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RESEARCH ARTICLE

Effect of nutritional status on cognitive function in adolescents

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ABSTRACT

Background: Adolescents are considered to be the healthiest group among the entire population. However, due to fast food obsession, the nutritional habits of adolescent generation are changing and are unable to meet the increased nutrient requirement per unit body weight. Thus, adolescents are facing weight problems, that is, overweight/normal weight/underweight, but undernourished. **Aims and Objectives:** The aims of the study were (1) to assess the nutritional status using anthropometric measurements in the adolescents and (2) to correlate the anthropometric measurements with their cognitive performance. **Materials and Methods:** A total of 281 adolescents, height (cm), weight (Kg), and waist circumference (cm) were measured. Using these parameters, the body mass index (BMI) and waist-to-height ratio (WTHR) were calculated. Cognitive function test was carried out using Raven's Progressive Matrices (RPM). Statistical analysis was done using Pearson correlation coefficient and Fisher's exact type of Chi-square. **Results:** The gender and age distribution in the study population were not statistically significant. Gender-wise distribution of the WTHR, the BMI, and the standard RPM of the study population was statistically significant. Relation between BMI, WTHR, and RPM percentiles was not statistically significant, but regardless of the weight status, the scores were between the 25th and 50th percentile. **Conclusion:** With fast changing food habits among the adolescents, along with students, parents and teachers must also be made aware of importance of food containing all essential nutrients in optimum amounts for better cognitive functioning of the adolescent brain, and not merely focus on physically visible parameters such as weight and height.

KEY WORDS: Adolescents; Body Mass Index; Waist-to-Height Ratio; Raven's Progressive Matrices; Cognition

INTRODUCTION

Population of people falling in the age group of 10–19 years is called as adolescents. They are considered to be the healthiest group among the entire population.[1] Population of adolescents in India is documented to be around 243 million, that is, it approximately a quarter of the country's population.[2] Adolescents are the future of India and their cognitive abilities, directly or indirectly, will determine the progress of India in a decade. Scientifically, adolescence is a period wherein there are major physical, physiological, psychological changes, as well as changes in their approach to the social interactions and relationships.

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Nutrition is one of the most basic things, required by any living being on day-to-day basis. Nutrition is determined by the quantity and quality of food consumed, considering one's body's dietary needs. It is the cornerstone of good health.[3] Thus, nutrition, the intake aspect, is mainly concerned with the food consumed in terms of calories and the nutrients available in it. However, in this fast food obsessed adolescent generation, not much is thought before buying a burger, but there is lack of willingness toward buying vegetable-/fruit-based natural food products. This implies that nutritional habits are changing like never before due to the change in lifestyle and enhanced availability. Thus, adolescents are widely consuming fast foods (high in calorie and low in nutritive value), in spite of the fact that, it is an anabolic phase of life and there is increased nutrient requirement per unit body weight[4] and is affecting their health in all aspect. Nutrient needs increase for both males and females during adolescence.[5,6] Thus, adolescents and irrespective of their gender are facing weight problems, that is, overweight/normal weight/underweight, but undernourished.

Outward manifestations of nutritional status of an individual are usually obtained by anthropometric measurements, namely, height, weight, waist and hip circumference, triceps and subscapular skinfold thickness, etc., and consequently, body mass index (BMI), waist-to-height ratio (WTHR), and waist to hip ratio can be calculated.[7] Among these, BMI, as a measure to assess nutritional status, has been used since long and is very reliable, since it does not take into account age or sex.[8] Similarly, WTHR as a tool for assessment (introduced in mid-1990s) is not only a measure for body fat but also for its distribution, making it also an important tool in anthropometry.[9]

At the same time, changing technology and everything around are in a fast pace. It is a challenge posed to this generation of adolescents to keep up with it. The ability to confront the challenges depends largely on their thinking capacity as an individual, that is, the cognitive ability. The term cognition is referred to ability of the human-like processing of information, applying knowledge, and changing preferences.[10] Cognitive processes operate at every waking moment and they are also part of our personality, our intelligence, and the way we interact socially,[11] which indicates the importance of a proper cognitive function for normal life and logical decision-making, more so in most productive adolescent age group.

Different factors such as social and psychological factors play a key role in developing, functioning, and maintaining of cognitive abilities. Few of these are nutrition, exercise, and sleep.[12] It has been documented that nutritional status is an important factor for cognitive performance at school and in higher education.[13] Anthropometric measures are regularly considered to determine the nutritional status of the individual. Accordingly, it has been shown that multiple obesity indices were associated with poorer performance in a variety of cognitive domains.[14] People with higher levels of trans fats in their blood had poorer performance in thinking and memory tests.[15] At the same time, there were studies that demonstrated protein calorie malnutrition also to be having significantly impaired learning and behavior[16] along with all the organ systems in the body.[4] Nutritional status is now considered, also as looking into micronutrient deficiencies. People who had higher levels of B family vitamins as well as Vitamins C, D, and E had scored high on cognitive tests than people with lower levels. One of the reasons identified for micronutritional deficiencies is high intake of energy-dense foods that do not contain vitamins and minerals.[4] This indicates that both undernourished and overweight states have a negative impact on cognition. Thus, nutritional deficiencies play an important role in the cognitive functions of adolescents and are different from those of older adults.

For assessing cognitive function, commonly used tests are Kaufman Test of Educational Achievement, Wide Range Achievement Test 3, Wechsler tests, Stanford-Binet, Raven's Progressive Matrices (RPM), etc.[17] RPMs are widely used to determine the cognitive function test of individuals of any age group, with normal intelligence.[17]

Relationship between nutrition and cognition in adults and recently also in children has been in constant research,[14-16,18-20] but less literature is available in adolescents. Hence, the present study was taken up to determine the relationship between nutrition state in terms of anthropometric measurements and cognitive function in adolescents.

Objectives

The objectives of the study were as follows:
- To assess the nutritional status using anthropometric measurements in the adolescents enrolled into the study
- To correlate the anthropometric measurements of these adolescents with their cognitive performance.

MATERIALS AND METHODS

The research was carried out among the adolescents, who in the range of 12–18 years of age. For the same, students from a school and a polytechnic college, both in Bagalkot, Karnataka, were taken.

Sample size of the study was 281, calculated using OpenEpi software version 2.3.1 at the prevalence of overweight 9.2%,[21] at the relative precision of 20%, at 95% confidence limit.

Before the study was initiated, approval from the Institutional Ethics Committee was obtained. The general details of the student which included the name, age, gender, history of illness, and other details were asked which were entered in a pre-designed pro forma.

Inclusion Criteria

Students between 12 and 18 years of age were included in the study.

Exclusion Criteria

Students with any history of endocrinal abnormality or history of recent illness, those involved in rigorous sports training, drug and/or alcohol abuse, and those with family history of obesity were excluded from the study.

All students, included in the study, were subjected to the anthropometric measurements. Furthermore, cognitive function test was carried out on them using RPMs. Anthropometric measurements for each individual in the study were recorded, which included height (cm), weight (kg), and waist circumference (cm). Height was recorded using Holtain height stadiometer and weight by a weighing scale. Waist circumference was measured by a centimeter measuring tape. Using these parameters, the BMI and WTHR were calculated. BMI was calculated using the WHO anthroPlus software.[22] The Z score was considered. The standard classification[22] is shown in Table 1.

The overweight and obese classes were combined as the prevalence of obese was low in our study. Accordingly, in the present study, adolescents with BMI value falling in;

< −2 SD were considered underweight, −2 SD to + 1 SD were considered normal and >1 SD were considered overweight and obese.

The WTHR was calculated by a calculator, using the formula below mentioned:

WTHR = (Waist circumference)/(Hip circumference)

The nutritional status, for each adolescent in the study, was determined using Ashwell Shape Chart.[9] The chart is a plot between height (Y-axis) and waist circumference (X-axis) and the area is divided into four color zones – brown, green, yellow, and red. The grading is done, as shown in Table 2.

Cognition function test was recorded using standard RPMs.[17] RPM consisted of 60 questions. The questions were like puzzles, where a missing block of a puzzle was to be completed by choosing the correct option from multiple choices provided below each puzzle. Students were given an answer sheet and the questions were projected on a white board. The questions were timed, the students getting 7 s for the initial questions. The time progressed to 15 s as the difficulty level of questions increased. RPM was evaluated using the standard RPM key. The ranking and interpretation were done by percentile score for each adolescent in the study.

For determining statistical significance, Pearson correlation coefficient and Fisher's exact type of Chi-square tests were performed. The overall data analyzed using OpenEpi version 3.02, the results of which are presented below.

RESULTS

The data for the study were collected and analyzed for the 281 subjects based on the inclusion and exclusion criteria.

The age- and gender-wise distribution of the study population is shown in Table 3: Majority of the adolescents (both girls and boys) were between 13 and 15 years of age. Among adolescents of 12 years, girls (27.4%) were more in number than boys (7.5%). The gender and age distribution in the study population were not statistically significant.

The height, weight, and waist circumference of the study population were recorded and using this, the BMI and WTHR were calculated.

Gender-wise distribution of the WTHR of the study population is shown in Table 4: Considering the gender, the percentage of boys who were underweight was 39.8% and that of girls was 20% (33% of total study population). Of the total study population, the prevalence of students with above normal weight was 5% (including overweight and obese students). About 61.9% of adolescents of the total study population were normal weight. The above result was statistically significant.

The BMI of the study population is shown in Table 5: Considering the gender, 38.7% of them among boys and

Table 1: Reference values of BMI

Color	z score	Percentiles	Interpretation
Green	−1 SD ≤ z ≤ +1 SD	50th (at median value)	Underweight
Gold	−2 SD ≤ z < −1 SD or +1 SD< z ≤ +2 SD	15th and 85th (at −1SD or + 1SD)	Normal
Red	−3 SD ≤ z < −2 SD or +2 SD < z ≤ +3 SD	3rd and 97th (at −2 SD and + 2 SD)	Overweight
Black	z < −3 SD and z > +3 SD	NA (−3 SD and + 3 SD)	Obese

SD stands for standard deviation, z for the z score, NA stands for not available. BMI: Body mass index

Table 2: Reference values with color coding for WTHR

Color code	Ratio	Interpretation
Brown	<0.4	Underweight
Green	0.4–0.5	Normal
Yellow	0.5–0.6	Overweight
Red	>0.6	Obese

WTHR: Waist-to-height ratio

Table 3: Age- and gender-wise distribution of the study population

Age (years)	Gender (%)		
	Male	Female	Total
12	14 (7.50)	26 (27.40)	40 (14.20)
13–15	143 (76.90)	60 (63.2)	203 (72.2)
16–17	18 (9.70)	6 (6.30)	24 (8.50)
18	11 (5.90)	3 (3.20)	14 (5.00)
Total	186 (100)	95 (100)	281 (100)

22.10% of them among the girls were underweight (33.1% of the total study population). Almost 5% among boys and 10% among girls were overweight (6.4% of the total study population). About 60.5% of the total study population were of the normal weight. The above result was statistically significant.

The results of the standard RPMs of the study population are shown in Table 6: 60% of adolescent boys had scored <50th percentile, as compared to adolescent girls (49%). A higher percentage (32.60%) of girls had scored above 75th percentile as compared to 20.4% of boys. The difference in the score was statistically insignificant.

Relation between BMI and RPM percentiles is shown in Table 7: Most of the population, regardless of the weight status, had scored between the 25th and 50th percentile. A higher percentage (28%) of underweight adolescents had scored <25th percentile than normal weight (24%) and overweight students (16.7%). A lesser percentage of the underweight adolescents (31.8%) had scored above 50th percentile as compared to the 45% and 44% of normal weight and overweight adolescents, respectively. These data were not statistically significant.

Table 4: Distribution of waist-to-height ratio in the study population

WTHR	Gender (%)			
	Male	Female	Total	
Underweight (<0.4)	74 (39.80)	19 (20.00)	93 (33.10)	p=0.003*
Normal (0.4–0.5)	103 (55.4)	71 (74.7)	174 (61.9)	
Overweight (0.5–0.6)	8 (4.30)	5 (5.30)	13 (4.60)	
Obese (>0.6)	1 (0.50)	-	1(0.40)	
Total	186 (100)	95 (100)	281 (100)	

*Significant. WTHR: Waist-to-height ratio

Table 5: Distribution of BMI in the study population

BMI	Gender (%)			
	Male	Female	Total	
Underweight	72 (38.70)	21 (22.10)	93 (33.1)	p=0.012*
Normal	105 (56.50)	65 (68.40)	174 (60.5)	
Overweight and Obese	9 (4.80)	9 (9.50)	18 (6.40)	
Total	186 (100)	95 (100)	281 (100)	

*Significant. BMI: Body mass index

Table 6: Gender-wise distribution of RPM scores

RPM percentiles	Male (%)	Female (%)	Total (%)	
<25th	45 (24.20)	25 (26.30)	70 (24.90)	p=0.063**
25–50th	67 (36.00)	22 (23.20)	89 (31.70)	
50–75th	36 (19.40)	17 (17.90)	53 (18.90)	
>75th	38 (20.40)	31 (32.60)	69 (24.60)	
Total	186 (100)	95 (100)	281 (100)	

**Insignificant. RPM: Raven's Progressive Matrices

Relationship between WTHR and cognitive function is shown in Table 8: Most of the study population had scored between 25th and 50th percentiles regardless of weight status. About 50%, 46%, and 44% of the normal, overweight, and underweight adolescents, respectively, had scored above 50th percentile. These data were not statistically significant. The only obese individual of the study had scored below 25th percentile.

DISCUSSION

Food, that is, diet is the basic need of life. An apt cognitive function in adolescents decides their future. As already mentioned, relationship between nutrition and cognition in adults and also in children has been in constant research,[14-16,18-20] but less literature is available in adolescents. Hence, the present study was taken up to determine the relationship between nutritional status in terms of anthropometric measurements and cognitive function in them.

In the present study, according to the calculated WTHR and BMI, it was found that next to normal, most students were underweight. Furthermore, in the present study, proportion of overweight and obese students was less. Our study showed that obesity prevalence was 5% in both boys and girls (by WTHR); and 9% and 5% in girls and boys, respectively (by BMI). In another similar study, unlike in the present study, the prevalence of overweight for girls and for boys was 9.2% and 14.3%, respectively.[21] The low obesity and high underweight students in our study could be because the sample population was from aided institutes, where students belonging to not so affluent family take their admissions. The result of the present study, that is, a higher percentage of girls being overweight and a higher percentage of boys being underweight could be attributed to the early pubertal hormonal changes seen in girls compared to boys (majority of the adolescents in the study were between 13 and 15 years of age), resulting in weight gain, during this period. Furthermore, it could be said that boys have more calorie requirement compared to girls,[23] but have slightly higher physical activity causing more utilization of calories, which was not sufficiently provided by their diet.

In the present study, RPM scores showed that girls performed better than boys, though not statistically significant. Similar observation was documented in a study wherein the performance of girls was better compared to boys in their cognitive assessment.[24] This may be because of the different classroom behavior and approach to learning in girls than that of the boys. Researchers say that "learning" is an overall measure of child's attitude that includes attentiveness, task persistence, eagerness/willingness to learn, feeling of learning independence, flexibility, and organization.[25]

Table 7: RPM percentiles and BMI

RPM		BMI			
Percentiles	Total (%)	Underweight (%)	Normal (%)	Overweight (%)	
<25th	70 (24.90)	26 (28)	41 (24.10)	3 (16.70)	p=0.847**
25–50th	89 (31.70)	30 (32.30)	52 (30.60)	7 (38.90)	
50–75th	53 (18.90)	17 (18.30)	34 (20.00)	2 (11.10)	
>75th	69 (24.60)	20 (21.50)	43 (25.30)	6 (33.30)	
Total	281 (100)	93 (100)	170 (100)	18 (100)	

**Insignificant. BMI: Body mass index, RPM: Raven's Progressive Matrices

Table 8: WTHR and RPM

RPM	WTHR (%)				
	Underweight (<0.4)	Normal (0.4–0.5)	Overweight (0.5–0.6)	Obese >0.6	
<25th	21 (22.60)	45 (25.90)	3 (23.10)	1 (100)	p=0.987**
25–50th	31 (33.30)	53 (30.50)	5 (38.5)	0	
50–75th	19 (20.40)	44 (25.30)	3 (23.10)	0	
>75th	22 (23.70)	44 (25.30)	3 (23.10)	0	
Total	93 (100)	174 (100)	13 (100)	1 (100)	

**Insignificant. WTHR: Waist-to-height ratio, RPM: Raven's Progressive Matrices

Along with this, the better attention and ability to follow instructions among girls (which were given before the RPM was conducted) could have been one of the reasons for their better performance.

In the present study, the relation between BMI and WTHR with cognitive function was not statistically significant. Unlike the present study, association between BMI and cognitive functioning was found to be noteworthy by some studies wherein they noted that the test scores decreased as BMI increased.[26] Low anthropometric measurements were also associated with poor outcomes.[13] Studies have also indicated that poorer cognitive control acts as a risk factor for an increase in BMI.[26] This is suggestive of bidirectional association between weight status and cognitive control.[27] A research shows that students who are overweight are more likely than healthy students to report impaired school functioning[25] and thus affect their cognition. The reason for poor cognition could be that, the high calorie diets, diets high in trans fats and saturated fats negatively affecting their cognition.[15,21,28] Furthermore, other non-dietary factors that account for determining their BMI include hormonal factors such as underactive thyroid (hypothyroidism), Cushing's syndrome, and polycystic ovarian syndrome,[29] which also may independently affect the cognition in them and by mere physical examination cannot be ruled out.

Our study showed no statistical significance between BMI and WTHR with cognitive function, but there were more than 50% of the students irrespective of their anthropometric measures scoring <50th percentile in their RPM performance. This could be explained by the fact that increased consumption of convenient, that is, high calorie but low nutritive food among the adolescents may result in deficiency of various micronutrients, termed "hidden hunger.[30,31]" Such individuals with poor diet may meet/not meet/exceed calorie intake according to their energy needs, but may not have sufficient micronutrients for optimal cellular function.[32] Micronutrients are important for brain functioning including cellular energy production, maintenance, and repair; neuron, myelin sheath and glia cells generation, metabolism, and repair; neurotransmitter synthesis;[33,34] receptor binding; and the maintenance of membrane ion pumps.[35] Moreover, human body cannot synthesize sufficient vitamins and minerals to meet these requirements. Such micronutrients have to be acquired through diet or supplements.[36,37] Among the micronutrients, there are various vitamins and minerals that have been identified as essential for cognitive health.[38-40] The searches have confirmed the water-soluble vitamins such as B group and C, certain minerals such as calcium, magnesium, and zinc are essential for cognitive functions, since their deficiencies manifests as various neurological manifestations. Wernicke–Korsakoff syndrome is nothing but thiamine deficiency manifests as amnesia, ataxia, confusion, psychosis, and eventually leads to coma. Pellagra (combined deficiency of niacin and tryptophan) manifests as dementia. Vitamin B12 deficiency has shown to affect the spinal cord.[41] Vitamin B6 and Vitamin C are coenzymes for synthesis of dopamine. Deficiency of these vitamins leads to dopamine deficiency, causing attention deficit, impulsive behavior, and hyperactivity, that is, attention deficit hyperactivity disorder.[42] Likewise, zinc is identified to be an essential nutrient for neurogenesis, neuronal migration, and synaptogenesis.[43] Marginal deficiencies of one/more of such micronutrients are common and affect the cognitive performance.[44,45] Marginal deficiencies occur in people with lifestyle associated eating behaviors, for example, snatched meals, unhealthy food, fast food, fried foods, and people on chronic or periodical dieting, a behavior commonly seen in this generation adolescents. To substantiate this, there were studies wherein subjects who were given (relatively short), multivitamin/mineral supplementation showed improvements in a number of cognitive functions such as working memory and planning/processing speed.[34] Foods containing sources of Vitamins B1, B6, and C, that is, rice with multigrains, mushrooms positively affect the cognitive function. In contrast, processed foods, that is, white rice, noodles, any kind of fast food, and aerated drinks like Coca-Cola negatively affect the cognitive functions. Poor micronutrient intake negatively affects cognition in adolescence.[46-48] According to the Nutrition Cognition Initiative, continuously consuming food with low nutritional value makes them are low in energy, limiting their physical activity, and cognitive functioning such as motivation and attentiveness.[29] This also makes them more prone for illness, resulting in school absentism,[49] and affecting their cognitive functions in long term. This suggests that both weight (calories consumed) and proper nourishment (nutrients consumed), which cannot be measured purely by the anthropometric measures, contribute to the cognitive functioning of the brain.[24]

In the present study, only anthropometric measurements were considered for assessing the nutritional status indirectly assessing only the calories consumed, whereas carbohydrate, protein, fat, and mineral consumption were not calculated. Nutrient baseline levels of the nutrients, which affect the current nutritional status of an adolescent, were not measured. It was also difficult to exclude effects of other non-diet factors[19] such as hormonal factors and physical activity on the results of the present study (since exclusion for endocrinal disorder was done based on history given by the adolescent and not by biochemical parameters). The prevalence of overweight and obese students was less in the present study; hence, the cognition in overweight population could not be clearly tested.

This states that further research concentrating on acquiring a good and accurate dietary pattern by weighing the raw materials for detailed nutritive value of each food consumed, also by evaluating the blood levels of the nutrients, excluding subjects by laboratory values of hormones to avoid hormonal influences on results, equal sampling of subjects in all the categories of weight, and equal sampling from more number institutes could be done.

CONCLUSION

It is not a surprise that what we eat is what influences the brain.[19] Diet is the only door to recommended nutritional status and a proper brain cognitive functioning. This is the need of the hour and even more relevant, with fast changing food habits among the fast food obsessed (high calorie, but low in nutritive value) adolescent generation these days. Undernourishment leads to decreased, while appropriate nourishment helps in achieving optimum brain functioning. Along with students, parents and teachers must be stressed upon, on the importance of consuming adequate food, containing all essential nutrients in optimum amounts for better cognitive functioning of the adolescent brain, and not merely focus on physically visible parameters such as weight and height.

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