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Association of BMI and Visual Reaction Time Among Medical Students: A Cross-Sectional Observational Study

Dr.Y. Raghu Srinivas[1], Dr.P. Jersey Shiny[2], Dr. H. Ravi Kumar[3], Dr. B. Deepthi Rani[4*]

[1]Associate Professsor, Department of Physiology, GEMS&H, Ragolu, Srikakulam, Andhra Pradesh, India.
[2]Assistant Professor, Department of Physiology, GEMS&H, Ragolu, Srikakulam, Andhra Pradesh, India.
[3]Assistant Professor, Department of Physiology, Government Medical College, Vizianagaram, Andhra Pradesh, India.
[4*]Associate Professsor, Department of Pharmacology, GEMS&H, Ragolu, Srikakulam, Andhra Pradesh, India.

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ABSTRACT:

Background: Obesity has been increasingly recognized as a growing global public health burden that goes beyond metabolic and cardiac functions affecting the cognitive and sensory-motor processing abilities. Visual reaction time (VRT) is known as a reliable measure of the sensory-motor processing speed but its relationship with the variations in the body mass index (BMI) in medical students, who experience special mental and academic pressure, is under explored. **Objectives:** To assess the relationship between BMI category and VRT in medical students and to establish the predicting power of BMI on VRT. **Methods:** Cross-sectional observational study was carried out among 124 undergraduate medical students (aged 18–25 years) from a Tertiary care teaching hospital. Subjects were categorized into underweight, normal weight, overweight and obese using Asia-Pacific BMI cut-off values. VRT measurement was done using an online computerized reaction-timer with standardized testing procedure and recording of the mean reaction time from three trials each. One-way ANOVA and Tukey post hoc analysis and simple linear regression was applied to the data analysis with significance level set at $p<0.05$. **Results:** There was a statistically significant difference in the mean of VRT across BMI categories (underweight 234.6±24.3ms, normal weight 214.8±19.7ms, overweight 238.2±22.1ms, obese 252.4±27.6ms; $F(3,120)=14.87$, $p<0.001$). Post-hoc test revealed that the mean VRT in the normal weight category was significantly lower compared to other groups ($p<0.05$) while the mean VRT in obese category was the highest. Linear regression found that BMI is a significant predictor of VRT ($VRT = 168.4 + 3.62\times BMI$; $R^2=0.223$, $p<0.001$) with moderate positive correlation ($r=0.472$, $p<0.001$). **Conclusion:** At both extremes of BMI distribution, especially obesity, is associated with slower visual reaction time of medical students with the normal weight individuals showing the quickest sensory-motor response. BMI is a statistically significant but a weak predictor of VRT. These results suggest the inclusion of weight management counseling in the strategy for enhancing cognitive-motor

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performance in medical trainees.

INTRODUCTION:

Obesity can be considered as one of the most urgent problems in the area of global public health. In the past forty years, the incidence rate of obesity has increased dramatically not only in developed countries but also in developing nations (1–3). The adverse effects of excess adipose tissue on metabolism, heart system, and endocrine system are well known; additionally, recent research shows the adverse effects of obesity on cognitive abilities and motor performance (4). Reaction time (the time interval between the appearance of a stimulus and motor response) is a sensitive parameter reflecting the efficiency of central nervous system processes and sensory-motor coordination. The time interval depends on such variables as body composition, physical activity, diet, sleep and age (5–7). The time interval of visual reaction is an indicator of the speed of processing information in the visual cortex and motor response (6). Therefore, visual reaction time (VRT) provides a non-invasive method for studying effects of physiological changes in obesity on brain functions.

In terms of mechanisms, the effects of changes in systemic inflammatory markers, adipokine secretion, insulin signaling, and neuromuscular coordination on slowing down of reaction time have been suggested (4,13,15,18). On the other hand, the prolonged reaction time has been noted in the case of patients with a low body weight due to the effect of such mechanisms as increased sympathetic activity, decreased muscle mass or nutritional deficiency (6,16).

The association between obesity and impaired cognitive or motor function has been studied in general population and paediatric population (3,4,13,15). Moreover, some studies have investigated the association between body mass index and reaction time (6,14,16,17). However, results obtained by different authors are inconsistent. While some researchers have found a significant effect of body mass index on slowing down of reaction time (4,13,18), other authors did not find any correlation between BMI and reaction time (7,15). The results concerning reaction time in underweight individuals are especially inconsistent (6). Most of the current studies were carried out in the general population, athletes, or children. Therefore, it is necessary to investigate how variations in BMI affect sensory-motor performance in young adults with the specific features like intensive cognitive training (medical students). Thus, it is interesting in terms of medical education because the speed of sensory-motor processing has direct implications for learning of clinical skills and safety of patients in the future.

AIM AND OBJECTIVES:

Aim: To assess the relationship between BMI and visual reaction time in medical students.
Objectives:
1. To measure the BMI and group the subjects according to underweight, healthy weight, overweight, and obese individuals as per the Asia-Pacific standards.
2. To test the visual reaction time (VRT) of subjects falling into these different BMI groups.
3. To determine if there is any significant difference in the VRT of these different BMI groups.
4. To predict the relationship between BMI and VRT through regression analysis.

MATERIALS AND METHODS:

Study Design and Setting

The current study used a cross-sectional observational design for six months in the Department of Physiology, GEMS&H, Ragolu, Srikakulam, Andhra Pradesh, India.

Study Population

The population of the study consisted of medical undergraduate students from GEMS&H, Srikakulam.

Inclusion Criteria

Medical undergraduates aged between 18 to 25 years and of any gender who gave their informed consent.

Exclusion Criteria

- Individuals with any disease like diabetes mellitus, hypertension, thyroid disorders, and neurological problems that may affect BMI or reaction time in accordance with a self-reporting questionnaire and confirmed by an interview.
- Current smokers or regular tobacco users during the last year.
- Heavy drinkers (males: more than 14 drinks in a week or more than 4 drinks in a day; females: more than 7 drinks in a week or more than 3 drinks in a day).
- Consumers of illicit drugs or prescription drug abusers during the last year.

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- People on any medication which may affect reaction time (for example, sedative, stimulants).
- Patients with visual impairment without correction affecting visual reaction time (VRT).

Sample Size:
For a one-way ANOVA analysis involving comparison of VRT in four BMI groups, sample size was computed using the equation $n = k \cdot (\sigma/\Delta)^2 \cdot (Z1-\alpha + Z1-\beta)^2 / 2$, where k = 4 (groups), σ (assumed SD of VRT) = 20 ms, Δ (minimum detectable difference) = 15 ms, $Z1-\alpha = 1.96$ (confidence level 95%) and $Z1-\beta = 0.84$ (power 80%). The sample size estimated by the equation was about 28 participants per group (total of 112 participants); on adding 10% allowance for drop-out rate, the final sample size would be 124 participants.

Data Collection Procedure
Measurement of BMI: Height was measured using a stadiometer and weight using a calibrated digital weighing machine; BMI was computed as weight (kg)/height (m^2). Based on WHO Asia-Pacific BMI cut-offs for South Asian populations (19), BMI categories used were: underweight <18.5 kg/m², normal weight 18.5-22.9 kg/m², overweight 23-24.9 kg/m² and obese ≥25 kg/m².

Measurement of VRT: Before measuring VRT, adequacy of near vision was confirmed using Jaeger near-vision chart at a distance of 14-16 inches under standard lighting conditions, while wearing corrective glasses if needed. Participants were requested to have a good sleep (7-9 hours) the previous night and eat a light meal (1.5-2 hours prior to test); the test was conducted in a distraction free room following standard procedure of instruction. VRT was measured using a validated online computerized reaction-time system; participants responded to visual stimuli as fast as possible and the average of three tests was considered as VRT (in ms).

Statistical Analysis
Data entry and analysis were conducted using SPSS version 25 software. Continuous variables were reported as mean ± SD while categorical variables were represented in terms of frequencies and percentages. Mean VRT was compared between the four BMI groups using one-way analysis of variance (ANOVA) and Tukey's honestly significant difference (HSD) test for multiple pairwise comparisons. Simple linear regression analysis was carried out with VRT as the dependent variable (output) and BMI as the independent variable (input): $VRT = \beta 0 + \beta 1 \times BMI$. Coefficient of determination (R^2) was used to check the fitness of the regression model. Pearson correlation coefficient was calculated to determine the degree of correlation between BMI and VRT. Statistical significance was determined at p-value <0.05.

Ethical Considerations
Institutional Ethics Committee approval was obtained for this study (176/IEC/GEMS&H/2025). Informed consent was taken in written form from each participant before enrolment into the study. Personal details of participants were strictly kept confidential. The study involves only non-invasive anthropometric and behavioral assessments that carry minimal risk for participants.

RESULTS
The study included 124 medical undergraduate students of mean age 20.5±1.5 years consisting of 58 males (46.8%) and 66 females (53.2%). Using Asia-Pacific BMI cut-off points, the participants were categorized into four groups as follows: underweight (n=29, 23.4%); normal weight (n=32, 25.8%); overweight (n=31, 25.0%); and obese (n=32, 25.8%) (Table 1, Figure 1).

Table 1. Demographic and Anthropometric Characteristics of Study Participants by BMI Category (N=124)

Characteristic	Underweight (n=29)	Normal weight (n=32)	Overweight (n=31)	Obese (n=32)
Age (years), mean ± SD	20.1 ± 1.4	20.4 ± 1.5	20.6 ± 1.3	20.8 ± 1.6
Male / Female, n (%)	12 (41.4) / 17 (58.6)	14 (43.8) / 18 (56.2)	15 (48.4) / 16 (51.6)	17 (53.1) / 15 (46.9)
Height (cm), mean ± SD	162.4 ± 8.1	164.2 ± 7.9	163.8 ± 8.4	162.9 ± 8.0
Weight (kg), mean ± SD	46.8 ± 4.2	58.6 ± 5.1	64.3 ± 5.6	74.2 ± 7.8
BMI (kg/m²), mean ± SD	17.6 ± 0.8	20.9 ± 1.2	23.9 ± 0.6	27.8 ± 2.4

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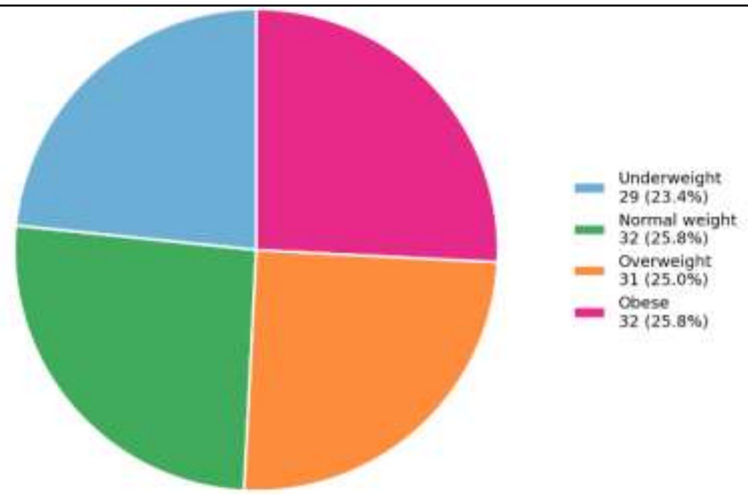

Figure 1. Distribution of Study Participants by BMI Category (n=124)

Visual Reaction Time Across BMI Categories

Mean VRT was the shortest in the normal weight group while it was longest in the obese group. The underweight and overweight groups exhibited mean VRTs of intermediate values (Table 2, Figure 2).

Table 2. Visual Reaction Time (VRT) by BMI Category

BMI Category	n	Mean VRT (ms)	SD	95% CI	Min–Max (ms)
Underweight	29	234.6	24.3	225.4–243.8	192–289
Normal weight	32	214.8	19.7	207.7–221.9	178–261
Overweight	31	238.2	22.1	230.1–246.3	198–294
Obese	32	252.4	27.6	242.4–262.4	204–318
Total	124	235.0	27.1	230.1–239.9	178–318

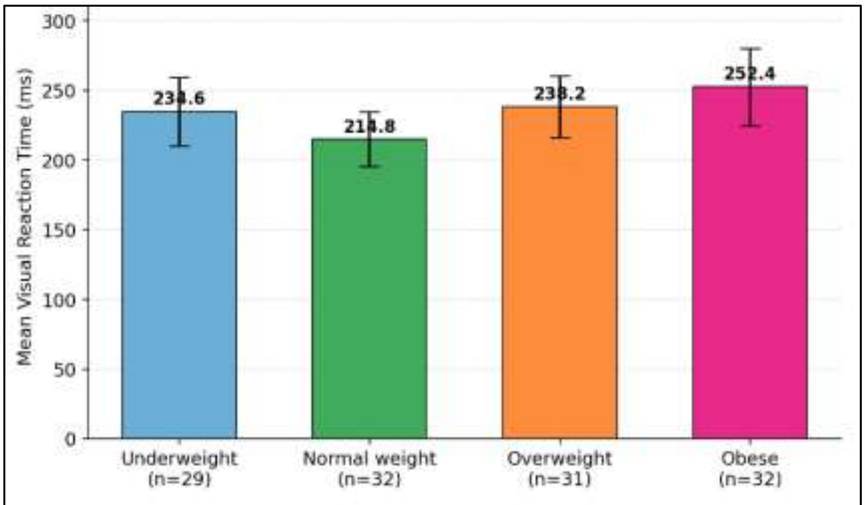

Figure 2. Mean Visual Reaction Time by BMI Category

One-Way ANOVA:

One-way ANOVA analysis indicated a statistically significant difference in mean VRT of four groups classified based on BMI cut-offs ($F(3,120) = 14.87$, $p<0.001$, $\eta^2 = 0.271$) and approximately 27.1% variance of VRT could be accounted for BMI group affiliation (Table 3).

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Table 3. One-Way ANOVA Summary for VRT Across BMI Categories

Source	Sum of Squares	df	Mean Square	F	p-value
Between groups	27,142.6	3	9,047.5	14.87	<0.001*
Within groups	73,014.2	120	608.5	—	—
Total	100,156.8	123	—	—	—

*Statistically significant at $p<0.05$.

Post-hoc Pairwise Comparisons (Tukey HSD)

Post-hoc analyses indicated statistically significantly faster mean VRTs in the normal weight group compared to underweight ($p<0.05$), overweight ($p<0.05$), and obese groups ($p<0.05$). In addition, the obese group also demonstrated significantly longer mean VRTs compared to the underweight group while there was no statistically significant difference in mean VRTs between the underweight and overweight groups and between the overweight and obese groups (Table 4).

Table 4. Tukey HSD Post-hoc Pairwise Comparisons of Mean VRT Between BMI Categories

Comparison	Mean Difference (ms)	95% CI	p-value	Significance
Underweight vs Normal weight	19.8	3.6 – 36.0	0.012	Significant
Underweight vs Overweight	−3.6	−19.9 – 12.7	0.542	Not significant
Underweight vs Obese	−17.8	−34.0 – (−1.6)	0.031	Significant
Normal weight vs Overweight	−23.4	−39.2 – (−7.6)	0.003	Significant
Normal weight vs Obese	−37.6	−53.4 – (−21.8)	<0.001	Significant
Overweight vs Obese	−14.2	−30.3 – 1.9	0.184	Not significant

Regression Analysis of BMI and VRT

Simple linear regression analysis showed that BMI significantly predicted mean VRT: VRT (ms) = 168.4 + 3.62 × BMI. Each one unit increase in BMI was associated with an increase of 3.62 ms in mean VRT (95% CI 2.40–4.84; $p<0.001$). Approximately 22.3% of variance of mean VRT was accounted for BMI ($R^2 = 0.223$; adjusted $R^2 = 0.217$) and the overall regression model was statistically significant ($F(1,122) = 34.99$, $p<0.001$). Pearson correlation analysis confirmed a moderate positive correlation between BMI and VRT ($r = 0.472$, $p<0.001$) (Table 5, Figure 3).

Table 5. Simple Linear Regression of VRT on BMI

Parameter	Coefficient (β)	SE	95% CI	t	p-value
Constant (β0)	168.4	14.62	139.5 – 197.3	11.52	<0.001
BMI (β1)	3.62	0.617	2.40 – 4.84	5.87	<0.001

$R^2 = 0.223$; Adjusted $R^2 = 0.217$; $F(1,122) = 34.99$, $p<0.001$; Pearson $r = 0.472$, $p<0.001$.

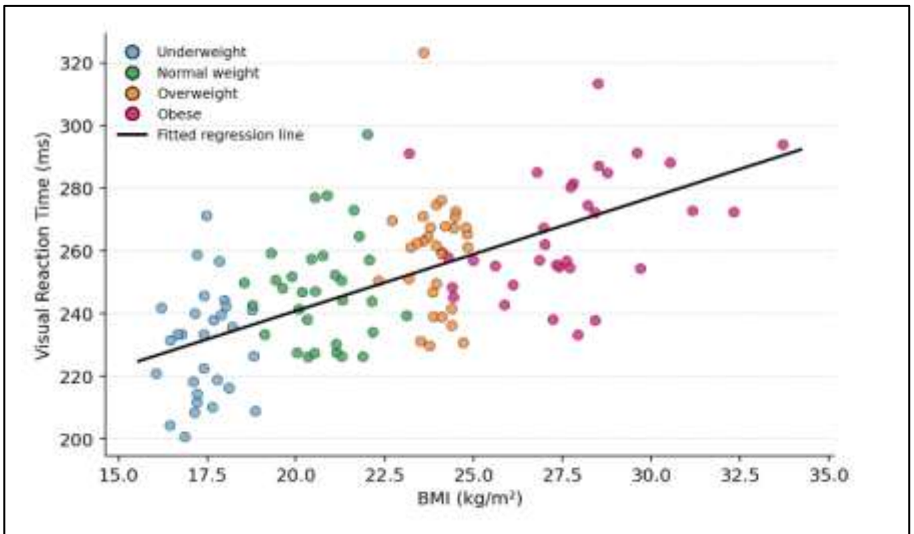

Figure 3. Scatter Plot of BMI vs Visual Reaction Time with Fitted Regression Line

DISCUSSION:

The cross-sectional study with a sample of 124 medical undergraduate students illustrated that there was a significant U-shaped tendency in the association between the BMI category and visual reaction time. Namely, the normal weight category exhibited the shortest VRT and the obese category the longest one, whereas the underweight participants experienced prolongation compared with the normal weight category. In turn, using the multiple linear regression analysis, it was revealed that BMI was a significant and independent positive predictor of VRT and explained almost 22% of the total variance in VRT.

The results illustrating prolonged VRT in the obese category are in accordance with the results in the previous studies. Deore et al. found a positive relationship between BMI and audiovisual reaction time among a cross-sectional cohort in India (14). Furthermore, Esmaeilzadeh et al. found that the reaction time indices were impaired in young people depending on the presence of adiposity and suggested that systemic inflammation due to obesity, abnormality in insulin signaling, and action of adipokines on central neural processing may be underlying factors in this case (15). Recently, Chalse et al. reported a positive correlation between the body fat percentage and simple reaction time, proving the idea that the presence of excessive adiposity either measured by BMI or by direct measurement of body fat is connected with a delay in the neuromotor response (17). The suggested reasons for that include decreased neuromuscular efficiency due to the presence of excessive adipose tissue, systemic inflammation due to obesity that impairs central processing speed, and decreased peripheral nerve conduction among people with higher body fat (4,13,15,17,18).

The findings about the prolonged VRT among underweight participants compared with the normal weight category correspond to the results obtained in the studies conducted by Jain et al. and Jha et al., where they found out that the reaction times were longer among the underweight and overweight participants compared with their normal-weight peers, thereby proving a U-shaped rather than a strictly linear correlation in the entire BMI range (6,16). The proposed reasons for that include low muscle mass and strength, high sympathetic activity, and possible malnutrition which influences neurotransmitter synthesis and axonal conduction velocity (6,16).

On the other hand, there have been studies indicating no significant relationship between BMI and reaction time among young people. Narimani et al., for instance, did not find any significant correlation between overall BMI and fat mass and simple reaction time and premotor time in young males; central adiposity, however, was related to longer premotor time, which means that central rather than overall adiposity might be more important from a mechanistic point of view (18). Another study conducted exclusively among subjects with normal BMI revealed only a non-significant positive correlation between anthropometric parameters and VRT, which can be explained by the limited BMI range considered in this study (5). The discrepancy in results might be attributed to the use of different study groups (general population vs. medical students), type of reaction time test (simple vs. choice reaction time), sample size, and range of BMI (5,7,18).

The relatively modest effect size obtained in the current study ($R^2 = 0.223$) suggests that, despite being a significant predictor of VRT, BMI is responsible for explaining less than one fourth of the variability in reaction time, which means that there must be other factors contributing to the reaction time of medical students, like quality of sleep, duration of screen time, amount of physical activity, working memory capacity, and psychological stress (7,9-12). For example, recently performed research revealed that screen time is an independent factor associated with increased visual and auditory reaction time among the first-year MBBS students (9).

From a physiological perspective, these results confirm the notion that both obesity-related neuroinflammation and metabolic disorders as well as underweight-related neuromuscular or sympathic alterations result in decreased efficiency of the central processing and lead to increased VRT (4,6,13,15,16,18). As visual reaction time serves as an index of the speed of clinical decision-making and psychomotor function, there exist practical implications of this study. Namely, programs aimed at maintaining normal BMI via nutritional counseling, physical activity promotion, and sleep hygiene education might help improve sensory-motor processing speed in medical students, who should possess the capability of rapid and precise sensory-motor reactions in their future professional life (4,17).

Strengths and Limitations

The current study is characterized by an adequate sample size, a homogenous and relatively unexplored population (medical students), standard pre-test conditions (sleeping, meal time, test setting), and use of a validated computer-based VRT measuring method. On the other hand, there are several weaknesses that must be mentioned. Firstly, a cross-sectional research design does not allow causal interpretation of the relationship between BMI and VRT. Secondly, VRT was measured with the help of only one online platform and not a combination of different ones (choice reaction time, auditory reaction time), which might restrict the results' generalization. Moreover, such potential confounders as physical activity level, screen time, eating patterns, and psychological stress were not assessed and controlled in the regression analysis. In addition to the above, a single-centre study design might constrain the external validity of the results for medical students from other institutions/cultural contexts.

CONCLUSION:

In medical undergraduate students, BMI category was significantly associated with VRT, being the longest among the obese, the shortest among the normal weight and also prolonged but to a lesser degree among the underweight students compared to normal weight. BMI was established as an independent and moderate predictor of VRT. These results emphasize the importance of the BMI optimization and maintaining it within the normal weight range as a potential measure to promote cognitive-motor performance in medical trainees.

Declarations:

CONFLICTS OF INTERESTS: The authors declare no conflicts of interest.
AUTHOR CONTRIBUTION: All authors have made contribution to the manuscript.
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