Deleterious Functional Impact of Anemia on Young Adolescent School Girls

A. Sen and S.J. Kanani

From the Department of Foods and Nutrition, M.S. University of Baroda, Vadodara, Gujarat India.

Correspondence to: Dr. Shubhada Kanani, 14, Anupam Society, Behind Pizza Inn, Jetalpur Road, Vadodara, Gujarat, India.
E-mail: s_kanani@yahoo.co.uk

Manuscript received: March 28, 2005, Initial review completed: June 23, 2005, Revision accepted: October 25, 2005.

Iron deficiency anemia during adolescence may reduce physical work capacity and cognitive function. ***Objectives:*** *To assess the physical work capacity and cognition of underprivileged anemic schoolgirls in Vadodara in early adolescence as compared to their non-anemic counterparts.* ***Design:*** *Prior to initiating anemia control interventions, schoolgirls in early adolescence were studied with regard to their hemoglobin status, physical work capacity and cognitive functions.* ***Setting:*** *Schoolgirls from four municipal primary schools in the age of 9 - 14 years were studied.* ***Methods:*** *In four Primary Municipal schools, hemoglobin of subjects was assessed using standard methods; physical work capacity using Modified Harvard's Step test and cognitive functions using selected tests from the modified Wechsler Intelligence Scale for Children (WISC), suitably adapted for this group (n = 230).* ***Results:*** *The mean hemoglobin was 11.32 g/dL, and anemia prevalence: 67 %. A higher number of steps were climbed and a shorter time was taken to revert to the basal pulse rate (recovery time) by non-anemic girls compared to anemic girls (P<0.001). Significantly lower scores in digit span and visual memory test were seen in anemic compared to non-anemic girls. The adverse impact of anemia remained after controlling for under – nutrition (BMI).* ***Conclusion:*** *Anemia is likely to adversely affect physical work capacity and cognition in young adolescent girls undergoing pubertal development. Further research should be conducted in both school and community based settings to cover non-school going children.*

Key words: *Anemia, Cognition, Physical work capacity, Young adolescent*

IRON deficiency anemia (IDA) is a formidable health challenge in developing countries and remains persistently high despite national programs to control this deficiency. In the period of later school age and early adolescence, nutrient requirements are high and reserves are being laid for the subsequent rapid growth and development. Iron deficiency in this age group has been primarily studied for its detrimental effect on hematinic status. However, anemia may compromise pubertal growth spurt, which has been reported in our earlier work(1). It may also reduce physical work capacity and cognitive function. This in turn may adversely affect learning and scholastic performance of the schoolgirls entering adolescence.

Physical work capacity is reduced because in IDA, the decrease in hemoglobin reduces the availability of oxygen to the tissues, which in turn affects the cardiac output(2). Further, in iron deficiency, changes in brain iron content and distribution, and in neurotransmitter function may affect cognition(3,4). Anemia may produce scholastic under-achievement and behavioral disturbances in school children(5). Research on preschool children has shown that iron deficient children performed less well on psychomotor tests than did non-anemics(6). However, little is known

as regards impact on children entering adolescence and those undergoing the pubertal growth spurt.

Hence, the present research was planned with the objective of assessing the physical work capacity and cognition of under-privileged anemic schoolgirls in early adolescence as compared to their non-anemic counterparts. This research is the first phase of an ongoing intervention study to combat anemia in early adolescence.

Subjects and Methods

This study was conducted in Vadodara municipal primary schools catering to the girls from low-income group families (LIG).

Study Design

A list of all the schools under the Vadodara Municipal Corporation was obtained. All the schools matching the following criteria were selected as the universe for purpose of sampling

- The school should have a primary section, as the age group of the study was preadolescent girls;
- The study focused on girls therefore listed schools should have girl students.
- Morning school timings: To be able to compare and pool data of schools, schools should have similar timings.

Thus, a sampling frame of 17 primary schools with morning timings and girl students was prepared. From this list four schools were randomly selected and all the girls studying in Standards V and VI were enrolled in the study (n = 350). This list excluded girls who had attained menarche to remove the confounding effect of menarche. Prior permission from the Primary School Board, Vadodara was taken and the schools were explained the purpose of the study. The students and their parents were also informed and informed consent was taken. The students were free to opt out of the study anytime they wanted.

Profile of the subjects

Majority of the girls (two third) were Hindu; and the rest were Muslim and Christian. The girls were in the age group of 9 to 14 years. Nearly half (46.2%) of the mothers were illiterate, and most of the fathers (81%) were educated only till primary level. Fathers of the girls were employed in low-income generating services such as peons in banks, hospitals, university or helpers in hotels, while almost half (43.1%) of the mothers were employed as maids.

Sample

Data on hemoglobin (n = 322), height and weight (n = 350) were collected on all girls willing and available in V and VI standards. A random sub-sample of 60% of the total students was taken for PWC and cognitive tests (n = 230).

The methods used were cyanmethemoglobin method for hemoglobin(7) and standard methods for height and weight(8). The tests for both physical work capacity (PWC) and cognition were modified and pre-tested to make them appropriate for this age group. These have been used in earlier studies on school children and adolescents in the department and found to be valid(9). Relevant training was obtained from an expert in the Department of Education and Psychology, M.S. University.

PWC

The physical work capacity of the subjects was assessed using Modified Harvard's Step test(10). The girls were asked to climb up and down a set of five steps for a period of three minutes as fast as they could. The total number of steps climbed up and down was counted.

The resting pulse rate was recorded before the girls began the test. Post exercise, the time taken (minutes) to revert to the basal pulse rate was also recorded (recovery time).

The cognitive functions of the girls were assessed using selected tests from the Gujarati version of Wechsler Intelligence Scale for Children (WISC)(11) which was suitably modified as mentioned. The various tests used were:

(*i*) Digit Span to assess short-term memory for non-meaningful information, concentration, and ability to remember the sequence of the numbers (backward and forward),

(*ii*) Maze test to assess visual-motor coordination and speed, and fine motor coordination,

(*iii*) Clerical task to assess the ability to concentrate and discriminate and,

(*iv*) Visual memory test to assess the short-term memory of girls.

Data Analysis

Means and standard deviations were calculated for PWC and cognition scores. Percentage of anemic girls was calculated using WHO cutoff of hemoglobin <12 g/dL. On a smaller subset of data, anemic and non-anemic girls were compared within well-nourished and undernourished groups. Undernutrition was defined as BMI <5th percentile of Must, *et al*. standards(12). Students '*t*' test was used to compare anemic and non-anemic subjects. All the data were coded, entered and analyzed in Epi Info, Version 6.04-d(13). All the girls who had attained their menarche were excluded during the analysis.

Results

The mean hemoglobin level of total sample of girls (n = 322) was 11.32 g/dL; 10.67 g/dL for anemics (n = 217) and 12.68 g/dL for non-anemics (n = 105). The prevalence of anemia (Hb <12g/dL) was very high (67%). Considering severity of anemia, 32.6 % girls were mildly anemic (Hb = 11.0-11.9 g/dL); 34.7 % girls were moderately anemic (Hb = 7.1-10.9 g/dL). There were no severely anemic girls. Using 12 g/dL as the cutoff level, the anemic and non-anemic girls were compared with regard to their physical work capacity and cognitive functions.

Physical work capacity

Though a trend was seen that the mean number of steps climbed (175 steps) by the 59 non-anemic girls in three minutes was higher than seen in the 171 anemic girls (mean = 172 steps), this difference was not statistically significant. However the time taken to recover to the basal pulse rate was significantly higher ($p < 0.001$) for anemic girls, *i.e*., anemic girls took longer than non-anemic girls to return to their basal pulse rate after finishing the step test (*Table I*).

Cognition

Table I further reveals that when cognitive function test scores were compared between anemic and non-anemic girls, the non-anemic girls scored higher than their anemic counterparts, the difference being significant in digit span and visual memory tests. Though non-anemics scored better in maze test (11.81 *vs.* 10.52) and clerical task (0.64 *vs.* 0.61) as well, this difference was not statistically significant.

Does the level of anemia significantly influence physical work capacity and cognition?

When anemic girls were categorized into mildly anemic and moderately anemic groups, even mildly anemic girls took longer to recover to their basal pulse rate compared to

TABLE I –*Physical Work Capacity and Cognition Test Scores of the School Girls.*

Age (in years)	9-11		12-14		All girls	
Indicator	N	Mean ± SD	N	Mean ± SD	N	Mean ± SD
Recovery time+						
Anemic[1]	142	3.38 ± 1.00	29	3.75 ± 0.78	171	3.44 ± 0.97
Non anemic[2]	53	2.60 ± 0.76	6	2.16 ± 0.98	59	2.55 ± 0.79
t-value		5.10***		4.33***		6.27***
Digit span						
Anemic	142	6.35 ± 2.14	29	5.93 ± 1.87	171	6.28 ± 2.09
Non anemic	53	7.54 ± 2.01	6	7.83 ± 1.16	59	7.57 ± 1.94
t-value		3.52***		2.38*		4.16***
VMT[3]						
Anemic	142	0.51± 0.21	29	0.43 ± 0.22	171	0.50 ± 0.21
Non anemic	53	0.60 ± 0.20	6	0.61 ± 0.30	59	0.61 ± 0.22
t-value		2.69**		1.74*		3.27***

+in minutes ,[1]Hb < 11.99 g/dL, [2]Hb > 12 g/dL, [3]VMT- Visual Memory Test,
*p < 0.05, **p < 0.01, ***p < 0.001

non-anemic girls. The moderately anemic girls similarly showed a longer recovery time than those mildly anemic. As regards cognition, a similar trend was seen. *Table II* indicates that both mildly anemic and moderately anemic girls fared significantly poorer as regards recovery time ($p < 0.05$) and digit span scores ($p < 0.01$). Even the mildly anemic girls tended to have lower scores than non-anemics, and the moderately anemics further had lower scores than those mildly anemic. Thus a trend was seen that even mild anemia could adversely affect the PWC and cognitive abilities of schoolgirls entering adolescence.

Does undernutrition have a confounding influence?

Analysis of a subset of the data compared anemic and non-anemic girls within the well-nourished group, and similarly within the undernourished groups, undernutrition being defined by BMI. This was done to control the confounding influence of undernutrition.

Physical work capacity

While in the wellnourished group there was no statistical significance between anemic (Mean: 148 steps) and non-anemic girls (Mean: 141 steps); in the undernourished group, non-anemic girls (Mean: 174 steps) performed significantly better than their counterparts (Mean: 143 steps). This indicates that the adverse effects of anemia are compounded due to overall undernutrition and that being wellnourished is as important as being non-anemic for normal PWC.

Cognition

It was observed that anemic girls, whether in the well-nourished group or the undernourished group, showed a significantly poorer performance as regards the digit span test (*Fig.1*). Thus, irrespective of the overall nutrition status, anemia in itself is likely to

TABLE II – *Physical Work Capacity and Cognitive Abilities of Non-anemic, Mildly and Moderately Anemic Subjects*

Indicators	Non-anemic[1] (A) N = 59 Mean ± SD	Mild anemia[2] (B) N = 85 Mean ± SD	Moderate anemia[3](C) N = 86 Mean ± SD	F-value	*t*-value (A *vs*. B)	*t*-value (A *vs*. C)
Physical Work Capacity						
Steps climbed	175 ± 39.59	175 ± 51.9	165 ± 27.4	2.43*	0.69 NS	0.77NS
Recovery time	2.55 ± 0.79	3.18 ± 0.80	3.69 ± 1.06	27.4***	2.07 *	3.45***
Cognitive Abilities						
Digit span	7.57±1.94	6.40 ± 2.00	6.16 ± 2.19	8.94***	2.24*	2.62**
VMT[4]	0.61±0.21	0.53 ± 0.21	0.48 ± 0.22	6.55***	1.50 NS	2.23*
Maze	11.81 ± 4.89	11.22 ± 4.36	9.82 ± 4.76	3.62*	0.003 NS	1.63 NS
Clerical Task	0.65 ± 0.20	0.64 ± 0.18	0.59 ± 0.21	1.99NS	0.74 NS	1.75 NS

[1]non-anemic Hb >11.99g/dL, [2]mild anemia, Hb = 11.00-11.99 g/dL, [3]moderate anemia Hb <11.00 g/dL , [4]Visual memory test, NS = not significant, *p < 0.05, **p < 0.01, ***p<0.001

adversely affect cognition.

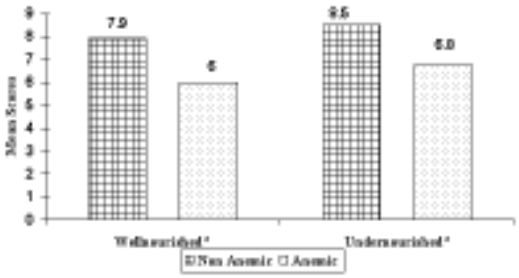
Discussion

The findings of this study indicate that anemia is likely to compromise physical work capacity and cognitive functions of girls in the pubertal phase of development. Further, even mild anemia can have a deleterious effect on these functions. The adverse impact is especially aggravated if both undernutrition and anemia are present. Cognition in particular appears to be adversely affected by anemia in both wellnourished and under-nourished subjects.

Literature in this age-group of children entering adolescence which relates anemia to functional consequences is scarce. However, studies are available on younger children. In rural Varanasi, India, a study was conducted on school children (6-8 years) for three years to assess their nutritional status, mental function and physical work capacity (using Harvard Step test)(14). It was found that both the sexes combined showed significant increase in steps taken with rise in hemoglobin ($p < 0.01$). It was reported that with increasing severity of undernutrition, the number of steps completed in the step test became fewer and the recovery time was prolonged. Similarly, verbal and performance IQ scores progressively decreased with fall in hemoglobin levels. The differences were significant for digit span test between non-anemics and severely anemic children.

A study assessing the mental and motor abilities of school children of 6-11 years in Coimbatore noted that the motor performance in various athletic events were significantly poorer among anemic children compared to the non-anemics(15). Further in cognitive tests, significant difference ($p < 0.01$) was observed between the mean scores of anemic and non-anemic children, the performance being better for the non-anemics than their anemic counterparts.

The effect of sub-clinical iron deficiency (as measured by total iron binding capacity,



Nonanemic: Hb ≥12 g/dL, Anemic: Hb <12.00 g/dL, Wellnourished: BMI ≥5th percentile, Undernourished: BMI <5th percentile, *p <0.05.

Fig. 1. Effect of nutritional status on digit span scores of the girls.

serum ferritin and serum iron) on physical fitness using Harvard Step Test was reported in Punjab, India, among 18-23 year old college girls(16). A significantly ($p < 0.05$) lower rapid fitness index (RFI: calculated from total exercise time and pulse rate 1 to 1½ min after the exercise) was observed among anemic subjects against non-anemics, on paired comparison revealing that even sub-clinical iron deficiency reduces physical fitness. Research assessing the impact of under-nutrition in villages of Kashi Vidhyapith block, UP(17) found that undernourished rural boys (10-12 years) demonstrated lower scores compared to normal nourished children for abilities related to mental control, logical memory, digit span, visual reproduction and associative learning ($p < 0.001$). A study conducted on rural primary school children 6-8 years of age in Varanasi, India, reported significant difference between the IQ scores of anemic and non-anemic groups (n = 388) in sub-test digit span. There was an effect of nutritional status on IQ scores and anemics showed lower levels of attention and concentration in the arithmetic test(18).

These findings are in agreement to those in the present study; that is, various PWC and cognitive functions are compromised at different degrees of severity of anemia.

Even among adults, anemia compromises work capacity. In a Coimbatore study on twenty young adult women of same age (age not specified), it was found that non-anemic women performed much better than anemic women in various physical activities like walking, running, skipping, number of steps climbed and mopping/cleaning (area swept). After supplementation with iron, the anemic young women showed improvement in work capacity(19).

In Vadodara, India, a positive impact of iron folate supplementation on physical work capacity and cognitive abilities of school children was seen(9). On supplementing girls (9-15 yrs) with 60 mg elemental Fe + 0.5 mg folic acid for 3 months, there was a significant increase in the number of skips done by the girls using a skipping rope; and also in selected cognitive tests, as compared to the baseline values.

It appears, therefore, that not just preschool children, but even older school children and those entering adolescence are vulnerable to the adverse functional consequences of IDA, that is, poor growth and physical work capacity, and compromised cognitive abilities. In the absence of interventions, iron deficiency will not only compromise the quality of life of these children; but the subsequent poor school performance and drop-outs will especially affect girls, as it is known that girls who do badly in school are likely to drop out earlier compared to boys. Their future reproductive health may also be jeopardized, as these girls continue to be anemic and may enter pregnancy with little iron stores, poor height and weight. It is time to focus on this neglected group of early adolescence for anemia control interventions.

Key Messages

- Compared to the non-anemic girls, anemic girls took longer to return to their basal pulse rate after finishing the Modified Harvard Step test and also had a lower score in cognition tests.
- Anemia significantly compromise physical work capacity and cognitive abilities in pubertal schoolgirls in early adolescence; including mild to moderate anemia.
- Both in undernourished and wellnourished girls, anemia adversely affects cognitive abilities.
- In children entering adolescence, anemia leads to several adverse consequences.

Contributors: AS carried out the data collection, analysis and interpretation of data, review of literature and drafting of manuscript. SJK developed the conceptual framework and experimental design; developed the data collection tools, guided and supervised each stage of data collection and analysis, and revised as well as approved the manuscript of the paper for important intellectual content.

Funding: None.

Competing interests: None stated.

REFERENCES

1. Kanani S, Poojara R. Supplementation with iron folic acid enhance growth in adolescent Indian Girls. J Nutr 2000; 130: 452S-455S.
2. Beaton GH, Corey PN, Steel C. Conceptual and methodological issues regarding the epidemiology of iron deficiency. Ann Clin Nutr 1989; 50: 575-585.
3. Beard JL. Iron biology in immune functions, muscle metabolism and neuronal functioning. J Nutr 2001; 131: 568S-580S.
4. Agarwal KN. Iron and the Brain: Neurotransmitter receptors and magnetic resonance spectroscopy. British J Nutr 2001; 85, Supplement 2: S147-S150.
5. Pollitt E, Liebel RL. Iron deficiency and behaviour. J Pediatr, 1976; 88: 372-381.
6. Bhatia D, Seshadri S. Growth performance in anemia and following iron supplementation. Ind Pediatr 1992; 30: 195-200.
7. International Nutritional Anemia Consultancy Group. Guidelines for eradication of iron deficiency anemia. A report of International nutritional anemia consultancy group. New York and Washington DC. 1985.
8. Gibson RS. Principals of nutritional assessment. New York, Oxford University Press, 1989.
9. Kanani S, Singh P, Zutshi R. The impact of daily iron *vs.* calcium supplementation on growth, physical work capacity and mental functions of school going adolescent boys and girls (9 to16 yrs) of Vadodara. Department of Foods and Nutrition, M.S. University of Baroda, Vadodara, India. 1999.
10. Skubie V, Hodgikns J. Cardiovascular efficiency test scores for junior and senior high school girls in the United States. Res Quart 1964; 35: 184-192.
11. Bhatt M. Gujarati adaptation of Wechsler Intelligence Scale for Children Ahmedabad-India: Jayshree Mudranalaya Press. 1973.
12. Must A, Dalla EG, Dietz HW. Reference data for obesity: 85th and 5th percentiles of body mass index and triceps skinfold thickness. Am J Clin Nutr 1992; 53: 839-846.
13. Epi Info, Version 6.04-d. Centre for Disease Control and Prevention (CDC), Epidemiology Program Office, Atlanta, Georgia and World Health Organization, Global Program on AIDS, Geneva, Switzerland. 2001.
14. Agarwal DK, Upadhyay SK, Tripathi AM, Agarwal KN. Nutritional status, physical work capacity and mental function in school children. Scientific report 6, Nutrition Foundation of India. 1987.
15. Gowri AR, Sargunam HJ. Assessment of

mental and motor abilities of school going children with anemia. The Indian J Nutr Dietet 2005; 42: 99-105.

16. Baini K, Mann SK. Sub-clinical iron deficiency: A major factor in reducing physical fitness of young women. The Indian J Nutr Dietet 2000; 37: 296-302.

17. Agarwal KN, Agarwal DK, Upadhyay SK. Impact of chronic malnutrition on higher mental functions in Indian boys aged 10-12 years. Acta Paediatr 1995; 84:1357-1361.

18. Agarwal DK, Upadhyay SK, Agarwal KN, Singh RD, Tripathi AM. Anemia and mental functions in rural primary school children. Annals of Trop Pediatr 1989; 9: 194-198.

19. Vijayalakshmi P, Selvasundari S. Relationship between iron deficiency anemia and energy expenditure of young adult women. The Indian J Nutr Dietet 1983; 20: 113-117.