Influence of Body Mass Index on Visual Reaction Time: A Cross-sectional Analytical Study

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Authors' contributions

This work was carried out in collaboration between all authors. Author CWN designed the study, wrote the protocol, and analyzed the statistical data. Authors CWN, HYL and GAC wrote the first draft of manuscript. Authors RV and MA managed the literature searches. All authors read and approved the final manuscript.

Original Research Article

ABSTRACT

Aims: To determine the relationship between Body Mass Index (BMI) and Visual Reaction Time (VRT) in medical students.
Study Design: Cross-sectional Analytical Study.
Place and Duration of Study: Melaka Manipal Medical College, Melaka, Malaysia, between October 2014 and November 2014.
Methodology: We included 112 students (47 men, 65 women; age range 17-27 years) without medical conditions including neurological disorders, cardiovascular disorders and diabetes, which are known to affect cognitive function. Students were asked to complete a standard questionnaire before having their height measured using calibrated measuring tape in Frankfort plane, recorded to nearest 1cm and their weight measured using electronic weighing balance, recorded to nearest 0.1 kg. Body Mass Index (BMI) was calculated using Quatelet Index, and categorized using Asian

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BMI. Visual Reaction Time (VRT) was recorded using validated Human Benchmark program.
Results: Significant difference was seen in different groups in BMI, namely underweight, normal and overweight, with respect to visual reaction time. The other variables such as gender, ethnicity, caffeine consumption, fatigue level, exercise and handedness are not significantly associated with VRT.
Conclusion: Underweight individuals have been shown to have prolonged median visual reaction time as compared to their normal and overweight BMI counterparts. Further study on this is needed as BMI may not correlate well with the body fat composition of subjects, for which we propose further study to use waist-hip ratio instead.

1. INTRODUCTION

The reaction time is the time interval between the onset of the stimulus and the initiation of the response, under the condition that the subject has been instructed to respond as rapidly as possible [1]. The reaction time is an indirect index of the processing capability of the central nervous system (CNS) and a simple means of determining the sensorimotor performance [2]. It is divided into simple reaction time, recognition reaction time, choice reaction time and serial reaction time experiments. In simple reaction time experiment, there is only one stimulus and one response. Stimulus used in experiment is divided into 3; namely, visual reaction time (VRT), auditory reaction time (ART) and tactile reaction time (TRT) [3].

Worldwide, more than 1.9 billion adults, 18 and older, were overweight. Of these overweight adults, over 600 million were obese. Overall, more than 13% of the world's adult population were obese. (2014) [4], normal BMI is 74.6 %, underweight is 20.1% [5] In Malaysia, overweight and obesity prevalence were 41.1% and 14.4% (2003) [5]. The normal BMI of adult Malaysians aged 18 - 59 years was 24.37 kg/m^2 [6]. The prevalence of underweight among Asian is very high in which in Malaysia it is 9.6% (2003) [5]. Prevalence of overweight was highest in the South Zone (Negeri Sembilan, Johor, Melaka) which is 29.44%. The mean BMI was highest for adults in the South Zone which is of 24.88 kg/m^2 (CI: 24.52,25.25). Prevalence of underweight or chronic energy deficiency (CED) (BMI < 18.5 kg/m^2) among Malaysian adults was reported 9.02% (CI: 8.82,10.61) (BMI < 18.5 kg/m^2) [6].

Body Mass Index (BMI), calculated as weight (in kg) divided by height squared (m^2) influences cognitive function, memory, reasoning, processing speed and sensorimotor performance, has been shown in neurophysiological studies [7,8,9,10,11,12]. BMI of an individual affected the audio visual reaction time, which indirectly measures the sensory motor association [13].

Obese individuals have an increased risk of developing nerve conduction slowing and small fibre neuropathy, owing to the increase sensory threshold which could be expected to alter reaction time, according to nerve conduction studies [14,15]. Studies have shown that altered inhibition capacity in obese, resulting in impairment in attention and mental flexibility can influence the speed of mental processing and response time [16,17,18]. Obesity has also been associated with various pathophysiological changes including systemic inflammation, impaired insulin regulation [19], vascular changes. All of these can influence executive function via the vascular pathway. Other mechanism that have been suggested includes that cytokines, chemokines and tissue necrosis factor, which are secreted by the adipose tissue can cross blood brain barrier and may alter brain function [20]. Abnormal level of adipokines results in abnormalities in myelination [21,22], which could cause disrupted axonal transmission. Therefore, neuronal and/or myelin abnormalities along with axonal degeneration might be responsible for the prolongation of reaction time.

Underweight people have shown poor cognition and it has been attributed majorly to preclinical dementia. Another possibility is that the underweight people experience a dysregulation in the hormone secretion which corresponds to that in anorexia [23]. This might lead to delay in reaction time. This provides a possible physiological explanation for BMI influencing reaction time, but the present knowledge remains incomplete. Other factors that have been found to affect reaction time includes age, gender, handedness, fatigue level, alcohol and caffeine,

exercise, stimulants and depressants drugs, and illnesses [3].

The visual system faces the challenging task of rapidly processing an enormous range of information in day to day perception. In any provided scene, the visual system must identify the items, determine their layout, and perform the action accordingly. Majority of motor action is done based on visual information in order for humans to explore and interact successfully with the environment [24].

How do BMI of Melaka Manipal Medical College (MMMC) students affect their visual reaction time? The present study was an attempt to determine the association between BMI and the visual reaction time. We hypothesized that there is an association between BMI and VRT.

2. METHODOLOGY

This was a cross-sectional study done on the effect of body mass index (BMI) on visual reaction time (VRT) among Melaka Manipal Medical College Students (Malaysia). The study was conducted from October 2014 to November 2014. Our study considered a total of 112 healthy voluntaries. We calculate sample size by comparing two means at 95% confidence level, and 80% power. The minimum sample size is 10 in each BMI category; underweight, normal and overweight.

The subjects, who have medical conditions including disorders of visual pathway, neurological disorders, cardiovascular disorders and diabetes, which are known to affect the cognitive function, were excluded from the study. Also subjects which are on psychotropic drugs (sedatives, hypnotic and tranquilizers), antihistaminic and antiepileptic were not included in our study.

BMI was calculated using Quetelet Index. The height and weight of each subject were measured at clinical examination. The height was measured with a measuring tape fixed on a straight wall while the subjects stood completely erect with their heads in the Frankfort plane and was measured to the nearest 1 cm. The weight was measured with an electronic weighing balance with the subjects being without their shoes and with light clothes. Data were recorded to the nearest 0.1 kg. BMI was calculated by dividing body weight in kilograms by square of height in meters. The categorisation of BMI was

done according to the BMI criteria for Asian population (refer to Table 1) [25].

Table 1. Asian population BMI criteria

Categories	BMI (kg/m^2)
Underweight	≤18.49
Normal	18.5 – 22.99
Overweight	≥ 23

The Visual Reaction Time (VRT) was recorded in a quiet computer lab with the ambient temperature maintained at 26±1ºC. Each subject was given proper instructions and a one time trial on the validated Human Benchmark program to alleviate any fear or apprehension. Subjects were sitting comfortably in a chair with the visual signal given from the front of subjects to prevent the effect of a lateralized stimulus. Human Benchmark program requires the subject to click on the computer mouse using their right hand whenever they see the screen turns from red to green. The program measures reaction time in millisecond with an accuracy of ± one digit. Subjects are required to perform the test for 5 times and the mean reaction time in millisecond was recorded.

Self-administered questionnaire was used in this study. Part I (Demographic Profile) comprises of 6 sets of questions to identify the basic information of the participant. The questions include roll number, course, batch, age, gender and ethnicity. Part II comprises 6 sub-parts; Medications for the past 24 hours, alcohol-related food and beverages for the past 24 hours, caffeinated food and beverages for the past 12 hours, Visual Analogue-Fatigue [26,27], Godin Leisure-Time Exercise Questionnaire[28], and Revised Edinburgh Handedness Inventory[29].

The data was analyzed and interpreted using Epi Info 7 (version 7.1.3) [30] and SPSS (version 12). Student's *t* test and Kruskal-Wallis test are used to compare underweight, normal, overweight and obese students and their visual reaction time. P values of 0.05 or less were considered as significant.

3. RESULTS AND DISCUSSION

3.1 Results

This study was conducted amongst 112 students as 4 students declined to participate in the study, which makes the rejection rate of 3.4% owing to unwillingness of participation.

3.1.1 Descriptive statistics

Table 2 reports analytical data regarding descriptive statistics of socio-demographic characteristics linked to variables of interest among subjects.

Table 2. Descriptive statistics of socio-demographic characteristics among subjects

Variable	Values
Age	22.5±1.7
(Mean±Standard deviation)	
Gender	
Female	65 (58.0%)
Male	47 (42.0%)
Ethnicity	
Chinese	55 (49.1%)
Indian	29 (25.9%)
Malay	28 (25.0%)
Medication	
No	112 (100.0%)
Yes	0 (0%)
Alcohol	
No	112 (100.0%)
Yes	0 (0%)
Caffeine	
No	81 (72.3%)
Yes	31 (27.7%)
Fatigue level	
No	8 (7.1%)
Mild	48 (42.9%)
Moderate	52 (46.4%)
Extreme	4 (3.6%)
Exercise	
Insufficiently active	68 (60.7%)
Active	44 (39.3%)
Handedness	
Ambidextrous	14 (12.5%)
Left	2 (1.8%)
Right	96 (85.7%)
Body Mass index	
Underweight	12 (10.7%)
Normal	52 (46.4%)
Overweight	48 (42.9%)
VRT (ms)	279.3±44.9
(Mean±Standard deviation)	

3.1.2 Association between socio-demographic characteristics and VRT

According to Fig. 1, there is weak negative association between age and VRT. Based on the calculation, there is a little degree of correlation with the r value of - 0.28 with p-value of *0.002*. If the age increases, the VRT will be shorter with little degree of correlation.

Table 3 shows the quantitative analysis via Student's *t* test or Kruskal-Wallis test amongst subjects. The P-value for gender, ethnicity, medication, alcohol, caffeine, fatigue level, exercise and handedness show no statistically significant difference in results. BMI shows the statistically significant p-value of *0.02,* which shows that the BMI of subjects affects their VRT.

3.2 Discussion

The aim of this study is to investigate the relationship between BMI and VRT. In the present study, we found that BMI is significantly associated with VRT that are in parallel with the studies existing in the literature [8,24].

BMI was found to be linked with the nerve conduction velocity, small fiber neuropathy [13,14], alteration of nerve inhibition capacity [15,16,17] and causing abnormalities in myelination due to high levels of adipokines [20,21]. Hypothesis raised by Deore et al. [13] also supported that extreme BMI especially underweight persons experience a dysregulation in the hormone secretion which corresponds to that in anorexia; as a result, cognitive disorders might occurs [31]. Alternatively, muscle weakness might be a reason, and this should be investigated further with respect to fatigue variable.

We also found that age has weak negative correlation to VRT. This is in contradiction to one of the study which showed that advancing age can results in axonal degeneration and axonal shrinkage which not only prolongs mental processing time but also decreases speed of conduction of neurons [32]. This could be due to the fact that our study population consisted mainly from adolescents group, and a bigger age range would be desirable.

However, other confounding factors such as gender, caffeine, fatigue level, exercise and handedness made no difference for the significance in our results.

The present study is subjected to several limitations. First, BMI status was categorized based on standard Quetelet Index in which the demographic factors such as age and sex were not considered. Furthermore, the cut off points used for BMI categories do not represent the actual body fat composition as it does not distinguish overweight due to excess fat mass from overweight due to excess lean mass [33].

For example, an individual classified as obese according to Quetelet Index may be lean with high muscle mass. These factors are inaccurate to conclude the significant difference in the visual reaction time between the underweight, normal and overweight. Thus, waist-hip ratio is a more accurate indicator compare to BMI on the VRT which would be an important topic for future research [34]. Second, the present sample's relative homogeneity may minimize the confounding effects such as occupational status and educational attainment. Third, the current study sample age group is within 17-27, which is not statistically representative of the general population, which may limit the observed VRT. Lastly, there is no subject in our study subjects taking alcohol or medication (stimulant or depressant) 24 hours prior to our study, thus we cannot conclude the relationship between alcohol or medication and VRT. Future study should be carried out to conclude our result.

Majority of work in our daily life is done by use of visual information. This information can be useful in day-to-day regular life. It is helpful especially to medical personnel, as they are required to identify the red flag signs in patients to assess the severity of disease. It is recommended that by maintaining an optimum BMI and a healthy balanced lifestyle, medical personnel can understand, interpret and respond quickly. Apart from education field, visual information is useful in physically reactive sports such as basketball, car racing, army personals and fighter airplanes pilots.
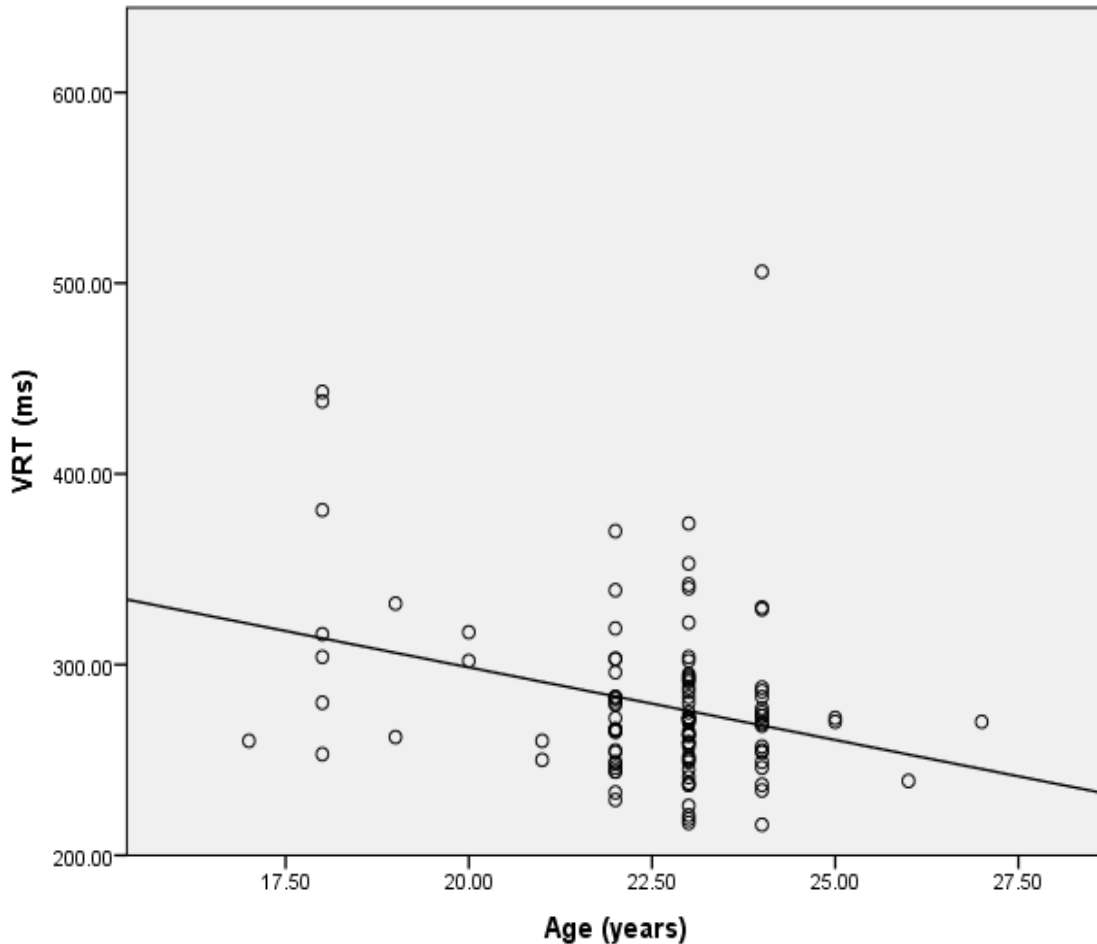

Fig. 1. Scatter plot of association between age (years) and VRT

Table 3. Characteristics via Student's t test or Kruskal-Wallis test amongst study subjects

Independent variable	n=112 No. (%)	VRT (ms) mean (SD)/ median (Q1-Q3)	P-value
Gender			0.37[t]
Female	65 (58.0%)	282.8 (42.8)	
Male	47 (42.0%)	274.8 (47.7)	
Ethnics			0.70[k]
Chinese	55 (49.1%)	270.0 (257.0-286.0)	
Indian	29 (28.9%)	270.0 (248.5-310.0)	
Malay	28 (25.0%)	272.5 (249.8-292.5)	
Caffeine			0.87[t]
No	81 (72.3%)	279.8 (42.2)	
Yes	31 (27.7%)	278.2 (52.1)	
Fatigue level			0.15[k]
No	8 (7.14%)	258.5 (245.0-271.5)	
Mild	48 (42.9%)	271.0 (257.5-291.8)	
Moderate	52 (46.4%)	270.5 (249.3-287.5)	
Extreme	4 (3.6%)	348.5 (266.5-427.5)	
Exercise			0.95[t]
Insufficiently Active	68 (60.7%)	279.1 (37.8)	
Active	44 (39.3%)	279.6 (54.5)	
Handedness (mean rank)			0.38[k]
Ambidextrous	14 (12.5%)	59.8	
Left	2 (1.8%)	88.3	
Right	96 (85.7%)	55.4	
BMI			0.02[k*]
Underweight	12 (10.7%)	279.0 (267.5-360.0)	
Normal	52 (46.4%)	272.0 (257.5-290.3)	
Overweight	48 (42.9%)	264.0 (246.0-282.8)	

[k] *Kruskal-Wallis test. Median (Q1-Q3)*
[t] *Student's t test. Mean (SD)*
* p value < 0.05 as statistically significant

4. CONCLUSION

Our study has been done in exploring the influence of BMI on VRT and revealed that BMI deviated below the optimum range negatively affects the VRT of that individual. These are individuals who fall under the underweight category of BMI who have significantly shown prolonged VRT. Thus, maintenance of an optimal BMI, neither underweight nor overweight/obese, is very much encouraged to everyone, especially among medical personnel.

CONSENT

All authors declared that written informed consent was obtained from the subjects.

ETHICAL APPROVAL

Approval from Ethics Committee of MMMC was taken prior to the commencement of this study. Ethical considerations were ensured on voluntary participation of the subjects. Informed consent was taken both verbally and in written consent form after explanation. Confidentiality was ensured for the participants.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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