% of the nonheme iron when no enhancing factors are present and a maximum 8% when enhancing factors equal a value of 75. The bioavailability of heme iron is 23% for the reference individual. The amount of absorbable nonheme iron is determined by percentage of nonheme iron bioavailability multiplied by the total nonheme iron (mg) in an eating occasion. Likewise, 23% multiplied by the total dietary heme iron (mg) determines the amount of absorbable heme iron. Summation of the absorbable heme and nonheme iron is the value of the total amount of absorbable iron for the meal or snack. Daily totals are found by adding the total amounts of absorbable iron for every meal and snack. The percentage of bioavailable iron will express how much dietary iron was available for absorption. The method of calculation is presented in Figure 1. Thus, calculation of absorbable iron of the day's intake should provide a more accurate measure of dietary adequacy than the total dietary iron intake calculated from a table of food composition.

Step 1 % Nonheme iron bioavailability

Enhancing factors (EF) < 75: % = $3 + 8.93 \log_n (\frac{EF + 100}{100})$

EF $\geq$ 75: % = 8

Step 2 Absorbable nonheme iron (mg)

% Nonheme iron bioavailability (Step 1) x mg dietary nonheme iron

Step 3 Absorbable heme iron (mg)
23% x mg dietary heme iron

Step 4 Total absorbable iron (mg)

Absorbable nonheme iron (mg) (Step 2)

+

Absorbable heme iron (mg) (Step 3)

Step 5 % Iron bioavailability

$$\frac{\text{Total absorbable iron (mg) (Step 4)}}{\text{Total dietary iron (mg)}} \times 100$$

Figure 1. Calculation of iron bioavailability.

CHAPTER III

METHODOLOGY

Sample Selection

Adolescents were selected as the target group for this study because of their low dietary iron intake and their increased need for iron. Another researcher, Salvetti (81), chose the sample of 224 adolescent students from 7 randomly selected eastern Tennessee high schools. From a list of Tennessee public high schools (82) and a map of standard metropolitan statistical areas in Tennessee (83), high schools were categorized in eastern Tennessee as small town/ rural or metropolitan. Four metropolitan and three small town/ rural schools were randomly selected; 7 schools were chosen as alternates.

Approval to conduct the study was obtained from principals of the selected high schools. Students enrolled in two required junior and/or senior classes in each school were invited to participate in the study; participation of students was voluntary. Written consent was obtained from adolescents who were 18 years of age, and written consent was obtained from parents of adolescents who were less than 18.

Development of Instruments

The sample survey was the method of data collection chosen to obtain information about adolescents' dietary habits. Investigation

of the relationship between methods of evaluating dietary iron intake and its bioavailability was the focus of this portion of the study. Dietary data were collected using the 24-hour food record, a preferred alternative to the food recall method because of limited time and available personnel for field work. The food record form was designed to obtain information about all foods consumed, the time of day and places food was consumed, the person(s) who prepared food, and the number of persons eating with the respondent at each eating occasion (Appendix I).

In addition to the 24-hour food record, a sociodemographic questionnaire was included in the study (Appendix II). Salvetti (81) developed the sociodemographic questionnaire consisting of 69 closed response questions.

Data Collection

Data were collected on a weekday, Monday through Thursday in May 1980. A researcher (81) visited each school to teach adolescents how to keep the food records. Adolescents were instructed to record all foods consumed in the 24-hour period immediately following the researcher's visit to class. Adolescents recorded each eating occasion and the kinds and amounts of food consumed.

Coding and Nutrient Analyses

All eating occasions were classified as either meals or snacks. Breakfast was defined as an eating occasion that included any calorie-

containing food or beverage eaten between 6 a.m. and 10 a.m.; lunch consisted of an eating occasion between 11 a.m. and 2:50 p.m. that included two or more foods providing kilocalories. The evening meal, occurring between 3:30 p.m. and 10 p.m., was based on the provision of more than one food, including a protein-rich food. When more than one eating occasion that met the outlined criteria occurred in one of the specified time periods, the eating occasion having the widest variety of calorie-containing foods was selected as the meal for that period. All eating occasions defined as meals were coded for analyses as separate eating occasions. All other eating occasions that were not meals were defined as snacks. Snacks also were coded as separate eating occasions and were further classified by the time of day they were consumed. Morning snacks were defined as those eaten between the time the adolescent awoke and 11:59 a.m. Snacks consumed between 12:00 noon and 6:00 p.m. were defined as afternoon snacks, and those snacks eaten after 6:00 p.m. until bedtime were evening snacks.

The Nutritive Value of Foods, Home and Garden Bulletin No. 72 (35), was used as the data base in coding foods for nutrient analysis by computer. For purposes of determining iron bioavailability, all combination foods containing meat, fish, or poultry were coded by their ingredients. This was done so that the heme and nonheme iron content of the foods could be determined separately. Food package nutrition information provided additional data.

The Statistical Analysis System (SAS) (84) was used to develop a computer program for nutrient analysis. Values for

energy, protein, ascorbic acid, and iron of foods consumed were calculated. SAS (84) also was used to develop a computer program based on the Monsen and Balintfy (80) refined method of calculating iron bioavailability (Appendix III).

Individual's intakes of energy, protein, total iron, heme iron, nonheme iron, and ascorbic acid were calculated for breakfast, lunch, the evening meal, and for each snack occasion. For calculating iron bioavailability, the amount of meat, fish, or poultry (g) consumed in an eating occasion was determined and when summed with the nutrient intake of ascorbic acid (mg), became the enhancing factor value. The enhancing factor value was necessary for determination of nonheme iron bioavailability. Bioavailability of nonheme iron (percentage absorption) then was calculated for each eating occasion. The amounts of absorbable nonheme iron, dependent on enhancing factors, and the amounts of absorbable heme iron were summed to describe the total amount of absorbable iron of an eating occasion. Bioavailability of total iron (percentage absorption) was determined by dividing total absorbable iron by total iron. Values from each eating occasion were summed for the 24-hour period. Mean values of males and females were calculated for each eating occasion and for the total day. Means were determined for energy; protein; total iron; heme iron; nonheme iron; ascorbic acid; meat, fish, and poultry; enhancing factors; absorbable nonheme iron; percentage of bioavailable nonheme iron; absorbable heme iron; total absorbable iron; and percentage of bioavailable iron. Individual's intakes for each eating occasion also

were expressed per 1000 kilocalories (kcal) as a measure of nutrient density, and means were calculated for males and females.

Statistical Analyses

Means and standard deviations for the recorded 24-hour period were used to describe selected nutrient intakes and dietary factors contributing to iron bioavailability in diets of adolescent males and females. Factors included energy; protein; ascorbic acid; total iron; heme and nonheme iron fractions; absorbable amounts of heme, nonheme, and total iron; amount of meat, fish, and poultry; and the percentages of bioavailable nonheme iron and total iron. Pearson's product-moment correlation coefficient was used to assess the relationship between the two measures of dietary iron adequacy: total iron and amounts of absorbable iron. Means and standard deviations also were computed for the same dietary factors from the 24-hour food records for adolescents in the regions, rural and metropolitan.

The variations of dietary iron intake, iron bioavailability, and iron adequacy were investigated through analyses of eating occasions defined by time. The program PROC GLM in SAS (84), which uses least-squares analysis of variance, was used to compare dietary patterns among breakfast, lunch, and evening meal intakes of males and of females. This procedure was suitable for data of unbalanced design. Nutrient intakes per 1000 kcal from meals were compared by PROC GLM analyses of covariance (84) for protein, ascorbic acid, total iron, heme iron, nonheme iron, and the absorbable amounts of

iron and iron fractions. Nutrient intakes and dietary components in the first snack consumed in a time period, defined as morning, afternoon, and evening, were tested to identify patterns of iron bioavailability in snack occasions of adolescent males and females. PROC GLM least-squares analysis of variance with contrast was used to test the effects of time on iron bioavailability. PROC GLM analyses of covariance with contrast were used to test for differences among nutrient intakes per 1000 kcal in snack occasions of males and females.

To enable further description of adolescents' dietary patterns related to iron nutrition, adolescents' values of absorbable iron were ranked from highest to lowest. Food records of males and females whose values fell into the top 25% and bottom 25% were chosen for additional analysis. Three male and four female adolescents who exhibited extremely low values of absorbable iron were eliminated from the subsample. These individuals had unusually low intakes of foods and foods containing iron for the 24-hour period. Mean 24-hour intakes for energy, protein, ascorbic acid, total iron, heme iron, nonheme iron, the absorbable amounts and percentage of bioavailable iron, as well as the amount of meat, fish, or poultry consumed were determined for both males and females in the upper and lower quartiles. Nutrient analysis per 1000 kcal also was performed on the data.

Percentage of iron bioavailability for the recorded 24-hour period also was selected as a criterion to describe dietary patterns

of iron nutrition among adolescents. Percentage of iron bioavailability values were ranked from highest to lowest. Subjects with values in the top 25% and bottom 25% were chosen for the subsamples. There were two adolescent males who were omitted from the group of males with low iron bioavailability percentages and three females omitted from the group of females with low iron bioavailability percentages because of their extremely low iron bioavailability values due to a low consumption of foods and foods containing iron. Mean 24-hour intake data for nutrients and dietary factors contributing to iron bioavailability were analyzed.

Comparison of the relationship between iron intake and iron bioavailability required investigation of dietary patterns of persons exhibiting high or low values of absorbable iron and percentages of iron bioavailability. The subsamples created on the basis of absorbable iron were tested for differences among nutrients and dietary factors of adolescent males' and females' 24-hour foods records. Analyses were performed by groups within gender. One-way analyses of variance were employed to test for statistical differences. Nutrient intakes per 1000 kcal for protein, ascorbic acid, total iron, heme and nonheme iron, and the absorbable amounts of each were tested by analysis of variance.

Subsamples based on the criterion of percentage of iron bioavailability were selected for analysis. The groups of adolescent males and females who had low iron bioavailability percentages were compared to the respective groups of males and females who had

dietary patterns of high iron bioavailability percentages. Intakes of nutrients and dietary factors from the food records were compared with one-way analyses of variance. All analyses were tested at the $p \leq 0.05$ level of significance.

CHAPTER IV

RESULTS AND DISCUSSION

Description of Sample

Descriptive data on the sample of adolescents are presented in Table 1. The sample of 224 adolescents was almost equally distributed between males and females. Approximately one-half of the adolescents (51.2%) were 17 years of age; ages ranged from 15 to 18. The majority (92.4%) of adolescents were white. Enrollment in rural or metropolitan schools was almost equally distributed among the sample.

Description of Nutrients and Dietary Factors for the 24-Hour Period

Means and standard deviations of adolescents' intakes of selected nutrients and dietary factors related to iron bioavailability from 24-hour food records are shown in Table 2. Mean nutrient intakes for energy, protein, and ascorbic acid of adolescent males and females met 100% of the RDA for this age group. However, mean dietary iron intakes were below recommendations for both males and females but were similar to reported iron intakes among adolescents (3,31).

Another criterion employed in assessing dietary quality is determination of nutrient density: nutrient intake per unit of energy.

TABLE 1

Demographic characteristics of selected 15-18 year old adolescents[1]

Characteristic	% Respondents
Gender	
Male	50.4
Female	49.6
Age	
15	1.4
16	36.6
17	51.2
18	10.8
Region	
Rural	42.9
Metropolitan	57.1
Race	
White	92.4
Black	6.7
Other	0.9

[1]Random sample of 224 adolescents in 7 high schools in eastern Tennessee (3 rural, 4 metropolitan), spring 1980.

TABLE 2

Intakes of selected nutrients and dietary factors contributing to iron bioavailability in 24-hour food records of adolescents in eastern Tennessee[1]

Factor	Males	Females
	Mean ± SD	
Energy (kcal)	3099 ± 1252	2053 ± 882
Protein (g)	106 ± 42	64 ± 31
Ascorbic acid (mg)	113 ± 145	67 ± 85
Iron (mg)	16.1 ± 6.2	11.1 ± 5.6
Nonheme iron (mg)	14.2 ± 5.7	9.7 ± 5.1
Heme iron (mg)	2.0 ± 1.3	1.3 ± 0.9
Meat, fish, poultry (g)	191 ± 119	120 ± 76
Absorbable nonheme iron (mg)	0.93 ± 0.40	0.60 ± 0.32
Absorbable heme iron (mg)	0.45 ± 0.29	0.30 ± 0.21
Total absorbable iron (mg)	1.38 ± 0.60	0.91 ± 0.47
Bioavailability of iron (%)	8.6 ± 1.9	8.3 ± 2.1[2]

[1]Random sample of 224 adolescents in 7 high schools in eastern Tennessee (3 rural, 4 metropolitan), 113 males, 111 females.

[2]Only subjects who consumed foods that contained iron were included in calculation of mean; n=110 females.

The typical American diet contains an estimated 6 mg iron/1000 kcal (23). Adolescent males need to consume approximately 6.4 mg iron/ 1000 kcal based on a recommended 2800 kcal intake, and females' diets should have 8.6 mg iron/1000 kcal in a 2100 kcal intake (85). Adolescent males and females in this sample received less than these amounts; average intakes were about 5.2 and 5.4 mg iron/1000 kcal, respectively. Thus, adolescents' diets were low in both total iron and nutrient density of iron.

Between the two fractions of dietary iron, heme iron usually constitutes a small amount of total dietary iron intake, but accounts for about one-third of total absorbable iron. According to Hallberg (56), Western-type diets contain 10-15% of total iron as heme iron, but Cook (86) considers heme iron to represent 5-10% of total dietary iron. Diets of adolescent males contained 12.4% and diets of females contained 11.7% of total dietary iron as heme iron. Absorbable amounts of iron in adolescents' diets also followed the usual pattern with 33% of total absorbable iron in both adolescent males' and females' diets from absorbable heme iron. Thus, nonheme iron constituted the majority of total dietary iron, as indicated in Table 2. The average percentage of absorbable nonheme iron, 6.5% in males and 6.1% in females, was within the estimated range of 3-8% for the reference individual with 500 mg iron stores. Essential to the determination of iron bioavailability is the amount of meat, fish, and poultry consumed (MFP g). Male adolescents consumed 191 g daily of meat, poultry, and fish, and females consumed 120 g.

The Recommended Dietary Allowance for iron at 18 mg is based on the assumption that 1.8 mg dietary iron will be absorbed. This allowance is based on 10% absorption, an average of the expected amounts of heme and nonheme iron in the diet and their percentage absorption, 23% for heme iron absorption and 3-8% for nonheme iron absorption. Results in Table 2 indicate that the bioavailability of iron for adolescent males and females was less than 10%, resulting in low values of total absorbable iron. Cook and Monsen (48) reported that females consuming 1800 kcal and 11 mg iron/day can maintain a positive iron balance if iron absorption is equivalent to 12%. The literature varies in recommendations for adolescents for absorbable dietary iron, but Bothwell et al. (4) recommended 1.6 mg absorbable iron for adolescent males, and Monsen (27) stressed that 1.2-1.4 mg absorbable iron is necessary for adolescent females. Values of absorbable iron in Table 2 indicate that adolescents' diets were poor with respect to absorbable iron in that neither males' nor females' diets met recommended amounts. Dietary patterns of adolescent males and females therefore were below recommendations for total iron and total absorbable iron, indicating inadequacy of dietary iron by both measures.

Pearson's product-moment correlation coefficients of $r = 0.88$ ($p = 0.001$) for males and females were found for the correlation between values of total iron from Tables of Food Composition and absorbable iron as calculated by Monsen and Balintfy's method of iron

bioavailability (80). Sixty-four percent of the variability was explained by this correlation. Thus, the possibility exists that for some individuals the measures differ.

Because mean values can obscure variability among subjects, another criterion of dietary adequacy used is the number of subjects consuming less than two-thirds of the RDA. A high percentage (65%) of females had less than two-thirds RDA for iron. Iron intakes ranged from 0.0 to 11.9 mg per day among those females whose intakes did not meet two-thirds RDA. A smaller group of males (27%) than females had iron intakes less than two-thirds RDA; their iron intakes ranged from 1.7 to 11.8 mg per day.

Dietary patterns and nutrient intakes among subjects living in rural or metropolitan areas were investigated. Total daily dietary iron intakes of both groups were below the RDA; 12.8 mg and 14.2 mg iron, respectively, were consumed by individuals living in a rural or metropolitan region. The consumption of meat, fish, and poultry foods was significantly higher ($p \leq 0.05$) among metropolitan residents than among those living in rural areas. Mean intakes of 176 g of meat, fish, or poultry foods by metropolitan residents and 128 g of animal tissue foods by rural subjects were found. Therefore, heme iron and absorbable heme iron were higher ($p \leq 0.05$) in diets of metropolitan subjects than in diets of rural subjects. There were no differences in total iron, nonheme iron, and ascorbic acid intakes between the groups. Total absorbable iron was higher in diets of metropolitan subjects (1.24 mg) than in diets of rural

subjects (1.03 mg), although neither value approached levels recommended for adolescent males and females. Percentages of bioavailable iron were not different between regions. Evaluation of iron nutrition in diets of rural and metropolitan adolescents indicated that diets were inadequate in total iron and total absorbable iron, and increased iron bioavailability may not improve dietary iron status.

Description of Nutrients and Dietary Factors of Meals

In order to delineate the relationships between eating patterns and dietary adequacy of iron, adolescents' intakes were classified into specific eating occasions categorized by time. Analyses of selected nutrients that contributed to iron bioavailability of meals are presented in Tables 3 and 4.

Least-squares means of selected nutrients and dietary components contributing to iron bioavailability in meals consumed by adolescent males are presented in Table 3. Analyses of nutrient intakes expressed per 1000 kcal also are presented for meals in Table 3. The breakfast meal was consumed by 69% of the males on the day of the survey. About 88% had lunch, and 95% ate the evening meal. Energy and protein intakes were highest at the evening meal. Iron intakes were highest at the evening meal but were not different between breakfast and lunch. Contribution of the highly available heme iron was very low at breakfast meals consumed by males and represented an average 5.9% of total breakfast dietary iron intake.

TABLE 3

Least-squares means of selected nutrients and dietary factors contributing to iron bioavailability in meals of adolescent males[1,2]

Factor	Meals					
	Breakfast[3]	Lunch[4]	Evening[5]	Breakfast[3]	Lunch[4]	Evening[5]
	Intake			Intake/1000 kcal		
Energy (kcal)	495±48[a]	880±40[b]	1039±38[c]	--	--	--
Protein (g)	15±2[a]	36±2[b]	44±2[c]	29±2[a]	35±1[b]	37±1[b]
Ascorbic acid (mg)	42±9[a]	16±7[b]	39±7[a]	49±10[a]	15±7[b]	35±7[a]
Iron (mg)	3.4±0.4[a]	4.3±0.3[a]	6.6±0.3[b]	5.4±0.3[a]	4.2±0.2[b]	5.6±0.3[a]
Nonheme iron (mg)	3.2±0.4[a]	3.7±0.3[a]	5.6±0.3[b]	4.9±0.3[a]	3.6±0.2[b]	4.7±0.2[a]
Heme iron (mg)	0.2±0.1[a]	0.6±0.1[b]	1.1±0.1[c]	0.5±0.1[a]	0.6±0.1[a]	0.9±0.1[b]
Meat, fish, poultry (g)	13±8[a]	65±6[b]	107±6[c]	--	--	--
Enhancing factors (units)	55±11[a]	80±10[a]	145±9[b]	--	--	--
Absorbable nonheme iron (mg)	0.17±0.02[a]	0.26±0.02[b]	0.41±0.02[c]	0.30±0.02[ab]	0.25±0.02[a]	0.34±0.02[b]
Bioavailability of nonheme iron (%)[6]	5.4±0.2[a]	6.6±0.2[b]	7.3±0.2[c]	--	--	--
Absorbable heme iron (mg)	0.04±0.02[a]	0.14±0.02[b]	0.25±0.02[c]	0.12±0.02[a]	0.14±0.02[a]	0.21±0.02[b]
Total absorbable iron (mg)	0.22±0.04[a]	0.41±0.03[b]	0.66±0.03[c]	0.42±0.03[a]	0.39±0.03[a]	0.55±0.03[b]
Bioavailability of iron (%)[6]	6.1±0.3[a]	8.5±0.3[b]	9.8±0.3[c]	--	--	--

[1]Least-squares means ±SE of data from random sample of 113 males in 7 high schools in eastern Tennessee (3 rural, 4 metropolitan).

[2]Means within the same row within groups having different superscripts differ ($p \leq 0.05$) as tested by least-squares analysis of variance with contrast.

[3]n=78.

[4]n=100.

[5]n=107.

[6]Only subjects who consumed foods that contained iron were included in calculation of means; n=75 breakfast, n=100 lunch, n=107 evening meal.

TABLE 4

Least-squares means of selected nutrients and dietary factors contributing to iron bioavailability in meals of adolescent females[1,2]

Factor	Meals					
	Breakfast[3]	Lunch[4]	Evening[5]	Breakfast[3]	Lunch[4]	Evening[5]
	Intake			Intake/1000 kcal		
Energy (kcal)	371±43[a]	671±37[b]	738±33[b]	--	--	--
Protein (g)	9±2[a]	24±2[b]	30±2[c]	19±1[a]	21±1[a]	26±1[b]
Ascorbic acid (mg)	32±5[a]	16±5[a]	22±4[a]	38±6[a]	15±5[b]	19±4[b]
Iron (mg)	2.1±0.3[a]	3.7±0.3[b]	4.9±0.2[c]	3.6±0.2[ab]	3.3±0.2[a]	4.1±0.2[b]
Nonheme iron (mg)	2.0±0.3[a]	3.2±0.2[b]	4.1±0.2[c]	3.2±0.2[ab]	2.9±0.1[a]	3.4±0.1[b]
Heme iron (mg)	0.2±0.1[a]	0.5±0.1[b]	0.8±0.1[c]	0.4±0.1[a]	0.4±0.1[a]	0.7±0.1[b]
Meat, fish, poultry (g)	10±7[a]	49±6[b]	71±5[c]	--	--	--
Enhancing factors (units)	43±9[a]	65±8[a]	93±7[b]	--	--	--
Absorbable nonheme iron (mg)	0.09±0.02[a]	0.23±0.02[b]	0.29±0.02[c]	0.19±0.01[a]	0.20±0.01[a]	0.24±0.01[b]
Bioavailability of nonheme iron (%)[6]	4.8±0.3[a]	6.5±0.2[b]	6.8±0.2[b]	--	--	--
Absorbable heme iron (mg)	0.04±0.02[a]	0.11±0.02[b]	0.18±0.01[c]	0.09±0.02[a]	0.10±0.01[a]	0.15±0.01[b]
Total absorbable iron (mg)	0.13±0.04[a]	0.34±0.03[b]	0.47±0.03[c]	0.28±0.03[a]	0.30±0.02[a]	0.39±0.02[b]
Bioavailability of iron (%)[6]	5.9±0.4[a]	8.3±0.4[b]	9.0±0.3[b]	--	--	--

[1] Least-squares means ±SE of data from random sample of 111 females in 7 high schools in eastern Tennessee (3 rural, 4 metropolitan).

[2] Means within the same row within groups having different superscripts differ ($p \leq 0.05$) as tested by least-squares analysis of variance with contrast.

[3] n=70.

[4] n=88.

[5] n=103.

[6] Only subjects who consumed foods that contained iron were included in calculation of means; n=70 breakfast, n=83 lunch, n=103 evening meal.

Thus, absorbable heme iron represented a small percentage of total absorbable iron at breakfast. Nonheme iron comprised 94% of the total dietary iron consumed at breakfast but was moderately absorbed. Ascorbic acid intakes were high at breakfast but the consumption of meat, fish, or poultry foods was low. The low intake of these meat, fish, or poultry components contributed to the low bioavailability of nonheme iron (5.4%) at breakfast. Low iron intake, low iron bioavailability, and low amounts of total absorbable iron were most apparent at the breakfast meal.

Lunch meals of adolescent males contained the lowest amount of ascorbic acid. Intake of the other nutrients and factors, except for total iron and nonheme iron, were higher at lunch than at breakfast but were lower than intakes of all nutrients and dietary factors at the evening meal. Neither iron nor ascorbic acid intakes at lunch met one-third RDA. Nutrient intakes per 1000 kcal in Table 3 show that ascorbic acid and iron intakes at the lunch meal were lower than intakes at breakfast and the evening meal and did not meet recommendations for dietary adequacy.

Values of absorbable heme and total absorbable iron, based on energy intake, were higher at the evening meal than other meals. Meal patterns of adolescent males suggest that iron intakes were inadequate at all meals yet patterns at the evening meal tended to approach desirable patterns which favor increased iron bioavailability. The consumption of meat, fish, or poultry foods and ascorbic acid were high at the evening meal contributing to enhancement of

nonheme iron bioavailability. Heme iron, nonheme iron, and nonheme iron absorption also were highest at the evening meal. Total iron bioavailability and total absorbable iron were highest at the evening meal, indicating the importance of animal tissue foods in iron bioavailability. Iron intakes at the evening meal contributed 41% to the total iron intake of the 24-hour period, and absorbable iron from the evening meal represented 48% of the day's total of absorbable iron.

Table 4 contains least-squares means of meal-defined eating occasions in adolescent females. A breakfast meal was consumed by 63% of the respondents; protein and iron intakes were lowest at this meal. About 79% of the females consumed lunch, and 93% ate an evening meal. While energy intakes were not different between lunch and the evening meal, protein and iron intakes were lower at lunch than in the evening meal. Contribution of heme iron to total iron at breakfast was lowest (4.8%) of the three meal occasions. Nonheme iron content also was different among the three meal occasions but did comprise the majority of dietary iron consumed at all meals. Thus, eating patterns that affect iron bioavailability are important to understand.

Intakes of ascorbic acid were not different among the meal occasions but the consumption of meat, fish, and poultry foods did differ and was highest at the evening meal. Absorbable heme iron averaged 25% of total absorbable iron of breakfast meals and over one-third of total absorbable iron at the other meals. Percentage of nonheme iron bioavailability was lowest at breakfast (4.8%).

Patterns between lunch and the evening meal were not different with respect to nonheme iron bioavailability, but amounts of absorbable nonheme iron were different between lunch and the evening meal due to differences in nonheme iron content of these meals. Therefore, total absorbable iron was different among all meal occasions, and bioavailability percentages for lunch and the evening meal occasions differed from breakfast. Percentage of bioavailable iron at breakfast was considerably less than 10%, but approached this level at the lunch and the evening meal.

Analysis of nutrients per 1000 kcal indicates that nutrient density for iron was very low in comparison to recommendations. Because females consume less food energy than males, they need to consume 8.6 mg iron/1000 kcal (85). Ascorbic acid intakes were adequate in nutrient density at breakfast only. Adolescent females' dietary patterns were low in total iron and were not of adequate nutrient density. According to Hallberg (56), menstruating females need to absorb 1.1 mg iron/1000 kcal, assuming a 2000 kcal intake. None of the meal occasions approached this value.

Description of Nutrients and Dietary Factors of Snacks

Data in Table 5 represent least-squares means of the first snack consumed in a time period (morning, afternoon, evening) by adolescent males. Snacks contributed substantial amounts of energy but were low in total iron and percentages of iron bioavailability. The iron in snacks was mostly nonheme iron. Iron from meat, fish,

TABLE 5

Intakes of selected nutrients and dietary factors contributing to iron bioavailability in snacks of adolescent males and females[1,2]

Factor	Snacks					
	Males			Females		
	Morning[3]	Afternoon[4]	Evening[5]	Morning[3]	Afternoon[4]	Evening[5]
	Least-Squares Means ± SE			Least Squares Means ± SE		
Energy (kcal)	421±64[a]	441±39[a]	440±38[a]	219±60[a]	334±38[a]	359±37[a]
Protein (g)	7±2[a]	11±1[a]	10±1[a]	2±2[a]	6±1[ab]	8±1[b]
Ascorbic acid (mg)	7±6[a]	19±4[a]	19±3[a]	4±5[ab]	4±3[a]	14±3[b]
Iron (mg)	1.2±0.3[a]	1.9±0.2[a]	1.3±0.2[a]	0.7±0.5[a]	1.1±0.3[a]	1.5±0.3[a]
Nonheme iron (mg)	1.2±0.3[a]	1.7±0.2[a]	1.1±0.2[a]	0.7±0.5[a]	1.1±0.3[a]	1.4±0.3[a]
Heme iron (mg)	0.1±0.1[a]	0.2±0.0[a]	0.1±0.0[a]	0.0±0.1[a]	0.1±0.0[a]	0.1±0.0[a]
Meat, fish, poultry (g)[6]	5±7[a]	18±4[a]	11±4[a]	0±5.0[a]	5±3[a]	7±3[a]
Enhancing factors (units)	12±9[a]	37±5[b]	30±5[ab]	4±7[a]	9±5[ab]	21±5[b]
Absorbable nonheme iron (mg)	0.06±0.02[ab]	0.10±0.01[a]	0.06±0.01[b]	0.02±0.03[a]	0.04±0.02[a]	0.07±0.02[a]
Bioavailability of nonheme iron (%)[7]	3.7±0.4[a]	5.1±0.3[b]	4.4±0.3[ab]	3.5±0.4[a]	4.1±0.2[a]	4.1±0.2[a]
Absorbable heme iron (mg)	0.02±0.02[a]	0.05±0.01[a]	0.03±0.01[a]	0.00±0.01[a]	0.02±0.01[a]	0.02±0.01[a]
Total absorbable iron (mg)	0.08±0.03[ab]	0.15±0.02[a]	0.08±0.02[b]	0.02±0.04[a]	0.06±0.02[a]	0.09±0.02[a]
Bioavailability of iron (%)[7]	4.0±0.7[a]	5.9±0.4[b]	4.8±0.4[ab]	3.6±0.6[a]	4.5±0.4[a]	4.5±0.4[a]

[1] Random sample of 113 males and 111 females in 7 high schools in eastern Tennessee (3 rural, 4 metropolitan).

[2] Means within the same row within groups having different superscripts differ ($p \leq 0.05$) as tested by least-squares analysis of variance with contrast.

[3] n=33 males; n=33 females.

[4] n=73 males, n=68 females.

[5] n=76 males, n=70 females.

[6] Least-squares mean at morning snack was slightly negative for females.

[7] Only subjects who consumed foods that contained iron were included in calculation of mean; n=27 morning, n=58 afternoon, n=60 evening for males; n=27 morning, n=55 afternoon, n=62 evening for females.

and poultry foods contributed little to total iron. All snacks consumed in these time periods contained low amounts of ascorbic acid. The total amounts of enhancing factors were low in the diet, thus nonheme iron bioavailability of snacks was low. Percentage of bioavailable iron tended to be higher in afternoon snacks than in morning snacks but was not significantly higher than that in evening snacks. Percentage of nonheme iron bioavailability was not different between afternoon and evening snacks, but absorbable nonheme iron was different. Because afternoon and evening snacks were different in terms of total absorbable iron, and afternoon and morning snacks were different in relation to iron bioavailability, the combinations of enhancing factors, ascorbic acid, and meat, fish, and poultry, probably affected these differences.

It appears that snacks consumed by adolescent males were low in nutrient density for protein, iron, and ascorbic acid. None of the snack occasions met recommended nutrient levels for those nutrients. Analyses of nutrients per 1000 kcal revealed no differences ($p \leq 0.05$) in nutrient content among snack occasions.

In Table 5, the least-squares means of the first snack consumed by adolescent females in a time period are presented. Differences were found among snack occasions for intakes of protein, ascorbic acid, and enhancing factors. Overall, iron content of snacks was very low, and although the nonheme fraction of iron formed the majority of iron in snacks, percentage of nonheme iron

bioavailability was at the low end of the potential range of nonheme iron bioavailability. As was present in snacks consumed by adolescent males, snacks consumed by adolescent females provided substantial amounts of energy to the diet yet were low in total iron and contributed little to total absorbable iron.

Table 5 indicates that similar percentages of males and females consumed a snack in each time period. About 29% of the sample consumed a morning snack, 63% an afternoon snack, and 65% an evening snack. It is apparent from the data that a single snack occasion contributed reasonable amounts of food energy to the total diet, about as much as breakfast meals contributed to males' and females' diets. However, snacks were low in nutrient density for iron, protein, and ascorbic acid.

Evaluation of Dietary Patterns and Iron Bioavailability

In evaluation of dietary patterns affecting iron bioavailability, the amount of total absorbable iron is the most pertinent value to use in assessing dietary iron adequacy. Evaluations of the subsamples of adolescent males and females selected on the basis of high or low total absorbable dietary iron are presented in Tables 6 and 7.

Differences were found among all nutrients and dietary components between males who had patterns contributing to low amounts of total absorbable iron and males who had patterns of high amounts of total absorbable iron. Intake of iron evaluated from

TABLE 6

Mean intakes of selected nutrients and dietary factors contributing to absorbable iron in diets of adolescent males[1,2]

Factor	Low Absorbable[3] Iron	High Absorbable[4] Iron	Low Absorbable[3] Iron	High Absorbable[4] Iron
	Intake		Intake/1000 kcal	
Energy (kcal)	2605±1001[a]	4011±1173[b]	--	--
Protein (g)	86±31[a]	148±39[b]	35±9[a]	38±7[a]
Ascorbic acid (mg)	67±120[a]	182±172[b]	23±32[a]	49±51[b]
Iron (mg)	11.6±3.5[a]	23.6±4.7[b]	4.8±1.5[a]	6.1±1.2[b]
Nonheme iron (mg)	10.7±3.9[a]	20.2±4.6[b]	4.4±1.5[a]	5.2±1.2[b]
Heme iron (mg)	0.9±0.5[a]	3.4±1.3[b]	0.4±0.4[a]	0.9±0.4[b]
Meat, fish, poultry (g)	105±68[a]	302±144[b]	--	--
Absorbable nonheme iron (mg)	0.60±0.14[a]	1.43±0.31[b]	0.25±0.08[a]	0.37±0.08[b]
Absorbable heme iron (mg)	0.21±0.11[a]	0.77±0.31[b]	0.10±0.08[a]	0.20±0.08[b]
Total absorbable iron (mg)	0.81±0.12[a]	2.20±0.45[b]	0.35±0.14[a]	0.58±0.13[b]
Bioavailability of iron (%)	7.5±2.0[a]	9.4±1.2[b]	--	--

[1]Means ± SD of data from random sample of 7 high schools (3 rural, 4 metropolitan); 24-hour food records.

[2]Means within the same row within groups having different superscripts differ ($p \leq 0.05$) as tested by analysis of variance.

[3]n=28.

[4]n=28.

TABLE 7

Mean intakes of selected nutrients and dietary factors contributing to absorbable iron in diets of adolescent females[1,2]

Factor	Low Absorbable[3] Iron	High Absorbable[4] Iron	Low Absorbable[3] Iron	High Absorbable[4] Iron
	Intake		Intake/1000 kcal	
Energy (kcal)	1471±469[a]	2829±930[b]	--	--
Protein (g)	43±13[a]	95±36[b]	31±10[a]	34±7[a]
Ascorbic acid (mg)	26±13[a]	95±85[b]	19±12[a]	35±33[b]
Iron (mg)	7.2±2.3[a]	17.0±6.2[b]	5.0±1.0[a]	6.3±2.0[b]
Nonheme iron (mg)	6.6±2.5[a]	14.7±5.9[b]	4.5±0.9[a]	5.4±1.9[b]
Heme iron (mg)	0.6±0.4[a]	2.3±1.0[b]	0.5±0.5[a]	0.9±0.4[b]
Meat, fish, poultry (g)	66±49[a]	196±85[b]	--	--
Absorbable nonheme iron (mg)	0.34±0.10[a]	0.98±0.32[b]	0.24±0.06[a]	0.36±0.10[b]
Absorbable heme iron (mg)	0.13±0.09[a]	0.52±0.23[b]	0.11±0.11[a]	0.20±0.08[b]
Total absorbable iron (mg)	0.47±0.13[a]	1.51±0.42[b]	0.35±0.16[a]	0.56±0.13[b]
Bioavailability of iron (%)	7.1±2.5[a]	9.1±1.4[b]	--	--

[1]Means ± SD of data from random sample of 7 high schools (3 rural, 4 metropolitan); 24-hour food records.

[2]Means within the same row within groups having different superscripts differ ($p \leq 0.05$) as tested by analysis of variance.

[3]n=28.

[4]n=28.

24-hour food records indicated that mean iron intake from the group with low patterns was considerably less than the recommended 18 mg, but the mean iron intake of 23.6 mg in the group with high amounts of total absorbable iron exceeded recommended levels. Contribution of heme iron from meat, fish, and poultry foods and ascorbic acid was significantly higher in dietary patterns of males who had high amounts of total absorbable iron. The consumption of meat, fish, and poultry foods by the group with low amounts of total absorbable iron was about 3.5 oz. in the 24-hour period; about 8% of total iron was represented by the heme form of iron from these foods. Selection of animal tissue foods low in iron probably was the reason for this value. On the other hand, the group with the high amounts of total absorbable iron had about 10.5 oz. of meat, fish, and poultry, which provided about 14% of total iron as heme iron. Differences in ascorbic acid values indicate that levels of intake in both groups met the RDA but were exceedingly high among those with high amounts of absorbable iron. Percentage of bioavailable iron approached 10%, and total absorbable iron (2.20 mg) met desirable levels in this group. The group with low amounts of total absorbable iron (0.81 mg) had a value for iron bioavailability that was considerably less than 10%. Their caloric intake was low, and many had relatively few eating occasions on the day of the survey.

In Table 6 are results of the nutrient analyses per 1000 kcal. Results indicated that diets with a high quantity of total absorbable iron approached the recommended 6.4 mg iron/1000 kcal and were more

nutrient dense for nonheme iron, heme iron, and ascorbic acid than were diets with a low quantity of total absorbable iron. The nutrient density data suggest that the two groups of subjects had different dietary patterns that cannot be explained by differences in energy intake. Diets of adolescent males exhibited patterns that enhanced iron absorption when meat, fish, or poultry foods were included in large amounts and in combination with foods rich in ascorbic acid. Thus, some adolescent males did exhibit dietary patterns that contributed to desirable levels of absorbable iron. These patterns reflected high intakes of energy, animal tissue foods, iron, and ascorbic acid.

Adolescent females who followed dietary patterns that contributed to high iron absorption had significantly higher intakes of the selected nutrients and dietary factors than did females whose diets were low in total absorbable iron. The mean intake of 17 mg iron in this group approached the RDA of 18 mg, and the 1.5 mg absorbable iron met recommendations for adolescent females. The mean iron intake of 7.2 mg was an extremely low daily intake of iron for females in the low group, and 0.47 mg absorbable iron was inadequate to support iron balance. Meal patterns between groups show that about 6.5 oz. of meat, fish, and poultry foods were consumed by individuals with high amounts of absorbable iron while only 2.2 oz. of these foods was the mean intake in the low group. Contribution of 2.3 mg heme iron to 17.0 mg total iron was at a reasonable percentage of 14%, within the expected range present in most Western diets (56). There were

significant differences in ascorbic acid intakes between groups, and the mean intake of 26 mg in the low group was considerably less than the RDA. Percentage of bioavailable iron for both groups was less than the expected 10% but approached this value in the group with high amounts of total absorbable iron.

Differences between groups for nutrients/1000 kcal in Table 7 show that adolescent females in the high group consumed 6 mg iron/1000 kcal, still below the suggested 8.6 mg iron/1000 kcal (85). Nutrient density of ascorbic acid was significantly different between groups and was inadequate in the group with low amounts of total absorbable iron. Nutrient density of absorbable iron was insufficient in both groups of females based on the recommended 1.1 mg absorbable iron/1000 kcal to meet the needs of adolescent females (56).

On the basis of selecting dietary patterns that enhanced iron bioavailability, some adolescent females approached adequate iron intakes and absorbable iron. High amounts of absorbable iron probably were most related to the inclusion of meat, fish, and poultry foods that enhance nonheme iron bioavailability. The nutrient density data also suggest that dietary patterns of these adolescent males and females were very similar. That is, the males who were in the low group based on amounts of absorbable iron had diets similar in nutrient density to females in the low group; diets of the high groups also were similar. Thus, gender does not appear to be an important factor in explaining different patterns of total absorbable iron. The mean energy intakes by adolescent males and

and females who exhibited adequate levels of absorbable iron were unusually high, but not atypical of adolescents. Males who consumed high amounts of energy had high amounts of total absorbable iron. Adequate amounts of absorbable iron still would be present in their diets if energy intakes approximated the recommended 3000 kcal. Females who consumed high amounts of energy had high amounts of total absorbable iron, but absorbable iron would be inadequate if energy intakes approximated the recommended 2000 kcal for females.

Subsamples of adolescent males and females exhibiting the lowest and highest percentages for iron bioavailability also were analyzed. It was believed that determination of the percentage of iron bioavailability would be a good measure of dietary iron adequacy. Inspection of diets of high bioavailability would thus reveal desirable patterns. However, results of this study suggest that although percentage of iron bioavailability reflects total absorbable iron, especially when calculated for eating occasions, it is not a good indicator of dietary iron adequacy. Data in Tables 8 and 9 illustrate this point. Energy intakes were significantly lower in males and females who consumed diets of high iron bioavailability, suggesting that iron bioavailability was not a function of energy consumption. Scanning of food records indicated that some individuals in the high groups tended to have relatively few eating occasions daily. If those eating occasions included food combinations of high iron bioavailability, such as often were typical of evening meals, then those individuals were classified in the high bioavailability

TABLE 8

Mean intakes of selected nutrients and dietary factors contributing to high and low iron bioavailability in diets of adolescent males[1,2]

Factor	Low % Iron[3] Bioavailability	High % Iron[4] Bioavailability
	----------Mean ± SD----------	
Energy (kcal)	3456±1381[a]	2525±1020[b]
Protein (g)	105±43[a]	102±43[a]
Ascorbic acid (mg)	60±44[a]	84±115[a]
Iron (mg)	16.8±4.7[a]	14.8±6.1[a]
Nonheme iron (mg)	15.9±4.6[a]	11.7±5.0[b]
Heme iron (mg)	0.9±0.6[a]	3.1±1.3[b]
Meat, fish, poultry (g)	109±69[a]	278±143[b]
Absorbable nonheme iron (mg)	0.86±0.28[a]	0.89±0.39[a]
Absorbable heme iron (mg)	0.21±0.13[a]	0.71±0.30[b]
Total absorbable iron (mg)	1.07±0.35[a]	1.60±0.65[b]
Bioavailability of iron (%)	6.4±1.0[a]	10.9±0.6[b]

[1]Random sample of 7 high schools (3 rural, 4 metropolitan); 24-hour food records.

[2]Means within the same row having different superscripts differ ($p \leq 0.05$) as tested by analysis of variance.

[3]n=28.

[4]n=28.

TABLE 9

Mean intakes of selected nutrients and dietary factors contributing to high and low iron bioavailability in diets of adolescent females[1,2]

Factor	Low % Iron Bioavailability[3]	High % Iron Bioavailability[4]
	----------Mean ± SD----------	
Energy (kcal)	2133±851[a]	1710±675[b]
Protein (g)	55±24[a]	61±25[a]
Ascorbic acid (mg)	53±49[a]	70±103[a]
Iron (mg)	11.2±5.2[a]	9.3±4.0[a]
Nonheme iron (mg)	10.7±4.9[a]	7.3±3.2[b]
Heme iron (mg)	0.5±0.4[a]	1.9±1.0[b]
Meat, fish, poultry (g)	57±44[a]	173±77[b]
Absorbable nonheme iron (mg)	0.53±0.26[a]	0.54±0.25[a]
Absorbable heme iron (mg)	0.12±0.10[a]	0.44±0.22[b]
Total absorbable iron (mg)	0.65±0.34[a]	0.99±0.45[b]
Bioavailability of iron (%)	5.7±0.9[a]	10.6±0.7[b]

[1]Random sample of 7 high schools (3 rural, 4 metropolitan); 24-hour food records.

[2]Means within the same row having different superscripts differ ($p \leq 0.05$) as tested by analysis of variance.

[3]n=28.

[4]n=28.

group. However, their total iron intakes often were low because of the limited amount of food consumed in only one or two eating occasions. Moreover, protein intakes did not differ between high and low groups, but intakes of meat, fish, and poultry did, suggesting that the groups with low percentages of iron bioavailability relied on other sources of protein, such as vegetables and milk products.

Inspection of 24-hour food records for the frequency of foods consumed supported the idea of different patterns of food consumption among groups. Milk and milk products were consumed more often by adolescent males with diets of low iron bioavailability than by males in the high group. Males in the group with low percentages of iron bioavailability consumed an average 2.3 servings of milk and milk products. Males in the high group consumed 0.9 servings. There was a tendency for adolescents with dietary patterns of low iron bioavailability to consume more processed meat, which is low in iron, than did persons with high iron bioavailability. As a group, an average 0.6 and 0.5 servings of these foods were consumed by males and females, respectively, in the low bioavailability groups, whereas the consumption by males and females in the high groups averaged 0.3 servings. Legumes such as peas, beans, and peanut butter were included in diets of adolescent males and females with low iron bioavailability; 0.9 servings of these foods were included in diets of males and 0.7 of the servings were included in diets of females. About 0.2 servings of legumes were included in diets of males and females with high iron bioavailability percentages. These

findings illustrate that nonheme sources of iron often were consumed in diets of low iron bioavailability, and other patterns were not conducive to enhanced nonheme iron bioavailability.

There has been a trend to emphasize the importance of meat, fish, and poultry in the diet as an enhancer of nonheme iron bioavailability; however, it has been shown that ascorbic acid has as great an effect as meat has on nonheme iron absorption when included in a vegetarian meal. Absorption of nonheme iron was higher from a vegetarian meal containing 74 mg ascorbic acid than nonheme iron absorption from a meal containing meat (51). Consumption of vegetarian-type diets and those low in animal tissue foods may be popular in this region. Adolescents who had low values of absorbable iron and low percentages of iron bioavailability tended to consume fewer meals containing meat than did adolescents in high absorbable and iron bioavailability groups. Ascorbic acid levels also were low, thus nonheme iron absorption was not enhanced.

Limitations of Study

The Monsen and Balintfy model (73), on which the methodology of this study was based, does not consider the effect of dietary inhibitors on total iron bioavailability. The presence of some inhibitors in the diet may be a common occurrence and so should be included in evaluation of dietary iron bioavailability. Tea, a known potent inhibitor, was consumed by 19% of the adolescents in an eating occasion with food. Five of these adolescents consumed

tea at more than one eating occasion. Although tea was not consumed by a large number of adolescents in this study, tea is a very popular beverage among adults in this region. Thus, the impact of tea drinking on iron bioavailability may be more significant with other age groups in the population than with adolescents. Other inhibitors of iron bioavailability such as coffee, egg, bran, soy, and EDTA, also should be evaluated in terms of their presence in dietary patterns.

CHAPTER V

IMPLICATIONS

In interpretation and use of the Recommended Dietary Allowances as guidelines for evaluation of food consumption data of groups, it is assumed that diets low in nutrients could lead to marginal nutrient deficiencies over a period of time. While a margin of safety has been incorporated in the RDA, the margin may be more narrow for iron than for many other nutrients. Achievement of the elusive 18 mg iron allowance by dietary means is difficult for some persons, a fact supported by the prevalence of iron deficiency in various populations. Based on evidence of nutrient bioavailability, researchers and nutritionists have recommended analysis of dietary patterns in terms of iron bioavailability. With the existence of a model to estimate available dietary iron, dietary patterns potentiating iron's absorption can be identified and utilized in making recommendations, especially to groups whose dietary iron intake is marginal. Thus, recommendations to improve bioavailability of dietary iron intakes involve inspection of food consumption patterns and eating occasions.

Results of this study of adolescents in eastern Tennessee show that mean 24-hour dietary iron intakes of males approximated the RDA, but bioavailability of iron was less than 10%, possibly resulting in less than desirable levels of total absorbable iron available to the body. Mean 24-hour dietary iron intake by adolescent females was

less than two-thirds of the RDA for iron, and the amount of total absorbable iron available from the diet also was below recommended amounts. Inadequacy of iron, determined by total iron intake and by calculated iron bioavailability, was apparent for both males and females. The findings of this study revealed that the consumption of some meals and snacks contributed little to enhancing iron bioavailability. Evaluation of adolescents' food habits revealed that the inclusion of meat, fish, and poultry was higher in meals with higher amounts of absorbable iron than in those meals with lower amounts of absorbable iron. Because patterns differed among eating occasions, recommendations for dietary changes are specific for meals and snacks.

Ascorbic acid content was highest at breakfast meals of both males and females but not in amounts sufficient to maximize absorption of nonheme iron, the primary source of iron at breakfast. Consumption of total iron and meat, fish, and poultry was low at breakfast. Quality of breakfast could be improved by increasing amounts of ascorbic acid and adding a small serving of meat, fish, or poultry that would not only provide some highly available heme iron but also would increase absorption of nonheme iron.

Lunch meals were lowest in ascorbic acid content. Bioavailability of iron could be improved by including good sources of ascorbic acid at this meal. The nutrient density of total iron was low, but consumption of meat, fish, and poultry was adequate. The promotion of consumption of foods adequate in iron and foods high in ascorbic acid is advisable.

Iron intakes and consumption of animal tissue foods were highest at evening meals. Ascorbic acid intakes were high at evening meals consumed by males but not in those of females. Iron intakes and total absorbable iron in evening meals of adolescents were higher than at the other meals but still below recommended levels. Evening meal patterns of adolescents approached desirable patterns which favor increased iron bioavailability, attributable to the consumption of animal tissue foods.

Choices of snack foods enhancing iron bioavailability have the potential to contribute to the total daily absorbable iron. The total iron content of the first snack consumed in a time period was low among these snacks consumed by males and females. Meat, fish, and poultry content of snack occasions was low, suggesting that the poorly available nonheme iron comprised the majority of iron in snacks. Inclusion of a good source of ascorbic acid would significantly enhance the absorption of the nonheme iron. Adolescents' intake of ascorbic acid from snacks was low; therefore adolescents should be advised to choose juice or fruit high in ascorbic acid as an accompaniment to snacks. Adolescents frequently consume meals and snacks at fast food eating establishments that offer a limited variety of beverages. Juice beverages may be available at breakfast time but are not widely promoted as beverage choices for other eating occasions. Availability of juices and fruit drinks at these restaurants should be encouraged.

Findings of this study indicate that some adolescents did consume diets of adequate amounts of iron and/or of enhanced iron bioavailability. Dietary patterns of males and females with desired levels of total absorbable iron appeared to include high amounts of ascorbic acid and meat, fish, and poultry foods. Thus, eating patterns tended toward a high nutrient density. Dietary patterns consistent with low amounts of absorbable iron were related to an overall low intake of iron, a low frequency of eating occasions, and/or low consumption of factors enhancing iron bioavailability.

A low intake of meat, fish, and poultry foods often is associated with a high intake of legumes and is common to this region of the country. For such diets or for vegetarian-type diets, high amounts of ascorbic acid can contribute to enhanced iron bioavailability, and intake of ascorbic acid-rich foods should be encouraged at each meal.

Substantial improvement of iron bioavailability from meals might be expected when consumption of the enhancing factors is increased. However, because of some adolescent females' low iron intake, increased iron bioavailability may not be sufficient to improve their dietary iron status. Thus, adolescent females can improve dietary patterns enhancing iron bioavailability by increasing their intake of dietary iron and their intakes of enhancing factors.

CHAPTER VI

SUMMARY

The purpose of this study was to describe the bioavailability of dietary iron in adolescents' diets by comparing total iron intake values calculated from a table of food composition and values of total absorbable iron that are dependent on eating patterns. Dietary intake data were collected with 24-hour food records from 224 adolescents attending high schools in eastern Tennessee.

A high correlation was obtained between the two methods of calculating dietary iron intake, resulting in similar assessment of dietary iron adequacy. Mean iron intakes of males and females were below recommendations for total iron, and the mean bioavailability percentage of dietary iron was less than the generally assumed 10%. Thus, values of total absorbable iron in diets of males and females also were less than desirable levels.

Analysis of eating occasions, which is necessary to determine amounts of absorbable iron, identified differing patterns among eating occasions. Adolescent males consumed evening meals that were of high iron bioavailability and desirable levels for absorbable iron for the amount of energy consumed. Adolescent females consumed evening meals that were of higher iron bioavailability than their other meals but lower than recommended levels. Breakfast meal patterns of both males and females had the lowest percentages of iron bioavailability and amounts of absorbable iron among the meal

occasions. Dietary patterns of lunch meals consumed by adolescent males and females had the lowest nutrient density of total iron but provided more absorbable iron than breakfast. Snack occasions, which occurred several times per day, typically were low in nutrients and dietary components contributing to iron bioavailability. However, food energy provided by snacks was significant; therefore, iron content and iron bioavailability of snacks should be improved.

Analyses of adolescents' dietary patterns consistent with high levels of absorbable iron and percentages of iron bioavailability indicated higher consumption of meat, fish, and poultry foods than in diets of those with low percentages of iron bioavailability and low amounts of absorbable iron. Adolescent males whose diets met desirable levels of absorbable iron had iron intakes in excess of the RDA, but diets of males that achieved a high percentage of iron bioavailability contained less than the RDA for iron. Total absorbable iron from males' diets with high percentages of iron bioavailability was adequate, suggesting that dietary patterns with high percentages of iron bioavailability are associated with adequate levels of absorbable iron. Estimation of the amount of absorbable iron, however, is a more accurate measure of dietary iron adequacy than either percentage of iron bioavailability or amount of total iron. Adolescent females whose diets provided adequate levels of total absorbable iron approached the 18 mg RDA for iron. Dietary patterns of females consuming diets of high iron bioavailability were less than adequate for iron as assessed by the two measures of iron intake. Inclusion of

more foods that enhance iron bioavailability and more dietary sources of iron would improve dietary iron status in adolescent females. However, mean energy intakes in the groups consuming high amounts of total absorbable iron were unusually high and exceeded recommended energy intakes. Analysis of intakes per 1000 kcal suggests that dietary patterns of males in the high group were such that amounts of absorbable iron still would be adequate if energy intakes were approximately 3000 kcal. For females, however, absorbable iron would not be adequate with approximately 2000 kcal with current dietary patterns. Thus, some differences between the groups with high and low amounts of absorbable iron were related to energy intake; other differences, such as the amounts of heme iron, were not related to energy intake.

It was not ascertained from this study what foods or food groups commonly were eaten by adolescents who exhibited patterns of enhanced iron bioavailability. Replication of this study and further research on adolescents' food habits related to iron bioavailability should include identification of these foods. Inclusion of foods of animal origin have been identified as enhancers of nonheme iron absorption. Consumption of these foods is desirable at all eating occasions to increase dietary nonheme iron absorption and total amounts of absorbable iron.

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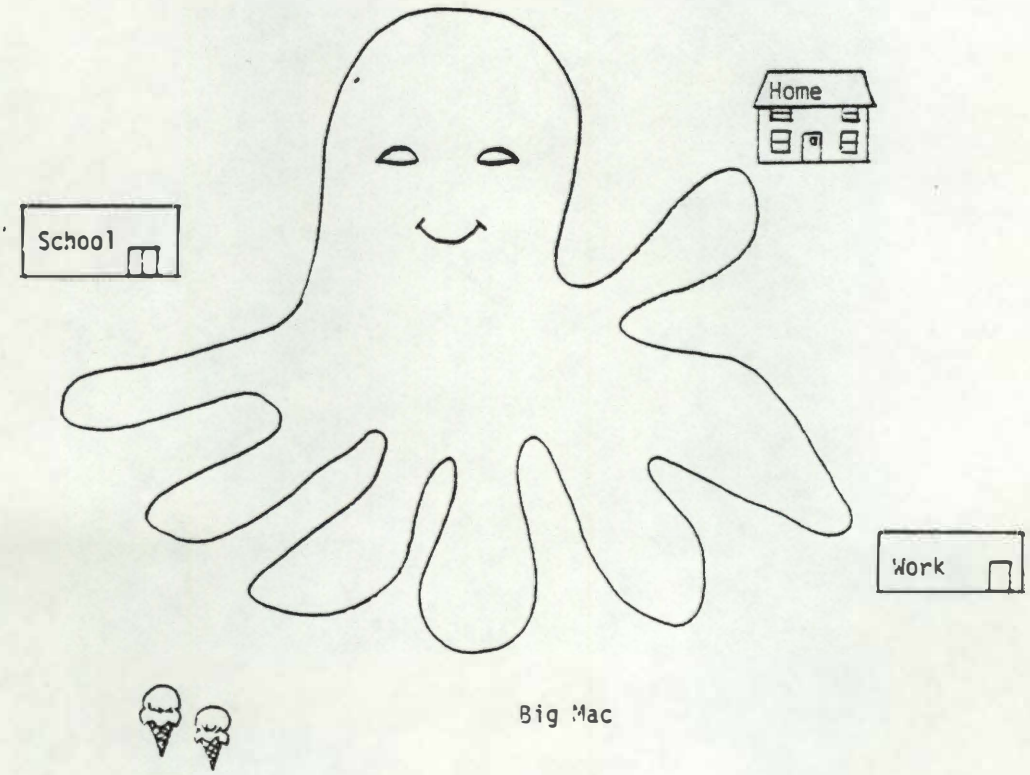
APPENDICES

APPENDIX I

TEEN QUESTIONNAIRE

WHAT DO I EAT?

Using the form on the following two pages please keep track of all food and beverages you eat between now and this time tomorrow. You do not need to consider water, but include everything else - milk, low-calorie soft drinks, tea, coffee, butter, gravy, mayonnaise, ketchup, salad dressing, etc. Try to estimate the amounts of food eaten as closely as possible using common measures - cups, ounces, slices, etc. Don't forget to include second helpings. If the food is a combination of several things, such as pizza or tossed salad, describe the ingredients as best you can - be a detective! Be sure to include all the food you eat - at meals and in between - even those "tastes" and "nibbles". It will be easiest to remember what you eat if you write it down as soon as possible. Take the form with you today, fill it out, and bring it back to class tomorrow.



Date_____

Food Record Form

Height_____(inches) Weight_____(pounds)

Sex _____(male)
_____(female) Age_____

	Food and Description	Amount	How many people ate with you?
1st time Food was eaten time_____a.m.___ p.m.___ where_____ who prepared_____			
2nd time Food was eaten time_____a.m.___ p.m.___ where_____ who prepared_____			
3rd time Food was eaten time_____a.m.___ p.m.___ where_____ who prepared_____			
4th time Food was eaten time_____a.m.___ p.m.___ where_____ who prepared_____			
5th time Food was eaten time_____a.m.___ p.m.___ where_____ who prepared_____			
6th time Food was eaten time_____a.m.___ p.m.___ where_____ who prepared_____			

	Food and Description	Amount	How many people ate with you?
7th time Food was eaten time_____a.m.___ p.m.___ where_____ who prepared_____			
8th time Food was eaten time_____a.m.___ p.m.___ where_____ who prepared_____			
9th time Food was eaten time_____a.m.___ p.m.___ where_____ who prepared_____			
10th time Food was eaten time_____a.m.___ p.m.___ where_____ who prepared_____			
11th time Food was eaten time_____a.m.___ p.m.___ where_____ who prepared_____			
12th time Food was eaten time_____a.m.___ p.m.___ where_____ who prepared_____			

If you ate more than 12 times use the back of this sheet.

APPENDIX II

CIRCLE THE LETTER CORRESPONDING TO THE APPROPRIATE RESPONSE:

Information About You

1. Sex:
   a. male
   b. female

2. Age:
   a. 15 years
   b. 16 years
   c. 17 years
   d. 18 years
   e. 19 years or over

3. Race:
   a. White
   b. Black
   c. Asian
   d. American Indian
   e. Hispanic
   f. Other, please specify_____

4. Religious Preference:
   a. Jewish
   b. Mormon
   c. Seventh Day Adventist
   d. Protestant
   e. Catholic
   f. Eastern Orthodox
   g. Other, please specify_____
   h. no religious preference

5. Did you take a vitamin/mineral supplement today?
   a. yes
   b. no

   If yes, what brand(s)?_____

6. How often do you take a vitamin/mineral supplement?
   a. never
   b. less often than once a month
   c. once or twice a month
   d. once or twice a week
   e. almost every day
   f. every day

7. How much choice did you have in selecting your food today?
   a. No choices, all my food was served to me
   b. No choices for meals, but some choices for snacks.
   c. Limited choice for meals, many choices for snacks.
   d. Complete choice for some meals, limited choice for other meals, many choices for snacks.
   e. Complete choice of all food eaten today.

8. On the average, how many snacks per day do you eat?

   a. 0
   b. 1
   c. 2
   d. 3
   e. 4
   f. 5 or more, (specify number)_____

9. Have you been employed in a paying job this school year?

   a. yes
   b. no

IF YOU ARE EMPLOYED AT THE PRESENT TIME ANSWER THE NEXT 15 QUESTIONS. IF NOT EMPLOYED GO TO QUESTION NUMBER 25.

10. Where do you work? (name)_____

11. How long have you worked at this job?

   a. less than 1 month
   b. 1 month - 4 months
   c. 5 months - 8 months
   d. 9 months - 12 months
   e. more than 1 year

12. What type of work do you do?

   a. food service (such as cafeteria, restaurant, hospital kitchen)
   b. factory (industrial, manufacturer)
   c. sales (such as clerk, cashier, sales person)
   d. self-employed (such as babysitting, handyperson, lawn-mowing)
   e. other (specify)_____

13. If you are working in a food service, which type is it?

   a. cafeteria
   b. fast food restaurant
   c. full-service restaurant (waitress served)
   d. institutional kitchen (hospital, school, nursing home, etc.)
   e. other (describe)_____

14. What is your hourly rate of pay, including tips?

   a. less than $3.10
   b. $3.10 - $3.50
   c. $3.51 - $4.00
   d. $4.01 - $4.50
   e. more than $4.50
   f. on salary (not paid by the hour)

15. How much did you spend on food last week from your own earnings?

    a. less than $1.00
    b. between $1.00 and $4.99
    c. between $5.00 and $9.99
    d. between $10.00 and $20.00
    e. $20.00 or more

16. How many days per week do you usually work?

    a. 1 day or less
    b. 2 - 3 days
    c. 4 - 5 days
    d. 6 - 7 days

17. How many hours did you work last week (most recent 7 days including today)?

    a. less than 5 hours
    b. 5 - 10 hours
    c. 11 - 20 hours
    d. 21 - 30 hours
    e. 31 hours or more

18. What days did you work last week (most recent 7 days including today)?

    a. no days
    b. Monday
    c. Tuesday
    d. Wednesday
    e. Thursday
    f. Friday
    g. Saturday
    h. Sunday

19. Do you normally work on school days (Monday thru Friday)?

    a. yes
    b. no

20. How many hours do you normally work on a <u>school day?</u>

    a. 1 - 2 hours
    b. 3 - 4 hours
    c. 5 - 6 hours
    d. 7 - 8 hours

21. How many <u>weekdays</u> (Mon. - Fri.) last week did your work hours include the supper hours (5:00 - 7:00 p.m.)?

    a. 0
    b. 1
    c. 2
    d. 3
    e. 4
    f. 5

22. How many weekend days last week did your work hours include the supper hours (5:00 - 7:00 p.m.)?

a. 0
b. 1
c. 2

23. How many days last week did you eat at work?

a. 0
b. 1
c. 2
d. 3
e. 4
f. 5
g. 6
h. 7

24. If you eat at work, what foods do you usually eat? Circle as many as apply. If not go on to next question.

a. snacks from vending machine (crackers, candy, soft drinks)
b. meal from vending machine (sandwiches, milk)
c. food prepared where you work
d. food brought from home
e. food bought at nearby store
f. food bought at nearby restaurant
g. other, please specify_____

25. Have you participated in any extracurricular school activities this school year?

a. yes
b. no

IF YOU ARE PRESENTLY PARTICIPATING IN AN EXTRACURRICULAR SCHOOL ACTIVITY ANSWER THE NEXT 7 QUESTIONS. IF NOT GO ON TO QUESTION NUMBER 33.

26. In which of the following activities are you presently participating? Circle as many as apply.

a. sports
b. school newspaper/yearbook
c. music
d. student government
e. club or organization
f. other (describe) _____

27. If you are presently participating in sports, how often are your activities scheduled? If not, go on to next question.

a. more than 5 days per week
b. 4 or 5 days per week
c. 2 or 3 days per week
d. 1 day per week
e. 1 day every two weeks
f. 1 day per month

28. If you are presently participating in music activities at school, how often are your activities scheduled? If not, go on to next question.

a. more than 5 days per week
b. 4 or 5 days per week
c. 2 or 3 days per week
d. 1 day per week
e. 1 day every two weeks
f. 1 day per month

29. If you are presently participating in the school newspaper/yearbook, club, student government or other activity, how often are your activities scheduled? If not, go on to next question.

a. more than 5 days per week
b. 4 or 5 days per week
c. 2 or 3 days per week
d. 1 day per week
e. 1 day every two weeks
f. 1 day per month

30. How many hours did you spend total in extracurricular activities outside of school time last week (most recent 7 days; including today)?

a. less than 5 hours
b. 5 - 10 hours
c. 11 - 20 hours
d. 21 - 30 hours
e. 30 hours or more

31. How many weekdays last week did your extracurricular school activity hours include the supper hours (5:00 - 7:00 p.m.)?

a. 0
b. 1
c. 2
d. 3
e. 4
f. 5

32. How many weekend days last week did your extracurricular school activity hours include the supper hours (5:00 - 7:00 p.m.)?

a. 0
b. 1
c. 2

33. Have you participated in any regularly scheduled community or church activities (besides Sunday Worship Service) this school year?

a. yes
b. no

IF YOU ARE PRESENTLY PARTICIPATING IN ANY REGULARLY SCHEDULED COMMUNITY OR CHURCH ACTIVITIES (besides Sunday morning worship service) ANSWER THE NEXT 4 QUESTIONS. IF NOT GO TO QUESTION NUMBER 38.

34. In what type of community or church activity do you participate? Circle as many as apply.

a. hospital volunteer work
b. church youth group organization (including choir, music or sports group)
c. community volunteer work (including fund raising)
d. national youth organization (such as Scouts or 4-H)
e. local youth organization (such as Teen Board)
f. other (describe) _____

35. How many hours did you spend in community or church activities last week (most recent 7 days; including today)?

a. less than 5 hours
b. 5 - 10 hours
c. 11 - 20 hours
d. 21 - 30 hours
e. 31 hours or more

36. How many weekdays last week did your community and/or church activity hours include the supper hours (5:00 - 7:00 p.m.)?

a. 0
b. 1
c. 2
d. 3
e. 4
f. 5

37. How many weekend days last week did your community and/or church activity hours include the supper hours (5:00 - 7:00 p.m.)?

a. 0
b. 1
c. 2

Evening Meal Patterns

38. Do you usually have a regularly scheduled meal with other members of your household in the evening?

a. yes
b. no

39. Circle the days last week that your evening meal was eaten away from home (away from other family members).

a. no days
b. Monday
c. Tuesday
d. Wednesday
e. Thursday
f. Friday
g. Saturday
h. Sunday

40. Circle the days last week that your evening meal was eaten away from home (with one or more other family members).

a. no days
b. Monday
c. Tuesday
d. Wednesday
e. Thursday
f. Friday
g. Saturday
h. Sunday

41. When eating away from home - to which type of eating establishment do you go most often?

a. Fast food - Hamburger/Fish
b. Pizza Parlor
c. Cafeteria
d. Full Service Restaurant-Moderate price, i.e. $3 - 5/person
e. Full Service Restaurant-High price, i.e. $5/person or more

42. Who prepares most of the evening meals that you eat at home?

a. mother
b. father
c. brother or sister
d. yourself
e. other (specify) _____

43. Is the person who prepares most of the evening meals employed outside the home?

a. not employed
b. part-time
c. full-time

44. How many days did you help prepare the evening meal last week?

a. 0
b. 1
c. 2
d. 3
e. 4
f. 5
g. 6
h. 7

45. How many times did you skip eating supper last week?

a. 0
b. 1
c. 2
d. 3
e. 4
f. 5
g. 6
h. 7

46. Circle the days last week that all family members (those presently living at home; including yourself) ate at the evening meal together. Circle no days if evening meals were not eaten together last week.

a. no days
b. Monday
c. Tuesday
d. Wednesday
e. Thursday
f. Friday
g. Saturday
h. Sunday

47. Circle the days last week that you ate the evening meal by yourself at home. Circle no days if evening meals were eaten with others at home last week.

a. no days
b. Monday
c. Tuesday
d. Wednesday
e. Thursday
f. Friday
g. Saturday
h. Sunday

Family Characteristics

48. How many persons live in your household, including yourself?

a. 1
b. 2
c. 3
d. 4
e. 5 or more (specify number) _____

49. How many children and teenagers (20 years or younger) are living in your household, including yourself?

a. 1
b. 2
c. 3
d. 4
e. 5 or more (specify number) _____

50. How many adults (21 or older) are presently living in your household?

a. 1
b. 2
c. 3
d. 4
e. more than 4 (specify number) _____

51. What is your family income?

a. less than $10,000 per year
b. between $10,000 and $25,000 per year
c. more than $25,000 per year
d. I don't know

52. What food supplements does your family receive? Circle all that apply.

a. food stamps
b. free or reduced lunches at school
c. Women, Infants and Children (WIC) supplements
d. other (specify) _____
e. No supplements

53. Does your father, stepfather or a male guardian live in the same household in which you live?

a. yes
b. no

If yes, answer the next three questions.
If no, go to question 57.

54. How many hours does your father (or stepfather, or male guardian) work per week? If not employed go to question number 57.

a. less than 10 hours
b. 10 - 19 hours
c. 20 - 29 hours
d. 30 - 39 hours
e. 40 hours or more

55. Which time of day are your father's (or stepfather's, or male guardian's) hours scheduled?

a. morning hours only
b. morning and afternoon hours
c. afternoon and evening hours
d. evening hours
e. night hours (after 11:00 p.m. and before 7 a.m.)

56. Circle the days last week that your father (or stepfather or male guardian) worked(most recent 7 days; including today).

a. no days
b. Monday
c. Tuesday
d. Wednesday
e. Thursday
f. Friday
g. Saturday
h. Sunday

57. If you are presently living with or receiving financial support from your father, stepfather or male guardian, what is his education level? If not go to question number 59.

a. less than high school
b. high school graduate
c. vocational school graduate
d. some college, but no degree
e. Bachelor of Science; Bachelor of Arts
f. Master of Science, Master of Arts, Master of Fine Arts
g. Doctorate (M.D., Ph.D., Ed.D., D.DS., J.D., L.L.B.)

58. What is his present occupation? _____

59. Does your mother, stepmother or a female guardian live in the same household in which you live?

a. yes
b. no

If yes, answer next three questions.
If no, go to question number 63.

60. How many hours does your mother (or stepmother or female guardian) work outside the home per week? If not employed go to question number 63.

a. less than 10 hours
b. 10 - 19 hours
c. 20 - 29 hours
d. 30 - 39 hours
e. 40 hours or more

61. Which time of day are your mother's (or stepmother's or female guardian's) hours scheduled? Circle as many as apply.

a. morning hours only
b. morning and afternoon hours
c. afternoon and evening hours
d. evening hours
e. night hours (after 11:00 p.m. and before 7 a.m.)

62. Circle the days last week that your mother (or stepmother or female guardian) worked (most recent 7 days; include today).

a. no days
b. Monday
c. Tuesday
d. Wednesday
e. Thursday
f. Friday
g. Saturday
h. Sunday

63. If you are presently living with or receiving financial support from your mother, stepmother or female guardian, what is her educational level? If not, go to page 11.

a. less than high school
b. high school graduate
c. vocational school graduate
d. some college, but no degree
e. Bachelor of Science; Bachelor of Arts
f. Master of Science, Master of Arts, Master of Fine Arts
g. Doctorate (M.D., Ph.D., Ed.D., D.D.S., J.D., L.L.B.)

64. What is her present occupation? _____

IF YOU ARE PRESENTLY MARRIED AND LIVING WITH SPOUSE ANSWER THE NEXT 5 QUESTIONS. IF NOT THIS IS THE END OF THE QUESTIONNAIRE.

65. What is your spouse's educational level?

a. less than high school
b. high school graduate
c. vocational school graduate
d. some college, but no degree
e. Bachelor of Science; Bachelor of Arts
f. Master of Science, Master of Arts, Master of Fine Arts
g. Doctorate (M.D., Ph.D., Ed.D., D.D.S., J.D., L.L.B.)

66. What is your spouse's present occupation? _____

67. How many hours does your spouse work per week? If not employed go on to Part II of questionnaire.

a. less than 10 hours
b. 10 - 19 hours
c. 20 - 29 hours
d. 30 - 39 hours
e. 40 hours or more

68. Which time of day are your spouse's hours scheduled? Circle as many as apply.

a. morning hours only
b. morning and afternoon hours
c. afternoon and evening hours
d. evening hours
e. night hours (after -1:00 p.m. and before 7 a.m.)

69. Circle the days last week that your spouse worked (most recent 7 days: include today).

a. no days
b. Monday
c. Tuesday
d. Wednesday
e. Thursday
f. Friday
g. Saturday
h. Sunday

THANK YOU!

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INPUT TIME$1 REGION 4 ID 5-7 SEX 8 AGE 9-10 F1 11-13 SF1 14-17 2 F2
18-20 SF2
21-24 2 F3 25-27 SF3 28-31 2 F4 32-34 SF4 35-38 2 F5 39-41 SF5 42-45 2
F6 46-48 SF6 49-52 2 F7 53-55 SF7 56-59 2 F8 60-62 SF8 63-66 2
F9 67-69 SF9 70-73 2 F10 74-76 SF10 77-80 2;
IF TIME='6' THEN TIME='X';
IF TIME='8' OR TIME='9' THEN TIME='Y';
IF TIME='2' THEN TIME='Z';
F=F1; SF=SF1; OUTPUT;
F=F2; SF=SF2; OUTPUT;
F=F3; SF=SF3; OUTPUT;
F=F4; SF=SF4; OUTPUT;
F=F5; SF=SF5; OUTPUT;
F=F6; SF=SF6; OUTPUT;
F=F7; SF=SF7; OUTPUT;
F=F8; SF=SF8; OUTPUT;
F=F9; SF=SF9; OUTPUT;
F=F10; SF=SF10; OUTPUT;
CARDS;
PROC SORT; BY F;
DATA T; SET VALUES.GOOD; PROC SORT; BY F;
DATA M; MERGE P T; BY F;
IF FE=. THEN FE=0;
IF SF=. OR SF=0 THEN DELETE;
IF ASA=. THEN ASA=0;
FPRO=PRO*SF;
FCAL=CAL*SF;
FWT=WT*SF;
FFE=FE*SF;
FASA=ASA*SF;
IF F=807 THEN TEA=SF;
KEEP ID WT SEX TIME SF AGE F FE ASA TEA FWT FFE FASA FPRO FCAL;
DATA H; SET M;
IF 145<=F<=222 THEN FHFE=FFE*0.40;
IF 145<=F<=222 THEN FNHFE=FFE - FHFE;
IF 145<=F<=222 THEN MWT=FWT;
PROC SORT; BY ID SEX TIME F;
DATA NM; SET M;
IF F LE 144 OR F GE 223;
FNHFENM=FFE;
PROC SORT; BY ID SEX TIME F;
DATA MNM; MERGE NM H; BY ID SEX TIME F;
IF FNHFE=. THEN FNHFE=0;
IF FNHFENM=. THEN FNHFENM=0;
FNHFET=FNHFE+FNHFENM;
PROC SORT; BY ID SEX TIME;
PROC MEANS NOPRINT; BY ID SEX TIME;
VAR MWT FASA FFE FHFE FNHFET FWT TEA FPRO FCAL;
OUTPUT OUT= TIMETOT SUM= TMWT TASA TFE THFE TNHFET TFWT TTEA
```

```
TFPRO TFCAL;
DATA TIMETOT; SET TIMETOT;
IF THFE=. THEN THFE=0;
IF TMWT=. THEN TMWT=0;
EF=TASA + TMWT;
IF EF LT 75 THEN BNHFE=(3 + 8.93*LOG((EF + 100)/100))/100;
IF EF GE 75 THEN BNHFE=0.08;
ANHFE=BNHFE*TNHFET;
AHFE=.23*THFE;
AFET=ANHFE + AHFE;
AB=(AFET/TFE)*100;
IF AB=. THEN BNHFE=.;
PROC MEANS NOPRINT; BY ID SEX;
VAR TASA TMWT TFE TNHFET THFE ANHFE AFET AHFE EF TTEA TFPRO TFCAL
AB BNHFE;
OUTPUT OUT=DATTOT SUM=TTASA TTMWT TTFE TTNHFET TTHFE TANHFE
TAFET TAHFE TEF TTEAT TTFPRO TTFCAL TAB BNHFET;
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1

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         F = Food.
        SF = Serving factor.
VALUES GOOD = Data base from USDA Handbook No. 72 (35).
        FE = Iron.
       ASA = Ascorbic acid.
       PRO = Protein.
       CAL = Kilocalories.
        WT = Weight of food.
       MWT = Weight of meat, fish, poultry.
       HFE = Heme iron.
      NHFE = Nonheme iron.
    NHFENM = Nonheme iron of meat, fish, poultry.
     NHFET = Total nonheme iron.
        EF = Enhancing factors.
     BNHFE = Bioavailable nonheme iron.
     ANHFE = Absorbable nonheme iron.
      AHFE = Absorbable heme iron.
      AFET = Absorbable total iron.
        AB = Bioavailable total iron.
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VITA

Gina C. Viglietti was born on April 11, 1958 in Memphis, Tennessee. She attended elementary schools there and graduated from Immaculate Conception High School in 1976. She entered The University of Tennessee, Knoxville in September 1976 and received the Bachelor of Science degree in Nutrition Science in June 1980.

In September 1980 she accepted a position as Dietetic Technician at William F. Bowld Hospital, UTCHS in Memphis. She enrolled in the Graduate School at The University of Tennessee, Knoxville in September 1981. During her graduate program, she was employed by the Tennessee Agricultural Experiment Station as a research assistant. In June 1984 she received the Master of Science degree with a major in Nutrition.