Body Mass Index (BMI) and Cognitive abilities in school going boys: A Cross sectional study

Dr. Parthasarathi Debray*

ABSTRACT

BMI represents an index of an individual's fatness and acts as a risk factor for the development of or the prevalence of several health issues. Cognition refers to mental processes such as attention, memory, problem-solving, and decision-making. Childhood is a crucial period for cognitive development. Factors such as genetics, environment, nutrition, and socioeconomic status can influence cognitive abilities in children. The cognitive control of behavior has been studied in a popular paradigm is the task developed by Stroop. It is important to note that research in these areas is ongoing, and individual differences, environmental factors, and other variables can influence the relationships between Body mass index (BMI), cognition, and stroop performance in children. Three Hundred Ninety eight (398) apparently healthy school going boys studying in class I to Class X standard of different socio-economic background were recruited randomly from different schools of Udaipur subdivision, Gomati District, Tripura. After taking height and weight all participants were tested individually a mobile based modified 'Stroop color word' test based on the original Stroop test (Stroop, 1935) to identify cognitive abilities of mental attention. Reaction time was measured by the mobile based apps "Reaction Time (Bensoft, 2016). It is concluded in the present study that the cognitive abilities in terms of stroop performances and RT are not significantly differed among under-weight, normal and overweight-obesity subjects classified based on BMIP (BMI percentile). In partial correlation when age is controlled showed that BMI did not have any significant correlation, but RT's have significant negative correlation with BMI. So, BMI is associated with RT.

Keywords: *Cognitive abilities, stroop performance, stroop effect, Reaction time (RT), Boys, BMI*

About Author:

**Associate Professor, Department of Human Physiology, NS Mahavidyalaya, Udaipur, Gomati District, Tripura, India*

Introduction

Growth and development starts before infancy and continues up to the adolescent period (**Ranbhaat, 2016**). Physical growth is the geometric growth of cells and can be directly observed. BMI can be measured by height and weight. It represents an index of an individual's fatness. It also is widely used as a risk factor for the development of or the prevalence of several health issues (**Nuttall, 2015**). Like physical growth, it is difficult to measure cognitive development. There are many tests to measure different types of development of children including Cognitive development (**Ranabhat et al., 2016**). Childhood is a crucial period for cognitive development. Factors such as genetics, environment, nutrition, and socioeconomic status can influence cognitive abilities in children. However, it is difficult to predict as many factors influences this such as age, gender, socio-economic factors etc (**Brooks & Duncan, 1997**).

Currently, the problem of child obesity has been highlighted in developed countries but factors related to child growth and development in developing countries are less noticed (**Ezzati, 2002; Steves, 2012**). Globally, more than one-third and 60% of families in developing countries are suffering from poor nutrition and this impact would reflect in the physical and cognitive development of children (**Doak, et., 2005; Kelly et., al., 2008**).

The developing human brain requires all essential nutrients to form and to maintain its structure. Infant and child cognitive development is dependent on adequate nutrition. Children who do not receive sufficient nutrition are at high risk of exhibiting impaired cognitive skill (**Roberts, et al., 2022**). Malnutrition or over nutrition (obesity) may have implications for cognitive function (**Khan et al., 2014**).

The cognitive control of behavior has been studied in many experimental paradigms of human information processing. A popular paradigm is the task developed by Stroop (**Macleod, 1991**). Research on the relationship between BMI and cognitive performance, including Stroop performance, has been mixed, and findings vary across studies. Some studies suggest that higher BMI is associated with poorer cognitive performance, while others find no significant relationship (**Li et al., 2008; Bauer, 2010; Pearce et al., 2016; Rannabhat, et al., 2016; Meo et al., 2019**). Hence, the current study was undertaken healthy school going boys to identify relationship between BMI and cognitive abilities including mental attention and reaction time.

Materials and Methods

Participants:

Three Hundred Ninety eight (398) apparently healthy school going boys studying in class I to Class X standard of different socio-economic background were recruited randomly from different schools of Udaipur subdivision, Gomati District, Tripura. Subjects were inhabitants of Udaipur subdivision, Gomati District, Tripura, India. Udaipur is a plain area surrounding by hilly areas. **Udaipur** is the third biggest urban area in the Tripura. Udaipur is located at 23.53°N 91.48°E. It has an average elevation of 22 metres (72 feet). (**https://en.wikipedia.org/wiki/Udaipur, Tripura**) .

Students with known case of chronic diseases such as diabetes mellitus, asthama, epilepsy, cognitive disorders, sleep disorders, vision problems, anxiety, attention deficit, skeletal muscle disorders, and those who had a history of sleep disturbances or were using sedetives were excluded from the study (**Durazzo, 2010, Meo, 2017; Meo, 2019**) and did not follow any physical conditioning program, apart from some recreational sports.

Data were collected during school time. Prior to initial testing an informed consent were taken after giving a complete explanation of the purposes, procedures and potential risks and benefits involved in the present study. They had a light breakfast 2-3 hours before the test and refrained from any energetic physical and mental activity.

Experimental design:

Age was computed from the date of birth and date of tests. Body weight was taken using a weighing machine when boys were without shoes and wearing minimum clothes. Height was measured by an anthropometric rod. Body Mass Index (BMI) was calculated from height and weight by the following formula:

BMI = weight in kilograms divided by the square of the height in meters (kg/m^2).

After taking height and weight all participants were tested individually with a mobile based modified

'Stroop color word' test based on the original Stroop test (**Stroop, 1935**) to identify cognitive abilities of mental attention.

Stroop performance

Stroop performance was measured by the mobile based app called 'Stroop Effect Challenge' (**Dungan, 2014**).This apps will test attention skills, cognitive flexibility and processing speed.

Procedure: In this app a sequence of 30 words with different color. Subject will sit on a stool and kept the mobile phone (smart phone, android based) on the table in front of the subject keeping in mind the subject was comfortable to complete the test. He identified color used to display each word as quickly as possible irrespective of the written word like Stroop Subtask III. In the original stoop test in Subtask III subjects will ask the name the colors in which the words are written to measure the stoop effect. The important thing in the app is that unless until subject comples one task correctly, next step will not be shown in the mobile phone screen. After completion the whole task timings of the stoop performance are shown in the mobile screen.

The procedure of the tests adopted in the present study was described to all participants. They were tested three times and best one was recorded in milli seconds from the mobile phone.

Reaction time:

Reaction time was measured by the mobile based apps "Reaction Time (**Bensoft, 2016**).

Procedure: In this app there is a blue screen. By clicking blue screen a red screen will appear showing 'wait for green'. When screen turns 'Green' then the subject will have to touch by the fingers to the screen as quickly as possible. Then software immediately counts reaction time in mills seconds (ms). There are five trials. Best one is given by the app automatically in the mobile screen.

After collecting data it was stored in the computer (PC) and data analysis was performance using the SPSS.

Mean, standard deviation, minimum value, maximum value was obtained for all the selected variables of the subject. Person's products moment correlation co-efficient and also bi-variate partial correlation was performed to examine the relationship of age, BMI and cognitive performances.

One way ANOVA was conducted to examine mean difference between the variables in each group and post–hoc multiple comparison tests (Scheffe's test) were performed for each of the variables to see the significant difference in each pair of group where the F values in the one way ANOVA are significant.

Results

Descriptive characteristics such as physical variables including cognitive abilities are presented in the Table 1 and Fig 1& 2. The mean age, height and weight of the boys are 12.1± 2.21 years, 146.3 ± 13.34 cm and 37.5 ± 11.64 kg respectively. The mean BMI is found to have 17.1 ± 3.30 $kg.m^2$. The mean stroop performance and reaction time is found to have 52.5 ± 23.68 sec and 459.7 ± 158.92 milli sec respectively.

BMI percentile (BMIP) of the boys are calculated from the age matched BMI percentile chart based on revised Indian Association of Pediatrics (IAP) Growth Chart (**Khodilkar, 2015**). According to these all the 398 boys were categorized as 'under-weight' (BMIP < 5), 'Normal' (BMIP 5-70), 'overweight-obese' (BMIP 71 or more) and tabulated in Table 2. It is shown that the mean stroop performance is greater in under-weight group i.e., 57.3 ± 25.95 sec and least in overweight-group i.e., 50.8±25.04 sec. Likewise stroop performance, RT also shows greater timings in under-weight group i.e., 491.4 ±188.68 milli sec and least in overweight-obese group i.e., 437.9 ±132.42 milli sec. However, in both the cases the observed mean values are not statistically significant.

Table: 1. Descriptive characteristics including cognitive abilities of the school going boys (standard I to X) of Udaipur, Tripura [n, 398]

Variables	Mean	SD	Minimum	Maximum
Age (years)	12.1	2.21	6.0	16.0
Height (cm)	146.3	13.34	109.0	175.5
Weight (kg)	37.5	11.64	15.0	74.0
BMI (kg. m^2)	17.1	3.30	8.7	**27.7**
Stroop performance (sec)	52.5	23.68	19.0	200.0
Reaction Time (milli sec)	459.7	158.92	117.0	1058.0

BMI, Body mass index;

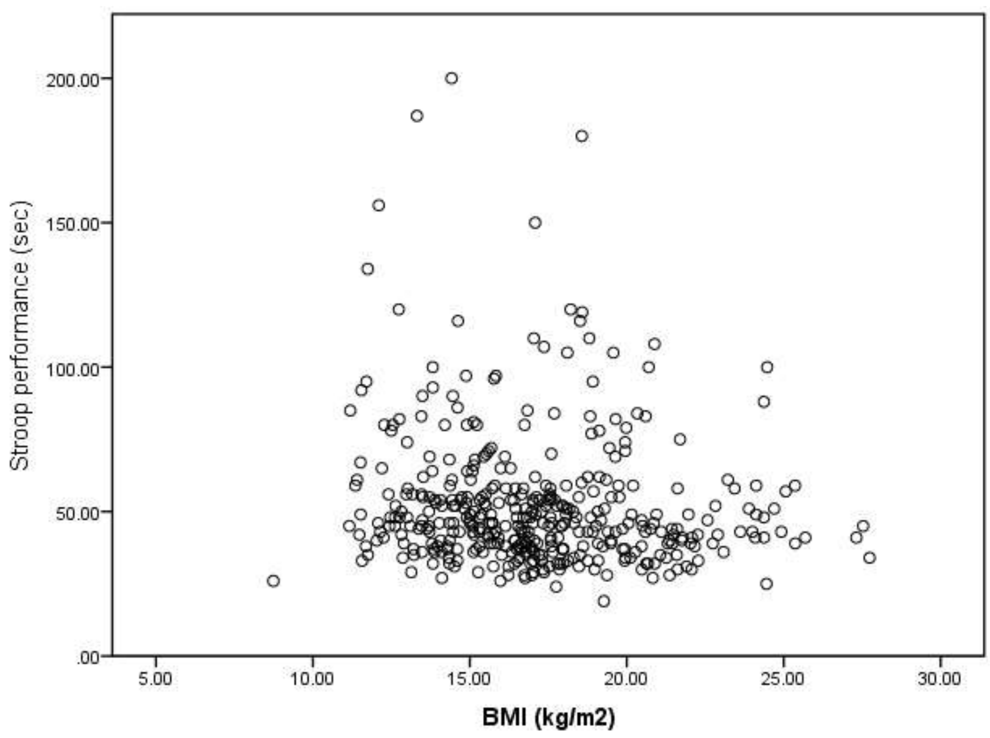

Fig. 1. Scatter Diagram of body mass index (BMI) vs stroop performance of the school going boys of the present study

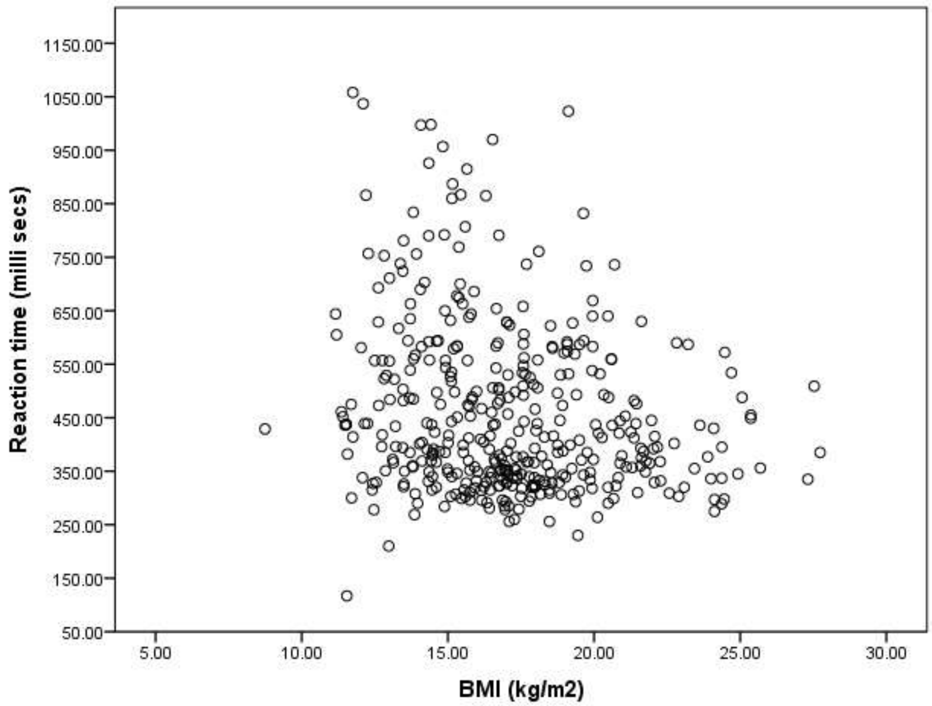

Fig.2. Scatter chart plot of body mass index (BMI) vs reaction time of the subject of the present study

Table: 4.2. Comparisons of the cognitive abilities of different level of obesity# of the subjects of the present study [n, 398]

Variables	Under weight (BMIP less than 5th percentile) (n, 52)	Normal (BMIP 5th to 70th Percentile) (n, 259)	Overweight & obese (BMIP >71th Percentile) (n, 87)	F value with level of significance
Age (years)	10.9 ± 2.30	12.5 ± 2.16	11.7 ± 1.99	13.0**
Stroop performance (sec)	57.3 ± 25.95	52.0 ± 22.68	50.8 ± 25.04	1.37ns
Reaction Time (milli sec)	491.4 ± 188.68	460.6 ± 159.8	437.9 ± 132.42	2.03ns

Values are Mean ± SD; BMIP, Body mass index percentile; Comparisons are made by one way ANOVA. BMIP are based on Revised IAP Growth Chart (Khodilkar, 2015). ** p <0.01, NS, Not significant

To find out relationship of age and BMI with Cognitive abilities such as stroop performance and RT, Pearson product moment correlation was done. It is interestingly noted that age is negatively and significantly (P<0.01)correlated with stroop performance (-0.34) and RT (-0.28). BMI also have negative and significant correlation (p < 0.01) with stroop performance (-0.13) and RT (-0.21). However when partial correlation are performed by controlling age, it shows BMI has only significant relationship with RTs, but significant level and value of r decreases (-0.13, p<0.05). Stroop performance does not have any significant relationship with BMI.

Table: 4.3. Pearson product moment correlation between age, BMI with cognitive abilities of the boys

Variables	Stroop Performance	Reaction Time
Age (years)	-0.34**	-0.28**
BMI (kg/m^2)	-0.13**	-0.21**

Pear son product moment correlation was performed, *P<0.01

Table: 4.3. Partial correlation of BMI with cognitive abilities of the school going boys when age is partialed out

Variables	Stroop Performance	Reaction Time
BMI (kg/m^2)	-0.03 ^{ns}	-0.13*

Bivariate correlation was performed, *P<0.05, NS, Not significant

Discussion

The cognitive control of behavior has been studied in many experimental paradigms of human information processing. A popular paradigm is the task developed by Stroop (**1935**). During his task, color names are presented in compatible or incompatible colors with the instruction to ignore the prepotent inclination to read the name and, instead, name the color in which it is printed. The challenge to cognitive control occurs when the inclination and the required response are in conflict (e.g. the word 'blue' presented in a red font). The recognition and resolution of the conflict is controlled, in part, by neural systems within the prefrontal cortex and anterior cingulated (**Pardo et al., 1990; Carter et al., 2000; Barch et. al., 2001; Kerns, 2006**).

It is concluded in the present study that the cognitive abilities interms of stroop performances and RT are not significantly differed among under-weight, normal and overweight-obesity subjects classified based on BMIP (BMI percentile). In partial correlation when age is controlled showed that BMI did not have any significant correlation, but RT's have significant negative correlation with BMI. So, BMI is associated with RT. Research on the relationship between BMI and cognitive performance, including Stroop performance, has been mixed, and findings vary across studies. Some studies suggest that higher BMI is associated with poorer cognitive performance, while others find no significant relationship (**Li et al., 2008; Bauer, 2010; Pearce et al., 2016; Rannabhat, et al., 2016; Meo et al., 2019**).

Inhibitory tasks stroop, was adopted to be as homogeneous as possible in terms of visual-spatial presentation and motor requirements. This cognitive tasks (strop test) activate different task-relevant fronto-cingulo-striatal neural networks, i.e left-hemispheric parieto-temporal and fronto-striatal regions during the Stroop task (**Rubia et al., 2006**).

Leptin produced by white adipose tissue and can cross the blood-brain barrier have been proposed to be an early indicator of cognitive impairment (**Johnston ,2014**). Higher levels of leptin, consistent with more adipose tissue, are also associated with worse cognitive function (**Gustafson et al., 2015; Tsai et al., 2017**). Although inhibitory control capacity has been explored in obese children **(Tsai, et al., 2016**), this type of cognitive deficit should be considered from a developmental psychopathology perspective due to the protracted development of the neural networks underlying inhibitory control (**Nigg et al., 2017)**. However, the neurophysiological and biochemical mechanisms underlying the relationship between inhibitory control deficits and obesity remain poorly understood (**Wen et al., 2020**).

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