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Exploring the correlation between the Body Mass Index and short-term memory tasks among young adult males: A cross-sectional study

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Abstract
Although the correlation between indices of adiposity and short-term memory has been previously explored, the results obtained have been inconclusive. In view of this lack of certainty in literature, the current cross-sectional study sought to explore a potential correlation between the body mass index and short-term memory among a group of south Indian males aged between 18 and 25. After anthropometric measurements were made, the short-term memory was assessed using tests such as immediate word and immediate object recall. Pearson's Correlation test was employed to detect a correlation between body mass index and short-term memory. It was found that there was a positive trend between body mass and short-term memory, although it did not reach significance ($p>0.05$). This study observed a nonsignificant positive trend between adiposity and short-term memory; however, given conflicting evidence in literature, the findings should be interpreted with caution and must be explored further in larger studies.

Keywords: Immediate word recall, immediate object recall, overweight, obese, adiposity

Introduction
Although it has been well documented that an increase in body adiposity was associated with cardiovascular, endocrine and musculoskeletal disorders, the potential effects of adiposity on cognitive performance has not received as much attention. Recent neuro-imaging studies have indicated that overweight states may negatively influence brain structure thereby resulting in a potential impairment of cognitive functions such as learning and memory. Short-term memory, is the ability of the brain to retain a limited amount of information for a limited period of time and plays a pivotal role in daily cognitive tasks, including executive functions and decision-making. The Body Mass Index (BMI) has been extensively utilized as a screening tool to assess body adiposity. According to WHO guidelines there are five BMI groups: individuals with a BMI under 18.5 kg/m^2 are considered underweight, those with a BMI between 18.5 and 22.9 kg/m^2 are of normal weight, those with a BMI from 23 to 24.9 kg/m^2 are overweight, those with a BMI between 25 and 29.9 kg/m^2 are obese and individuals with a BMI equal to and above 30 kg/m^2 are considered severely obese [1]**.** Several studies over the years have investigated the relationship between indices of adiposity such as body mass index (BMI) and short-term memory. Most of these studies concluded that there was a negative association between the BMI and short-term memory [2-5]. Vascular changes in the brain, neuro-inflammation and endothelial dysfunction were some of the explanations offered for obesity-related cognitive impairment [6, 7]. Imaging studies in obese individuals have specifically demonstrated volumetric reductions in the hippocampus and other parts of the brain involved in short-term memory [8]. Although most studies have demonstrated a negative correlation between the BMI and cognitive function, a few studies seem to suggest that an increase in BMI was actually associated with an improvement in short-term memory [9-11]. On the other hand, some researchers were convinced that a lower than normal BMI adversely affected short-term memory [12], and yet others opined that there was no association whatsoever between indices of adiposity and short-term memory [13]. Since results obtained so far have been uncertain at best, the present study was undertaken. The objective of this study was to explore a potential correlation between the BMI and the performance in short-term memory tasks such as immediate word and immediate object recall among south Indian males between the ages of 18 and 25 - a demographic group

increasingly affected by sedentary lifestyles and rising obesity rates. Based on existing literature we hypothesised, at the beginning of the study, that there would be a negative correlation between the BMI and short-term memory performance. Since most similar studies were performed in specific demographic groups such as children, older adults [14] and women [15], the present study chose as its subject population, a group of physically, psychologically and neuro-developmentally homogenous young adult males. The study sought to investigate if minor variations in BMI even within non-pathological ranges, might result in early cognitive consequences, and in so doing contributes to existing information. Given the growing public health concerns regarding obesity and the importance of cognitive performance for academic and occupational success, this study by exploring potential correlations between the BMI and memory might contribute towards future preventive strategies targeting both physical and cognitive well-being.

2. Materials and Methods

2.1 Study design

This cross-sectional study was carried out over a nine-month period from August 2009 to the month of March 2010 in the Department of Physiology at PIMS, Pondicherry. Fifty participants volunteered for the study.

2.2 Sample size

Given the study's focus on a narrowly defined homogenous group and the exploratory nature of the investigation, we set a sample size of 50. This provides adequate power to detect correlation effects while remaining feasible within available resources and recruitment constraints. This study is a sufficiently powered, internally valid investigation suitable for hypothesis generation.

2.3 Inclusion criteria

The participants for this study were all members of the workforce of the Institute and were recruited by word of mouth. The fifty volunteers who participated in this study were all males between the ages of 18 and 25 years. They all spoke English, were all graduates and were all from a similar socioeconomic background (modified BG Prasad's scale). The narrow age window was purposely chosen to include young adults just after the adolescent neuro-developmental miles stones had been reached and before any early age-related cognitive changes set in. It therefore provided a more physically, psychologically and neuro-developmentally homogenous set of participants. By studying males only, we sought to avoid the cyclical hormonal changes in women which might certainly have been a confounding factor. This further ensured the homogenous nature of the group.

2.4 Exclusion criteria

The exclusion criteria that we set at the beginning of the recruitment process were, systemic illnesses such as uncontrolled Diabetes and hypertension, neurological diseases such as epilepsy, psychiatric disorders such as depression and anxiety, neuromuscular diseases, sleep deprivation or abnormal sleep patterns, auditory or visual impairment, alcohol or substance use. Since none of those who volunteered had any of these conditions, they were all included in the study. All fifty individuals who volunteered were included in the study; no volunteer was excluded. Since the subjects were required to come only once for the recordings, the possibility of drop outs was eliminated.

2.5 Ethical approval

Before the project began, clearance was obtained from the research and ethical committees of the institute. A written consent was obtained from each subject before the recordings commenced. All procedures were performed in accordance with the principles stated in the Declaration of Helsinki

2.6 Procedure

The participants, as per instructions, had at least seven hours of sleep the night before. They were instructed to have breakfast without coffee or tea at 7 am on the morning of the recordings and to report at 9 am at the research laboratory of the Department of Physiology.

Step 1: An informed consent was obtained detailing the procedure and potential inconveniences involved. The subject was then required to fill in the proforma furnishing their sociodemographic details.

Step 2: Anthropometric measurements: The height of the subject was next measured using a stadiometer. The subject was required to stand barefoot looking straight ahead, with back and buttocks pressed against the vertical ruler and the horizontal headpiece resting firmly on top of the head. The height was thus measured accurate to the centimeter. The weight of the subject was next measured using a digital scale. The body mass index was later calculated (at the time of statistical analysis) by dividing the weight in kilograms by height in m^2. The following tests were then performed in the order mentioned below.

Step 3: Immediate Word recall

Twenty English nouns were electronically generated at random and printed on a card. There were several such cards, each with exactly twenty comparable but different nouns. The cards were placed face down on a table. The participant was instructed to choose only one card at random, without being aware of the words it contained. The investigator then read out all twenty words printed on that card in the same tone of voice and at a constant rate of one word every two seconds. The participant was then instructed to recall and write down on a piece of paper, as many words as possible from memory in the given time of sixty seconds [16].

Step 4: Immediate Object recall

Twenty objects were placed on a table. The objects included familiar house hold objects, picture cards of fruits and vegetables and miniature models of animals. The objects were initially hidden from sight using a curtain. The curtain was then pulled back revealing the objects for fifteen seconds and then hidden again. The participant was then required to write down as many objects as he could remember in the given time of sixty seconds [17].

After all the data was recorded, at the time of statistical analysis, the BMI was calculated and the short-term memory data from the fifty participants was assigned into one of five groups based on the individual's BMI. At the time of data collection, neither the subject nor the investigator knew the subject's BMI and consequently did not know which BMI group the subject's data would be assigned to. Hence this was in effect a double-blind study.

2.7 Statistical analysis

The collected data was entered and compiled by using Microsoft Excel 2010 [Office 360, Microsoft Ltd., USA]. The data was analysed by using SPSS 23.0 version [IBM Ltd, USA]. Categorical data were expressed as frequency and proportions. Continuous data were expressed as mean and standard deviation. Pearson's Correlation was employed to look for correlation between the BMI and immediate word and object recall. The association of mean between immediate word recall and immediate object recall in all five groups was compared using ANOVA test. p-value less than 0.05 was taken as statistically significant.

3. Results

Short-term memory data from individuals with a BMI under 18.5 kg/m^2 was placed in the first group (n=6), group two had data from subjects with a BMI between 18.5 to 22.9 kg/m^2 (n=23), group three had data from subjects with a BMI between 23 to 24.9 kg/m^2 (n=11), subjects' data with a BMI between 25 to 29.9 kg/m^2 were in group four (n=6) and data from subjects with a BMI equal to and above 30 kg/m^2 was included in group five (n=4). Most of the participants found themselves in groups two (46%) and three (22%). The participants were all between the ages of 18 and 25 as shown in Table: 1. As evidenced by Table-2, there was a progressive increase in both immediate word recall (WR) and immediate object recall (OR), as one proceeds from groups 1 through 4. The Correlation between BMI and WR and OR was determined using Pearson's Correlation test. It was found that there was a positive correlation between BMI and both WR and OR, although it did not reach significance (p>0.05). The Pearson's correlation value was higher for WR as shown in Table-3. During the performance of the ANOVA test, it was found that the comparison of WR between groups and within groups showed F-value of 2.349, which neared significance, p = 0.069 (>0.05). The analysis of OR by ANOVA was not significant. as shown in Table-4.

4. Discussion

This study sought to determine if indices of adiposity, particularly the BMI, had any relation to short-term memory. The study limited itself to the immediate recall of words and objects as tests of short-term memory. We noticed a positive correlation between the BMI and both immediate word and immediate object recall, implying that as adiposity increased, the ability to recall both visual and auditory information also increased. However, it must be emphasized that these findings did not reach statistical significance. Very few of the previous studies have reported a significant positive correlation between the BMI and short-term memory [18]. Researchers concluded that the increased levels of myelination encountered in individuals with greater body mass, could possibly be the explanation for better performance in short-term memory tasks [18].

Most other studies of this nature have actually reported a negative association between indices of obesity such as BMI and working memory performance [19, 20]. More specifically, researchers reported a poor performance in the immediate recall of spoken words [21, 22] and visually presented pictures and objects [23] in individuals with a higher than normal BMI. This negative association between adiposity and working memory was true in both young adults and in older people [24]. Studies have demonstrated that those with higher than normal BMI also had compromised episodic [25] and semantic memory [26] without much change in other aspects of cognitive function. Studies employing other measures of adiposity such as waist-to-hip ratio and waist circumference have reported similar findings [27].

It has been proven that the hippocampus was involved in integrating the various components of short-term memory [28]. It has also been demonstrated that the right anterior prefrontal area was specifically involved in the immediate recall of words and pictures [29]. Most obesity-related structural alterations in the brain were observed in the Hippocampus [30, 31]. Studies have demonstrated hippocampal volumetric reductions in obese diabetics [32] and non-diabetic individuals with obesity [33, 34]. Voxel-based morphometry studies using Magnetic resonance imaging (MRI), have revealed that a higher BMI was associated with decreased grey matter volumes in the left hippocampus in both adults and children [35]. Other similar studies have revealed decreased thickness of the left orbitofrontal and Para hippocampal gyri [36, 37], the left post-central gyrus [38] and the temporal lobe [39]. Tensor-based morphometry (TBM) demonstrated that those with higher BMI have atrophy of the hippocampus and frontal lobes [39]. Studies employing single photon emission computed tomography (SPECT) have demonstrated decreased blood flow in the prefrontal cortex [40], while others have shown decreased metabolic activity in the prefrontal cortex of obese individuals [41]. Researchers are of the opinion that the obesity-related structural and functional alterations in the brain may be caused by the co-morbidities associated with obesity such as diabetes, hypertension and sleep apnoea. More specifically it has been demonstrated that a higher than normal BMI was associated with neuroinflammation and even hippocampal neuronal injury [42].

Other studies, however, concluded that a lower than normal BMI was associated with cognitive decline affecting both semantic and episodic memory [43, 44]. Yet other studies have reported no difference in memory performance between obese and non-obese individuals [45].

Table 1: Distribution of anthropometric variables among participants (N = 50)

Groups	No. of Participants	Percentage
Study Groups based on Body Mass Index (BMI)		
Group 1: < 18.5 (Underweight)	6	12.0
Group 2: 18.5 - 22.9 (Normal weight)	23	46.0
Group 3: 23 - 24.9 (Over weight)	11	22.0
Group 4: 25 - 29.9 (Grade I Obesity)	6	12.0
Group 5: 30 and above (Severely obese)	4	8.0
Mean Body Mass Index	22.79±4.14 (15.79 - 36.65)	
Mean Weight (in Kgs)	63.46±11.64 (43 - 101)	
Mean Age (in years)	20.98±2.84 (18 - 25)	
Age-Groups (in years)		
≤ 18	26	52.0
> 18	24	48.0

BMI: Body mass index kg/m^2

Table 2: Distribution of immediate word recall and immediate object recall in groups (N = 50)

Groups		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Immediate Word Recall (WR)	Group-1	6	7.00	0.632	0.258	6.34	7.66	6	8
	Group-2	23	9.74	2.562	0.534	8.63	10.85	6	17
	Group-3	11	9.82	2.316	0.698	8.26	11.37	7	14
	Group-4	6	11.33	3.670	1.498	7.48	15.18	8	16
	Group-5	4	8.75	3.202	1.601	3.66	13.84	6	12
	Total	50	9.54	2.712	0.384	8.77	10.31	6	17
Immediate Object Recall (OR)	Group-1	6	9.17	0.983	0.401	8.13	10.20	8	10
	Group-2	23	11.83	2.933	0.612	10.56	13.09	8	20
	Group-3	11	10.36	2.873	0.866	8.43	12.29	7	16
	Group-4	6	12.17	1.722	0.703	10.36	13.97	9	14
	Group-5	4	11.50	2.082	1.041	8.19	14.81	9	14
	Total	50	11.20	2.680	0.379	10.44	11.96	7	20

WR: Immediate word recall (numbers / min); **OR:** Immediate object recall (numbers / min)

Table 3: Correlation between body mass index and Immediate word recall and immediate object recall

BMI Mean±SD	WR Mean±SD	OR Mean±SD	Correlation between BMI and WR		Correlation between BMI and OR	
			(r) value	p - value	(r) value	p - value
22.79±4.14	9.54±2.71	11.20±2.68	0.155	0.284	0.100	0.489

BMI: Body mass index kg/m^2; **WR:** Immediate word recall (numbers / min); **OR:** Immediate object recall (numbers / min); (r)value: Pearson's Correlation

Table 4: Comparison within and between the groups (ANOVA) and F-values and p-values

		Sum of Squares	df	Mean Square	F-value	p value
Immediate Word Recall (WR)	Between Groups	62.266	4	15.566	2.349	0.069
	Within Groups	298.154	45	6.626		
	Total	360.420	49			
Immediate Object Recall (OR)	Between Groups	47.484	4	11.871	1.754	0.155
	Within Groups	304.516	45	6.767		
	Total	352.000	49			

WR: Immediate word recall ; OR: Immediate object recall ; df - Degrees of Freedom; p-value > 0.05 Statistically Not Significant

5. Conclusion

The present study observed a nonsignificant positive trend between adiposity and short-term memory; however, given conflicting evidence in literature, the findings should be interpreted with caution and explored further in larger, well-designed studies.

6. Limitations

Although the sample size of 50 provides reasonable power to detect moderate associations within a homogenous cohort, the modest size limits our power to detect small correlations. Findings should be interpreted as exploratory and hypothesis-generating, replication in larger samples is required for external validation.

7. Declaration by Author

- **Conflict of Interest:** The authors report that there are no conflicting interests to declare
- **Ethical Approval:** Approved

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