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Research Article

# Changes in Cognition Functions and Depression Severity After Bariatric Surgery: A 3-Month Follow-up Study

Masoud Ahmadzad-Asl [1], Bita Dinarvand [2], Fatemeh Bodaghi [2], Seyed Vahid Shariat [3], Zainab Sabzevari [4], Mina Talebi [5], Behnoush Shariati [6], Abdolreza Pazouki [7, 8] and Behnam Shariati [9, 3, *]

[1] Department of Psychiatry, Sunnybrook Health Sciences Centre, University of Toronto, Toronto, Canada
[2] Iran University of Medical Sciences, Tehran, Iran
[3] Mental Health Research Center, Iran University of Medical Sciences, Tehran, Iran
[4] Central Tehran Branch, Islamic Azad University, Tehran, Iran
[5] Clinical Psychology, Islamic Azad University, West Tehran Branch, Tehran, Iran
[6] Health Psychology, Karaj Islamic Azad University, Tehran, Iran
[7] Minimally Invasive Surgery Research Center, Division of Minimally Invasive and Bariatric Surgery, Department of Surgery, Rasool Akram Medical Complex, Iran University of Medical Sciences, Tehran, Iran
[8] Center of Excellence of International Federation for Surgery of Obesity and Metabolic Disorders, Tehran, Iran
[9] Minimally Invasive Surgery Research Center, Iran University of Medical Sciences, Tehran, Iran

[*] *Corresponding author*: Mental Health Research Center, Iran University of Medical Sciences, Tehran, Iran. Email: behnamshariatimd@gmail.com

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## Abstract

**Background:** Changes in cognitive profile, such as memory and other functions in patients with morbid obesity after bariatric surgery have been reported in the literature with inconsistent results.
**Objectives:** This study aimed to evaluate cognitive changes, executive function and depression severity before and after bariatric surgery in patients with morbid obesity.
**Methods:** In this prospective cohort study, 70 patients with morbid obesity (40 patients undergoing bariatric surgery and 30 patients in the waiting list) referred to the Rasool Akram Medical Complex, obesity clinic, Tehran, Iran, in 2016entered the study. The two groups were assessedusing the Wechsler Memory Scale (WMS) (consists of 7 subscales and assesses memory), the Wisconsin Cart Sorting test (WCST) (includes 64 cards and assesses cognitive skills), the Hamilton Depression Scale (HAM-D) (for measuring depression) and bariatric analysis and reporting outcome system (BAROS) questionnaire (scale to report of the therapeutic results of bariatric surgery and including the three criteria of the weight loss percentage, the change in health state, and the quality of life) at the beginning of the study and three months after the surgery. Moreover, the Bariatric Analysis and reporting outcome system (BAROS) questionnaire was filled three months after surgery.
**Results:** The average changes in WMS score (P = 0.043), working memory (P = 0.002), HAM-A (P = 0.032), weight, and BMI (P = 0.0001) in the surgery group were significantly higher than the control group. There was a significant positive correlationbetween change in the number of preservative errors in WCSTwithin the surgery group withBAROS score (P = 0.004). Moreover, there was a significant correlationbetween changes in the score of WMSand those in BMI in the surgery group.
**Conclusions:** Bariatric surgery is associated withimprovements insome cognitivefunctionsand worsening of depressive scores in patients with morbid obesity.

*Keywords:* Memory, Cognitive Function, Morbid Obesity, Bariatric Surgery, Depression

## 1. Background

Regarding the pervasive nature of obesity (that affects one-third of the general population), its 0.4% annual growth, unfavorable effects on physical and mental health, and high expenses, there is a need to treat obesity (BMI $\geq$ 30) and morbid obesity (BMI $\geq$ 35) (1-3). Also in Iran, overweight and obesity is growing at an alarming rate, with a prevalence of 42.8% to 57.0% in people aged 15–65 years , and it is responsible for 60% of the deaths in an Iranian population (4).

Several pieces of evidence suggest the role of obesity in cognitive and neuronal dysfunction. Higher BMI is considered as an independent risk factor for Alzheimer's disease, vascular dementia, and stroke. Furthermore, recent investigations have shown that high levels of BMI are related to cognitive dysfunction, especially in terms of memory and executive functions (5-7). Cognitive complications caused by obesity include reduced performance on activities of daily life, decreased executive function, and slower processing speed (8-11).

Bariatric surgery is the most effective intervention in the treatment of morbid obesity. Weight-loss after surgery improves many obesity comorbidities such as hypertension, cardiovascular diseases, diabetes mellitus, sleep apnea, hyperlipidemia and osteoarthritis (4). On the other hand, postoperative cognitive functions would be improved (12, 13). Some otherstudies have shown that bariatric surgery can enhance obesity-related cognitive functions (14, 15). Several studies have also suggested that improvement of cognitive and functional complications is sustainable by two years after bariatric surgery (14).

According to some studies, compared to general population, obese people get a lower score in cognitive tests including memory, attention, and executive functions. However, after bariatric surgery, their cognitive function is improved, especially in terms of memory. Also, it is suggested that bariatric surgery candidates with a higher cognitive function before surgery report more weight loss after surgery. Regarding improvement in some comorbidities and psychological conditions after bariatric surgery, cognitive indicators affected by such diseases including memory and other cognitive functions may change after surgery (14, 16). To measure patients' response to bariatric surgery, a scoring system named the Bariatric Analysis and reporting outcome system (BAROS) was designed which its efficiency has been approved in many studies (17).

## 2. Objectives

No investigation has simultaneously investigated patients' cognitive function and response to bariatric surgery based on the BAROS yet. Therefore, the present study aimed to assess the association between obesity surgery and cognitive function. Then we assessed cognitive changes and executive function before and after bariatric surgery. Additionally, we investigated depression severity among participants.

## 3. Methods

### *3.1. Participant*

This prospective cohort study was approved by Iran University of Medical Sciences ethics committee (IR.IUMS.REC1394.26512). In this study, seventy patients referred to the Obesity Clinic of Rasool Aram Medical Complex were studied in two groups in 2014 - 2015. All participants were recruited in the study before surgery and they had ok for surgery. The first group included 40 obese patients who underwent bariatric surgery from one day to one week after the initial evaluation (surgery group), and the second group included 30 obese patients who had the inclusion criteria but were in the wait list to undergo surgery in near future (about 8 month later) (control group).

Inclusion criteria for both groups included: being candidates for bariatric surgery and age range of 20 - 70 years. The exclusion criteria included history of nervous system disorders, severe psychiatric disorders (such as schizophrenia, bipolar disorder, and severe major depressive disorder diagnosed based on the DSM-5 criterion before surgery), learning disabilities, neuro developmental problems, sensory processing disorder, substance dependency, and alcoholism.

### *3.2. Evaluation and Follow-up*

In the beginning of study, the patients' demographic information (age, gender, and BMI) were collected by a checklist. The Wechsler Clinical Memory Scale (WMS), the Wisconsin Card Sorting Test (WCST), the Hamilton Anxiety Scale (HAM-A), the Hamilton Depression Scale (HAM-D), and the BAROS tests were filled and repeated after 12 weeks in the both groups.

#### *3.2.1. Measurement Tools*

##### *3.2.1.1. The Wechsler Clinical Memory Scale (WMS)*

This test consists of 7 subscales including information, orientation, mind control, logical memory, number repetition, visual reproduction, and learning association. The total score of memory is obtained by the sum of the scores of the subscales. The sum of the scores is added to a constant modified score included in age groups tables, and the result indicates the standardized score of memory. By matching the resulted number with the table, the equivalent memory quotient (MQ) is determined. Its Persian version has had acceptable validity and reliability (18).

##### *3.2.1.2. The Wisconsin Card Sorting Test (WCST)*

This scale is a standard neuropsychological test designed for measuring skills of problem solving, classification, abstract thinking, concept formation, and cognitive flexibility. It includes 64 cards. The validity of this test was previously approved in an Iranian population (19). Also, Rahimi et al. approved the reliability in Iranian subjects (19).

##### *3.2.1.3. The Hamilton Rating Scale of Anxiety (HAM-A)*

The Hamilton's anxiety scale is currently one of the most well-known anxiety tests (20). The Hamilton scale includes 14 items, each related to a specific symptom of anxiety. In this test, each item is scored 0 - 4 by the therapist regarding the severity of symptoms. Zero indicates that the symptom is not observed, and 4 indicates the severity of the same symptom. This scale is graded by an evaluator. Questionnaires were filled by interview from patients or their relatives, history taking, and observation. Paul F Slater approved the validity and reliability of the translated version of this questionnaire in the Iranian population (21).

#### 3.2.1.4. The Hamilton Depression Inventory

This questionnaire is one of the first scales designed to assess depression. The main version of the HAM-D includes 21 items (22). Ebrahimi et al. approved the reliability of its translated version (0.81) in an Iranian population (23).

#### 3.2.1.5. The BAROS Questionnaire

This questionnaire was designed by NIH (1998) (24) to standardize the report of the therapeutic results of bariatric surgery. The BAROS is a scoring system including the three domains of weight loss percentage, change in health state, and quality of life and granting each $\leq 3$ points. On BAROS the complications may be classified into surgical and clinical, major or minor, early or late, including almost all the diseases related to the procedures. In case of surgery complications or the need fora secondary surgery, a negative score is considered. BAROS' scoring is defined by the type of complication that occurred, and three types of different scores are possible: without complications (0 point), minor complication (-0, 2 points), major complication (-1 point), independently from the number of injuries that occurred, receiving the highest scoring of -1, 2 points. The new surgeries, on the other hand, may receive two possible classifications: with new surgery (-1 point) and without (0 point). The summing up of the complications and reoperations may vary from 0 to -2, 2 points. Finally, based on the final score, patients are classified in five groups of excellent, very good, good, medium, and failed treatment. In this project, statistical analysis is performed based on both the quantitative score and the BAROS rank group. This criterion has been introduced as an efficient way of evaluating bariatric surgery success with approved reliability. In the present study, the Persian translation of this questionnaire was used for the first time. The reliability of the translated version was evaluated by back translation in another investigation and its reliability was found to be 83%.

### 3.3. Ethics Statement

Ethical approval was obtained based on the principles of the World Medical Association Declaration of Helsinki. This study was approved by the institutional review board of Iran University of Medical Sciences ethics committee (IR.IUMS.REC1394.26512). All patients signed informed consent statements.

### 3.4. Statistical Analyses

Data was analyzed using SPSS 22 software (IBM Corp., Armonk, N.Y., USA). The basic variables were reported based on descriptive statistics and central tendency indicators such as frequency, mean, SD, and other central tendency and dispersion statistics. We checked the normal distribution of data using the Kolmogorov-Smirnov test. Considering non-significant results of normality, we compared cognitive states before and after surgery using paired-*t* test. Besides, *t*-test was used to compare quantitative variables between the two groups. The qualitative variables were compared by chi-squared test. The relationship between changes of cognitive state and BAROS score was studied by repeated measures analysis. A P value below 0.05 was considered as statistically significant.

## 4. Results

Seventy patients with obesity (40 patients after surgery and 30 patients in the waitlist as controls) were studied in this research. The surgery and control groups included 35 (87.5%) and 28 (9.33%) women, respectively; also, there were 5 (22%) and 5 (16.6%) patients with diabetes mellitus, correspondingly. Mean BMI ($\pm$ SD) were 45.1 $\pm$ 1.3 and 46.9 $\pm$ 2.4 kg/m$^2$ in the surgery and control groups, respectively without a statistically significant difference. Meanwhile, there was no significant difference between the two groups in terms of serum cholesterol level and prevalence of heartburn, sleep apnea, cardiovascular diseases, high blood pressure, demographic variables and clinical characteristics (P-value > 0.05) (Table 1).

The results showed a significantly higher score of immediate auditory memory and working memory in the surgery group (71.6 $\pm$ 3.8) (22.2 $\pm$ 1.6) than control group (64.6 $\pm$ 5.5) (18.6 $\pm$ 1.7) three months after the surgery (P-value = 0.042) (P = 0.003). In the surgery group, the average total score of quality of life (1.8 $\pm$ 0.4) and the mean BAROS score (3.9 $\pm$ 0.5) was significantly higher than the control group (0.9 $\pm$ 0.4) (P = 0.001) (0.3 $\pm$ 0.5) (P = 0.001).Also, the qualitative score of BAROS in the surgery group was reported significantly higher than the control group (P = 0.001) (Table 2). Three months after surgery, using repeated measure ANOVA, the average change in the raw scores of the Wechsler test in surgery group (399.2 $\pm$ 16) was significantly higher than the control group (378 $\pm$ 22) (P = 0.043).

Three months after surgery, the HAM-D score in the surgery group (-4 $\pm$ 2) was significantly higher than the

**Table 1.** Comparison of Demographic Characteristics in the Two Groups [a]

| Variables | Control Group (n = 30) | Surgery Group (n = 40) | Total (n = 70) | P Value |
|---|---|---|---|---|
| **Age** | 40.6 ± 12 | 38.9 ± 11.2 | 39.8 ± 11.6 | 0.18 |
| **Sex** | | | | 0.42 |
| Male | 2 (6.67) | 5(12.5) | 7(10) | |
| Female | 28 (93.33) | 35 (87.5) | 63 (90) | |
| **BMI(Kg/m2) (Means)** | 46.9 ± 2.4 | 45.11 ± .3 | 45.9 ± 1.6 | 0.29 |
| **Educations level** | | | | 0.29 |
| < Diploma | 10(33.3) | 9 (22.5) | 19(27.1) | |
| ≥ Diploma | 20(67.4) | 31 (77.5) | 51(72.9) | |
| **Marital Status** | | | | 0.42 |
| Married | 22(73.3) | 27 (67.5) | 49(70) | |
| Unmarried | 8(26.7) | 13 (32.5) | 21(30) | |
| **Occupation** | | | | 0.36 |
| Indoor | 22(73.3) | 26 (65) | 48(68.6) | |
| outdoor | 8(26.7) | 14 (35) | 51(31.4) | |
| **Number of children** | 1.6 ± 0.44 | 1.3 ± 0.5 | 1.5 ± 0.34 | 0.34 |
| **Diabetes** | 5 (16.7) | 9 (22.5) | 14 (20) | 0.54 |
| **Hypertensions** | 8 (26.7) | 5 (12.5) | 13 (18.6) | 0.24 |
| **Sleep apnea** | 3 (10) | 3 (7.5) | 6 (8.6) | 0.71 |
| **Hyperlipidemia** | 9 (30) | 12 (30) | 21 (30) | 1 |
| **Cardiovascular disease** | 1 (3.3) | 0 | 1 (1.4) | 0.75 |
| **Osteoarthritis** | 12 (40) | 9 (22.5) | 21 (30) | 0.29 |
| **Heartburn** | 10 (33.3) | 8 (20) | 18 (25.7) | 0.31 |
| **Urinary Incontinence** | 3 (10) | 7 (17.5) | 10 (14.3) | 0.56 |
| **History of referral to a psychiatrist** | 3 (10) | 8 (20) | 11 (15.7) | 0.38 |
| **History of referral to a psychologist** | 4 (13.3) | 9 (22.5) | 13 (18.6) | 0.44 |
| **Suicide attempthistory** | 1 (3.3) | 0 | 1 (1.4) | 0.56 |
| **Family history of diabetes** | 20 (66.7) | 25 (62.5) | 45 (64.2) | 0.12 |
| **Family history of Hypertension** | 7 (23.3) | 16 (40) | 23 (32.9) | 0.091 |
| **Family history of Hyperlipidemia** | 5 (16.7) | 10 (25) | 15 (21.4) | 0.45 |
| **Family history of obesity** | 16 (53.3) | 23 (57.5) | 39 (55.7) | 0.72 |
| **Family history of depression** | 3 (10) | 5 (12.5) | 8 (11.4) | 0.47 |
| **History of smoking** | 3 (10) | 5 (12.5) | 8 (11.4) | 0.11 |

[a] Values are expressed as No. (%) or mean ± SD.

control group (-0.2 ± 2.6) (P = 0.032). Also, the patients' weight and BMI in the surgery group were significantly lower than the control group three months after surgery (P = 0.001) (Table 3).

There was no significant relationship between the scores of cognitive tests, the Hamilton's depression, anxiety scales, weight change and BMI over the three months and the results of BAROS questionnaire in the surgery group (Table 4). However, there was a significant relationship between change in the number of perseverative errors in the Wisconsin test of surgery group and the results of the BAROS questionnaire (P = 0.004).

After adjusting for confounding variables (gender, age, changes in anxiety and depression) with repeated measures analysis, there was a significant relationship between changes in the raw score of the Wechsler and

**Table 2.** Distribution of Memory, the Hamilton Score, the BAROS Test and Quality of Life in the Two Groups Three Months Postoperatively

| Variables | Control Group (n = 30) | Surgery Group (n = 40) | Total (n = 70) | P Value |
|---|---|---|---|---|
| **HAM-A score (means)** | | | | |
| Before | 6.6 ± 3 | 6.5 ± 2.2 | 6.55 ± 1.85 | 0.68 |
| After | 8.4 ± 3.25 | 5 ± 1.87 | 6.45 ± 1.8 | 0.098 |
| **HAM-D score (means)** | | | | |
| Before | 6 ± 2.8 | 4.6 ± 1.8 | 5.2 ± 1.6 | 0.58 |
| After | 6.3 ± 2.4 | 8.5 ± 2.2 | 7.6 ± 1.6 | 0.17 |
| **WMS score (means)** | | | | |
| Before | 83.9 ± 8 | 92.3 ± 16.5 | 88.7 ± 10 | 0.42 |
| After | 93.4 ± 8 | 99.3 ± 7.4 | 96.8 ± 5.4 | 0.21 |
| **Immediate Auditory memory score (means)** | | | | |
| Before | 59.6 ± 5.7 | 63.5 ± 4.8 | 61.8 ± 3.8 | 0.301 |
| After | 64.6 ± 5.5 | 71.6 ± 3.8 | 68.6 ± 3.3 | 0.042 |
| **Immediate visual memory score (means)** | | | | |
| Before | 79.1 ± 5.4 | 73.9 ± 5.2 | 76.1 ± 3.8 | 0.173 |
| After | 81.9 ± 6 | 83.1 ± 4.6 | 82.6 ± 3.7 | 0.756 |
| **Immediate memory score (means)** | | | | |
| Before | 79.1 ± 5.4 | 73.9 ± 5.2 | 76.1 ± 3.8 | 0.173 |
| After | 81.9 ± 6 | 83.1 ± 4.6 | 82.6 ± 3.7 | 0.756 |
| **Delayed auditory memory score (means)** | | | | |
| Before | 29.9 ± 3.4 | 31.9 ± 2.6 | 31 ± 2 | 0.340 |
| After | 33.6 ± 3.2 | 37.7 ± 2.6 | 35.9 ± 2 | 0.053 |
| **Delayed Auditory memory score (means)** | | | | |
| Before | 78.8 ± 5.2 | 77.2 ± 4 | 77.9 ± 3.4 | 0.622 |
| After | 83.7 ± 5 | 83.7 ± 4.4 | 83.7 ± 3.4 | 0.990 |
| **Delayed auditory recognition memory score (means)** | | | | |
| Before | 49 ± 1.2 | 49.3 ± 1 | 49.2 ± 0.8 | 0.656 |
| After | 49.8 ± 1.4 | 50.4 ± 0.9 | 50.2 ± 0.8 | 0.411 |
| **General memory score (means)** | | | | |
| Before | 8.4 ± 157.6 | 158.4 ± 6.4 | 158.1 ± 5 | 0.889 |
| After | 167 ± 8.4 | 171.7 ± 6.9 | 169.7 ± 5.3 | 0.383 |
| **Working memory score (means)** | | | | |
| Before | 20.4 ± 1.6 | 21.1 ± 1.6 | 20.8 ± 1.2 | 0.544 |
| After | 18.6 ± 1.7 | 22.2 ± 1.6 | 20.7 ± 1.2 | 0.003 |
| **Number of Perseveration errors in WCST (means)** | | | | |
| Before | 12.3 ± 2 | 12 ± 2 | 12.1 ± 1.5 | 0.803 |
| After | 9.9 ± 2 | 7.8 ± 2 | 8.7 ± 1.5 | 0.164 |
| **Number of blocks in WCST (means)** | | | | |
| Before | 1.8 ± 5.6 | 2.1 ± 5.4 | 2 ± 0.4 | 0.383 |
| After | 2.4 ± 0.8 | 2.6 ± 0.7 | 2.5 ± 0.7 | 0.682 |
| **Total number errors in WCST (means)** | | | | |
| Before | 34.7 ± 3.2 | 34.2 ± 3.6 | 34.4 ± 2.6 | 0.834 |
| After | 30.4 ± 3.9 | 27.1 ± 3.4 | 28.5 ± 2.6 | 0.204 |
| **Quality of life score (Means)** | 0.9 ± 0.4 | 1.8 ± 0.4 | 1.4 ± 0.3 | 0.001 |
| **Numerical score BAROS (means)** | 0.3 ± 0.5 | 3.9 ± 0.5 | 2.4 ± 0.6 | 0.001 |
| **Categorical score BAROS (means)** | | | | 0.001 |
| Failure | 19 (63.3%) | 1 (2.5%) | 20 (28.6%) | |
| Fair | 11 (36.7%) | 12 (30%) | 23 (32.9%) | |
| Good | 0 | 20 (50%) | 20 (28.6%) | |
| Very good | 0 | 6 (15%) | 6 (8.6%) | |
| Excellent | 0 | 1 (2.5%) | 1 (1.4%) | |

Abbreviations: HAM-A score, Hamilton Rating Scale of Anxiety; HAM-D score, Hamilton depression inventory; WMS score, Wechsler Clinical Memory Scale; Working memory score, Working memory; WCST, Wisconsin Card Sorting test.

**Table 3.** Comparison of Cognitive Tests, the Hamilton Test, Weight and BMI Before and After in the Two Groups [c]

| Test Scores (Mean ± SD) | Control Group | | | Surgery Group | | | P Value Difference [b] |
|---|---|---|---|---|---|---|---|
| | Before | After | Difference | Before | After | Difference | |
| Average final WMS test score | 83.9 ± 8 | 93.4 ± 8 | -9.5 ± 5.6 [a] | 92.3 ± 16.4 | 99.3 ± 7.4 | -6.9 ± 15.9 | 0.794 |
| WMS raw test score | 358.1 ± 21 | 378 ± 22 | -19.8 ± 11.6 [a] | 357.4 ± 20.4 | 399.2 ± 16 | -41.8 ± 16.2 [b] | 0.043 |
| Immediate Auditory memory score | 59.6 ± 5.7 | 64.6 ± 5.5 | -5.1 ± 3.4 [a] | 63.5 ± 4.8 | 71.6 ± 3.8 | -8.1 ± 3.2 [b] | 0.207 |
| Immediate visual memory score | 79.1 ± 5.4 | 81.9 ± 6 | -2.8 ± 3.8 | 73.9 ± 5.2 | 83.1 ± 4.6 | -9.1 ± 5.8 [a] | 0.096 |
| Immediate memory score | 138.6 ± 9.4 | 146.5 ± 10 | -7.9 ± 5.2 [a] | 139.6 ± 6.8 | 154.6 ± 7 | -15.1 ± 5 [b] | 0.055 |
| Delayed auditory memory score | 29.9 ± 3.4 | 33.6 ± 3.2 | -3.7 ± 1.6 [b] | 31.9 ± 2.6 | 37.7 ± 2.6 | -5.7 ± 2.1 [b] | 0.163 |
| Delayed visual memory score | 78.8 ± 5.2 | 83.7 ± 5 | -4.9 ± 3.6 [a] | 77.2 ± 4 | 83.7 ± 4.4 | -6.6 ± 3.8 [a] | 0.542 |
| Delayed Auditory memory score | 49 ± 1.2 | 49.8 ± 1.4 | -0.8 ± 0.8 | 49.3 ± 0.1 | 50.4 ± 0.9 | -1.1 ± 0.6 [b] | 0.548 |
| General memory score | 157.6 ± 8.4 | 167 ± 8.4 | -9.4 ± 4.5 [b] | 158.4 ± 6.4 | 171.7 ± 6.9 | -13.4 ± 4.6 [b] | 0.232 |
| Working memory score | 20.4 ± 1.6 | 18.6 ± 1.7 | 1.9 ± 1.2 [a] | 21.1 ± 1.6 | 22.2 ± 1.6 | -1.1 ± 1.2 | 0.002 |
| Number of Perseveration errors in WCS | 12.3 ± 2 | 9.9 ± 2 | 2.5 ± 2.2 [a] | 12 ± 2 | 7.8 ± 2 | 4.2 ± 2 [b] | 0.292 |
| Number of blocks in WCST | 1.8 ± 5.6 | 2.4 ± 0.8 | 0.7 ± 0.6 | 2.1 ± 5.4 | 2.6 ± 0.7 | -0.6 ± 0.6 | 0.773 |
| Total number errors in WCST | 34.7 ± 3.2 | 30.4 ± 3.9 | 4.4 ± 4.2 | 34.2 ± 3.6 | 27.1 ± 3.4 | 7.1 ± 3.2 [b] | 0.316 |
| HAM-A test score | 6.6 ± 3 | 8.4 ± 3.3 | -1.8 ± 2.9 | 6.5 ± 2.2 | 5 ± 1.9 | 1.6 ± 2.4 | 0.089 |
| HAM-D test score | 6 ± 2.8 | 6.3 ± 2.4 | -0.2 ± 2.6 | 4.6 ± 1.8 | 8.5 ± 2.2 | -4 ± 2 [b] | 0.032 |
| Weight | 123 ± 7.4 | 122.5 ± 7 | 0.6 ± 1.4 | 123.8 ± 6.5 | 99.1 ± 5.5 | 24.7 ± 2 [b] | 0.001 |
| BMI | 46.9 ± 2.4 | 46.6 ± 2.1 | 0.3 ± 0.6 | 45.1 ± 1.3 | 36.1 ± 1.2 | 9.1 ± 0.6 [b] | 0.001 |

[a] P value ≤ 0.05 (within each group).
[b] P value ≤ 0.001 (within each group).
[c] Between groups.

changes in BMI in the surgery group over the three-month period; this finding can indicate the fact that following weight loss, cognitive state of patients with morbid obesity significantly improved independent from mood (P = 0.001).

## 5. Discussion

Investigation of patient's cognitive function and response to bariatric surgery by the BAROS system can indicate success of surgery and its effect on patient's quality of life (24, 25).

According to our findings, three months after surgery, the average scores of immediate auditory and working memory, and the mean raw score of quality of life in surgery group were significantly higher than the control group. Also, the mean qualitative and quantitative scores of the BAROS test for the surgery group were reported significantly higher than the control group. The results suggest that three months after bariatric surgery, the average changes in the raw scores of WMS and HAM-Din the surgery group were higher than the control group. Three months after bariatric surgery, weight loss and BMI reduction were significantly higher in the surgery group; whereas, there was no significant relationship between changes of scores of cognitive tests, HAM-D, HAM-A, weight change and BMI and the results of BAROS test in surgery group. After controlling the confounding variables (gender, age, changes in anxiety and depression), there was a significant relationship between changes in the raw score of WMS and changes in BMI in the surgery group over the three-month period; this finding can indicate that memory function improves independent from their mood following bariatric surgery.

According to the findings, three months after surgery, the mean scores of immediate auditory memory and working memory in surgery group were reported significantly higher than the control group, which is consistent with the results of previous relevant studies (14, 16, 26-28).

Gunstad (26) found that cognitive dysfunction, especially in terms of memory, is prevalent among bariatric surgery candidates. However, they become significantly improved 12 weeks after surgery; whereas, no change was observed in the same period of time in the control group. This finding is consistent with the results of our study.

Alosco et al. (14) reported that the mean scores of memory, attention, executive function, and language

**Table 4.** Comparison of Cognitive Tests and the Hamilton Tests Based on the BAROS Questionnaire in the Surgery Group

| Tests | The BAROS Modified Scoring Key for Patients with Surgery | | | | | |
|---|---|---|---|---|---|---|
| | Failure | Fair | Good | Very Good | Excellent | Total |
| Change the final score of the WMS test | -6.9 ± 15.8 | 11.1 ± 31 | -12.4 ± 5.8 | -17.5 ± 10.8 | -15 | -6.9 ± 15.8 |
| Change the raw WMS test score | -41.9 ± 16.2 | -64.5 ± 46 | -28.7 ± 13.4 | -34.5 ± 19.6 | -30 | -41.9 ± 16.2 |
| Changing the Immediate memory score | -8.1 ± 3.2 | -7.4 ± 6.8 | -8.3 ± 4.6 | -10 ± 7.4 | -5 | -8.1 ± 3.2 |
| Immediate visual memory score change | -9.2 ± 5.6 | -8.6 ± 6.4 | -8.5 ± 10.2 | -12.1 ± 13.4 | -6 | -9.2 ± 5.6 |
| Immediate memory score change | -15 ± 4.8 | -16 ± 10.2 | -12.3 ± 6.6 | -22.2 ± 13 | -11 | -15 ± 4.8 |
| Delayed auditory memory score change | -5.7 ± 2 | -5.9 ± 4.4 | -5.6 ± 2.9 | -5.1 ± 5.8 | -5 | -5.7 ± 2 |
| Changing the late visual memory score | -6.5 ± 3.8 | -10.9 ± 6.8 | -5.3 ± 5 | -1.8 ± 12.2 | 0 | -6.5 ± 3.8 |
| Change the memory score of the delayed auditory recognition | -1.1 ± 0.6 | -1.3 ± 1.6 | -0.7 ± 0.7 | -2 ± 1.4 | -1 | -1.1 ± 0.6 |
| Change public memory score | -13.4 ± 4.6 | -17.8 ± 9 | -11.7 ± 6.4 | -9 ± 11.6 | -6 | -13.4 ± 4.6 |
| Change the active memory score | -1.1 ± 1.2 | -1 ± 2.4 | -1.2 ± 1.6 | 0.5 ± 3.4 | -2 | -1.1 ± 1.2 |
| Change the Number of Perseveration errors in WCS | 4.2 ± 2* | 2 ± 3.6 | 6.4 ± 2.4 | 1.8 ± 2.8 | -12 | 4.2 ± 2* |
| Change the Number of blocks in WCST | -0.5 ± 0.6 | -1.4 ± 1 | -0.4 ± 1.1 | -0.4 ± 1.2 | 0 | -0.5 ± 0.6 |
| Change the total number errors in WCST | 7.1 ± 3.2 | 7.3 ± 5.8 | 8.3 ± 4.6 | 3.6 ± 4 | -16 | 7.1 ± 3.2 |
| Change the HAM-A test score | 1.6 ± 2.4 | 3.5 ± 5.4 | 1.4 ± 3.4 | 0.9 ± 2.2 | -14 | 1.6 ± 2.4 |
| Change the HAM-D test score | -3.9 ± 2 | -3.1 ± 5 | -4.2 ± 2.6 | -2.8 ± 1.6 | -14 | -3.9 ± 2 |
| Weight change | 24.7 ± 2 | 24.4 ± 4.6 | 24.2 ± 2 | 26.8 ± 5.6 | 21.6 | 24.7 ± 2 |
| BMI change | 9 ± 0.6 | 8.5 ± 1.2 | 9 ± 0.7 | 9.6 ± 1.6 | 8.6 | 9 ± 0.6 |

for surgery candidates were significantly lower than the control group in the beginning of study. However, 24 months after surgery, memory function was significantly improved in surgery candidates as a result of BMI reduction, whereas no significant change was observed in BMI and memory scores in the control group. Moreover, in our research, patients demonstrated lower scores of cognitive tests, especially in terms of working memory, immediate and delayed auditory memory, and immediate memory compared to the population mean. However, 12 weeks after surgery, memory and executive functions were significantly improved in the surgery group associated with BMI reduction. Interestingly, the cognition and memory measures showed that improvements were less prominent in the control group compared to the surgery group (27, 29). It might be due to the fact that after 12 weeks in the control group, other variables such as weight gain, sleep apnea and worsening of depressive severity were added, which might have affected cognition and memory functions.

This expressed a decrement in the control group unlike the surgery group in which working memory was improved during the study. Some of the previous studies investigated cognitive function as a factor predicting weight loss following bariatric surgery. They suggested that cognitive state, especially in terms of memory, attention, and executive function, before the surgery is effective in weight loss percentage over 12 months after surgery. Also, patients' cognitive state over 12 weeks after surgery is correlated with their weight loss rate over 24 months postoperatively (26, 27). In our study, there was no significant relationship between the primary cognition level and changes in weight and BMI 12 weeks after surgery; this finding can be related to the short period of post-surgery follow-up, and delineates the need for longer follow-up.

Different studies have reported contradictory results of the effect of bariatric surgery on quality of life. According to our findings, the mean raw score of quality of life in surgery group (BAROS) was significantly higher than the control group three months after surgery. This finding is consistent with the results reported by Myers et al. who indicated that patients' quality of life significantly improved following bariatric surgery (17, 30).

The results highlighted a significantly higher mean of changes in raw scores of WMS and HAM-A in the surgery group than the control one. This finding is consistent with the results reported by Alexandra Osterhues et al. (30). However, several studies have reported a significant improvement in depression, quality of life, self-confidence, and body image, especially in women. Nevertheless, the relationship between depression and weight loss following bariatric surgery is not clear. In our study, there was a significant difference between changes in depression in the surgery and control groups. In the surgery group, depression symptoms were significantly increased three months postoperatively, which might be due to skin changes following intense weight loss leading to dissatisfaction with their body image. Furthermore, depression may be intensified by changes in lifestyle until coping with new conditions. Despite the fact, a longer period of follow-up is necessary. Another explanation for this phenomenon is that patients may try to present themselves doing well before surgery. Some patients believe that talking about depressive symptoms before surgery may get them deprived of surgery. Also food intake restriction could be another reason for increasing depression scale after bariatric surgery.

The mean qualitative and quantitative scores of BAROS criterion in surgery groups were reported significantly higher than the control group. Myers et al. (17) introduced the BAROS questionnaire as an efficient tool for evaluation of bariatric surgery success. In our study, quality of life and BAROS qualitative and quantitative scores in the surgery group were reported significantly higher than the control group. However, the patients' primary cognition and cognitive changes over the three-month period did not have any effect on the BAROS score. Obesity independently impacts the cognitive function. These findings indicate the mutual interaction of cognitive function and obesity that was proved in this study.

The most important limitations of this study were the short period of follow-up after surgery and lack of screening for sleep disorders such as sleep apnea. Therefore, it is suggested to conduct further studies with longer follow-ups and larger sample size to elucidate more accurate findings. Since some of the vitamins and nutrients were depleted after surgery and may be associated with depression, lack of evaluation of them among participants was another limitation. Because participants were recruited from a single clinic, generalizability of results might not be logical.

Also imprecision, and multiplicity of analyses created potential bias. Another limitation of our study was that we did not measure social and income levels which suggested to be evaluated in further trials.

### 5.1. Conclusions

Bariatric surgery can improve some cognitive functions and increase depression symptoms in patients with morbid obesity in short term. However, conducting further studies with larger sample sizes, higher power, and longer periods of follow-up and observing other confounding variables can shed light on the research subject. Also, we suggest screening patients for depression after bariatric surgery.

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## Footnotes

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