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# Cognitive Functioning in Relation to Body Mass Index

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Deviations in body weight at both extreme ends of the continuum are a world-wide health issue and the incidence is reaching alarming proportions. Societal changes have resulted in a shift towards less physically demanding, more passive leisure pursuits, increasing urbanization, and unrealistic notions of anatomical "perfection", which have led to the prevalence of deviations in body mass. Several life threatening problems are associated with deviations in body weight along with many non-fatal but debilitating health problems. The present research was planned to study cognitive functioning in relation to body mass index – a measure of body adiposity. A single phase multi-group design was employed. A sample of 230 adult healthy females was divided into five groups on the basis of their BMI (Gr I:< 18. 5; Gr II: 18.5-22.9; Gr III: 23-24.9; Gr IV: 25-29.9; Gr V:> 30).Height and Weight of respondents were obtained in order to calculate Body Mass Index. Measures of cognitive functioning (Reaction Time, Digit Symbol Test, Stroop Color test, Paired Association test, Visual Reproduction test and Ascending Digit task) were administered. The scores were analyzed statistically by using descriptive statistics, ANOVA and Tukey's HSD. The results revealed significant differences among the five BMI groups on all cognitive functioning except for Paired associates. Performance of the deviant BMI groups was significantly poorer on almost all measures of cognitive function in comparison to the normal BMI groups except on working memory (Ascending Digit task). The present results indicate that BMI could be used as an index for prediction of cognitive functioning.

**Keywords:** Body Mass, body weight, cognitive functioning

Cognitive functioning is a fundamental condition necessary for performing competent actions in different spheres of life. It is defined as any task in which correct or appropriate processing of mental information is critical for successful performance. It refers to the process through which information coming from the senses is "transformed, reduced, elaborated, recovered and used" (Neiser, 1967). Cognitive abilities take many forms and consist of a number of different factors and traits. Although fundamental differences exist in the views of psychologists regarding the organization and factors influence cognitive abilities, it is an accepted fact that cognitions are strongly correlated with good health. Several health problems account for cognitive impairments and most of these health concerns are lifestyle diseases. Obesity is one of the key risk factors for these life style diseases and it is a disease in itself. Further, obesity is found to result in impairments /deviation in psycho-physiological functioning

Deviation in body weight is a world-wide health issue and its incidence is reaching to alarming proportions. Besides genetic factors, environmental factors such practising a sedentary life style and having unrealistic notions of anatomical "perfection" are playing a decisive role in prevalence of deviations in body mass. Increased consumption of more energy-dense food, availability of processed foods and foods with high levels of sugar and saturated fats and sedentary life style have led to deviation at the upper end of body mass continuum i.e. obesity, while promotion of 'zero-figure' body shape, imitation of fashionable role models and of course, to a large extent, being under nutrition, have led to deviation at the lower end of body mass continuum i.e. under weight.

According to the World Health Organization (WHO), 1.2 billion people worldwide are officially classified as overweight. This is probably the most sedentary generation of people in the history of the world. In the Indian scenario, even with the growing awareness about health and fitness, more than 3 percent (3 crores ) of the Indian population is obese(Obesity foundation of India,2013).Report from National Family Health Survey-3 (2005-06) shows an increasing prevalence of both overweight and underweight in India, especially among females. More than 35% of women have been reported to have a BMI below 18.5. Further, the percentage of ever married women, aged 15-49 years who are overweight or obese increased from 11% in NFHS-2 (1998-99) to 15% in NFHS-3 (2005-06). According to NFHS-3 (2005-06) the Haryana State ranks 6 in India with 17.6% of overweight or obese females and ranks 11 with 14.4% of overweight or obese males. In a recent study on adult healthy females of Haryana by Pooja, Yadava and Sharma (2012) the distribution of body mass index was reported to be inverted "U" shaped with 46.3% normal weight, 11.64% underweight, 17.3% overweight, 17.3% pre-obese and 7.47% obese.

Several life threatening problems are associated with deviated body mass index along with many non-fatal but debilitating health problems. A deviated BMI has been shown to be associated with adverse changes in health and poor quality of life. It increases vulnerability for certain diseases such as cardiovascular diseases, adult onset diabetes, high blood pressure, dental caries, and some types of cancer, depression, growth retardation, menstrual disorders, risk of osteoporosis, poor self-esteem, and even death (Velegar, 2005). Obesity has been found to be related to diabetes, hypertension, myocardial infarction, other heart diseases, hemorrhoids, cholelithiasis, urolithiasis, and arthritis (Negri, Pagano, Decarli, & La Vecchia, 1988). Obesity is also associated with lower pulmonary functions and pulmonary complications. Lowered pulmonary efficiency typically makes physical activities more difficult. Therefore, functional illness is also found to be associated with obesity (Ferraro & Booth, 1999).

Deviation in BMI not only results in biomedical complications but also compromises psychosocial functioning. Mayers and Rosen (1999) reported that obese people face stigmatizing situations. More frequent exposure to stigmatizing was associated with greater psychological distress, more attempts to cope, and more severe obesity. Greater fluctuations in anxiety, depression and hostility have been reported in overweight individuals (Lingsweiler, Crowther & Stephens, 1987). Perez, Guttierrez, Vioque and Torres, (2001) reported that obese people have an increased odd ratios of hypertension compared to normal BMI.

BMI also exerts a great influence on cognitive functioning. Kilander, Nyman, Boberg, and Lithell (1997) revealed an inverse relation of obesity to cognitive functioning. In a study by Skurvydas, Gutnik, Zuoza, Nash, Zuoziene and Mickeviciene (2009) subjects from the higher BMI group reacted significantly slower on reaction time than other groups. BMI was inversely related to performance on tests of attention and executive functions. Results provide evidence for elevated BMI and reduced cognitive performance (Gunstad, Paul, Cohen, Tate, Spitznagel & Gordan, 2007). Increased body weight is independently associated with decreased visuospatial organization and general mental ability among children (Li, Dai, Jackson & Zhang, 2008). Jeong, Nam, Son, Son and Cho, (2005) reported that general obesity (BMI ≥ 25) and poor cognitions were strongly associated. ). Poorer vigilance performance has been reported amongst bulimics while a specific pattern of cognitive task performance impairments has been observed amongst anorexia nervosa patients (Hamsher, De Halmi, & Benton, 1981). Below normal BMI in the presence of chronic co-morbidity is independently associated with cognitive impairments (Te-Pin Ng, Lei Feng, Mathew Niti & Keng Bee Yap, 2008). Fox (1981) reported that anorexics displayed impairments in short-term memory. Walther, Birdsill and Glisky (2010) reported that higher BMI was

associated with decreased gray matter in certain brain regions and the same was further associated with lower executive functioning. Gazdinski, Millin, Derazzo, Mueffer, Weiner, and Meyerhoff (2010) also reported that higher BMI is associated with neuronal abnormalities in frontal brain regions that sub serve the higher cognitive functions.

Since BMI is associated with physiological and psychological dysfunctions and some parameters of cognitive functioning have also been reported to be compromised in individuals with deviant BMI, it was felt that a study of cognitive functioning in adult females in relation to BMI could be fruitful in implicating it as an index of cognitive functioning, may be for specific aspects of cognitions.

It was hypothesized that cognitive functioning of deviant BMI groups would be significantly poorer than that of the normal BMI groups.

## Method

### *Design:*

A multi-group design, with five groups, was used to study the cognitive functioning in relation to body mass index.

### *Sample:*

A purposive sample of 230 adult females (age range 20-42 years, mean age 26.9 years) were selected from patients from the medicine OPD of Government hospital of Jhajjar who were suffering from acute infection, and were certified to be free from any kind of hormonal disturbance by the medical officer. The assessment of BMI and cognitive functions were done at the residences of the patients after they had recovered from the infection. They were assigned to the various BMI groups on the basis of Body Mass Index criterion of World Health Organization (WHO). Minimum education level of all the subjects was secondary (matriculation) level.

### *Tools:*

*The Personal Information Blank*: A semi-structured blank prepared by the investigator in order to collect information regarding Demographic (name, age, occupation, place of residence and nature of diet consumed) and General Health status (information about presence of any chronic or acute disease and about history of obesity in family).

*Body Mass Index (BMI)*: BMI is one of the standard measures for determination of body fatness like weight charts, hydrostatic weighing and waist to hip ratios etc. The calculation of BMI can be made by dividing weight (Kg) by Height $(m)^2$.For calculation of BMI the weight of respondents was measured by weighing machine and height was measured by using height scales (in meters).

*Measures of specific cognitive functioning*: Mental speed, Attention, Cognitive flexibility, Long-term memory, Visual short-term memory and Working memory was assessed with the various cognitive tasks as tabulated in Table 2.

*Reaction Time Apparatus*: Jensen's Reaction Time (RT) apparatus was used as a measure of mental speed. Reaction time is the time between the end of stimulus presentation and onset of the response. For assessing RT, 110 trails were given (in which 10 trails were catch trails) where the respondent had to press the button corresponding to the visual stimuli. Mean scores were obtained for both decision time and motor/ movement time.

*Digit Symbol test:* Digit Symbol test is one of the performance tests of The Wechsler Adult Intelligence Scale- Revised (WAIS-R). Digit Symbol was used as a measure of attention. There are 93 sample items. Some symbols are assigned to the digits and subject have to draw the appropriate symbol of the digit (e.g. +

**Table 1. Distribution of the sample on the basis of BMI (N=230)**

| BMI | Underweight <18.5 | normal 18.5-22.9 | normal 23.0-24.9 | Pre obese 25.0-29.9 | obese >30 |
|---|---|---|---|---|---|
| Group | I | II | III | IV | V |
| N | 39 | 50 | 58 | 58 | 25 |

symbol to digit 1). Subjects had been instructed to complete as many items as possible within 90 second time limit. Number of accurate responses given in the prescribed time ware noted.

*Stroop Color Test*: Stroop procedures appear to measure a specific higher cognitive function, the cognitive flexibility – the ability to shift between conflicting verbal responses modes. In its common form, the procedures consist of three sets of stimuli and corresponding tasks. The first set of stimuli is a series of color names (e.g. red, blue), printed in black ink, which the subject reads aloud. The second set is a series of color patches. The subject is required to identify the color of each patch. The third set of stimuli is a series of color names printed in non- matching colored inks (e.g. the word 'red' in blue or the word 'tan' in red ink ). The subject's task for the color-word portion of the test was to name the color of the ink in which the word was printed. Number of accurate responses was recorded. The Stroop procedures are very reliable and the Stroop effect is maintained even with the practice.

*Paired Associates(PA)*: It is probably the most common method of presentation used in verbal learning. It is the model example of the traditional view of association and is commonly viewed as being representative of a wide variety of problems people face in mastering verbal materials. The subjects were exposed to the list of stimulus and response item together by flash card technique. The list of paired associates was adapted from the subtest 'Associate Learning' of Wechsler Memory Scale Form-II. Hindi translation of the test was done and both English and Hindi lists were by five judges for equivalence of language in terms of meaning. The test-retest reliability was found to be .79 to .87. The items were presented and sequence of the presentation was varied on each trial. Responses were recorded in the terms of response accuracy.

*Visual Reproduction Test (VRT)*: VRT from Wechsler Memory Scale Form-II was used for assessing the visual short-term memory. The test requires the subject to draw simple geometric figures from memory after being exposed for a period of 10 seconds. The respondents had to draw the figures. The test is brief, easy to administer and reliable. The test is also very important because the obtained memory quotient of this test is directly comparable to the subject's I.Q.

*Ascending Digit Task (ADT)*: It is a simple task used to measure working memory. In this task, subjects are asked to record a sequence of numbers in ascending order. This type of mental activity is carried out by the central executive system of working memory. In this task, the examiner reads a series of numbers and asks the subject to reorder the numbers in ascending order, from the smallest to the largest. In this study, participants were read the series of digits from the digit forward test of Wechsler Adult Intelligence Scale-R. All the series used for tasks were comprised of unitary digits. The task was stopped if the subject made two errors at a given level or completed the task correctly. Number of the series completed correctly was recorded.

***Procedure:***

Respondents were informed about the nature of assessment procedure. The respondents who voluntarily agreed to participate in the study were administered the measures of personal information at their residences. Height and weight of respondents were obtained in order to calculate Body Mass Index. The cognitive tasks were administered by strictly adhering to the procedure as mentioned in respective manuals. Responses of each respondent were recorded in record sheet. Scoring was done as per manual guidelines and analyzed statistically.

## Results and Discussion

To analyze the data, descriptive statistics, and One-way Analysis of Variance (ANOVA) were applied. Post-hoc analysis was conducted by Tukey's Honestly Significant Difference (HSD) test when between five-group comparison was made. The data was analyzed using the SPSS17.0 version for Windows Inc, Chicago, IL, USA. The statistical significance level was considered minimum at $p \leq 0.05$.

**Table 2. Cognitive tasks and their specific area of cognitive functioning**

| Sr. no. | Cognitive Task | Relative area of functioning |
|---|---|---|
| 1 | Reaction Time (RT) | Mental speed |
| 2 | Digit Symbol (DS) | Attention |
| 3 | Stroop color-word Test (C-W) | Cognitive flexibility |
| 4 | Paired Associates (PA) | Long-term memory |
| 5 | Visual Reproduction Test (VRT) | Visual short-term memory |
| 6 | Ascending Digit Task (ADT) | Working memory |

The measures of cognitive functioning along with the specific cognitive area assessed in the present study are tabulated in Table 2.

Table 3 shows the mean and SD of the scores on various tests of cognitive functioning for the five BMI groups. From Table 3, it can be seen that on Reaction time, both Decision time and Motor time, Group II, had the best performance while the deviated BMI groups Group I and Group V had performed poorly on reaction time with higher chronometry scores and a poor mental speed. On Digit symbol, the Group III performed better than other groups exhibiting better performance on attention while again the deviated BMI groups Group I and Group V performed poorer than other three groups with notions of poor attention abilities. On Stroop Color test of interference, the Group I performed better than other groups exhibiting a better cognitive flexibility while Group V has the lower performance on color-word test. On Paired Associates there was no apparent difference among the five BMI groups on long-term memory. On Visual Reproduction test the Group II and Group III performed better than other three groups with a good visual short-term memory while Group V performed poorer on test of visual short-term memory. Further on Ascending Digit task the Group III and Group IV performed better than other group exhibiting a better working memory while deviated BMI groups i.e. Group I and Group V performed poorer.

Group II have best performance on tests of mental speed, long-term memory and visual short-term memory. Group III performed best on tests of attention and working memory, Group IV had better performance on test of cognitive flexibility and working memory. Group I and Group V performed poorer than other BMI groups.

Thus, from the means it appears that the deviant BMI groups performed poorer than normal BMI groups on tasks of mental sped, attention, cognitive flexibility, visual short term memory and working memory. On long term memory no apparent difference were observed among the five BMI groups.

To determine whether the mean differences among the five BMI groups were significant, ANOVA was applied.

**Table 3. Mean scores of the Five BMI Groups on the Cognitive tasks (N=230)**

| Cognitive Task | Group I | Group II | Group III | Group IV | Group V |
|---|---|---|---|---|---|
| Decision Time | 0.350±0.061 | 0.270±0.033 | 0.280±0.027 | .280±.024 | 0.410±0.035 |
| Motor Time | 0.770±0.054 | 0.580±.041 | 0.680±.034 | 0.670±0.03 | 0.870±0.110 |
| Digit symbol | 31.62±5.4 | 37.7±3.94 | 41.02±3.79 | 34.67±4.68 | 27.76±4.34 |
| Stroop color | 94.41±2.97 | 91.72±4.8 | 90.43±4.30 | 90.43±4.04 | 86.52±5.7 |
| Paired Associate | 15.1±1.44 | 15.06±2.02 | 14.71±2.25 | 15.03±2.39 | 15±1.73 |
| Visual Reproduction | 8.31±1.779 | 10.12±1.35 | 9.79±1.64 | 8.86±1.801 | 7.36±1.534 |
| Ascending Digit | 6.44±1.77 | 7.36±1.89 | 7.74±1.70 | 7.74±1.792 | 6.84±1.993 |

**Table 4. Significance of differences among five BMI Groups (N=230)**

| Dependent variable | F Value |
|---|---|
| Decision time (DT) | .81.817** |
| Motor time (MT) | 153.353** |
| Digit symbol (DS) | 48.422** |
| Stroop Color (SC) | 13.166** |
| Paired Associates(PA) | .307 |
| Visual Reproduction (VR) | 15.699** |
| Ascending Digit (AD) | 3.034* |

df :4, 224 ,*p≤.05, **p≤.01

From Table 4 it is clear that the main effect of group on all the cognitive functioning scores was significant except for the Paired Associates which indicate that the groups differed on almost all cognitive tasks and exhibiting significant group differences in mental speed, attention, cognitive flexibility, visual short-term memory and working memory. For analysis of the significance of difference between the mean scores of the five BMI groups, Tukey's HSD post-hoc analysis was applied. Table 5 shows the results of the post-hoc analysis.

Post-hoc analysis revealed that one or more groups varied from the other BMI group on all the measures of cognitive functioning. On mental speed, which was measured by reaction time test, significant group differences were observed for Group I and Group V. These groups differed significantly from other three groups on measure decision time. On motor time, Group I and Group V differed significantly from other three groups however differences were also observed for Group II with Group III, IV and V. Attention was found to vary significantly between all BMI groups, except the comparison between Group II and Group III. On the variable of cognitive flexibility, the extreme BMI groups i.e. Group I and Group V varied significantly from normal BMI groups i.e. Group I and Group II and from overweight group i.e. Group IV. Short-term memory of the deviant BMI groups i.e. Group I, IV and V significantly differed from normal BMI groups i.e. Group II and III .Significant differences were not observed among combinations of Group I and IV, Group I and V and of Group II and III. On working memory, only one comparison i.e. Group I and Group III differed significantly. These results clearly indicate that the measures of cognitive functioning varied as a function of Body Mass Index (BMI).Thus, the proposed hypothesis which stated that cognitive functioning of deviant BMI groups would be significantly poorer than that of the normal BMI groups, was verified except for working memory and paired associate learning (long term memory) .

Considerations of the results indicated that the deviated body mass index accounts for the compromised cognitive functioning. The exact mechanism underlying the association between cognitive functions may be structural atrophy in certain brain regions due to adiposity. Higher BMI was associated with decreased gray matter volumes in the left orbitofrontal region which was associated with lower executive functioning (Walther, Birdsill, Glisky, & Ryan 2010). Deteriorations in sensory discriminations among high BMI was also reported (Gardner, Brake, Reyes, & Maestas, 1983; Gardner, Salaz, Reyes, & Brake, 1983).

**Table 5. Tukey's HSD Post-hoc analysis between Five BMI Groups (N=230)**

| Cognitive Task | Comparison Group | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | I-II | I-III | I-IV | I-V | II-III | II-IV | II-V | III-IV | III-V | IV-V |
| DT | .79* | .71* | .77* | -.52* | .008 | -.002 | -.13* | .006 | -.12* | -.13* |
| MT | .19* | .09* | .099* | -.10* | .09* | -.08* | -.28* | .002 | -.19* | -.20* |
| DS | -6.08* | -9.40* | -3.05* | 3.85* | -3.31 | 3.02* | 9.94* | 6.3* | 13.2* | 6.91* |
| SC | 2.69* | 3.97* | 3.9* | 7.8* | 1.28 | 1.289 | 5.200* | .000 | 3.911* | 3.911* |
| VR | -1.8* | -1.5* | -.554 | .948 | .327 | 1.258* | 2.760* | .931* | 2.433* | 1.502* |
| AD | -.992 | -1.30* | -.909 | -.404 | -.38 | .015 | .520 | .397 | .901 | .505 |

*p≤.05

Some researchers reported that obesity cause deterioration in attention and concentration abilities (Beutel, Klockenbrink, Wiltink, Dietrich, Thiede, Fan, & Posner, 2006; Cserjesi, Molnar, Luminet, & Lenard 2007; Gunstad, et al. 2007). Altered cognitive functioning among overweight and obese is also reported on tests of problem solving and planning (Boeka & Lokken, 2008; Gunstad, et al. 2007; Lokken, Boeka, Yellumahanthi, Wesley & Clements, 2010; Walther et al. 2010). Low numeracy skills were also reported in high BMI (Huizivga, Beech, Cavanaugh, Elasy & Rothman, 2008). Hassing, Dahl, Pedersen and Johansson (2010) reported the significant association of high BMI and poor performance on tests of verbal and spatial dexterity. Deteriorations in information processing speed among obese are also reported (Fergenbaum, Beuce, Lou, Hanley, Greenwood, & Young, 2009; Hassing et al., 2010). Decreased visuospatial organization is reported among overweight children by Li et al. (2008). Neurocognitive dysfunctions were also reported in a condition of high BMI by Brook, Zhang, Saar and Brook (2009). Hamsher et al. (1981) reported poorer vigilance performance among anorexics and bulimics.

These findings may have implication for optimal weight maintenance to keep cognitive functioning as best as possible. If one desires to prevent obesity-related cognitive decrements, intervention may have to be initiated at a very early stage. The relationship between deviated BMI (overweight and underweight) and cognitive dysfunction is worth investigating further, because both obesity and underweight are becoming major public health threats in view of the continuous increase in the prevalence of the condition. A better understanding of the mechanism linking body mass to cognitions may uncover new possibilities for the prevention of deviated body mass related cognitive decline.

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