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Determination of Iron Bioavailability in the Diets of Pregnant Adolescents in East Tennessee

Joanne L. Pierson
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To the Graduate Council:

I am submitting herewith a thesis written by Joanne L. Pierson entitled "Determination of Iron Bioavailability in the Diets of Pregnant Adolescents in East Tennessee." 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.

Betty Ruth Carruth, Major Professor

We have read this thesis and recommend its acceptance:

Jean D. Skinner, Betsy Haughton

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

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

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DETERMINATION OF THE BIOAVAILABILITY OF DIETARY IRON IN THE DIETS OF PREGNANT ADOLESCENTS IN EAST TENNESSEE

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Joanne Louise Pierson

August 1991

DEDICATION

This thesis is dedicated to my son

Ryan Edward Pierson

who made many sacrifices

to make this accomplishment possible.

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ABSTRACT

Determination of dietary iron intake and estimation of iron bioavailability in the diets of pregnant adolescents (ages 13 to 18 years) in East Tennessee (N=100) was performed to assess iron nutriture adequacy. Using a combination of two 24-hour recalls and 2-day diet records, results indicated daily total iron intake (14.8 ± 8.9 mg) was below the Recommended Dietary Allowance (RDA) of 30.0 mg/d for pregnancy. Mean intakes of protein and ascorbic acid were ≥ 150% of the RDA for these nutrients. Using the Monsen and Balintfy model to estimate overall iron bioavailability, the 8.96 ± 1.2% was less than the 10% absorption level assumed by the National Research Council. Breakfast, lunch, and evening meals provided 23%, 31%, and 36% of the daily energy intake, respectively. Breakfast contained significantly more ($p \leq .05$) ascorbic acid than either lunch or evening meals. Consumption of meat, fish, and poultry (MFP) was significantly more ($p \leq .05$) in the evening meal than breakfast and lunch meals. This resulted in MFP contributing to total enhancing factors (EF) and making total iron bioavailability significantly higher for the evening meal ($p \leq .05$) than for breakfast and lunch. Snacks contributed a moderate amount to overall iron nutriture; mean total iron intake was 2.6 mg, 1.7 mg, and 1.7 mg for morning, afternoon, and evening snack periods, respectively. Iron bioavailability between snacks was not

significant ($p \leq .05$). It was concluded that dietary iron status in pregnant adolescents in East Tennessee is less than the recommended standard. Dietary intervention and nutrition counseling should focus on total iron intake, food combinations, and preparation techniques to improve bioavailability.

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER I

INTRODUCTION

Pregnancy during adolescence is a national problem. The National Center for Health Statistics (1) reported 2,933,658 births in the United States and 357,216 infants were born to females between the ages of 15 and 19. In 1987, the Central South East region of the United States (Kentucky, Tennessee, Alabama, and Mississippi) had the highest birth rate for adolescents of any region in the U.S. (1).

Adolescents have been shown to have irregular eating habits. Known to skip meals and snack frequently, they often choose foods that are high in calories, and low in nutrient density (2-6).

Theoretically, during pregnancy additional energy is needed for the anabolic metabolism of both maternal and fetal tissues, for supplying energy to these new tissues, and for the increase in basal metabolic rate/resting metabolic rate (7,8). Rees and Worthington-Roberts (9) suggested that young females often see this need for energy as detrimental to their body image and, consequently, may elect to restrict kilocalorie intake in order to keep their weight down.

Using the ferritin model, the Second National Health and Nutrition Examination Survey (NHANES II) results

indicated that in the United States, 9.6% of non-pregnant women (20 to 44 years of age) and 14.2% of the female adolescent population (15 to 19 years of age) have impaired iron status/iron deficiency. Impaired status was considered as two abnormal laboratory values out of three tests, i.e. serum ferritin, transferrin saturation, and erythrocyte protoporphyrin. Iron deficiency anemia, defined as two or three abnormal iron laboratory values plus hemoglobin <11.9 g/dl, was found in less than 2% of the non-pregnant female population, 20 to 44 years of age (10). The Institute of Medicine (11) has suggested that if this low frequency rate of iron deficiency anemia was extrapolated to pregnant women, routine supplementation of iron may not be necessary. Iron therapy also has been associated with a depressed zinc status which may adversely effect the fetus (12-14).

Compliance rate of adolescent females is not known for iron supplements; however, the compliance rate of adolescent females (11 to 20 years of age) for keeping follow-up telephone appointments has been reported to decline as the time interval increases between the time the appointment is made and the date of the appointment (15). Compliance rates for keeping appointments could be extrapolated to iron therapy or taking prenatal vitamins, as both regimens may be out of the ordinary realm of an adolescent's daily routine.

Improvement of iron status through dietary intake would be appropriate to avoid the unpleasant side effects

associated with iron therapy including gastric distress and constipation. In addition, dietary food sources can provide both heme and nonheme forms of iron. The bioavailability of nonheme iron can be increased by the addition of enhancing factors (ascorbic acid and meat, fish, and poultry) to the diet. Skinner and Carruth (16) reported that pregnant adolescents improve their dietary intake as well as increase the number of eating occasions per day during pregnancy.

Recent studies concerned with pregnant adolescents' diets have given insight into the daily intake of dietary iron, but they failed to look at the bioavailability of iron reportedly consumed (16-19). Assessing iron bioavailability in the diets of pregnant adolescents is important because a) generally, as kilocalorie intakes decrease, the amount of dietary iron consumed also decreases, b) the increased iron need during pregnancy combined with possibly low compliance rates for iron supplementation by adolescents increases the importance of combining foods to maximize iron absorption, and c) the recommended allowances of 2500 kcal/d are not usually associated with meeting the non-pregnant female's allowance of 15 mg iron/d much less the 30 mg/d recommended for pregnancy.

The purpose of this study was to determine the bioavailability of iron in the self-reported diets of pregnant adolescents (N=100), ages 13 to 18 years, who resided in East Tennessee. Estimations of the amount of

iron available for absorption were determined and recommendations were made that related to dietary intervention and nutrition counseling.

The hypotheses addressed in this thesis were as follows:

Ho_1: The mean daily dietary intake of pregnant adolescents (ages 13 to 18 years) for kilocalories and iron is sufficient to meet the allowances for adolescent pregnancy (2500 kilocalories and 30 mg iron, respectively).

Ho_2: Diets of pregnant adolescents (ages 13 to 18 years) in East Tennessee contain sufficient amounts of protein from meat, fish, and poultry to provide greater than or equal to 10% of the 1989 Recommended Dietary Allowance (RDA) of dietary iron for adolescent pregnancy (3 mg iron).

Ho_3: Diets of pregnant adolescents (ages 13 to 18 years) in East Tennessee contain sufficient amounts of iron absorbing enhancing factors (ascorbic acid and meat, fish, and poultry) to increase the calculated absorption of nonheme iron consumed to 8%.

Ho_4: Those pregnant adolescents in East Tennessee who are 16 to 18 years of age, unmarried, and living with one or both parents will have a better dietary iron intake than those pregnant adolescents 13 to 15 years of age, married, and living with their spouse.

CHAPTER II

REVIEW OF LITERATURE

Standards for Assessing Nutrient Intake

Adolescence is a period of rapid growth with increased needs for energy and nutrients. These needs are individual according to physical activity levels, genetic capability, and the growth spurt experienced during this time period (4,20). However, current dietary allowances are estimated on the basis of chronological age rather than biological maturity National Research Council (NRC) (21).

The Recommended Dietary Allowances (RDA) are generally used as guidelines for assessing nutrient intakes. These guidelines for adolescents are set according to chronological age, grouped by 11 to 14 years of age and 15 to 18 years of age. In estimating energy and nutrient allowances for these age groups, reference heights and weights are based on median values from data collected by the National Center for Health Statistics, comprising data from three national studies conducted between 1960 and 1974. The individuals measured in these studies are considered to be representative of the population between 2 and 18 years of age (21).

Energy needs for adolescents are based on predicted resting energy expenditure (REE), which reflects body weight, and an assumed amount of activity (1.67 and 1.60

times REE for females 11 to 14 and 15 to 18 years of age, respectively). In spite of the decreased activity level of pubertal adolescent females, the energy allowance for female adolescents, 11 to 18 years of age is 2200 kcal/d, an increase of 200 kcal/d from prepubescent allowances for children 7 to 10 years of age. The RDA for protein (46 g, 44 g) reflect a 1.0 g/kg body weight and a 0.8 g/kg body weight intake for females 11 to 14 years of age and for females 15 to 18 years of age, respectively. These values are based on the mg of nitrogen/kg body weight/d necessary for growth and maintenance. The RDA was established using a high-quality, highly digestible protein such as egg or milk, as reference protein in addition to the amino acids required for growth and maintenance (21).

Bothwell et al. (22) reported average iron stores in women in the U.S. as approximately 300 mg. The RDA for iron has been set to attain this level of 300 mg of storage iron. The Food and Nutrition Board Subcommittee consider this level of storage iron adequate to meet the nutritional needs of healthy females (21). A dietary intake of 15 mg iron/d for females 11 to 18 years of age is thought to provide a sufficient amount to achieve a 300 mg storage level. The recommended allowance for female adolescents is equivalent to that recommended for adult females, 19 to 50 years of age, and assumes the onset of menses has occurred.

Ascorbic acid is important in the absorption of nonheme iron, in preventing scurvy, and in the formation of collagen (23,24). The RDA of 50 mg/d for adolescents 11 to 14 years of age, and 60 mg/d for 15 to 18 years of age, respectively, were set to provide a 1500 mg body pool of ascorbic acid along with a margin of safety.

Nutritional Needs of Pregnant Adolescents

Dietary Patterns

There are many factors that may influence the eating behavior of all adolescents. The family structure, influence of peers, and social pressures reportedly have an impact on eating patterns (25). Many adolescents skip breakfast, and often replace other meals with high kilocalorie snacks of low nutrient density (2,3,5). In addition, Skinner et al. (5) reported that foods chosen for snacks and meals by adolescent girls were inadequate in the same nutrients such as iron, calcium, and vitamin A instead of complementing each other.

Pregnancy may also influence the adolescent's eating pattern. In their chapter describing interrelationships between adolescents, nutrition, and pregnancy, Rees and Worthington-Roberts (9) state that some teens may be uncomfortable with physical changes due to pregnancy, and unable to accept the weight gain necessary for a healthy fetus. Emesis gravidarum, heartburn, and/or constipation

may also influence dietary intake (26). Although not substantiated by research, Loris et al. (17) and Rees and Worthington-Roberts (9), respectively believe that attitudes of the girl's parents, the baby's father, and the girl herself toward the pregnancy also have an impact on how maternal and fetal nutritional needs are met.

Energy

Adolescence is a period of rapid growth (27). However, controversy exists over the competition between the adolescent and the fetus for adequate energy to support maternal and fetal growth. Adolescents, 10 to 16 years of age, have been reported to produce smaller infants than older females, 17 to 25 years of age (28,29). Conversely, Sukanich et al. (30) found that birth weights of infants born to younger females (14 to 16 years of age) were not significantly different than birthweights of infants born to older mothers (20 to 24 years of age).

Over a two year span, Garn et al. (31) compared the growth of young females (13 to 20 years of age) between their first and second pregnancy. Height and weight were measured before the first and second pregnancy. Results indicated less than a 1.0 cm/year increase in stature and less than 1.5 kg/year gain in weight. Garn et al. (31) concluded that if any competition between the fetus and mother exists, it is probably due to the mother's smaller

size before pregnancy and not due to a larger energy requirement for growth by the mother.

These findings do not support substantial kilocalorie increases for maternal growth during pregnancy. It is known, however, that additional kilocalories are necessary for the anabolism of maternal and fetal tissue, to provide energy for the metabolism of this new tissue, and to insure sufficient energy to move the increased body mass as the pregnancy advances (7). The NRC (21) recommends a 300 kcal/d increase in energy during the second and third trimesters. Blackburn and Calloway (32) calculated the average daily energy expenditure of pregnant adolescents to be 2200 to 2300 kilocalories, with an additional 150 kcal/d for maternal and fetal tissue deposits. Worthington-Roberts (33) suggested that an increase of 50 to 100 kcal/d during the first 34 to 36 weeks gestation with an additional 200 to 300 kcal/d during the final weeks was sufficient for the proposed optimum weight gain of pregnancy.

Protein

In addition to extra kilocalories, the NRC (21) recommends additional protein intake during pregnancy. Pregnant females, ages 15 to 18 years, should consume 54 g protein/d, which represents an additional 10 g protein/d during pregnancy to provide the amino acids necessary for synthesis of new tissue.

Increasing protein intake is not necessary in most cases because of reported consumption in recent years in the U.S. Based on results of national surveys and data from individual investigators, adolescents' protein intakes meet or exceed the recommended intake of 54 g/d. The Nationwide Food Consumption Survey (34) reported that adolescent females (15 to 18 years of age) consumed an average of 186 g/d beef, pork, lamb, veal, and game, 22 g/d poultry, and 11 g/d of fish and shellfish. Kenney et al. (2) found that the meat, fish and poultry (MFP) group provided a majority of the protein in the diets of Southern adolescent girls. Although, the urban girls ate more beef, and the rural girls ate more pork, there was no significant difference in the total amount of protein intake from the MFP group. Skinner et al. (5) reported the protein intake of Appalachian female adolescents who omitted breakfast, as 157% of the 1980 RDA for females 15 to 18 years of age; when compared to the 1989 allowance for pregnancy, protein intake/d exceeded 130%. Skinner and Carruth (16) reported the mean protein intakes of pregnant adolescents to be 167% and 150%, respectively, of the 1989 allowance.

Ascorbic Acid

The NRC (21) recommends 70 mg L-ascorbic acid/d during pregnancy. This is an increase of 20 mg/d over the ascorbic acid allowance of 50 mg/d for females 11 to 14 years of age, and 60 mg/d for females, 15 to 18 years of age. Skinner et

al. (5) reported the mean ascorbic acid intake of female Appalachian adolescents to be 62 mg/d; this intake would meet the recommended allowance for non-pregnant adolescents but not for pregnancy. In other studies, however, it has been reported that ascorbic acid intakes of pregnant and non-pregnant adolescents were greater than the 1989 RDA (2,17,18,35).

Iron

Historically, diets of pregnant and non-pregnant adolescents have been reported to be inadequate in dietary iron (2,3,5,17,35-39). The National Health and Nutrition Examination Survey II (NHANES II) results indicate that the risk of iron deficiency increases during a) adolescence as a period of growth, b) the second and third trimesters of pregnancy as requirements increase and iron stores become depleted, and c) periods when individuals may consume a diet low in both meat and ascorbic acid. Jacobs and Dwyer (40) suggested that adolescents consuming a vegan diet may need iron supplementation as iron intake tends to be low with very restrictive diets; strict vegan or macrobiotic diets do not allow consumption of heme iron sources. Consequently, pregnant adolescents have dietary and physiological factors that place them at risk for iron deficiency (17-19).

Sufficient iron nutriture is necessary for the synthesis of hemoglobin and iron containing enzymes (22). During pregnancy iron requirements increase to a) compensate

for the increase in red blood cell mass, b) supply the placenta and fetus, and c) accommodate for basal iron loss by the mother (41). The NRC (21) recommends that pregnant women and pregnant adolescents increase their daily iron intake to 30 mg/d. This represents a 100% increase over the allowances for non-pregnant females, 11 to 18 years of age. Endres et al. (18,19) found that daily dietary iron intakes of pregnant adolescents, who participated in a supplemental food program, were less than the 1989 RDA for iron. According to Kenney et al. (2), dietary intakes of meat, fish, and poultry supplied greater than 10% of the iron intake for girls, 12 to 16 years of age.

Sources of Iron

Dietary

Dietary iron is found and absorbed in two forms: heme iron and nonheme iron. Heme iron is a constituent of animal tissue, is easily absorbed, and averages 40% of the iron present in animal tissue; the other 60% of the iron contained in animal tissue is nonheme iron (42). All of the dietary iron contained in vegetable sources and in noncellular animal sources (e.g. dairy sources and eggs) are nonheme iron.

Although ingestion of meat, poultry, fish, and organ meats can contribute a significant amount of heme iron to the diet, nonheme iron makes the largest contribution to

total dietary iron (43). Table 1 lists the estimated iron content of selected foods frequently eaten by the pregnant adolescents who participated in this study. Many of the foods listed are relatively high in dietary iron and may contribute significantly to the total amount of iron contained in the overall diet. The variability of iron values reported by different sources may be due to the number of laboratory samples analyzed and/or the biological variability in samples gathered from different locations or under different circumstances (44). For example, the generic category of ground meat may contain 2.63 - 2.71 g of iron/100 g cooked serving (45,46).

Food Fortification and Dietary Supplements

The fortification of food products and supplementation are common ways of providing extra iron to the diets of the U.S. population. Fortification involves the addition of an iron compound to specific food products that are widely available and ingested by the general public (55). Absorption of the iron depends on the iron compound used, iron status of an individual's body, and other constituents present in the meal. Ferrous sulfate is often used in the fortification of food items, because it has a high bioavailability compared to other iron compounds such as ferric pyrophosphate (55,56). Fortified food products often include cereals and breads.

Table 1: Range of total iron content of selected foods commonly reported on food records by pregnant adolescents in East Tennessee.[a,b]

Food	mg iron/ 100 g	Food	mg iron/ 100 g
Ground beef	2.63 - 2.71	Chuck roast	2.92 - 3.10
Beef liver	7.24 - 6.28	Chicken	1.24 - 1.26
Tuna in oil	1.39[a,b]	Pork sausage	1.25 - 1.49
Pinto beans	2.18 - 2.61	Cowpeas	2.02 - 2.51
Red beans	2.23 - 2.94	Spinach	3.57 - 4.97
Baked potato with skin	1.36 - 1.69	Potato chips	1.19 - 1.64
Raisins	2.03 - 2.08	Raisin bran	11.59 - 21.62
Cornbread	2.47[b]	French fries	0.75 - 1.35
Biscuit	3.57[b]		
Biscuit with sausage	2.08[a]	Hamburger (single) with condiments	2.15[a]
Corndog	3.53[a]	Hotdog	2.36[a]

[a]*Composition of Foods: Raw, Processed, Prepared.* Washington, DC: US Department of Agriculture; 1979-1990. Handbooks No. 8-5,7,9,10,11,13,15,16,21.

[b]Pennington JAT, Young BE, Wilson DB, Johnson RD, Vanderveen JE. Mineral content of foods and total diets: The selected minerals in foods survey, 1982 to 1984. *J Am Diet Assoc.* 1986; 86:876-891.

Iron supplementation frequently involves taking a tablet. Currently, the NRC (21) recommends 30 mg/d of iron in a ferrous sulfate compound for pregnant women, a 15 mg/d increase over the daily recommendation for non-pregnant adolescent females. Although iron supplements may be easily available, low in cost, and time saving compared to getting iron from food sources, iron supplementation has several disadvantages.

A side effect of iron supplementation relates to the nutrient interaction between iron and zinc during pregnancy. Human fetal malformations have been associated with zinc deficiency (57). Hambridge et al. (14) studied 20 pregnant women who were 19 to 33 years of age; 75% were in their first pregnancy. They were prescribed iron therapy by their obstetricians, and the total iron intake from routine supplements and therapy averaged 261 mg/day. Hambridge et al. (14) found that plasma zinc concentration significantly dropped ($p<.05$) between the onset of iron therapy and four weeks later. Other studies have also described a decrease in plasma zinc levels of pregnant women as the level of iron supplementation increased above 60 mg/d (12,13). In a study by Dawson et al. (58) pregnant adolescents (16 to 20 years of age) who received prenatal multivitamin-mineral supplementation with iron, had a mean serum zinc level of 10 ± 1 μmol/L at delivery compared to a mean serum zinc level of 14 ± 2 μmol/L at 8 to 17 weeks gestation. There was no

statistical significance between the prestudy mean serum zinc level and the mean level at delivery for those adolescents who received supplements with iron. However, the mean serum zinc level at delivery for those adolescents who took supplements with iron was 7 μmol/L less than the mean serum zinc level for those who took supplements without iron. Dawson et al. (58) concluded that supplementation with iron during adolescent pregnancy reduces serum zinc concentration.

Iron Metabolism During Pregnancy

Body Iron

The total body iron content of women is approximately 2.2 grams. Total iron is divided into two groups according to its function within the body, either essential or storage. Essential iron exists as a part of hemoglobin and myoglobin and as a cofactor for several enzymes. Hemoglobin contains the greatest amount of body iron and is the easiest to measure. It functions to carry oxygen by way of the bloodstream from the lungs to the body tissues. Myoglobin is a protein of the muscle, which gives muscle its characteristic red color and provides a small amount of oxygen to the muscle. Enzymes of the electron transport system contain iron and make up the smallest portion of total body iron (22).

Iron is stored in the body in the forms of ferritin and hemosiderin, which are found in the liver, spleen, and bone marrow. Iron is transported through the body to tissues by transferrin. Cell membranes have transferrin receptor sites that will bind with the transferrin-iron complex. This complex is then accepted into the cell and the iron released. Affinity of the receptors to the transferrin complex appears to be constant (59). There are, however, certain tissues, such as red blood cell precursors, the placenta, and the liver that have a very high number of receptor sites to accommodate the large amount of iron needed during pregnancy. The number of receptor sites are increased or reduced depending on the iron-rich or iron-poor environment in the body (60).

Physiological Need for Iron

The requirement for iron during a normal pregnancy is approximately 1000 mg (11). Plasma volume begins to increase early in pregnancy; red cell mass increases at a rapid rate beginning around the fourth month of gestation (41). Red cell mass will continue to increase as long as iron is available for the synthesis process (61,62).

The need for iron during pregnancy is not distributed equally over the period of gestation. Beginning at approximately the 20th week, the iron requirement is 3.2 mg/d and increases linearly to 10 to 12 mg/d in the final month (61,62). As a compromise to this increased

requirement, iron absorption increases approximately two-fold during the second trimester, and as much as three-fold during the final weeks of gestation (36 to 40 weeks) (63). The amount of iron required by the growing fetus presents the mother with an increasing iron deficit that must be met by iron stores or by supplementation (41).

Risk of Iron Deficiency

Adolescent females are at high risk for iron deficiency due to the rapid growth spurt and the mean onset of menses at 12.5 years (27). In addition, dieting behaviors of adolescent females may not promote adequate iron stores prior to pregnancy. Those adolescents who are extremely active or participate in organized sports also may be at risk for iron deficiency (64). When adolescents become pregnant, this added iron requirement to supply the increased plasma volume, the placenta, and the fetus (63) then may be added to those values required during growth. According to Hallberg (41), if this iron requirement is not met with diet or supplementation, depletion of maternal iron stores will begin.

Bioavailability of Dietary Iron

The absorption of dietary iron is dependent on current iron status of the body and the amount of iron and other constituents present in the meal at the same time (65). There are two types of dietary iron, heme and nonheme. Heme

iron is found in animal tissue and is absorbed intact and released into the body's iron pool; absorption of heme iron in nonpregnant individuals varies from 15 to 35%, depending on iron stores (43). Pregnant females, 18 to 32 years of age, were fed a radio-labeled test meal containing nonheme and heme iron at 12, 24, and 36 weeks gestation. Results indicated mean absorption of iron was 1.5%, 5.8%, and 14.6% for the 12th, 24th, and 36th week gestation, respectively (63). Participants in this East Tennessee study were in their third trimester and consequently, could be expected to have increased iron absorption over a non-pregnant adolescent.

According to Raper et al. (66) and Monsen (43) nonheme iron makes up the majority of dietary iron ingested, but it is not absorbed as well as heme iron, e.g. 3 to 8% of nonheme iron vs. 15 to 35% of heme iron. Nonheme iron consists of iron from all plant sources, noncellular animal products, such as eggs and dairy products, and is approximately 60% of the total iron in animal tissue (42). In addition, the nonheme iron present in animal tissue is increased with cooking (67). Schricker and Miller (67) suggested this change is due to the oxidative degradation of the heme iron found in myoglobin and hemoglobin in the tissue. The absorption rate of nonheme iron varies considerably and is contingent on body iron stores as well

as the dietary constituents in the meal, such as enhancing and/or inhibiting factors (68,69).

Enhancing or inhibiting factors in the meal complex with the nonheme iron in the gut, increasing its availability or preventing absorption. Enhancing factors (EF) include organic acids, e.g. ascorbic acid, citric acid, lactic acid, and MFP. Ascorbic acid is one of the most effective enhancers of nonheme iron absorption, substantially increasing iron absorption when taken with a meal (68). As a reducing agent, ascorbic acid chelates with iron to form a soluble complex that is easily absorbed (70). Hallberg and Rossander (71) reported that when orange juice was added to a standard meal containing a hamburger, string beans, and mashed potatoes labeled with an iron radio-isotope, iron absorption increased by 50% in men (mean age of 25 years) and women (mean age of 27 years). In another study also utilizing iron radio-isotopes, ascorbic acid was shown to increase nonheme iron absorption from maize meal in male and female students who were between 19 and 35 years of age. Iron absorption increased linearly as the dose was increased from 12.5 mg to 200 mg ascorbic acid (72). However, Hallberg et al. (73) showed that prolonged warming of foods, such as foods held on cafeteria serving lines that contained ascorbic acid, significantly reduced the bioavailability of nonheme iron. This decrease in bioavailability was reported to be due to the loss of

ascorbic acid in the food with the greatest loss occurring in the first hour.

MFP has also been shown to enhance the absorption of nonheme iron (65). Although the exact mechanism is unknown, it is the cellular protein from animal tissue that acts as an enhancer rather than noncellular protein found in eggs, cheese, or milk (65). Based on an average shrinkage of 25%, the enhancing power of 1.0 g cooked MFP is assumed to be equivalent to 1.3 g raw MFP (74); these are then assumed to be equivalent to 1.0 mg of ascorbic acid (42). Recent studies have described the ability of 30 mg and 50 mg ascorbic acid to reduce the inhibitory effects of phytates in a bread meal and in a meal containing Yod Kratin (popular Southeast Asian vegetable), respectively (75,76). Therefore, the addition of ascorbic acid to a predominately vegetarian meal of low bioavailability can greatly increase the absorption of iron in the meal.

Inhibitors to nonheme iron absorption include tea (71,77), coffee (71,78), calcium phosphate (79), bran (80), ethylene diamine tetra-acetic acid (EDTA) (81), and various soy products (82). Tea, a strong inhibitor of iron, contains tannin that complexes with iron and makes the iron unavailable for absorption into the mucosal cell (71,77).

Determination of Iron Bioavailability

A computerized method for determining the bioavailability of dietary iron has been proposed by Monsen and Balintfy (74). The calculation of iron bioavailability from dietary records in this method is based on several assumptions: a) dietary iron is either heme or nonheme; b) subjects to be assessed have 500 mg body iron stores; c) 23% of heme iron is absorbed; and d) nonheme iron is poorly absorbed without the presence of EF.

Using Monsen and Balintfy's model, calculations of total iron, heme iron, nonheme iron, and EF are performed for each eating occasion (meal or snack) within a day. The number of EF present in an eating occasion have a logarithmic relationship to the amount of nonheme iron absorbed. When EF are not present in an eating occasion, it is assumed that 3% of the nonheme iron is absorbed (74). Absorption continues to increase until 75 units of EF are present and the rate of nonheme absorption reaches a maximum of 8%. The amount of heme iron and nonheme iron available is summed to give an estimate of total iron available for the day.

Summary

During adolescence there is an increased need for energy and nutrients to compensate for rapid growth and the increase in lean body mass. Guidelines set by the NRC (21)

for energy and nutrient intakes are based on chronological age and population means for height and weight rather than biological maturity. When the adolescent becomes pregnant, the pregnancy is imposed upon the adolescent's normal development pattern. However, the recommendations for additional calories and nutrients for pregnancy are the same regardless of chronological or biological age (21,83). Because of this discrepancy between recommended allowances based on age, there is controversy over the theory that competition for available energy sources between the adolescent's requirement and the requirement of the fetus exists (28-30). Results of recent studies indicated that adolescents' intakes of protein and ascorbic acid exceed the 1989 allowances for pregnancy (2,5,16-18,35). Therefore, adequate energy and iron intakes are the crucial dietary factors to study in the pregnant adolescent population.

Adolescents have been recognized for inadequate intakes of dietary iron for several decades (2,3,5,17,35-39), and as pregnancy proceeds, the requirement for iron increases (41). The NRC (21) recommends a dietary iron intake for pregnant adolescents of 30 mg/d. Meeting this recommended allowance through diet alone may be difficult; therefore, it is important to understand how dietary iron is absorbed in order to maximize the absorption of iron consumed.

Dietary iron is found as heme and nonheme iron, which are absorbed through different mechanisms (22). Because

heme iron is easily absorbed and not influenced by other factors in the meal, it is an important component to total available iron (mg) and consequently, to iron bioavailability. On the other hand, nonheme iron absorption is highly influenced by MFP and ascorbic acid present in the same meal (43). Estimating the bioavailability of dietary iron will provide information about the general adequacy of iron intake as well as the patterns of iron consumption. The reportedly high intakes of MFP and ascorbic acid in the diets of pregnant adolescents warrant investigation of iron bioavailability in their diets.

The purpose of this study was to estimate the bioavailability of dietary iron in the diets of 100 pregnant adolescents residing in East Tennessee. A description of this method and the patterns of dietary intake are provided as a basis for recommending dietary intervention and nutrition counseling for dietary improvement. A prototype menu was developed to demonstrate how dietary iron intake and enhancement of dietary iron absorption could be improved through food combinations.

Limitations of the Study

The Monsen and Balintfy model is a noninvasive and cost effective means of estimating the availability of iron in the diet. This model neither takes into account the effect that inhibiting factors may have on absorption, nor the

diversity of storage iron among individuals. In addition, the Monsen and Balintfy model may underestimate the amount of dietary iron available to pregnant adolescents in this study, because during the final weeks of pregnancy iron absorption is reportedly increased (63).

The dietary data collected for this study were self-reported. While every effort was made to assure accuracy, reliability of self-reported data may be questionable (84). The 24-hour recalls from adolescents have been reported to be valid for kilocalories and protein but not for iron (85).

For this study, MFP and heme iron were added as new nutrients in a computer software dietary analysis program (Nutritionist III). Every effort was made for accuracy; heme iron was calculated from the total iron values from the appropriate U.S.D.A. Handbook #8 (46-54), *Food Values of Portions Commonly Used* (86), or the Home and Garden Bulletin #72 (87). MFP was determined by the reported serving sizes recorded on the food records. MFP in combination foods was based on the meat exchanges as designated in Nutritionist III, and no effort was made to account for the amount of fat that may be included in each serving of MFP. Grams of MFP were added together with mg of ascorbic acid to yield total EF in each eating occasion. This total amount of EF may be inflated, which could artificially increase the percent bioavailability of dietary iron.

CHAPTER III

METHODOLOGY

Recruitment of Participants

This research study used existing dietary data from a comprehensive study entitled "Factors Influencing the Nutritional Health of Adolescents During and Post Pregnancy". The TN 860 project was funded by The University of Tennessee Agricultural Experimental Station (AES TN 860). The purpose of the project was to identify and assess dietary behaviors and social factors that may contribute to adolescents' nutritional health during and post pregnancy.

Sample Selection

A sample of 100 white, pregnant adolescents, 11 to 18 years of age, were recruited from private and public health clinics, public schools, residential programs, The University of Tennessee Medical Center, and other similar sites within approximately 120 miles of Knoxville, Tennessee. Participants were in their third trimester (28 to 35 weeks gestation), based on expected date of delivery. The working staff within each cooperating agency initially approached potential participants for permission to release their name, address, and telephone number to the University of Tennessee research staff.

For those agencies who preferred not to approach potential participants, a poster advertising the study was displayed in clinic waiting areas. The poster included tear-off postage-paid cards that could be completed and returned by those pregnant adolescents seeking more information about the study.

As names, addresses, and telephone numbers of potential participants were received from the agencies or via postcards, a letter was sent to the pregnant adolescent explaining the nature of the study together with a similar letter the girls could provide to their parents. Each letter was then followed up with a phone call within two to three days. During the telephone conversation, it was explained to the participants that they would provide dietary data and questionnaires would be administered via personal interviews. Then, an invitation to be involved in the study was extended. The potential participant was informed that participation was on a voluntary basis, and she could withdraw at anytime without affecting her school status, healthcare services, or any other services she may be receiving. She also was told that any information provided would be coded for confidentiality, and she could not be identified as a participant. If she agreed to participate, an appointment was made for the first interview.

If the pregnant adolescent did not have a telephone, the initial contact letter included a request that the she call the researchers collect. If no response was received, a second letter was sent to the individual. If the second letter failed to elicit a response, no further attempt was made to recruit the individual.

Human Subjects Approval

This project was approved by the Committee on Research Participation involving Human Subjects at The University of Tennessee, Knoxville. There were no invasive procedures undertaken, and no known risk to the participants was involved. Parental consent was not obtained as the laws involving confidentiality and rights of individuals do not require parental consent for pregnant adolescents in Tennessee. For this reason, the pregnant adolescents were not required to present the aforesaid introductory letter to their parents.

Research Instruments and Data Collection

Dietary and Demographics

Data on dietary intake of pregnant adolescents were obtained through the use of two 24-hour recalls and two days of food records. On each dietary form a space was provided for subjects to furnish information related to a) the date and time of day that each food and beverage was consumed, b) where the food was consumed, c) whether the individual was

eating alone or the name of the individual(s) who was(were) with the subject, and d) whether or not television was watched during the eating occasion (Appendix A). For the purpose of this study, television viewing habits were not considered.

In first interview, the pregnant adolescents were asked to complete the Information form (Appendix B) and the Demographics and Background Information form (Appendix C). Completion of the Information form required the participant's name, address, and telephone number, and the name, address, and telephone number of person(s) through whom the participant could be reached. The Demographic and Background Information form also included the participant's age, educational level and occupation of mother, father, and spouse, estimated date of delivery, where delivery was expected to take place, and the name of the pregnant adolescent's present physician.

Data Collection

All data were collected by Registered Dietitians (R.D.) with Master of Science degrees in nutrition or nutrition-related fields, and all had clinical experience in hospitals, medical clinics, and/or public health agencies. The study involved a two-stage interview design during which each participant was interviewed on two different occasions. To avoid transporting pregnant adolescents in their third trimester to the laboratories at the University of

Tennessee, the participants were interviewed in a mobile home at a time and place that was convenient to the participant.

First Interview

During an initial interview, pregnant adolescents were told about a) the purpose of the study, b) their responsibilities as participants, and c) the protocol that would be followed during the study. Voluntary participation and coding for confidentiality were reiterated also at that time. The pregnant adolescents were asked to sign a consent form indicating they would participate. An appointment date for the second interview was established at this time.

Interviews were conducted by an R.D. to obtain the first 24-hour recall. Following the recall of food intake, the pregnant adolescents were asked to keep a two-day food record for specific days of the week. The food record described serving sizes and brand names, as well as the date and time of consumption, where the food was consumed, and any other individual(s) present during the eating occasion. The participants received oral and written instructions on keeping the two-day food record (Appendix A). Then, they were requested to return food records at the second interview. Every effort was made to obtain dietary information for at least one week-end day, either by the designated days for keeping their food records or by appointment dates established when the 24-hour recalls were

obtained. Information about dietary supplementation was not collected, e.g. pre-natal, iron, or multivitamin.

Second Interview

The second interview was conducted within approximately two weeks after the first interview. A second 24-hour dietary recall was obtained by the same R.D. who completed the first 24-hour recall. As indicated earlier, the pregnant adolescents were requested during the first interview to bring their completed two-day food records to the second interview. It was at this time that the R.D. and the participant discussed the completeness and accuracy of the food records.

Participants were paid $5.00 for each interview. Payment for the second interview was conditional upon completion of the second interview as well as return of the completed two-day food records.

This protocol was followed for 90 subjects during the data collection period from April, 1989 to October, 1989. The subsequent 10 participants were interviewed at a time and place that was convenient to them, i.e. the participant's home, fast food restaurants, or coffee shops. This was done because the mobile home was available for data collection only at specific times during the year and was unavailable for the 10 individuals.

Data Coding and Analysis

Classifying Meals and Snacks

Criteria for coding eating occasions were modified from the method of Viglietti and Skinner (6). These modifications are shown in Table 2. The standard for breakfast was not modified for this study. However, lunch was changed to include foods from two food groups. This was done to avoid categorizing a less nutritious eating occasion as a meal simply because a greater number of foods was consumed. Additionally, the time frame for lunch was set to include those participants who may have eaten lunch after arriving home from school. The criteria for the evening meal were very similar to those of Viglietti and Skinner (6). This study required that along with the greatest number of foods, one protein food (not including a beverage such as milk) be present. Criteria for snacking occasions were the same with the exception of the evening snack. Evening snacks in this study were designated to include those eating occasions until 5:59 a.m. that did not qualify as the evening meal. This was done because some participants snacked during the early morning hours (e.g. 3:00 a.m.).

All eating occasions from the recalls/records were classified as either meals or snacks. An eating occasion was classified as "breakfast", if it occurred between 6:00 a.m. and 10:00 a.m. and consisted of any calorie containing

Table 2. A comparison of criteria used to classify eating occasions by Viglietti and Skinner[a] and by the current study[b].

	Criteria[a]	Criteria[b]
Meals		
Breakfast	6:00 a.m.-10:00 a.m. Calorie containing food or beverage	Same
Lunch	11:00 a.m.-2:50 p.m. Two or more foods providing calories[a]	11:00 a.m.-3:00p.m. Greatest number of foods including two food groups[b]
Evening	3:30 p.m.-10:00 p.m. More than one food including one protein-rich food[a]	3:30 p.m.-10:00 p.m. Greatest number of foods plus one protein food[b]
Snacks		
Morning	Time awake-11:59 a.m.	6:00 a.m.-11:59 a.m.
Afternoon	12:00 p.m.-6:00 p.m.	Same
Evening	6:01 p.m.-Bedtime	6:01 p.m.-5:59 a.m.

[a]Viglietti GC, Skinner JD, Estimation of iron bioavailability in adolescents' meals and snacks, *J Am Diet Assoc*. 1987; 87; 903-908.
If more than one eating occasion qualified as a meal, the one with the widest variety of calorie-containing foods was selected.

[b]Modified criteria. If more than one eating occasion qualified as a meal, the more "traditional meal" in terms of foods, place eaten, and eating companion(s) was chosen.

food or beverage. Similarly, "lunch" as an eating occasion occurred between 11:00 a.m. and 3:00 p.m., and contained the greatest number of food items that provided energy, as well as foods from at least two food groups. The "evening meal" was classified as an eating occasion that included the greatest number of food items, contained one protein food, and occurred between 3:30 p.m. and 10:00 p.m.

Classification of the "lunch" and "evening" meals was based on foods consumed. The criterion classification of the evening meal required a protein source be included. This protein source was specifically intended to be a meat or legume source; thus, a rich protein beverage such as milk was not considered as the source of protein for the evening meal. If, during the specified time, more than one eating occasion qualified as a meal, the one considered as a meal included a) the greatest variety of energy containing foods, b) where the food was consumed, and c) whether or not the participant was with someone. That occasion which appeared to be the most "traditional meal" in terms of foods consumed, place, and company was then coded as a meal. For instance, an eating occasion of cube steak, mashed potatoes, peas, corn, macaroni and cheese, a roll, and soda pop consumed in the kitchen with a parent and sibling was designated as a meal over an eating occasion of macaroni and cheese, mashed potatoes, corn, bread, and milk that was consumed in the living room with her boyfriend. Other

eating occasions that did not qualify as a meal were coded as snacks and considered separate eating occasions.

Snacks were classified according to the reported time of food consumption. Snacks consumed between 6:00 a.m. and 11:59 a.m. were defined as "morning snacks". Snacks that occurred between 12:00 p.m. and 6:00 p.m., and 6:01 p.m. until 5:59 a.m., were classified as "afternoon snacks" and "evening snacks", respectively. For convenience and consistency, those eating occasions that occurred within one hour of each other were considered as one eating occasion (Monsen, E.R., personal communication). Classification of eating occasions within a short time period is important because nonheme iron is chelated rapidly; thus, EF must be consumed during the same meal to invoke their enhancing properties (68).

Components of Eating Occasions

The pregnant adolescent's dietary intake of energy, total protein, total iron, and ascorbic acid was determined for each eating occasion. MFP in an eating occasion was determined by using the serving sizes reported on food records. Heme and nonheme iron in an eating occasion were extrapolated from total iron using the method described below. Each of the above components also was reflected in a calculated mean of each eating occasion for the daily intake.

Combination foods containing MFP (e.g. lasagna, beef stew) were coded for g MFP according to the meat exchange listed by Nutritionist III, Version 5 (88). Using 28.4 g MFP per meat exchange, the amount of total iron was determined from the appropriate Handbook #8 (46-54), *Food Values of Portions Commonly Used* (86), or the Home and Garden Bulletin #72 (87). The amount of iron (mg) reported by Nutritionist III was checked against the original source to verify accuracy in the analysis program. If a discrepancy existed, further investigation was done to rectify the problem and assure accuracy. The majority of the data base for Nutritionist III was compiled from Handbook #8 and other sources previously cited; therefore, it was deemed appropriate to use these same sources as a basis for heme iron determination and to verify reliability of the software program. The amount of heme iron in animal tissue was assumed to be 40% (42). Therefore, upon verification of iron (mg) and MFP (g), the amount of heme iron contained in each serving of MFP was calculated by multiplying the mg of total iron by 0.40 (40%). Heme iron and MFP were then added to Nutritionist III program as dietary components. Each food that was considered in the analyses had the appropriate amount of heme iron and MFP entered into the data base. Nonheme iron was then calculated as the difference between the total iron and heme iron.

Using the original dietary recalls/records provided by each pregnant adolescent, eating occasions were determined according to the criteria presented previously. The foods in each eating occasion were then coded according to protocol established earlier in the study, and data were entered into Nutritionist III as a separate file. Using a random numbers table, 100 days of the dietary data (25%) were chosen and recorded to verify the reliability of the investigator's earlier coding. Then energy, total protein, total iron, ascorbic acid, heme iron, MFP, and demographic and background information were entered into the Quatro Pro Spreadsheet Program (89).

SAS (90) was used to design a computer program to fit the Monsen and Balintfy (74) model of estimating the bioavailability of dietary iron. To calculate the bioavailability of the nonheme iron consumed in an eating occasion, the amount of MFP (g) and ascorbic acid (mg) were summed. This number served as the number of units of EF present in that meal or snacking occasion. The percent absorption of nonheme iron was then calculated using one of the following formulas:

1) When EF<75: $\% = 3 + 8.93 \ln \frac{(EF + 100)}{100}$

2) When EF>75: % = 8

3) When EF=0 : % = 3

The amount of nonheme iron (mg) was then multiplied by the calculated percentage to yield the estimated nonheme iron (mg) absorbed. Based on the Monsen and Balintfy (74) model, heme iron absorption is assumed to be 23%; thus, heme iron (mg) absorbed also was calculated. For each eating occasion containing iron, the amount of nonheme iron (mg), the number of EF units, and the estimated amount of nonheme (mg) and heme iron (mg) absorbed were calculated.

In order to compare iron absorption between eating occasions, i.e. snacks vs. meals, the estimated amounts of heme and nonheme iron absorbed were summed to give total absorbable iron for that eating occasion. Total iron available for each day was estimated by summing the iron available per eating occasion over each 24-hour period. The bioavailability (percent absorption) of the total iron intake was calculated by dividing the sum of absorbable heme and nonheme iron (mg) by the total iron (mg) intake/d. From the four days of dietary data, the means for energy, protein, MFP, iron, ascorbic acid, enhancing factors, available heme and nonheme iron, total available iron, and percent of iron bioavailability were calculated.

Statistical Analysis

Using SAS (90), means and standard deviations for the four-day dietary data were calculated for the variables of energy, total protein, MFP, total iron, heme iron, nonheme

iron, and ascorbic acid. Means and standard deviations of the absorbable amount of heme and nonheme iron and the percentages of available nonheme and total iron also were calculated. The same variables listed above were used to describe each meal and snacking occasion as well as to estimate total daily means. Using the Hollingshead Four Factor Index (91), a score for socioeconomic status was calculated for each pregnant adolescent.

The Student t-test (90) was performed to test the hypotheses that a) pregnant adolescents consume adequate calories and iron for pregnancy, b) the consumption of MFP was sufficient to supply 10% of the RDA for dietary iron during pregnancy, and c) the consumption of enhancing factors was sufficient to increase nonheme iron absorption to 8%.

The Scheffe method (90) was used to perform multiple t-tests on the mean nutrient intakes and other factors differences among snacks and meals. The Univariate procedure (90) was used to differentiate the sample data into quartiles according to percent iron bioavailability (n=25 per quartile). Means were then calculated for the appropriate dietary components within the high and low quartiles.

CHAPTER IV

RESULTS AND DISCUSSION

Sample Demographics

Data describing the sample of pregnant adolescents are presented in Table 3. A majority of the 100 subjects were 16 and 17 years of age (63%) during their third trimester; ages ranged from 13 to 18 years of age. School grade completed ranged from 7th to 12th, and 22% had completed high school. Approximately two-thirds of the adolescents were unmarried; 49% lived with either one parent or with both parents. Scores on the Hollingshead Four Factor Index (91) ranged from 11 to 59; the mean for this group was 26.25, indicating the subjects came from a lower socio-economic status.

Description of Energy, Nutrients and Other Dietary Factors Determined From Daily Food Records

The means and standard deviations for energy, selected nutrients, and other dietary factors related to the bioavailability of dietary iron are shown in Table 4. The mean energy intake of 2472.8 ± 981.2 kcal/d was slightly less than the recommended amount of 2500 kcal/d for pregnant adolescents. To test the hypothesis that energy intakes would equal 2500 kcal, a Student t-test was performed. Results indicated no significant difference in the means

Table 3. Demographic characteristics of a White pregnant adolescent sample residing in East Tennessee (N=100).

Characteristic	Mean ± S.D.	Percent Respondents
Age (years)		%
13		1.0
14		7.0
15		13.0
16		30.0
17		33.0
18	16.4 ± 1.2	16.0
Grade		
7th		3.0
8th		8.0
9th		21.0
10th		24.0
11th		22.0
12th	10.2 ± 1.4	22.0
Married		33.0
Unmarried		67.0
Living Arrangements		
With one parent		25.0
With two parents		24.0
With spouse		19.0
With spouse and parents		10.0
Other[a]		22.0

[a]Other includes living with other relatives, in a group home, or with other acquaintances.

Table 4. Mean daily intake of energy, selected nutrients, and other factors affecting iron bioavailability in the diets of pregnant adolescents residing in East Tennessee (N=100).

Energy/Nutrient/ Factor	Mean ± S.D.	Mean/1000 kcal[1,2]
Energy (kcal)	2472.8±981.2	-----
Protein (g)	88.2±38.8	36.2±6.0
MFP (g)[3]	132.5±89.5	126.9±17.1
Ascorbic Acid (mg)	104.7±117.8	55.0±18.6
Total Enhancing Factor(units)[4]	237.3±164.2	97.1±35.9
Iron (mg)	14.8±8.9	6.1±2.0
Heme Iron (mg)[5]	1.05±0.87	0.44±0.19
Nonheme Iron (mg)[6]	13.78±8.58	5.68±1.89
Available Heme Iron (mg)[7]	0.24±0.20	0.10±0.04
Available Nonheme Iron (mg)[8]	1.09±0.69	0.45±0.15
Total Available Iron (mg)[9]	1.33±0.78	0.55±0.17
Nonheme Iron Bioavailability (%)[10]	7.8±0.68	3.5±1.1
Iron Bioavailability (%)[11]	8.96±1.20	4.0±1.3

[1]Nutrient Density = $\frac{\text{Intake of Nutrient}}{2472.8 \text{ kcal}} \times 1000$

[2]Adapted from Hansen RC, Wyse BW. Expression of nutrient allowances per 1,000 kilocalories. *J Am Diet Assoc*. 1980; 76:223-227.

[3]Grams of meat, fish, and poultry (MFP)

[4]MFP (g) + ascorbic acid (mg)

[5]MFP iron (mg) x 0.40

[6]Iron (mg) - heme iron (mg)

[7]Heme iron (mg) x 0.23

[8]When enhancing factors (EF)<75: % = $3 + 8.93 \ln \frac{(EF + 100)}{100}$; when EF>75: % = 8; when EF = 0: % = 3. Then % x nonheme iron (mg).

[9]Available heme iron (mg) + available nonheme iron (mg)

[10]When enhancing factors (EF)<75: % = $3 + 8.93 \ln \frac{(EF + 100)}{100}$; when EF>75: % = 8; when EF = 0: % = 3.

[11][Total available iron (mg)/iron (mg)] x 100

($p \leq .05$). Therefore, the mean daily energy intake of these adolescents was sufficient to meet the RDA for adolescent pregnancy. This energy intake represents an increase of 419 kcal/d increase over intakes previously reported by non-pregnant adolescents (6).

As shown in Table 4, the mean dietary iron intake of 14.8 ± 8.9 mg was 49% of the recommended allowance for pregnancy (30 mg/day). This iron intake was, however, comparable to intakes of 13.6 mg/d (16,19) reported by pregnant adolescents in earlier studies but 3.7 mg more than intakes reported by non-pregnant adolescents (6). Results of a Student t-test indicated a significant difference between mean iron intake reported in this study and the 30 mg/d recommended allowance ($p \leq .05$). Because dietary iron intake did not reach the recommended allowance, statistical tests were not performed to test the hypothesis that sufficient amounts of protein from MFP were adequate to provide 10% of the RDA for iron during pregnancy. Also, studies were not found in the literature that quantified possible increases of heme iron absorption during pregnancy; thus, it was not possible to propose increased absorption of heme iron associated with pregnancy.

Mean intakes of protein and ascorbic acid were 163% (88.2±38.3 g) and 150% (104.7±117.8 mg) of the 1989 RDA for these adolescents, respectively. These intakes were similar to intakes of 88 g protein/d, and 121 mg ascorbic acid/d

reported by Skinner and Carruth (16). However, the reported protein and ascorbic acid intakes of 64 g and 67 mg, respectively, by non-pregnant adolescents was considerably less than the adolescents in this study (6).

In general, heme iron provided a small portion of the total iron intake in the diet. Raper et al. (66) reported that the contribution of heme iron to total iron intake of non-pregnant women, 15 years and older, ranged from 7 to 10%. Cook (92) suggested heme iron contributed 5 to 10% of total iron in the Western diet. Viglietti and Skinner (6) estimated heme iron intake in diets of non-pregnant adolescents to be 11.7%. Heme iron content in this sample of pregnant adolescents averaged 7.1%, which was comparable to data reported by Cook (92) and Raper et al. (66).

As anticipated, the major portion of dietary iron was nonheme. Therefore, the availability of nonheme iron for absorption is important to iron status; consequently, EF (MFP and ascorbic acid) present in the diet are important to the amount of nonheme iron available. In this study, the average amount of MFP consumed daily was 4.7 ounces/d, which was less than the 5 to 7 ounces/d recommended by Cronin et al. (93). In this study, the mean intake of ascorbic acid contributed almost 50% to the mean total EF; the mean bioavailability of nonheme iron was 7.8% and falls within the expected 3 to 8% range. A Student t-test was performed to test the hypothesis that the diets of these pregnant

adolescents contain enough EF to increase nonheme iron bioavailability to 8%. Test results indicated a significant difference in the means of the percent bioavailability of nonheme iron ($p \leq .05$), signifying these pregnant adolescents did not have an optimal EF intake. Therefore, calculated nonheme iron bioavailability was not maximized by MFP and ascorbic acid intakes during eating occasions (meals and snacks). Overall iron bioavailability was estimated to be 8.96±1.2%, an increase of 0.66% over the estimated amount from non-pregnant adolescents' diets (6).

Nutrient intake/1000 kcal (94) is another criterion for assessing dietary quality. As shown in Table 4, the diets of pregnant adolescents in this study had nutrient densities of 6.1 mg/1000 kcal and 0.55 mg/1000 kcal for total iron and available iron, respectively. These are similar to national survey results from the 1977-78 Nationwide Food Consumption Survey data. Assessment of this data by Raper et al. (66) described total dietary iron density of females' diets, 15 to 18 years of age, as 6.2 mg/1000 kcal and available dietary iron density as 0.5 mg/1000 kcal for the same group.

In order to further describe daily intake and iron bioavailability, participants' data were divided into quartiles according to the estimated percent iron bioavailability. The results of these calculations are shown in Table 5. The mean percent iron bioavailability for the low and high quartiles was 8.4% and 9.7%, respectively.

Table 5. Mean daily intake of energy, selected nutrients, and other factors contributing to high and low iron bioavailability in the diets of pregnant adolescents (N=100) residing in East Tennessee.

Energy/ Nutrient/Factors	High % Iron Bioavailability[1]	Low % Iron Bioavailability
	<----------means ± S.D.-------->	
Energy (kcal)	2384.9±537.3	2413.4±770.5
Protein (g)	90.5±21.1	78.7±25.3
MFP (g)[2]	158.0±41.2	85.7±45.2
Ascorbic Acid (mg)	90.1±44.1	81.8±54.5
Total Enhancing Factor (units)[3]	248.1±59.8	167.4±81.2
Iron (mg)	12.9±3.7	16.3±8.7
Heme Iron (mg)[4]	1.43±0.43	0.58±0.34
Nonheme Iron (mg)[5]	11.49±3.37	15.72±8.44
Available Heme Iron (mg)[6]	0.33±0.99	0.13±0.08
Available Nonheme Iron (mg)[7]	0.92±0.27	1.24±0.69
Total Available Iron (mg)[8]	1.25±0.36	1.38±0.75
Nonheme Iron Bioavailability (%)[9]	8.0±0.0	7.9±0.7
Iron Bioavailability[10] (%)	9.7±0.2	8.4±0.8

[1]N=25 per quartile segment
[2]Grams of meat, fish, and poultry (MFP)
[3]MFP (g) + ascorbic acid (mg)
[4]MFP iron (mg) x 0.40
[5]Iron (mg) - heme iron (mg)
[6]Heme iron (mg) x 0.23
[7]When enhancing factors (EF)<75: % = 3 + 8.93ln $\frac{(EF + 100)}{100}$; when EF>75: % = 8; when EF = 0: % = 3. Then % x nonheme iron (mg).
[8]Available heme iron (mg) + Available nonheme iron (mg)
[9]When enhancing factors (EF)<75: % = 3 + 8.93ln $\frac{(EF + 100)}{100}$; when EF>75: % = 8; when EF = 0: % = 3.
[10][Total available iron (mg)/iron (mg)] x 100

Numerically, protein intake was higher in the high bioavailability group, as were MFP and ascorbic acid. These increased values resulted in maximum bioavailability of nonheme iron (8.0%), whereas both energy and daily iron intakes in the low bioavailability group were higher than the high bioavailability group. The amount of heme iron consumed by the high bioavailability group contributed approximately 26% (0.33 mg/1.25 mg x 100) to the total available iron versus a contribution of approximately 10% in the low bioavailability group. This shows the importance of including dietary sources of heme iron and EF (MFP and ascorbic acid) in a meal.

Description of Energy and Dietary Factors Associated With Eating Occasions

Meals

Meals, as eating occasions, were delineated according to content and the time eaten. Means, nutrient density, and standard deviations for energy and other factors affecting iron bioavailability for breakfast, lunch, and dinner intakes are presented in Table 6. Breakfast was eaten by 73% of the participants; 81% ate lunch; and 86% consumed an evening meal.

The breakfast meal contained significantly less energy than the lunch and evening meals ($p \leq .05$) and provided 23% of the daily energy intake. Protein and MFP intakes were also

Table 6. Means and nutrient density for energy, selected nutrients, and other factors affecting iron bioavailability in the meals of pregnant adolescents residing in East Tennessee (N=100).

Energy/ Nutrient/ Factors	Meals By Time of Day[1]					
	Breakfast	Lunch	Evening	Breakfast	Lunch	Evening
	<----------Intakes (mean ± S.D.)---------->			<-------Intakes/1000 kcal (mean ± S.D.)[2,3]------->		
Energy (kcal)	564.7±301.5[a*]	758.7±357.0[b]	901.2±409.8[c]	------	------	------
Protein (g)	18.2±10.8[a]	29.0±17.0[b]	40.1±21.3[c]	33.1±12.1[a]	38.8±13.2[b]	46.0±17.9[c]
MFP (g)[4]	8.8±17.4[a]	51.2±47.5[b]	84.9±67.0[c]	------	------	------
Ascorbic Acid (mg)	44.0±66.2[a]	26.9±45.9[b]	26.4±43.4[b]	89.6±142.6[a]	38.4±63.0[b]	26.6±40.8[b]
Total Enhancing[5] Factor (units)	52.8±66.8[a]	78.0±69.4[b]	111.3±80.6[c]	------	------	------
Iron (mg)	5.0±6.3[a]	4.1±2.3[b]	5.6±4.3[a]	10.3±12.4[a]	5.6±2.4[b]	6.2±3.5[c]
Heme Iron (mg)[6]	0.05±0.11[a]	0.41±0.50[b]	0.70±0.72[c]	0.09±0.21[a]	0.52±0.53[b]	0.80±0.81[c]
Nonheme Iron (mg)[7]	5.0±6.3[a]	3.7±2.0[b]	5.0±4.1[a]	10.2±12.4[a]	5.1±2.3[b]	5.4±3.3[b]
Available Heme[8] Iron (mg)	0.01±0.03[a]	0.09±0.12[b]	0.16±0.17[c]	0.02±0.05[a]	0.12±0.12[b]	0.18±0.19[c]
Available Nonheme[9] Iron (mg)	0.28±0.40[a]	0.25±0.17[a]	0.36±0.31[b]	10.2±12.4[a]	0.34±0.17[b]	0.39±0.24[b]
Total Available[10] Iron (mg)	0.29±0.40[a]	0.35±0.25[a]	0.52±0.40[b]	0.56±0.75[a]	0.46±0.24[b]	0.57±0.35[a]
Iron Bioavailability (%)[11]	5.8±2.2[a]	8.0±2.6[b]	9.2±2.4[c]	------	------	------

[1]Breakfast: Calorie containing food or beverage, 6:00 a.m. - 10:00 a.m.; Lunch: Greatest number of foods including foods from two food groups, 11:00 a.m. - 3:00 p.m.; Evening: Greatest number of foods plus one protein food, 3:30 p.m. - 10:00 p.m.

[2]Nutritient Density = $\frac{\text{Intake of Nutrient}}{\text{kcal (in meal)}} \times 1000$

[3]Adapted from Hansen RC, Wyse BW. Expression of nutrient allowances per 1,000 kilocalories. *J Am Diet Assoc*. 1980; 76:223-227.

[4]Grams of meat, fish, and poultry (MFP)

[5]MFP (g) + ascorbic acid (mg)

[6]MFP iron (mg) x 0.40

[7]Iron (mg) - heme iron (mg)

[8]Heme iron (mg) x 0.23

[9]When enhancing factors (EF) <75: % = 3 + 8.93ln $\frac{(EF + 100)}{100}$; when EF >75: % = 8; when EF = 0: % = 3. Then % x nonheme iron (mg).

[10]Available heme iron (mg) + available nonheme iron (mg)

[11][Total available iron (mg)/iron (mg)] x 100

*Values with different letters are significantly different from each other ($p \leq .05$).

significantly different from the lunch and evening meals ($p \leq .05$). Heme iron contributed only 1% (0.05 mg) to the total iron content of the breakfast meal (5.0 mg) and only 3% to the total available iron (0.29 mg). Forty-five percent of the daily intake of ascorbic acid was provided by breakfast and ascorbic acid represented 85% of the total EF for that meal. The percent of iron bioavailability for the breakfast meal was 5.8%, indicating the importance of enhancing factors.

The lunch meal contributed 31% of the energy for the day. Many of these girls still were attending school and had access to the school cafeteria or frequented fast food restaurants. MFP made a significant contribution to the enhancement of nonheme iron and contributed 10% of the total iron in the meal. The percent iron bioavailability was 8.0% for lunch, a significant ($p \leq .05$) increase over breakfast despite a lower total dietary iron intake (4.1 mg vs. 5.0 mg) at lunch.

The evening meal provided 36% of the daily energy intake, a significant difference over breakfast and lunch ($p \leq .05$). More protein was consumed during the evening meal than during breakfast or lunch. Consumption of MFP at the evening meal (approximately three ounces) was considerably more than breakfast and lunch, collectively. Consequently, heme iron contributed more to the evening meal dietary iron intake (12.5%) than was found in the other meals. Nonheme

iron intake at the evening meal was not different from breakfast but significantly more than at lunch ($p \leq .05$). Ascorbic acid intake at the evening meal did not differ from ascorbic acid intake at lunch but was significantly less than at breakfast ($p \leq .05$). The influence of MFP on the enhancement of nonheme iron absorption can be seen when comparing the available nonheme iron at the evening meal with the amount shown at breakfast.

Intakes reported by pregnant adolescents in this study showed the mean total iron density at breakfast (10.3 ± 12.4 mg/1000 kcal) was significantly higher than lunch or evening meals ($p \leq .05$). The total available iron density values for breakfast and the evening meal (0.56 ± 0.75 mg/1000 kcal and 0.57 ± 0.35 mg/1000 kcal) are not statistically different. The availability of iron in the evening meal is a reflection of the amount of EF consumed in the meal (111.3 ± 80.6 units).

Snacks

Snacks were classified as those eating occasions that did not qualify as meals. Differentiation of morning, afternoon, and evening snacks was according to the timing of foods eaten. Snacks were consumed at some time during the day by all except two participants. Table 7 shows the means and standard deviations for energy and factors affecting iron bioavailability in snacks reported by the participants.

Table 7. Means and nutrient density for energy, selected nutrients and other factors affecting iron bioavailability in the snacks of pregnant adolescents residing in East Tennessee (N=98)[1].

	Snacks By Time of Day[2]					
Energy/ Nutrient/ Factors	Morning	Afternoon	Evening	Morning	Afternoon	Evening
	<----------Intakes(means ± S.D.)---------->			<--------Intakes/1000 kcal(means ± S.D.)[3,4]--------->		
Energy (kcal)	432.0±297.0[a*]	449.4±298.9[a]	389.6±273.8[a]	------	------	------
Protein (g)	11.0±12.0[a]	11.7±13.2[a]	9.7±10.4[a]	23.2±16.5[a]	23.4±20.1[a]	22.5±17.7[a]
MFP (g)[5]	6.0±18.2[a]	11.1±32.2[a,b]	5.7±20.7[a,c]	------	------	------
Ascorbic Acid (mg)	21.3±44.5[a]	14.5±30.9[a]	18.3±45.3[a]	75.5±176.4[a]	51.8±169.2[a]	84.3±232.1[a]
Total Enhancing[6] Factor (units)	27.3±49.3[a]	25.7±44.6[a]	24.0±48.9[a]	------	------	------
Iron (mg)	2.6±2.9[a]	1.7±2.1[b]	1.7±3.4[b]	7.6±14.4[a]	4.1±6.4[b]	4.8±10.3[b]
Heme Iron (mg)[7]	0.05±0.17[a]	0.08±0.26[a]	0.04±0.14[a]	0.06±0.19[a]	0.12±0.36[a]	0.08±0.29[a]
Nonheme Iron (mg)[8]	2.5±2.9[a]	1.7±2.0[b,c]	1.7±3.4[c]	7.5±14.4[a]	4.0±6.3[b]	4.7±10.3[b]
Available Heme[9] Iron (mg)	0.01±0.04[a]	0.02±0.06[a]	0.01±0.03[a]	0.01±0.05[a]	0.03±0.08[a]	0.02±0.07[a]
Available Nonheme[10] Iron (mg)	0.13±0.16[a]	0.08±0.11[b]	0.08±0.17[b]	0.34±0.6[a]	0.18±0.24[b]	0.22±0.59[a,b]
Total Available[11] Iron (mg)	0.14±0.18[a]	0.10±0.15[a,b]	0.09±0.18[b]	0.35±0.6[a]	0.21±0.27[a]	0.24±0.6[a]
Iron Bioavailability (%)[12]	4.7±2.1[a]	4.8±2.5[a]	4.5±2.1[a]	------	------	------

[1] Two subjects did not consume snacks.
[2] Morning Snack: 6:00 a.m.-11:59 a.m. Afternoon Snack: 12:00 p.m.-6:00 p.m. Evening Snack: 6:01 p.m.-5:59 a.m.
[3] Nutrient Density = $\frac{\text{Intake of Nutrient}}{\text{kcal (in snack)}} \times 1000$
[4] Adapted from Hansen RC, Wyse BW. Expression of nutrient allowances per 1,000 kilocalories. *J Am Diet Assoc*. 1980; 76:223-227.
[5] Grams of meat, fish, and poultry (MFP)
[6] MFP (g) + ascorbic acid (mg)
[7] MFP iron (mg) x 0.40
[8] Iron (mg) - heme iron (mg)
[9] Heme iron x 0.23
[10] When enhancing factors (EF) <75: % = 3 + 8.93ln $\frac{(EF + 100)}{100}$; when EF >75: % = 8; when EF = 0: % = 3. Then % x nonheme iron (mg).
[11] Available heme iron (mg) + available nonheme iron (mg)
[12] [Total available iron (mg)/iron (mg)] x 100

*Values with different letters are significantly different from each other ($p \leq .05$).

Snacks consumed in the morning or afternoon generally contained more energy than the evening snack. Consumption of protein and MFP was limited in all snacks; thus ascorbic acid was the major contributor (>50%) to total EF. Total EF was not sufficient to increase nonheme iron absorption to 8% for any snacking occasion. The contribution of heme iron to the dietary iron intake in snacks was low, ranging from 1.9 to 4.7%. Consequently, the percent of iron bioavailability was less than 5% in all snacks. The iron density (mg/1000 kcal) is also shown in Table 7. The morning snack had significantly higher total iron density (7.6 ± 14.4 mg/1000 kcal) and nonheme iron density (7.5 ± 14.4 mg/1000 kcal) compared to the afternoon and evening snack values ($p \leq .05$).

Prediction of Iron Intake

The fourth hypothesis, stated that those pregnant adolescents 16 to 18 years of age, unmarried, and living with one or both parents would have a better dietary iron intake than those pregnant adolescents 13 to 15 years of age, married, and living with their spouse. It was not possible to test this hypothesis because the number (n=3) of married participants, aged 13 to 15 years was too small.

Summary

The findings of this study suggest that these pregnant adolescents in East Tennessee have an energy intake that meets the RDA for pregnancy. However, the mean iron intake

of these adolescents was only 49% of the Recommended Allowance; the MFP intake did not meet the 5 to 7 ounces recommended (93) and only supplied 7.1% of daily total iron. Mean daily intake of ascorbic acid was well above the RDA of 70 mg/d, although total EF were not sufficient to increase nonheme bioavailability to 8%. Those diets with a high percent of bioavailable iron reflected intakes of heme iron greater than 10% of total iron intake, and MFP and ascorbic acid intakes that maximized the bioavailability of nonheme iron. Nutrient density of dietary iron in this study was similar to values published from national survey data and other researchers (6,66,95).

Total available iron increased consistently from meal to meal as the day progressed and as MFP and total EF increased. However, the same was not true for snacking occasions. MFP was highest in the afternoon snack, but total EF and total available iron in snacks decreased as the day advanced.

In comparison to intakes reported by non-pregnant adolescents (6), pregnant adolescents reported higher intakes of daily energy, protein, ascorbic acid, total iron, and MFP. Meal and snacking patterns for pregnant and non-pregnant adolescents were similar but the pregnant adolescents again reported higher intakes in energy, protein, ascorbic acid, total iron, heme iron, and MFP. Percent iron bioavailability for all meals was higher in

pregnant adolescent diets than in non-pregnant adolescents diets. With the exception of the evening snack, which was equivalent for both pregnant and non-pregnant adolescents, the percent bioavailability of morning and afternoon snacks was greater in the diets of pregnant adolescents.

The findings of this study suggest that pregnant adolescents make positive changes in their dietary intake. However, a need for increased intake of dietary iron and to plan for food EF components that enhance iron absorption still exists. Dietary intervention and nutrition counseling during prenatal visits could promote improvement of iron intake and absorption that would help to achieve and maintain iron status during pregnancy.

CHAPTER V

RECOMMENDATIONS AND CONCLUSIONS

The Recommended Dietary Allowances (RDA) are currently used as an evaluation tool for assessing adequate nutrient intake. The RDA for iron during pregnancy, regardless of age, has been established as 30 mg/d (21). Assuming 10% absorption, the average amount of iron necessary during the entire gestation period would be 3 mg/d (21). In this study of 100 pregnant adolescents residing in East Tennessee, results showed dietary iron intake of less than 50% of the recommended allowance for pregnancy. In addition, the amount of total absorbable iron was 44% of the 3 mg/d recommended.

Ascorbic acid intake was the highest at breakfast, because of consumption of juices. Consumption of MFP was the lowest at breakfast compared to lunch and evening meals. Total absorbable iron was lowest at breakfast; this meal could be improved by adding a serving of lean meat, fish, or poultry. Bacon was a popular breakfast item reported in this study, but a poor source of iron. Cooking bacon in an iron skillet has been reported to significantly increase iron content (96) and the use of iron skillets in cooking is popular in the South; this practice should be encouraged to increase iron content in the diets of pregnant adolescents.

The intake of ascorbic acid in the lunch meal significantly declined from amounts consumed at breakfast. In addition, MFP intake was less than two ounces and total absorbable iron contributed only 26% to the daily amount of iron available for absorption. However, the bioavailability of nonheme iron during lunch was approaching 8%. Thus, selection of fruits and vegetables rich in ascorbic acid and a three ounce serving of lean meat, fish, or poultry should be encouraged to increase the iron content of the lunch meal and to improve nonheme iron bioavailability.

At the evening meal, ascorbic acid intake was similar to lunch; however, consumption of MFP was the greatest at the evening meal, approximately three ounces. Total absorbable iron at the evening meal exceeded values for breakfast and lunch meals. The percent bioavailability attained at the evening meal (9.2%) was the highest of any eating occasion reported. The amount of animal tissue present in the meal contributed significantly to EF and, consequently, to the total available iron. Adding iron fortified breads and cereals and/or iron rich fruits and vegetables, such as romaine lettuce and raisins in a salad, would enhance total iron content and improve total available iron as well as the percent iron bioavailability.

Because the pregnant adolescents in this study snacked frequently, snacks could contribute significantly to estimates of total available iron. Evening snacks were the

most popular; however, the morning snack was higher in ascorbic acid and total absorbable iron. Snacks were not significantly different from each other in energy, protein, ascorbic acid, EF, heme iron, available heme iron, and percent iron bioavailability ($p \leq .05$). Incorporation of small amounts of meat, fish, and poultry as well as juices and/or fruits rich in ascorbic acid would help to improve the bioavailability of the nonheme iron intake associated with snacking behavior.

The sample menu in Table 8 was developed to show how combinations of foods in meals and snacks can influence iron bioavailability within approximately 2500 kcal/d. The menu is in compliance with the 1990 Dietary Guidelines suggesting a variety of fruits and vegetables and selecting foods that are low in fat and cholesterol as well as sodium (97). The foods selected would not be unusual choices for an adolescent in this region of the country, and the energy content is compatible with pregnancy during adolescence (2500 kcal/d). This sample menu represents an intake of 2919 kcal, 137 g protein, and 27.97 mg iron. Table 9 shows nutrient and dietary factors affecting the iron bioavailability in the sample menu. Enhancing factors are sufficient in each meal to optimize nonheme iron bioavailability resulting in total iron bioavailability of 8.4%. Iron density for the sample menu, 9.6 mg/1000 kcal,

Table 8. A sample menu with food combinations planned to optimize bioavailability of iron in the diets of pregnant adolescents residing in East Tennessee.

Meal	Food	Amount
Breakfast		
	Cheerios	1 cup
	Wheat Toast	2 slices
	Peanut Butter	2 tablespoons
	Orange Juice	8 ounces
	Milk - 2%	4 ounces
Lunch		
	BBQ Chicken Breast	3 1/2 ounces
	Baked Potato	1 whole
	Margarine	2 teaspoons
	Corn-on-the-cob	1 ear
	Salad	
	Romaine	1 cup
	Tomato	1/2 whole
	Carrot - shredded	1 tablespoon
	Croutons	2 tablespoons
	Low-cal Italian Salad Dressing	1 tablespoon
	Roll	1
	Milk - 2%	8 ounces
Evening		
	Pinto Beans	1 cup
	Corn Bread	1 slice
	Green Beans	1 cup
	Stewed Tomato	1 cup
	Milk - 2%	8 ounces
	Strawberries	1 cup
Snack 1		
	English Muffin	1 whole
	Roast Beef - Lean	1 ounce
	Cranberry Juice	6 ounces
Snack 2		
	Fruit Flavored Yogurt	1 cup
	Raisins	2 tablespoons
	Orange	1 whole
	Cantaloupe	1/2 cup

Table 9. Nutrients and dietary factors affecting the iron bioavailability provided by a sample menu for pregnant adolescents residing in East Tennessee[1].

Nutrient/ Factor	Breakfast	Lunch	Evening	Snack 1	Snack2
MFP (g)[2]	0.0	86.0	0.0	28.4	0.0
Ascorbic Acid (mg)	110.1	60.4	128.8	81.0	105.6
Total Enhancing[3] Factor (units)	110.1	146.4	128.8	109.4	105.6
Iron (mg)	6.37	6.53	11.2	3.04	0.838
Heme Iron (mg)[4]	0.0	0.36	0.0	0.36	0.0
Nonheme Iron (mg)[5]	6.37	6.172	11.2	2.67	0.838
Available Heme[6]	0.0	0.081	0.0	0.084	0.0
Available[7] Nonheme Iron (mg)	0.51	0.494	0.896	0.214	0.067
Total Available[8] Iron (mg)	0.51	0.57	0.896	0.298	0.067
Iron[9] Bioavailability (%)	8.0	8.8	8.0	9.8	8.0

[1]Nutrient analysis performed on Nutritionist III, Version 5.0
[2]Grams of meat, fish, and poultry (MFP)
[3]MFP (g) + ascorbic acid (mg)
[4]MFP iron (mg) x 0.40
[5]Iron (mg) - heme iron (mg)
[6]Heme iron (mg) x 0.23
[7]When enhancing factors (EF)<75: $\% = 3 + 8.93 \ln \frac{(EF + 100)}{100}$;
when EF>75: % = 8; when EF = 0: % = 3. Then % x nonheme iron (mg).
[8]Available heme iron (mg) + available nonheme iron (mg)
[9][Total available iron (mg)/iron (mg)] x 100

is substantially greater than the iron density of 6.1 mg/1000 kcal reported in the present study.

The iron content of cooked food can be increased by using a cast iron skillet or pan, particularly for those foods requiring long cooking times such as pinto beans (96). In addition, increased iron requirements and depleted iron stores during the third trimester of pregnancy may increase nonheme iron absorption as high as 14% (63).

For those pregnant adolescents who are moderately active, 2500 kcal/d should be sufficient for weight gain. However, pregnant girls who are highly active may require more energy; the sample menu could easily be adapted by adding a morning and/or afternoon snack to increase kcal/d. Snacks should include iron dense foods, such as raisins, and should be complemented with juices or other foods rich in ascorbic acid. Dietary intervention and nutrition counseling should begin early in pregnancy during prenatal visits and continue throughout the gestational period.

Anderson and Shepherd (98) surveyed 95 pregnant and post-natal women (14 to 35+ years of age) about their attitudes and behavioral intent in relation to healthy eating. They concluded that attitudes toward healthy eating are strong predictors of intention, and pregnant women do respond to ideas about dietary change. Pregnant adolescents in this and in prior studies (16) increased milk consumption, and this was in agreement with their beliefs

that increased milk consumption during pregnancy was important (99).

If pregnancy is a period when change is more easily accepted, then eating habits of pregnant adolescents can be influenced. Dietary iron intake and bioavailability can be improved by dietary intervention and counseling that relate to food preparation skills and food combinations that enhance iron status. As reported by McDonald (100), dietary intervention made a positive ($p<.001$) change in energy and protein intakes in the diets of low-income, high risk pregnant adolescents.

Health professionals view pregnant adolescents as an at-risk population. However, adolescents lack a sense of urgency (101) and, consequently, it may be more difficult for them to internalize the need for dietary change. It is also obvious that some pregnant adolescents do modify their diets during pregnancy. Non-pregnant adolescents who resided in the same geographic region have reported lower energy, protein, and iron intakes (6) than the pregnant adolescents in this study. The nutrition counselor must provide guidance that acknowledges the discrepancies between a) current iron allowances for pregnancy, b) the reported dietary iron intakes for both pregnant and non-pregnant adolescents, and c) the low incidence of iron deficiency anemia (2%) reported for females (20 to 44 years of age) (10). Unfortunately, the national incidence of anemia in

pregnant adolescents is not known. However, if the incidence of anemia for older females can be extrapolated to adolescent females (<20 years of age) before becoming pregnant, then planning food patterns that optimize iron bioavailability may make the need for iron supplementation less crucial. That is, improving food intake provides a familiar, acceptable way to improve iron status of pregnant adolescents and teaching food combinations to enhance iron bioavailability should be a goal for changing food patterns in the postpartum period as well as during pregnancy.

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APPENDICES

APPENDIX A

TN860

Code Number _____
Date _____

Instructions for Completing Food Records Forms

1. Use the attached pages to record your food intake for two days. Please keep your records for _____ and _____. Do not change your normal eating pattern for those days.

2. Record everything you eat and drink (except water) in each 24-hour period.

3. Remember to record the time you eat, where you eat, who you eat with, and if you are watching TV.

4. It is easier to complete this form as you go, rather than waiting until the end of the day. Carry the form with you, and record each food when you eat it.

5. Describe in as much detail as possible each food eaten, and indicate how it was prepared and served.

   a. Tell whether fruits and vegetables are eaten raw or cooked.

   b. Identify preparation methods. Are foods fried, boiled, or steamed?

   c. Indicate brand names where possible (e.g., 2 c. Campbells Chicken and Noodle soup; 3 Mrs. Paul's Fish Sticks with 1 Tbsp. catsup; 1 Burger King Whopper Junior with tomato, mustard, catsup, and pickles).

   d. For mixed dishes and sandwiches, estimate and record amounts of major ingredients (e.g., Vegetable Salad - 1 c. lettuce, 1/2 c. tomato, 1/4 c. broccoli, 1/4 c. carrots, 1/2 egg, 1/4 c. Kraft reduced calorie French dressing; Ham and Cheese Sandwich - 2 slices whole wheat bread, 1 slice Mr. Turkey smoked turkey ham, 1 slice American cheese, 2 slices tomato, 1 leaf lettuce, 1/2 Tbsp. mayonnaise).

   e. Do not forget to record anything you add to foods and beverages before eating (e.g. butter, salad dressings, gravies, sauces, sugar, cream).

   f. Also, don't forget to record foods eaten between meals and desserts eaten after meals.

   g. Sometimes you can get information from labels (e.g., 1 1/2 oz. milky way candy bar).

6. Estimate as closely as possible the amounts of each food eaten. Use the following abbreviations for measures:

   cup = c.
   tablespoon = T. or Tbsp.
   teaspoon = t. or tsp.
   ounce - oz.

7. If you have questions, please contact Dr. Jean Skinner, Dr. Betty Ruth Carruth, or Janet Pope, Department of Nutrition and Food Sciences, The University of Tennessee, Knoxville, TN 37996-1900, 974-5445.

TN860

Code Number _____ _____
Date _____
Record _____ Recall _____

Food Recall/Record Form

	Food and Description	Amount
1st time food was eaten: time _____ am ___ pm ___ where _____ who, if anyone ate with you? _____ watching TV, yes__ no __		
2nd time food was eaten: time _____ am ___ pm ___ where _____ who, if anyone ate with you? _____ watching TV, yes__ no___		
3rd time food was eaten: time _____ am ___ pm ___ where _____ who, if anyone ate with you? _____ watching TV, yes__ no___		
4th time food was eaten: time _____ am ___ pm ___ where _____ who, if anyone ate with you? _____ watching TV, yes__ no___		
5th time food was eaten: time _____ am ___ pm ___ where _____ who, if anyone ate with you? _____ watching TV, yes__ no___		

APPENDIX B

TN860 Code Number _____

Date _____

Information Form

Name: _____ Phone Number: _____

Address: _____

_____

Name and address of person(s) through whom client may be reached:

Name: _____ Phone Number: _____

Address: _____

_____

Name: _____ Phone Number: _____

Address: _____

_____

Appointments:

Date	Time	Place	Comments

APPENDIX C

TN860

Code Number _____

Date _____

Demographics and Background Information

Age _____ Date of Birth _____

Grade in school or last grade completed _____

Living Arrangements (check one):
_____ live with one parent
_____ live with both parents
_____ live with spouse
_____ live with parents and spouse
_____ live with other relative, specify: _____
_____ live in group home
_____ other, specify: _____

Mother's Education: (check highest level)
_____ < 7th grade
_____ junior high school
_____ some high school
_____ high school graduate
_____ some college or specialized training
_____ college graduate
_____ graduate school or professional training
_____ not applicable

Father's Education: (check highest level)
_____ < 7th grade
_____ junior high school
_____ some high school
_____ high school graduate
_____ some college or specialized training
_____ college graduate
_____ graduate school or professional training
_____ not applicable

Spouse's Education:
_____ < 7th grade
_____ junior high school
_____ some high school
_____ high school graduate
_____ some college or specialized training
_____ college graduate
_____ graduate school or professional training
_____ not applicable

Mother's Occupation _____

Father's Occupation _____

Spouse's Occupation _____

Estimated Date of Delivery _____

Doctor's Name _____

Place of Delivery _____

VITA

Joanne Louise Pierson was born in St. Louis Park, Minnesota on July 13, 1951. She moved to Phoenix, Arizona with her family in 1956 where she attended Desert View Elementary School and graduated from Sunnyslope High School in June, 1969. She attended Phoenix and Mesa Community Colleges from 1982 through 1985. She then entered Arizona State University where she graduated with a Bachelor of Science degree in Nutrition, May, 1989. In May, 1989 she entered graduate school at the University of Tennessee, Knoxville and began the Approved Preprofessional Program. She graduated with a Master of Science degree in Nutrition in August, 1991. She has one son, Ryan, born March 1, 1982.