COGNITIVE FLEXIBILITY AND INHIBITORY CONTROL AMONG OBESE PATIENTS UNDERGOING BARIATRIC SURGERY

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ABSTRACT
Growth in obesity is leading to higher cognitive and psychological risks. Cognitive flexibility and inhibitory control as executive cognitive functions have been found to be compromised in obese individuals, all of which play an important role in human behavioural regulation. **Aim:** Considering bariatric surgery to be one of the obesity-cutting treatments, the main aim of this study was to compare Cognitive Flexibility and Inhibitory Control in obese individuals before and after the surgery. **Methods:** A sample group of 120 obese individuals with BMI higher than 30 (BMI Classification, WHO; 2006) were selected using purposive sampling technique from the Nobesity center of Ahmedabad, Gujarat. The sample group was divided into half: 60 individuals who underwent bariatric surgery as an experimental group and 60 individuals who did not undergo surgery as control group. Comprehensive Trail Making Test and Stroop Color and Word Test was administered before surgery and six months after the surgery for experimental group, and twice for the control group in the interval time of six months. The data was statistically analyzed by using t-test. **Result & Conclusion:** Bariatric surgery patients exhibited high rates of pre-operative cognitive impairment in both the executive functions. A significant difference was found in cognitive flexibility and inhibitory control pre and post bariatric surgery whereas there was no notable difference found with the control group in the same time interval of six months. With substantial percentage weight loss, improvement in the function of cognitive flexibility and inhibitory control was imaged in patients of obesity. **Keywords:** Cognitive flexibility, inhibitory control, executive function, obesity, bariatric surgery.

INTRODUCTION
Obesity is defined as accumulation of abnormal or excessive fat that can lead to various health risks (World Health Organisation; 2019). Obesity can be measured using Body Mass Index (BMI) which can be obtained by dividing weight in kilograms by square of height in meters. An individual with a BMI of 30kg/m² and higher is considered to be obese (BMI Classification, WHO; 2006). Major risk factors following obesity are chronic diabetes,
cardiovascular disorders and certain cancers. As per the reports of World Health Organization in 2016, 1.9 billion adults were overweight from which 650 million were obese. According to the State fact sheet of National Family Health Survey- 4 (2015-16), 34.5% of the urban women of Gujarat were overweight and obese, and 25.9 % of the urban men of Gujarat were overweight and obese. Obesity works on several different metabolic pathways that can affect the way we process information. ‘Obesity affects a number of physiological mechanisms that can have an adverse effect on the brain,’ quoted John Gunstad, of Kent State University. An international team of scientists’ report that obesity subtly diminishes memory and other features of thinking and reasoning even among seemingly healthy people (Raloff J., 2011).

Anatomically, obesity has seen to be affecting both white and grey matter in volume reduction, especially hippocampus, prefrontal cortex, and other subcortical regions, and poor cognitive performance (Stillman et al., 2017). Studies have found that obesity is associated with cognitive impairment, altered executive function, short-term memory and dementia (Kivipelto et al., 2005; Whitmer et al., 2009; Nguyen et al., 2014). Excess adipose tissue has negative vascular and metabolic consequences on the body and deterioration in vascular health leads to executive cognitive dysfunction. (Forman et al., 2008; Stillman et al., 2017). Body Mass Index and metabolic activity found in prefrontal cortex and cingulate gyrus were found to have a negative correlation in a 2009 study. This was measured with Positron Emission Tomography and was positively correlated with executive test performance (Volkow et al., 2009). Higher body mass index (BMI) is associated with poorer performance on measures of response inhibition/ inhibitory control. (Gunstad et al., 2006).

Many behavioural modification programmes like diet control and exercise and pharmacological treatments help reduce the initial 8 – 10 percentage of body weight. Despite of this, relapse in weight gain is commonly observed. Hence, in cases of severe obesity (> 35 kg/m²) and obesity where no other treatment helps, bariatric surgery is considered to be the most effective intervention.

The term Executive Functions refers to the higher-level cognitive skills used by a person to control and coordinate other cognitive abilities and behaviours (Diamond, 2013). These higher-level cognitive skills include set-shifting/cognitive flexibility, working memory and impulse inhibition/inhibitory control.

Cognitive Flexibility includes creatively thinking “outside the box,” seeing anything from different perspectives, and quickly and flexibly adapting to changed circumstances. More than the weight itself, reduced mental flexibility and sustained attention capacity was found
to be major problems that accompanied obesity along with depressive moods (Cserjési et al., 2009). Measures of central obesity were significantly related to be poorer performance on executive function and visuomotor skills (Wolf et al., 2007). John Gunstad in his study concluded an existing relationship between elevated BMI and reduced cognitive performance.

Impulse inhibition or inhibitory control as a function is involved in the ability to ignore distraction and resist to temptation. It includes delayed gratification, interrupting a routine behaviour, directing attention away from distractions. It helps in regulating emotions and keep from acting impulsively. Inhibitory control as an executive cognitive function has a vital role in human behavioral regulation which is much required in the patients with obesity. It is a cognitive process that permits individuals to inhibit their impulses and natural, behavioural responses to stimuli in order to select a more appropriate behaviour that is consistent with completing their goals.

As obesity is preventable, a question arises whether reduction of obesity has any improvement in executive cognitive function after the bariatric surgery. Better cognitive functions 12 weeks post bariatric surgery were found to be related with higher percentage weight loss (Spitznagel et al., 2013). Previous studies have worked upon relationship between obesity and cognition in obese and normal weight individuals. This paper focusses on measuring and comparing the function of Cognitive flexibility and Inhibitory control as executive cognitive functions in obese individuals pre and post bariatric surgery.

**Objectives of the Study**

- To compare cognitive flexibility among the patients of bariatric surgery before and six months after surgery.
- To compare cognitive flexibility, as an executive cognitive function among the obese controls in the interval of six months of test administration.
- To compare inhibitory control among bariatric surgery patients; pre-surgery and six months post-surgery.
- To compare inhibitory control among obese controls in the same interval time of six months.

**MATERIALS AND METHODS**

**Sample**

A sample group of 120 (60 males, 60 females) obese individuals with BMI higher than 30 (BMI Classification, WHO; 2006) were selected using purposive sampling technique from
the Nobesity center of Ahmedabad, Gujarat. The sample group was divided into half; 60 individuals who underwent bariatric surgery as an experimental group and 60 individuals who did not undergo surgery as control group. The sample selected was in the age range of 21 to 50 years and had at least 12 years of education. The obese group was required to have Body Mass Index (BMI Classification, WHO; 2006) more than 30 kg/m$^2$. Those with any diagnosis of mental disorders or any other chronic comorbidities were excluded from the sample group.

**Tools**

- **Comprehensive Trail Making Test (CTMT, Cecil R. Reynold; 2002)**
  CTMT, a neuropsychological test, is a set of five visual search and sequencing tasks that focus on attention, concentration, resistance to distraction, set-shifting (or cognitive flexibility). Suitable for individuals between the ages of 11 and 74 and it takes 5 to 12 minutes to complete. It also detects frontal lobe deficits; problems with psychomotor speed, visual search, sequencing, and attention; and impairments in set-shifting. The first part of this test assesses attention and psychomotor speed and the second part assesses executive function- cognitive flexibility. The test-retest reliability for CTMT is .84.

- **Stroop Color and Word Test (SCWT, Charles J. Golden & Shawna M. Freshwater; 2002)**
  SCWT has been revised for adults for examining executive functions and response inhibition. The cognitive dimension tapped by Stroop is associated with cognitive flexibility, resistance to interference from outside stimuli, creativity, and psychopathology-all of which influence the individual's ability to cope with cognitive stress and process complex input. In the first part, the subject is required to the name of each word as quickly as possible, assessing attention. In the second part, the subject is required to name to the color of each word as quickly as possible, assessing executive function. The dependent measure is total number of words correct. Test-retest reliability of is .86, .82 and .73 for Word, Color and Color-word scores respectively.

**Procedure**

To obtain the sample group in the current study, official permission was taken from the authorities in charge of the Nobesity clinic of Ahmedabad city. Clinically diagnosed obese patients were personally approached to be a part of the sample with due procedure. Followed
by a brief rapport, an informed consent was signed by each individual promising confidentiality and anonymity. The patients were administered Comprehensive Trail Making Test and Stroop Color and Word Test individually. Specific instructions about the tests were given to the patients so that they could perform accordingly. Privacy and comfortable atmosphere were ensured throughout the data collection. After completion of the data collection, responses of each respondent were scored with the help of the scoring keys of the manuals. The data was then tabulated accordingly.

**Statistical Analysis**

To find out the mean and significant difference of the independent variable of surgery (pre and post) on the scores of cognitive flexibility function and inhibitory control, t-test was applied as a statistical tool to compute the data with the help of SPPS v16. The lesser time taken by the subjects to complete the task scored them a higher value. BMI and percentage weight loss were calculated at both times of test administration.

**RESULTS**

**Baseline BMI and Percentage Weight loss** - The average baseline BMI of the bariatric surgery group before surgery was 42.57 kg/m² which reduced to 29.73 kg/m² 6 months after surgery. The average BMI for the obese control group was 40 kg/m² which changed to 38.27 kg/m² after 6 months. The average percentage weight loss after 6 months in bariatric surgery group was 21.53 kgs (SD= 5.14) and that for the obese control group was 3.87 kgs (SD= 3.0).

**Table 1: Mean scores, SD and ‘t’ values of Bariatric Surgery Group (pre and post-surgery) on the function of Cognitive flexibility.**

<table>
<thead>
<tr>
<th>CTMT Trails</th>
<th>Bariatric Surgery Group</th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>‘t’ value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-Surgery</td>
<td>60</td>
<td>37.23</td>
<td>6.74</td>
<td></td>
</tr>
<tr>
<td>CTMT - Trail 1</td>
<td>6 months</td>
<td>60</td>
<td>46.16</td>
<td>9.49</td>
<td>5.94**</td>
</tr>
<tr>
<td></td>
<td>Post-Surgery</td>
<td>60</td>
<td>34.66</td>
<td>6.84</td>
<td></td>
</tr>
<tr>
<td>CTMT - Trail 5</td>
<td>6 months</td>
<td>60</td>
<td>45.33</td>
<td>7.35</td>
<td>8.22**</td>
</tr>
</tbody>
</table>

**p .01**
Table 1 shows the Mean, SD and ‘t’ values of the Bariatric Surgery Group for CTMT Trail 1 and Trail 5. For both Trail 1 and Trail 5, a significant difference (p<.01) was found in the function of cognitive flexibility, pre-surgery and 6 months post bariatric surgery. The mean score of patients’ post-surgery was higher indicating better cognitive flexibility six months after surgery.

Table 2: Mean scores, SD and ‘t’ values of Obese Control Group (in the interval of 6 months) on the function of Cognitive flexibility.

<table>
<thead>
<tr>
<th>CTMT Trails</th>
<th>Obese Control Group</th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>‘t’ value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CTMT - Trail 1</td>
<td>1st Administration</td>
<td>60</td>
<td>39.63</td>
<td>7.45</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6 months post 1st Administration</td>
<td>60</td>
<td>42.80</td>
<td>7.62</td>
<td>2.30*</td>
</tr>
<tr>
<td>CTMT – Trail 5</td>
<td>1st Administration</td>
<td>60</td>
<td>36.66</td>
<td>6.77</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6 months post 1st Administration</td>
<td>60</td>
<td>38.58</td>
<td>5.81</td>
<td>1.62NS</td>
</tr>
</tbody>
</table>

*p .05, NS- Not significant

Table 2 shows the Mean, SD and ‘t’ values of the Obese Control Group for CTMT Trail 1 and Trail 5. There was a significant difference found between the two administration times for Trail 1 at 0.05 level of significance. Whereas, for Trial 2, there was no significant difference seen between the two administration times. This indicates that there was no change observed in cognitive flexibility after 6 months of 1st administration.

There was no significant difference between bariatric surgery pre group and obese control 1st test administration group for both Trail 1 and Trail 5. While there was a significant difference noted between post-surgery group and 2nd test administration control group for both Trail 1 (t=2.14, p=0.03) and Trail 5 (t=5.57, p=0.001).
Table 3: Mean scores, SD and ‘t’ values of Bariatric Surgery Group (pre and post-surgery) on the function of Inhibitory Control.

<table>
<thead>
<tr>
<th>Time of test administration</th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>‘t’ value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bariatric Surgery Group</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-surgery</td>
<td>60</td>
<td>48.16</td>
<td>4.91</td>
<td></td>
</tr>
<tr>
<td>6 months Post-surgery</td>
<td>60</td>
<td>58.58</td>
<td>5.20</td>
<td>11.26 **</td>
</tr>
</tbody>
</table>

**p < .01

Table 3 shows a significant difference in the function of inhibitory control pre and post the bariatric surgery at .01 level of significance. The post-surgery bariatric group found to have higher mean score compared to pre-surgery bariatric group. This indicates that inhibitory control was higher after 6 months of surgery than pre-surgery.

Table 4: Mean scores, SD and ‘t’ values of Obese Control Group (in the interval of 6 months) on the function of Inhibitory Control.

<table>
<thead>
<tr>
<th>Time of test administration</th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>‘t’ value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Obese Control Group</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1st administration</td>
<td>60</td>
<td>48.88</td>
<td>5.60</td>
<td>0.34 NS</td>
</tr>
<tr>
<td>6 months after the 1st admin</td>
<td>60</td>
<td>49.21</td>
<td>5.06</td>
<td></td>
</tr>
</tbody>
</table>

NS – Not significant

Table 4 indicates no significant difference between the 1st administration and 2nd administration (after 6 months) in the function of Inhibitory Control of the Obese control group. The mean score of obese control group was not significantly higher than the surgery group. This shows that at both the times of administration, the function of inhibitory control was more or less the same. It can be observed that the mean score of bariatric surgery group increased by 10.42 units (from 48.16 to 58.58) whereas in the obese control group the mean score increased by 0.33 units (from 48.88 to 49.21).

DISCUSSION

Executive cognitive functions help people to manoeuvre between different ideas and thoughts, taking time to think before acting, achieving new and unexpected challenges, resisting temptations and staying focused. All of it requires sustained attention, psychomotor speed, inhibitory control and more importantly cognitive flexibility of the brain. The main
aim of the study was to compare cognitive flexibility and inhibitory control in the patients of 
obesity before and after the weight-loss interventive bariatric surgery.

The results of the study demonstrate a significant difference before and after bariatric surgery 
for both Trail 1 and Trail 5 of comprehensive trail making test. The time taken by the 
experimental group lowered when tested 6 months after surgery which was not the case with 
the obese controls. Obese control group showed a slight improvement in time taken for 
completing Trail 1 when re-tested after 6 months (p=.05). However, there was no difference 
found in completing trail 5, that is, they completed Trail 5 within the same time frame at both 
times of administration. Although the level of sustained attention and psychomotor speed 
showed improvement, there was no change found in the function of cognitive flexibility.

Cognitive flexibility plays a vital part in the course of adherence when it comes to following 
new nutritional regimen (Brock et al., 2011). In this case, obese adults have a drawback 
situation because of their difficulties in changing or shifting. It would be difficult for them to 
come out of their previous regime and follow any new diet or physical exercise. The pattern 
of cognitive inflexibility in obese individuals have been supported by previous studies 
(Campoy et al., 2011).

Executive dysfunction is linked with high calorie food intake and sedentary lifestyle (Riggs et 
al., 2012). In order to reduce the accumulated fat in the body, rigorous change in the lifestyle 
is essential. Such a lifestyle involves restrained amount of high calorie food intake and 
curtailing sedentary lifestyle. This means all the favourite and the most desirable part of life-
‘tasty, junk, high-calorie food’ needs to be changed to ‘healthy, nutritious, low amount of 
food’. It was observed that most of the subjects under study had undergone diet and gym 
schedules various times in life but failed to maintain this change.

Bariatric surgery patients before surgery along with the obese control group had longer 
execution time in the SCWT tasks. These results indicate that the subjects reported difficulty 
in response maintenance and distractibility, cognitive interference, problems in regulating 
emotions as well as keep from acting impulsively and a decrease in the inhibition capacity. 
They are more vulnerable to eating without control leading to higher struggle in inhibiting 
unhealthy eating behaviour when exposed to food.

Because of difficulty in shifting attention, problems pertaining to inhibiting impulsive 
thoughts and inflexibility in adapting change, it is a struggle for this population to change, 
despite of knowing how beneficial they could be for them. This was also confirmed in the 
study done by Lokken et al. in 2010. Patients who undergo bariatric surgery have to 
mandatorily follow a set of guidelines involving a stringent diet, tracking physical activity
levels and medicine management (Mechanick et al, 2013). Hence, it may become difficult for them to adhere to the new routine initially. With the constant effort to follow a planned timetable, they learn to calculate each and every calorie and nutrition value they intake. Similar findings were observed by Alosco et al. in 2013. The level of ingestion in the initial 2-3 months after surgery is usually so low, that even if one desire to eat slightly more, his/her body will throw it up instantly. This may leave them with no choice but to follow their new timetable with little cheats as possible.

It was observed that the support group counselling every month held by the team of psychologist, dietician, endocrinologist and the bariatric surgeon motivates them to be on track. All that hard work and conscious effort to change for continuous six months may bring in changes in the executive functions of the brain and behaviour. Such an improvement in cognitive flexibility and inhibitory control was not found in obese controls after six months.

The results show that the average percentage weight loss after 6 months in bariatric surgery group was 21.53 kgs (SD= 5.14) and that for the obese control group was 3.87 kgs (SD= 3.0). This study like any other study has a few limitations. The sample size was less and only restricted to Ahmedabad city. The time period of comparison of cognitive flexibility and impulse inhibition was for six months. Extended time interval would have been beneficial to test this function in a longer run. Future research may consider direct evaluation of individual comorbid medical conditions for better understanding of participant characteristics that may be related to cognitive results.

CONCLUSION

The results of this study indicate better cognitive flexibility performance in the patients of bariatric surgery six months after surgery. However, there was no change in performance on cognitive flexibility found with obese controls in the interval time of six months. Performance on inhibitory control improved among the obese group post bariatric surgery and there was no significant difference found among the obese control group for the same.

Implications of the study – the present study found the need to address the importance of understanding, how cognitive flexibility and impulse inhibition play a fundamental role in obesity controlling behaviours. It is merely few of the factors but necessary ones to focus upon. Awareness of this fact can help obese individuals work towards their set-shifting and inhibiting behaviours. Caregivers and family members should understand the mind-set of the patients and offer loving care, warmth and emotional support. The research would help
physicians and psychologists to understand not just the pattern of change required but also the appropriate means to achieve them. Performance of executive function during the clinical screening of the bariatric surgery candidates may help in identifying individuals needing intensive psychological attention.

REFERENCES


