The iron status of Black and white female adolescents from eight Southern states

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ABSTRACT Hb, hematocrit, plasma iron, and transferrin saturation were measured in approximately 1000 girls aged 12, 14, or 16 yr in eight Southern states. The iron status parameters did not differ significantly among the three age groupings or between menstruating and nonmenstruating girls. Blacks had significantly lower mean Hb (p < 0.0001), hematocrit (p < 0.0001), and transferrin saturation (p < 0.05) levels than whites and a greater proportion of Blacks exhibited low Hb (p < 0.05) and low hematocrit levels (p < 0.01). Adjusting for dietary iron intakes and per capita income levels did not adequately account for significant race differences for iron status parameters. These findings support the contention that genetic as well as environmental factors are responsible for the frequently reported Black-white differences in Hb and hematocrit levels. Am J Clin Nutr 1983;38:109–114.

KEY WORDS Black and white adolescent females, hemoglobin, hematocrit, plasma iron, transferrin saturation

Introduction

Adolescent females are considered a nutritionally vulnerable segment of the population. A rapid growth rate combined with marginal nutrient intakes (1, 2) increases the risk of nutritional deficiencies in this population. A high incidence of iron-deficiency anemia has been noted in Black and in white teenage girls (2–5).

Several large surveys have indicated that Hb and hematocrit (Hct) levels are consistently lower in Blacks than in whites (3, 4, 6–9). Racial differences in these parameters associated with iron status have been observed from infancy through the eighth decade of life (3).

The present investigation reports Hb, Hct, plasma Fe (PFe), and transferrin saturation (TS) levels in Black and white adolescent females. The data were collected as part of a regional study to assess the nutritional status of adolescent females in the South. Effects of race, age, income, and dietary iron on the above mentioned parameters were investigated.

Methods

Subjects

A total of 1247 females (556 Black, 691 white) from eight Southern states, participated in this study. They were 12, 14, or 16 (±0.5) yr old and had no known metabolic disorders; potential subjects were also screened to exclude those with sickle cell trait. Girls were recruited from geographic areas near the 12 cooperating institutions without regard to income; however, each institution attempted to include a minimum of 10 to 15% of subjects for each race from families with incomes of ≤ $2500 and with incomes ≥ $4500 per capita, respectively, to insure that a spectrum of incomes was included. Each state attempted to recruit 80 girls aged 12, 80 aged 14, and 40 aged 16 yr, with each age grouping equally divided between Blacks and whites. Experimental procedures and consent forms were reviewed and approved at each state.

1 From the University of North Carolina (ML), Greensboro, NC; Oklahoma State University (MAK), Stillwater, OK; Winthrop College (WB), Rock Hill, SC; Auburn University (AJC), Auburn, AL; University of Tennessee (GWD), Knoxville, TN; Tuskegee Institute (EGE), Tuskegee, AL; University of Arkansas (EG), Pine Bluff, AR; Louisiana State University (HL, PS), Baton Rouge, LA; Virginia State University (SWM), Petersburg, VA; University of Arkansas (JHM), Fayetteville, AR; Virginia Polytechnic Institute and State University (FT), Blacksburg, VA; Tennessee State University (TW), Nashville, TN.

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cooperating station by the local review boards for research involving human subjects.

Data collection

Fasting blood samples were drawn into vacutainer tubes. Whole blood Hb and Hct levels were determined by the cyanmethemoglobin method (10) and by microhematocrit centrifugation (11), respectively. Plasma was obtained from heparinized vacutainers and frozen for later analyses. PFe and total iron-binding capacity were determined by the method of Ceriotti and Ceriotti (12), which uses the chromogenic agent ferrozine. TS was computed as the ratio of PFe/total iron-binding capacity × 100.

Reported mean values for the iron parameters measured in this study are based on subpopulations which are considerably smaller than the total subject population of n = 1247: Hb (n = 744), Hct (n = 1171), PFe (n = 1024), TS (n = 822). Blood samples were not obtained from all subjects, and in some cases the blood volume obtained was not sufficient to perform all four iron status measurements.

Trained interviewers with backgrounds in food and nutrition conducted two 24-h recalls on two separate occasions. Food models and/or calibrated utensils were used to aid the girls in estimating the quantities of foods they had eaten. Food consumption data were coded and analyzed using the computer data bank maintained by the Nutritional Analysis System. (Department of Experimental Statistics, Louisiana State University, Baton Rouge, LA). Information pertaining to the use of vitamin and/or mineral supplements was also obtained. Questionnaires that elicited information necessary to compute family per capita income levels were administered to a parent or guardian of each subject. The girls were questioned regarding their menstrual history.

Statistical analyses

Analysis of variance models (including the state source of variation) and specific postanalysis tests (13) were used to evaluate potential differences in mean Hb, Hct, PFe, and TS levels between various subject subdivisions based on race, age, dietary iron intake, iron supplement usage, income, and onset of menstruation. Analysis of covariance (13) was conducted to determine the extent to which dietary iron intakes could explain race differences in some of the iron status parameters. χ² tests (13) were used to determine whether there were significant differences between races and among age and per capita income groups in the distribution of low and adequate levels of the iron status parameters. Per capita incomes were categorized into three ranges which were determined after the study to include somewhat similar numbers of participants in each range. Pearson product moment correlation coefficients (r) and regression coefficients describing relationships between selected variables were also computed.

Results

Iron nutritional status

Mean and SEMs for iron status parameters for the total population and the Black and white subpopulations are presented in Table 1. Using the levels recommended by the Health and Nutrition Examination Survey, 1971 to 1972 (3) for classifying individuals into “low” categories (Hb < 11.5 g/dl; Hct < 36.0%; PFe < 40.0 μg/dl; TS < 15.0%), the percentage of subjects exhibiting low or deficient values ranged from 2.2% for Hct to 11.7% for TS. The proportions of Hb and PFe values falling below the acceptable range were approximately equal (4.0 and 5.0%, respectively).

Mean Hb (p < 0.0001), Hct (p < 0.0001), and TS (p < 0.05) levels were significantly lower for Black girls than whites. A significantly greater proportion of the Black girls exhibited low Hb (p < 0.05) and low Hct levels (p < 0.01) but there were no significant differences between the races in the percentage of subjects who exhibited low values for either PFe or TS (Table 1).

There were no significant differences in any of the mean iron parameters among the three age groupings, nor did mean iron parameters differ between those girls who had experienced menarche and those who had not (Table 2). Regression coefficients relating

<table>
<thead>
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<th>All subjects</th>
<th>Blacks</th>
<th>Whites</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>± SEM</td>
<td>% Low</td>
</tr>
<tr>
<td>Hb (g/dl)</td>
<td>774</td>
<td>13.5 ± 0.1</td>
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</tr>
<tr>
<td>Hct (%)</td>
<td>1171</td>
<td>41.4 ± 0.1</td>
<td>2.2</td>
</tr>
<tr>
<td>PFe (μg/dl)</td>
<td>1024</td>
<td>90.5 ± 1.1</td>
<td>5.0</td>
</tr>
<tr>
<td>TS (%)</td>
<td>822</td>
<td>26.4 ± 0.4</td>
<td>11.7</td>
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</tbody>
</table>

* Significantly different between races (p < 0.0001).
† Significantly different between races (p < 0.05).
‡ Significantly different between races (p < 0.01).
TABLE 2
Mean iron status parameters by age and menstrual status*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Age (yr)</th>
<th>Menstrual status</th>
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<tr>
<td></td>
<td>12</td>
<td>14</td>
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<td></td>
<td>Premenarche</td>
<td>Menarche</td>
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<tr>
<td>Hb (g/dl)</td>
<td>13.6 ± 0.1† (284)</td>
<td>13.6 ± 0.1 (269)</td>
</tr>
<tr>
<td>Hct (%)</td>
<td>41.4 ± 0.1 (432)</td>
<td>41.1 ± 0.1 (428)</td>
</tr>
<tr>
<td>PFe (ug/dl)</td>
<td>91.4 ± 1.9 (370)</td>
<td>90.9 ± 2.3 (367)</td>
</tr>
<tr>
<td>TS (%)</td>
<td>26.0 ± 0.6 (293)</td>
<td>26.8 ± 0.8 (294)</td>
</tr>
</tbody>
</table>

* No of subjects per cell are given in parentheses.
† ± SEM.

TABLE 3
Regression coefficients relating months past menarche to iron status parameters by age

<table>
<thead>
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<th>Age (yr)</th>
<th>12</th>
<th>14</th>
<th>16</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hb</td>
<td></td>
<td>0.0087</td>
<td>-0.0006</td>
<td>-0.0044</td>
</tr>
<tr>
<td>Hct</td>
<td></td>
<td>0.0068</td>
<td>-0.0075</td>
<td>-0.0198</td>
</tr>
<tr>
<td>PFe</td>
<td>1.6035*</td>
<td>-0.3566†</td>
<td>-0.0363</td>
<td></td>
</tr>
<tr>
<td>TS</td>
<td>0.4828*</td>
<td>-0.0083</td>
<td>-0.0031</td>
<td></td>
</tr>
</tbody>
</table>

* p < 0.001.
† p < 0.05.

months past menarche to Hb, Hct, PFe, and TS levels were computed separately for girls aged 12, 14, and 16 yr (Table 3). Although the slopes of the regression lines were of low magnitude, significant (p < 0.001) positive relationships were observed between PFe or TS levels, and months past menarche in girls aged 12 yr. The regression coefficients between the four iron parameters and months past menarche for 14- and 16-yr-old girls were consistently negative, but only the relationship between PFe and months past menarche in 14-yr-olds was significant (p < 0.05).

Relationships among iron parameters

Pearson correlation coefficients were calculated for all possible pairs of the iron status parameters in the total population and in the Black and white subpopulations (Table 4). Highly significant correlations (p < 0.0001) were observed between Hb and Hct levels in all three subject groupings. PFe and TS levels were significantly correlated with Hb (p < 0.001) and Hct (p < 0.05) levels only in the white subpopulation. However, neither PFe nor TS accounted for more than 4% of the variability in Hb or Hct levels, leaving at least 96% of the variability unexplained.

T tests were used to determine whether PFe and/or TS levels differed between subjects who exhibited adequate and those who exhibited low Hb and Hct levels (Table 5). In the total population, subjects with low Hb values exhibited significantly lower Hct (p < 0.0001) and TS (p < 0.01) levels than did those with adequate Hb levels. Hct levels in Black and white subpopulations were significantly lower (p < 0.0001) in those subjects who exhibited low Hb values. However, only in whites were low Hb levels associated with significantly lower PFe (p < 0.01) and TS (p < 0.0001) levels.

Low Hct levels were associated with significantly lower Hb (p < 0.01) in the total population, but PFe and TS levels did not differ according to Hct status. Similar to the finding with respect to Hb, low Hct levels were associated with significantly lower PFe (p < 0.01) and TS (p < 0.0001) levels in the white subpopulation only.

Income

Correlation coefficients relating per capita income (PCI) to Hb, Hct, PFe, and TS levels were determined for the entire population and for the Black and white subpopulations to assess potential associations between income and iron status. In the total population of girls, PCI was significantly correlated only with Hb (r = 0.12, p < 0.01) and Hct (r = 0.07, p < 0.05). No significant correlations between PCI and any of the iron parameters were observed in whites whereas Hct levels were significantly correlated with PCI in Blacks (r = 0.17, p < 0.001).

When PCI levels were divided into tertiles, no significant differences in mean Hb, Hct, PFe, and TS levels were demonstrated among girls grouped according to the three PCI cat-
egories. However, a $\chi^2$ analysis indicated that significantly more ($p < 0.01$) low Hct levels were observed among girls from the lowest PCI tertile. No other significant differences in iron status parameters between subjects who consumed greater and those who consumed less than 50, 67, or 100% of the iron Recommended Dietary Allowances. Analysis of covariance indicated that the significant Black-white differences observed in mean Hb, Hct, and TS levels were not appreciably altered by adjusting for dietary iron intake.

Approximately 10.2% of the girls in this study reported taking iron supplements on at least one of the two 24-h recalls Mean Hb, Hct, PFe, and TS levels were not significantly affected by the ingestion of iron supplements nor were the distributions of low and adequate iron status parameters significantly affected by iron supplementation.

Discussion

The Ten State Nutrition Survey (4) reported that among 13- to 16-yr-old females living in low income ratio states, 6.2% of the whites and 26.6% of the Blacks exhibited Hb levels less than or equal to 11.0 g/dl. The corresponding figures for white and Black adolescent females living in high income ratio states were 2.6 and 21.7%, respectively. Although the standard used in the present study to define "low" Hb status was slightly higher (11.5 versus 11.0 g/dl), the incidence of low Hb levels for whites (2.3%) was comparable, whereas the incidence of low Hb levels for Blacks (6.2%) was markedly less than the figures reported in the Ten State Survey.

Two relatively recent studies (5, 14) conducted in the US assessed the iron status of adolescent females. Gregor et al (14) reported Hb and Hct levels in over 100 girls (in grades 6 to 8) living in northwestern Indiana. The racial distribution of the subjects was not reported. The girls exhibited mean Hct and Hb levels of 42.0% and 13.8 g/dl, respectively, which were similar to values reported for the white girls in the present study.

The iron status of 51 white and 21 Black girls (mean age of 15.5 yr) living in central Kentucky was assessed by Lee (5). Reported mean Hb and Hct levels (12.0 g/dl and 39% in whites; 10.6 g/dl and 38% in Blacks) were markedly lower than the values reported in the present study, while mean PFe and TS levels (99 $\mu$g/dl and 29% in whites, 88 $\mu$g/dl and 20% in Blacks) were comparable to those observed in the present study. Deficiencies of other nutrients beside iron may have contributed to the particularly low Hb levels observed by Lee since a disproportionately large number of subjects (approximately 34%) exhibited low Hb levels while the percentage of Black and white subjects who exhibited low Hct, PFe, and TS levels ranged from 4 to 24%.

The significant differences observed in mean Hb and Hct levels between Blacks and whites in the present study are consistent with findings of other surveys (3, 4, 6–9). The effect of race persisted even after controlling for socioeconomic status (4, 7, 15) and TS levels (7, 15). The suggestion that the Hb and Hct differences could be attributed to difference in dietary iron intakes between Blacks and whites has not been supported in the literature (8, 9). Frerichs et al (8) determined

### TABLE 4
Pearson correlation coefficients between iron status parameters

<table>
<thead>
<tr>
<th></th>
<th>All subjects</th>
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<tbody>
<tr>
<td></td>
<td>Hct</td>
<td>PFe</td>
<td>TS</td>
<td>Hct</td>
<td>PFe</td>
<td>TS</td>
<td>Hct</td>
</tr>
<tr>
<td>Hb</td>
<td>0.57*</td>
<td>0.12†</td>
<td>0.15†</td>
<td>0.55*</td>
<td>0.08</td>
<td>0.06</td>
<td>0.58*</td>
</tr>
<tr>
<td>Hct</td>
<td>0.08‡</td>
<td>0.04</td>
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*p < 0.0001.
† p < 0.001.
‡ p < 0.05.
Table 5

Mean iron parameter levels associated with adequate and low Hb and Hct levels*

<table>
<thead>
<tr>
<th></th>
<th>Hct (%)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Total population</td>
<td>Blacks</td>
<td>Whites</td>
<td>Total population</td>
<td>Blacks</td>
<td>Whites</td>
<td>Total population</td>
</tr>
<tr>
<td>Hb ≥ 11.5 g/dl</td>
<td>41.0 (727)</td>
<td>40.8 (310)</td>
<td>41.2 (417)</td>
<td>91.4 (721)</td>
<td>89.8 (309)</td>
<td>92.6 (412)</td>
<td>27.3 (561)</td>
</tr>
<tr>
<td>Hb &lt; 11.5 g/dl</td>
<td>37.1† (33)</td>
<td>37.2† (22)</td>
<td>36.9† (11)</td>
<td>78.5 (35)</td>
<td>88.4 (22)</td>
<td>61.7† (13)</td>
<td>22.5‡ (32)</td>
</tr>
</tbody>
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<table>
<thead>
<tr>
<th></th>
<th>PFe (μg/dl)</th>
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</thead>
<tbody>
<tr>
<td>Hb (g/dl)</td>
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<tr>
<td>Hct ≥ 36.0%</td>
<td>13.6 (742)</td>
<td>13.4 (320)</td>
<td>13.7 (422)</td>
<td>90.4 (973)</td>
<td>87.8 (421)</td>
<td>92.3 (552)</td>
<td>26.4 (786)</td>
</tr>
<tr>
<td>Hct &lt; 36.0%</td>
<td>11.9† (18)</td>
<td>11.8† (12)</td>
<td>12.3‡ (6)</td>
<td>93.2 (23)</td>
<td>108.4 (16)</td>
<td>58.4‡ (7)</td>
<td>27.3 (18)</td>
</tr>
</tbody>
</table>

* No of subjects per cell are given in parentheses.
† Significantly different between subjects exhibiting adequate and low Hb or Hct levels (p < 0.0001).
‡ Significantly different between subjects exhibiting adequate and low Hb or Hct levels (p < 0.01).
presented data which supported this possibility in infants. However, the analyses reported herein support the contention that hereditary factors partially account for the observed Black-white differences in Hb and Hct levels. Separate criteria for screening iron deficiency anemia in Black and white populations may be warranted.

References