A Cross-sectional Assessment of Body Mass Index and Cognitive Abilities in School-Going Girls

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Abstract

Body Mass Index is a pointer for measuring nutritional health in children and adolescents. Cognition means attention, memory, problem-solving, and decision-making. Cognitive development mainly happened in childhood, and factors such as nutrition, environment, genetics, and socioeconomic status can influence cognitive abilities. Recent research has explored about BMI and cognitive functions, including attention and reasoning. A widely used paradigm to assess cognitive control is the Stroop task. In this study, 439 apparently healthy school-going girls from classes I to X, representing various socio-economic backgrounds, were randomly recruited from schools in the Udaipur subdivision, Gomati District, Tripura. After measuring height and weight, participants were individually tested using a mobile-based modified stroop test. to assess mental attention. Reaction time measured using the mobile app (Bensoft, 2016). The results indicate, there is no significant difference found among subjects classified by BMI percentiles as underweight, normal, and overweight-obese. However, reaction time is negatively correlated with BMI. But, correlation (partial)controlling for age revealed no significant relationship between BMI and either cognitive ability & reaction time. The present study suggest that BMI does not have an inhibitory effect on cognitive performance, as measured by Stroop performance and also reaction time, in school-going girls of the present study.

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

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Introduction

BMI is an indicator for assessing nutritional, health status etc in children and adolescents and reflects both undernutrition and overnutrition. It is measured by dividing weight in kilograms by the square of height in meters (**World Health Organization, 2007**). Now days research focuses on the relation in between Body mass index and cognitive abilities such as attention, memory, reasoning, and problem-solving (**Kail**, **2012**). These cognitive processes are essential for academic performance and overall developmental outcomes.

Both under nutrition and overnutrition can impair cognitive development. Undernutrition may hinder brain growth and concentration, while overnutrition, particularly obesity, is associated with inflammation, hormonal imbalance, and sleep disturbances that negatively affect cognitive performance (**Taras & Potts-Datema**, **2005**; **Singh et al**., **2014**; **Khan et al., 2014**). Less Physical activity and poor dietary practice linked with higher BMI. Besides, BMI is also related with lower academic achievement (**Donnelly et al.**, **2016**).

While childhood obesity is well-studied in developed countries, its effects in developing regions are less recognized. Over one-third of families and up to 60% of households in these regions face inadequate nutrition, which hampers children's physical and cognitive development (**Doak et al., 2005; Kelly et al., 2008; Ezzati, 2002**). Adequate nutrition is essential for brain growth, and deficiencies increase the risk of cognitive impairment (**Roberts et al., 2022**).

One of the most widely used paradigms to assess cognitive control and selective attention is the Stroop task, which measures the ability to inhibit automatic responses in the presence of conflicting stimuli (**Stroop, 1935**). Reaction time (RT), another important cognitive parameter, reflects the speed of information processing and motor response. Together, these measures provide valuable insights into executive function and attentional processes.

Cognitive development is controlled by genetics, environment, nutrition, and socioeconomic factors, making it difficult to predict and measure (**Brooks & Duncan, 1997; Ranabhat et al., 2016**). Research on the association between BMI and cognitive performance has shown mixed results i.e., remain inconsistent, with some reporting significant associations between BMI and cognitive performance, while others observe minimal or no relationship (**Macleod, 1991; Li et al., 2008; Bauer, 2010; Meo et al., 2019**).

The relationship between BMI and cognitive abilities is particularly important during childhood and adolescence, a critical period marked by rapid physical growth and neurocognitive development. In girls, this relationship may be further influenced by gender-specific factors such as pubertal hormonal changes, socio-cultural expectations, and differences in nutritional practices .

However, there is limited research available on the association between BMI and cognitive abilities on the particularly particularly using simple field-based cognitive measures in the regions like nort-east India.

So, the present study was undertaken among healthy school-going girls to find out the relationship between the Body mass index and cognitive abilities, specifically mental attention and reaction time.

Methods

Participants:

Four thirty nine (439) apparently healthy school going girls studying in class I to Class X standard of different socio-economic background were recruited randomly from different schools of Udaipur, Gomati District, Tripura. 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](https://en.wikipedia.org/wiki/Udaipur,_Tripura)**).

Students with health issues, including asthma, epilepsy, cognitive impairments, sleep-related disorders, visual impairments, anxiety disorders, attention deficits, sleep disorders, musculoskeletal conditions or or those currently using sedative medications, has excluded from study. (**Durazzo, 2010, Meo, 2017; Meo, 2019**). The subjects are also having no physical conditioning program except few recreational sports.

Prior to initial testing an 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.

Subjects were not allowed to do any energetic physical and mental activity before testing.

Experimental design:
The age in completed year, standing height in nearest centimeter without shoes and body weight in kilogram in minimum clothing were recorded for each subject.

BMI was calculated by the following formula:

$$BMI = \frac{\text{Weight in kilogram}}{\left(\text{Height in meter}\right)^2}$$

Stroop performance

Stroop performance measured by the mobile based app called 'Stroop Effect Challenge' (**Dungan, 2014**) based modified 'Stroop color word' test based on the original Stroop test (**Stroop, 1935**).

Procedure: In this app a sequence of 30 words with different color. Subject will sit comfortably on a stool and kept the mobile phone (smart phone, android based) on the table. He identified color used to display each word as quickly as possible irrespective of the written word like Stroop Subtask III i.e., 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. Three tests were taken and the best performance was recorded in milliseconds using a mobile phone.

RT: RT was assessed 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 analysed by the statistical software SPSS. Mean, standard deviation (SD), minimum value, maximum value were obtained. Person's products moment and partial correlation was performed. ANOVA was performed (one way) to examine significant difference in between the variables in each group.

However, both applications such as 'Stroop Effect Challenge' (**Dungan, 2014**) and "Reaction Time" (**Bensoft, 2016**), are based on well-established paradigms in Cognitive Psychology, namely the Stroop Effect and reaction time tasks are demonstrated with high validity and reliability in laboratory settings. Importantly, a notably an increasing no of studies, indicates that mobile-based adaptations of these paradigms show acceptable levels of reliability and construct validity, with only minor latency-related differences compared to laboratory instruments, while maintaining consistent relative performance across participants. Therefore, although the specific mobile based applications in the present study lack independent validation, their methodological use is supported by evidence from similar smartphone-based cognitive assessments in different studies (**Onnela & Rauch, 2016; Miller et al., 2018; Plant et al., 2019; Dyer et al., 2020**).

Results

Descriptive characteristics including cognitive abilities are presented (Table 1, Fig 1& 2). Girls are about 12.1± 2.24 years aged. The mean height and weight of the girls are found to have 143.7 ± 11.83 cm and 37.0 ± 11.27 kg respectively. The mean BMI is found to have 17.60 ± 3.72 $kg.m^2$. The mean stroop performance and reaction time is found to have 52.4 ± 22.98 sec and 464.7 ± 148.36 milli sec respectively.

BMI percentile (BMIP) of the girls 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 439 girls were categorized as 'under-weight' (BMIP < 5), 'Normal' (BMIP 5-74), 'overweight-obese' (BMIP 75 or more) and Tabulated in Table 2. It is revealed that the mean stroop performance is greater in normal group i.e., 51.97 ± 22.33 sec and least in under weight group i.e., 53.51±25.22 sec. On the other hand, RT shows greater timings in under-weight group i.e., 478.87±173.83 milli sec and least in overweight-obese group i.e., 450.30 ±131.91 milli sec. However, in both the cases the values are not significant.

Table 1: *Descriptive Characteristics Including Cognitive Abilities Of The School Going Girls (Standard I To X) Of Udaipur, Tripura (n, 439)*

Variables	Mean	SD	Minimum	Maximum
Age (years)	12.1	2.24	4.60	18.0
Height (cm)	143.7	11.83	111.0	199.0
Weight (kg)	37.0	11.27	15.0	74.0
BMI ($kg. m^2$)	17.60	3.72	10.41	31.50
Stroop performance (sec)	52.4	22.98	21.0	180.0
Reaction Time (milli sec)	464.7	148.36	125.0	1083.0

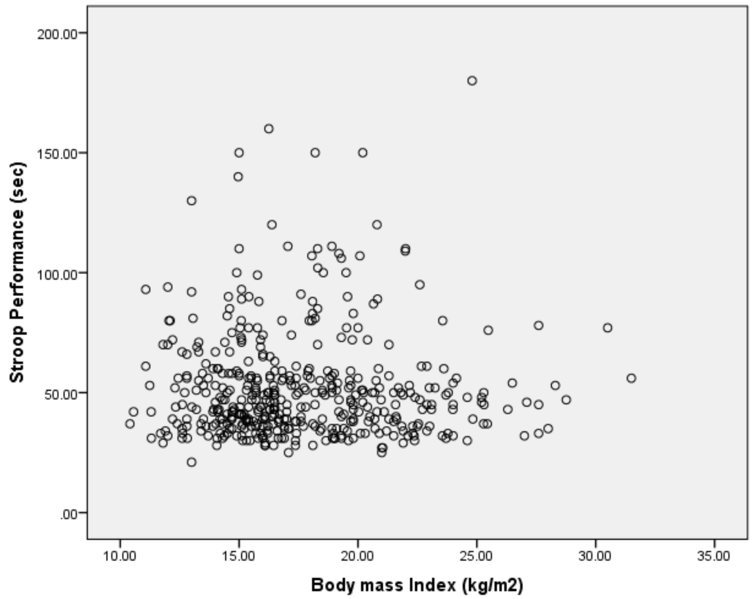

Figure. 1: Scatter Diagram of the BMI vs stroop performance of the school going girls

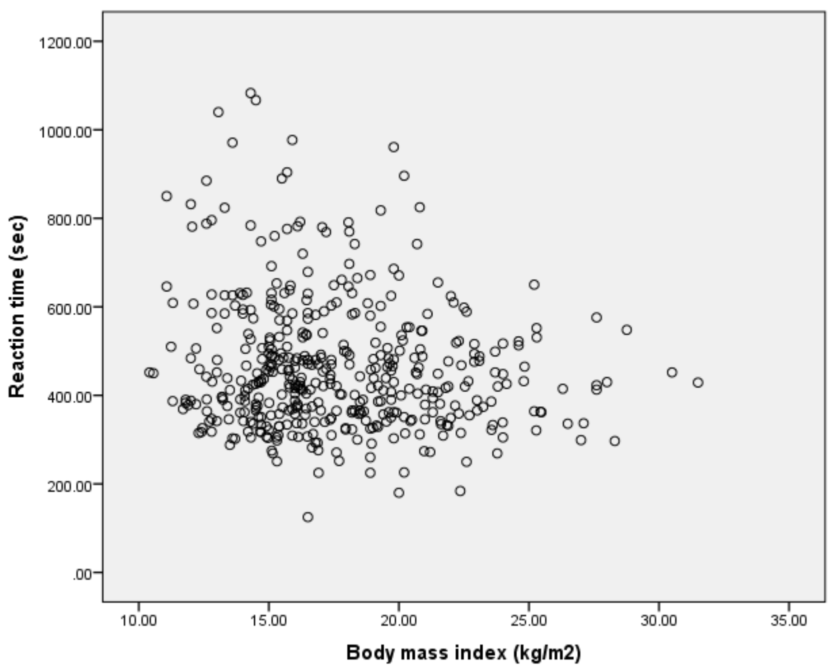

Figure 2: Scatter diagram of the BMI vs stroop performance of the school going girls

Table 2: *Comparisons of the cognitive abilities of different level of obesity# of the school going girls (n, 439)*

Variables	Under weight (BMIP less than 5th percentile) (n, 47)	Normal (BMIP 5th to 74th Percentile) (n, 291)	Overweight & obese (BMIP >75th Percentile) (n, 101)	F value with level of significance
Age (years)	10.8 ± 2.64	12.3 ± 2.04	12.1 ± 2.39	9.07^{**}
Stroop performance (sec)	53.5 ± 25.22	51.9 ± 22.33	52.9 ± 23.45	0.13^{ns}
Reaction Time (milli sec)	478.8 ± 173.83	467.2 ± 149.47	450.3 ± 131.91	0.73^{ns}

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

It is interestingly noted that age is negatively and significantly (P<0.01)correlated with stroop performance (-0.17) and RT (-0.17). BMI also have negative and significant correlation (p < 0.01) only with RT (-0.14) (Table 3). However when partial correlation are performed by controlling age, it shows Stroop performance and RT have no significant relationship with BMI (Table 4).

Table 3: Correlation of *age and BMI with cognitive abilities of the school going girls*

Variables	Stroop Performance	Reaction Time
Age (years)	-0.17**	-0.17**
BMI (kg/m^2)	-0.009^{ns}	-0.14**

*P<0.01

Table 4: *Partial correlation of BMI with cognitive abilities of the school going girls when age is partialed out*

Variables	Stroop Performance	Reaction Time
BMI (kg/m^2)	-0.06^{ns}	-0.08^{ns}

*P<0.05, NS, Not significant

Discussion

The cognitive control of behavior, observed through experimental paradigms of human information processing. This cognitive function is studied with Stroop task developed by **Stroop (1935),** in which participants are instructed to name the color of words rather than reading the word itself, especially when the color and the word meaning are incongruent (e.g., the word "blue" printed in red). Such tasks create conflict between the automatic tendency to read and the required response, challenging cognitive control. Neural systems in the frontal and cingulate cortex take part in recognizing and resolving this conflict (**Carter et al., 2000; Barch et al., 2001; Kerns, 2006).**

The present study examined the association between body mass index (BMI) and cognitive abilities, specifically Stroop performance and reaction time, among school-going girls. The findings indicate that there were no significant differences in cognitive performance across BMI categories (underweight, normal, and overweight-obese). In the present study it is noted that age is negatively and significantly (P<0.01)correlated with stroop performance Although BMI showed a weak negative correlation with reaction time, this association lost significance after controlling for age, suggesting that age may act as an important confounding variable in the relationship between BMI and cognitive function.

The absence of a significant association between BMI and cognitive performance in the present study corroborates with several previous investigations that have reported no clear relationship between adiposity and cognitive outcomes in children and adolescents (**Li et al., 2008; Bauer, 2010; Rannabhat et al., 2016; Meo et al., 2019**).These findings suggest that BMI alone may not be a sufficiently sensitive indicator to predict cognitive abilities, particularly when other developmental and environmental factors are taken into account.

In contrast, some studies have reported that higher BMI is associated with poorer cognitive performance, which is mediated through biological mechanisms such as systemic inflammation, insulin resistance, and altered levels of hormones like leptin that influence brain function (**Li et al**., **2008**; **Johnston**, **2014**; **Tsai et al**., 2017). However, such associations are often influenced by confounding variables including age, physical activity, nutritional quality, and socio-economic conditions (**Donnelly et al., 2016**). The present findings support the idea that when age-related developmental differences are accounted for, the independent effect of BMI on cognition may be minimal.

The significant negative correlation observed between age and both Stroop performance and reaction time suggests that cognitive efficiency improves with increasing age, likely reflecting maturation of neural circuits involved in attention and executive control. This observation is consistent with developmental neuroscience literature, which highlights progressive refinement of frontal and cingulate cortical regions during childhood and adolescence (**Barch et al., 2001; Kerns, 2006**).

Overall, the findings of the present study suggest that BMI does not have a significant independent effect on cognitive performance, as measured by Stroop task and reaction time, in school-going girls when age is taken into account. These results are consistent with earlier findings reported in similar populations (**Debray, 2024**).

However, A notable limitation of the present study is the absence of a structured assessment of socio-economic status (SES), despite its recognized influence on cognitive development. Although participants were drawn from diverse socio-economic backgrounds, detailed SES indicators such as parental education, occupation, and household income were not systematically collected and therefore could not be incorporated into the statistical analysis. This omission may have limited the ability to fully account for environmental and contextual factors that potentially influence both nutritional status and cognitive performance. Future studies are strongly recommended to include standardized measures of socio-economic status to enable a more comprehensive understanding of the relationship between body mass index and cognitive abilities in the children. Another consideration is the use of mobile-based applications for assessing cognitive performance. While these tools are based on established paradigms and offer practical advantages in field settings, they may not fully replicate the precision of standardized laboratory-based assessments. However, efforts

were made to ensure reliability through repeated trials and controlled testing conditions.
Future research should adopt a more comprehensive approach by incorporating detailed measures of socio-economic status, dietary quality, physical activity, and neuropsychological assessments

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