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Cognitive Function Predicts Weight Loss Following Bariatric Surgery

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Abstract

Background—Clinically significant cognitive impairment is found in a subset of patients undergoing bariatric surgery. These difficulties could contribute to reduced adherence to postsurgical lifestyle changes and decreased weight loss.

Objectives—The current study is the first to prospectively examine the independent contribution of cognitive function to weight loss following bariatric surgery. Executive function/attention and verbal memory at baseline were expected to negatively predict percent excess weight loss (%EWL) and body mass index (BMI) at follow-up.

Setting—Three sites of the Longitudinal Assessment of Bariatric Surgery (LABS) parent project were used: Columbia, Cornell, and Neuropsychiatric Research Institute

Methods—Eighty-four individuals enrolled in the LABS project undergoing bariatric surgery completed cognitive evaluation at baseline. BMI and %EWL were calculated at 12-week and 12-month post-surgery follow-ups.

Results—Clinical impairment in task performance was most prominent in tasks associated with verbal recall and recognition (14.3–15.5% of the sample) and perseverative errors (15.5%). After accounting for demographic and medical variables, baseline tests of attention/executive function and memory predicted BMI and %EWL at 12 months, but not at 12 weeks.

Conclusions—Results demonstrate that baseline cognition predicts greater %EWL and lower BMI 12 months following bariatric surgery. Further work is needed to clarify the degree to which

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cognition contributes to adherence, and the potential mediation of cognition on the relationship between adherence and weight loss in this group.

Keywords

memory; cognition; executive function

Introduction

Considerable variation exists in bariatric surgery outcomes. Up to 30% of patients experience failure to lose weight or regain a significant amount of weight by six-year follow-up[(1)]. Better understanding of contributing factors to successful post-surgical weight loss and maintenance is important. Behavioral and psychological factors have been often hypothesized[(2)]. Self-report behavioral variables including depressive symptoms and lack of dietary restraint or inhibition have been posited to play a role in weight loss success[(3,4)], and higher levels of pre-operative cognitive restraint are linked to greater post-operative adherence and percent weight loss[(5)]. However, questionnaire-based measurement of psychological factors is subjective and does not fully account for post-surgical outcomes[(6)]. Investigation of other potential behavioral predictors is necessary, including the contribution of performance-based variables, such as cognitive ability (e.g., memory and attention/ executive functioning).

Reduced memory and executive functioning have been consistently demonstrated in obese individuals[(7–9)]. Body mass index (BMI) is associated with executive function and attention tasks, such that increased BMI is linked to poorer performance on measures including tasks requiring response inhibition, working memory, planning, and ability to shift cognitive set [(7)]. Similarly, verbal learning and recall are lower in obese individuals when compared to both lean and overweight individuals[(8)]. Recent research indicates presence of clinically significant baseline cognitive impairment in up to 23% of patients undergoing bariatric surgery [(10)]. Given that executive functions include higher-order cognitive abilities such as inhibition, organization, planning, and complex focus [(11)], deficits in these functions as well as memory could lead to poor adherence to post-surgical lifestyle changes. Intuitively, it would seem that reduced inhibition skills could lead to greater difficulty resisting temptation while eating, or that someone with reduced organization and memory skills could have greater difficulty shopping for healthy foods or planning and adhering to a diet. This idea is borne out in recent research. Behavioral disinhibition is reported in obese patients[(12)] and this population appears to have an increased susceptibility to food-related cues and poor control of eating behavior as a result of disinhibition[(13,14)]. It has also been shown that disinhibited eating, as measured by the 3-Factor Eating Questionnaire, is linked to lower performance on cognitive tests of executive control [(15)]. Similarly, recent work demonstrates that executive function performance is negatively related to high calorie snack food intake and sedentary behavior, but positively associated with fruit and vegetable intake and leisure time physical activity in children [(16)].

Interestingly, cognitive performance appears to improve following bariatric surgery and weight loss[(10)]. As such, the cognitive difficulties associated with poor dietary choices and habits could actually be improved by surgery. However, the extent to which reduced cognition may impede the bariatric surgery patient’s ability to make successful post-surgical lifestyle changes is not fully understood. As reviewed above, diet and exercise appear to be influenced by executive function abilities. Cognitive deficits of an executive nature might preclude optimal adherence to lifestyle changes after surgery, including meal planning and resisting the impulse to eat tempting foods. Diminished memory function could lead to difficulty recalling post-surgical guidelines, or poor adherence to meal or exercise schedules.

Behavioral and cognitive findings in combination suggest cognitive function could play a role in how successful a patient is in losing weight after bariatric procedures.

This study is the first to prospectively examine the contribution of cognitive function to weight loss in bariatric surgery patients. Better baseline cognitive function, specifically, higher performance on measures of executive/attention and memory abilities, are expected to predict higher percent of excess weight loss (%EWL) and lower body mass index (BMI) at 12 weeks and 12 months following surgery.

Materials and Methods

Trial Design and Participants

A total of 84 consecutive bariatric surgery patients were recruited into this multi-site prospective examination of the cognitive effects of bariatric surgery. All participants were part of the Longitudinal Assessment of Bariatric Surgery (LABS) parent project and were recruited from three LABS sites [17]. Individuals participating in the parent project who were eligible for the current study were approached at the time of enrollment regarding this ancillary cognitive study. Greater than 80% of participants approached opted to enroll in the study. The current sample represents the individuals completing 12 month follow-up data. Of note, only 71 participants also completed the 12-week follow-up. A 5 day window was established as the necessary timeframe of data collection in order for it to count as the 12 week follow-up; as such, missed or rescheduled appointments precluded 12 week data collection for several participants. However, no differences on key variables emerged between those who did and did not complete the appointment and thus no additional analyses were conducted.

For study inclusion, participants were required to be enrolled in LABS, between the ages of 20–70, and English-speaking. Exclusion criteria included history of neurological disorder or injury (e.g. dementia, stroke, seizures), moderate or severe head injury (defined as >10 minutes loss of consciousness) [18], past or current history of severe psychiatric illness (e.g. schizophrenia, bipolar disorder), past or current history of alcohol or drug abuse (defined by DSM-IV criteria), history of a learning disorder or developmental disability (defined by DSM-IV criteria), or impaired sensory function that precluded cognitive testing (e.g. visual deficits preventing adequate perception of test stimuli) per participant report or examiner observation. Medical history was obtained via medical record review from the LABS study as well as participant self-report. Within the sample, just 4 patients underwent an adjustable gastric banding procedure and thus no comparisons for type of surgery were conducted. However, surgery type was adjusted for in statistical analyses to minimize possible confound. See Table 1 for sample demographic and clinical characteristics.

Interventions and Clinical Follow-Up

This study is registered with the National Institutes of Health, and all procedures were approved by the appropriate Institutional Review Boards. All participants provided written informed consent prior to study involvement. Participants completed a series of self-report instruments and a computerized cognitive test battery within 30 days prior to surgery and were weighed and reassessed 12 weeks and 12 months after surgery (± 14 days). Medical records were reviewed by research staff to corroborate and supplement participant self-report.

Outcomes

The primary goal of this study was to examine whether baseline cognitive function predicted %EWL and BMI at 12 weeks and 12 months following bariatric surgery. The Integneuro cognitive test battery was chosen based upon previous work from our lab, demonstrating that Integneuro tasks of attention/executive function and verbal memory are sensitive to the cognitive difficulties manifested in this population[7–8]. This cognitive test battery consists of estimated premorbid intellectual abilities as well as performance in multiple cognitive domains (e.g., Attention/Executive Function, Verbal Memory) and can be completed in 45–60 minutes. It has good psychometric properties and as described above, has been employed in past studies examining obesity and cognitive function[19,20]. Specific tests were categorized into Attention/Executive Function and Verbal Memory domains and included:

Attention/Executive Function

Switching of Attention—This test is a computerized adaptation of the Trail Making Test[21] and consists of two parts. In the first part, participants are presented with a pattern of 25 numbers in circles and asked to touch them in ascending order. In the second part, an array of 13 numbers (1–13) and 12 letters (A–L) is presented. Participants are asked to touch numbers and letters alternately in ascending order. The first part of this test assesses attention and psychomotor speed whereas the second part taps these abilities as well as executive function. Time to completion for each test is used as the dependent variable.

Digit Span—This test assesses auditory attention and working memory. Participants are presented with a series of digits on the touch-screen, separated by a one-second interval. The subject is then immediately asked to enter the digits on a numeric keypad on the touch-screen. The number of digits in each sequence is gradually increased from 3 to 9, with two sequences at each level. The dependent measure is the total number of correct trials forward and backward.

Maze Task—This task is a computerized adaptation of the Austin Maze[22] and assesses executive function. Participants are presented with a grid (8×8 matrix) of circles and asked to identify the hidden path through the grid. Distinct auditory and visual cues are presented for correct and incorrect responses. The trial ends when the subject completed the maze twice without error or after 10 minutes has elapsed. The dependent variable is the number of overrun (i.e., perseverative) errors on the task.

Verbal Memory

Verbal List-learning—Participants read a list of 12 words a total of 4 times and asked to recall as many words as possible following each trial. Following presentation and recall of a distraction list, participants are asked to recall words from the original list. After a 20-minute filled delay, participants are again asked to recall target words. Finally, a recognition trial comprised of target words and foils is completed. Four dependent variables are generated from this task, specifically total Verbal Learning (sum of words recalled on all learning trials), Short Delay Verbal Free Recall, Long Delay Verbal Free Recall, and Verbal Recognition.

Data Analyses

Hierarchical regression analyses determined the contribution of cognitive function to BMI and %EWL at 12 weeks and 12 months post-operatively. Analyses were conducted separately for BMI and %EWL at each timepoint and for each cognitive domain (i.e.,Attention/Executive Function and Verbal Memory). BMI and %EWL analyses were conducted as follows: Block one included BMI at baseline, gender (BMI only), and surgery type; Block 2 included cognitive test scores from either the attention/executive function or memory domain. BMI and %EWL analyses were conducted in the same manner, with the exception of omission of gender from EWL analyses, as the EWL formula accounts for gender.

Results

Baseline Cognitive Function in Bariatric Surgery Patients

The prevalence of impaired performance (i.e., >1.5 standard deviations below normative values based on age, sex, and estimated IQ) varied widely across the test battery. Impairments in brief delay verbal recall (Short Verbal Free Recall, 14.3%), identifying newly learned verbal material from distracters (Verbal Recognition, 15.5%), and perseverative errors on a maze task (Maze Overrun Errors, 15.5%) were most common. See Table 2 for descriptive statistics of baseline cognitive performances.

BMI and EWL at baseline, 12 weeks, and 12 months

BMI and EWL were calculated based upon standard formulas. Baseline BMI within the group was 46.13 ± 5.80. BMI decreased from baseline to the 12 week (37.46 ± 4.99) and 12 month (31.07 ± 6.44) timepoints, and EWL increased over this time period (12 week kg EWL = 17.77 ± 4.24; 12 month kg EWL = 32.67 ± 10.51).

Predicting BMI at 12 week follow-up

Analyses showed that cognitive testing did not independently predict BMI at 12 weeks, as neither attention/executive function [$R^2 = .88$, $R^2\Delta = .01$, $F\Delta\ (4, 63) = 1.31$, $p = .28$] nor verbal memory tasks [$R^2 = .88$, $R^2\ \Delta = .01$, $F\ \Delta\ (4, 63) = 1.33$, $p = .27$] accounted for incremental prediction. Table 3 describes the 12 week BMI regression analysis.

Predicting %EWL at 12 week follow-up

Similarly, cognitive testing did not independently predict %EWL at 12 weeks, as neither attention/executive function [$R^2 = .39$, $R^2\Delta = .04$, $F\Delta\ (4, 64) = 0.93$, $p = .45$] nor verbal memory tasks [$R^2 = .31$, $R^2\ \Delta = .01$, $F\ \Delta\ (4, 64) = 0.28$, $p = .89$] accounted for incremental prediction. Table 4 describes the 12 week % EWL regression analysis.

Predicting BMI at 2 month follow-up

Analyses showed both attention/executive function [$R^2 = .68$, $R^2\ \Delta = .04$, $F\ \Delta\ (4, 76) = 2.54$, $p = .05$] and verbal memory tests [$R^2 = .83$, $R^2\ \Delta = .05$, $F\ \Delta\ (4, 76) = 3.14$, $p = .02$] predicted BMI at 12 months after accounting for demographic and medical variables. Table 5 describes the 12 month BMI regression analysis. Maze Overrun Errors [$\beta = 0.18$, $p = .03$] and Short Delay Free Verbal Recall [$\beta = -0.29$, $p = .04$] were the significant predictors.

Predicting %EWL at 12 month follow-up

Verbal memory tests [$R^2 = .67$, $R^2\ \Delta = .08$, $F\ \Delta\ (4, 77) = 2.66$, $p = .04$] predicted %EWL at 12 months after accounting for demographic and medical variables, though no such pattern emerged for attention/executive function tests [$R^2 = .42$, $R^2\ \Delta = .05$, $F\ \Delta\ (4, 77) = 1.68$, $p = .16$] Table 6 describes the 12 month %EWL regression analysis. Short Delay Free Verbal Recall [$\beta = 0.46$, $p =.01$] was the significant predictor.

Discussion

The current study prospectively examined cognitive function as a predictor of weight loss following bariatric surgery. Results demonstrate that baseline cognition, specifically verbal memory and attention/executive functioning, is associated with success in weight loss 12 months following bariatric surgery. This association emerged over time and was not detected at the initial 12 week follow-up. In addition, baseline cognitive function was, on average, broadly within the normal range for surgical candidates; however, substantial variability was noted, with clinically impaired performances in aspects of both attention/executive and verbal memory functions occurring in approximately 16% of the sample.

These findings are important, as previous research demonstrates that executive dysfunction and reduced verbal memory are commonly found in obese individuals and in those planning to undergo bariatric surgery [(7–10)]. These cognitive deficits are associated with reduced adherence to medical regimens in other medical populations. For example, in type 2 diabetes (T2DM) [(23)] cognitive impairment predicts poorer management of diabetes care routines. Similarly, in HIV infected individuals, cognitive impairment is associated with poorer adherence to medication regimen, particularly among older adults; of the cognitive predictors, executive function was very strongly related to adherence [(24)]. Given the extensive lifestyle changes required following bariatric surgery, cognitive difficulties in this population could have substantial impact on adherence and outcomes. One significant difference between the current population versus these other patient groups, is that bariatric surgery patients are known to demonstrate improved cognition following surgery relative to obese controls who do not undergo surgery [(10)]. However, it is noted that while cognitive function improves in this group, it does not necessarily resolve to normatively “intact” (i.e., average or better) function [(10)]. Thus, even with cognitive improvement, residual difficulties may still impact adherence. In addition, much of the education about the necessary post-operative lifestyle changes occur prior to surgery or in the earliest period following surgery, while the patient’s cognition, including verbal learning and retention functions [(10)], may still be poorer.

Although the relationship between cognition and weight loss did not emerge in the early months following surgery, this may be due to the robust effects of surgery alone in early weeks. In addition, surgical programs generally closely monitor patients in early stages of surgical recovery [(25)], and patients may also have additional family support at home immediately following surgery. This support could enhance adherence for all patients, including those with cognitive difficulties. However, in subsequent months, professional monitoring of the bariatric surgery patient typically decreases [(25)], requiring the patient to more independently make decisions, control impulses, and remember post-surgical guidelines. Given the nature of cognitive difficulties found in some obese individuals, reduced adherence in later months, when medical monitoring is less frequent, might be anticipated in this group.

The current study is limited in several ways. The sample size was too small to directly compare weight loss outcomes in individuals with versus without cognitive impairment, which is a much needed future step. Similarly, the current sample was not large enough to stratify patients according to medical co-morbidities and examine their potential contribution. For example, there are known cognitive deficits associated with T2DM [(26, 27)], and there is evidence that the relationship between obesity and cognition is mediated by insulin sensitivity [(28)]. A comparison of cognition in individuals with T2DM versus those without the diagnosis, or examination of cognition in relation to T2DM resolution following surgery will be important in future research. Similar examination of other medical co-morbidities (e.g., cardiovascular disease, sleep apnea, hypoventilation syndrome) should also be considered. Additionally, the brief length of the follow-up time period should be extended (e.g., 24 months, 36 months post surgery); this would be of benefit in determining long-term contribution of cognition to weight loss and maintenance versus weight re-gain. In addition, while the link between cognition and weight loss following surgery suggests possible variability in adherence to lifestyle change, the direct association between adherence and cognition was not examined in the current study. More thorough examination of the role of cognition in adherence is needed. For example, identifying specific cognitive predictors for adherence to different aspects of post-surgical lifestyle changes could be of benefit in optimizing surgical candidate preparation and post-operative treatment planning. Future research will need to examine this more directly.

Although beyond the scope of the current study, comparing cognitive prediction of outcomes in bariatric procedures versus behavioral weight loss may also provide insight into essential cognitive factors contributing to successful weight loss. Future directions might also include an examination of possible additional interventions for individuals with poorer baseline memory and attention/executive function performance. It appears likely that evaluation of educational strategies in individuals with cognitive impairment (e.g., one-on-one versus group education) would be of benefit in determining if greater frequency of pre-operative sessions or post-operative monitoring yields larger weight loss or minimizes weight-regain. Given the executive nature of the deficits observed in a subset of this population, it would be worthwhile to examine if providing very structured, specific, and detailed post-surgical daily plans are more helpful to this group than more general guidelines. Comparison of such measures in individuals with such cognitive impairment versus those without is recommended to determine the degree to which these types of intervention facilitate positive outcomes.

In the publication of data such as these, there is a risk of misinterpretation of the findings that have implications for clinical care and treatment guidelines. Given that the sample size is not large enough for comparison of weight loss in those with cognitive impairment versus those without, these data should not be interpreted to suggest that individuals with such impairment would experience negative outcomes, or even be less successful in weight loss following surgery. Direct research must be done to determine whether cognitive impairment in fact does lead to reduced adherence or other complications in post-operative patients. Screening for cognitive impairment may be worthwhile to identify individuals who may be in need of more intensive services (e.g., increased pre-surgical education, greater frequency of follow-up appointments) to maximize positive outcomes, but it is noted that the degree to which these services might be of benefit is not yet determined. At present, it is recommended that providers recognize the following: 1) cognitive impairment is present in a subset of this population; 2) screening for cognitive impairment might help identify individuals in need of more intensive education or monitoring, but 3) to date, cognitive impairments have not been linked to *negative* surgical outcomes, but rather, to an amount of weight loss that may be somewhat less optimal.

Conclusions

Results of the current study indicate that in patients undergoing bariatric procedures, better cognitive test performance on measures of memory and executive function prior to surgery predicts greater weight loss (lower BMI, higher %EWL) 12 months following surgery. These findings should not be misinterpreted to indicate that cognitive impairment leads to negative outcomes, but rather suggests that cognitive screening could be an objective way to identify individuals who might benefit from additional support or intervention to facilitate optimal outcomes. Further work is necessary to clarify the degree to which cognition contributes to adherence to post-operative behavior changes, the potential mediation of cognition on the relationship between adherence and successful weight loss in this group, and whether targeted interventions for individuals with poorer baseline cognition optimizes outcomes.

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Table 1

Demographic and Medical Characteristics of 84 Bariatric Surgery Patients.

Demographic Characteristics	Mean ± SD	%
Age (years)	44.75 ± 9.99	
Sex (percent female)		79.8%
Race/Ethnicity		
White (non-Hispanic)		92.9%
Black		2.4%
Native American		3.6%
Latin American		2.4%
Highest Level of Education Achieved		
Completed Grade School		1.2%
Some High School		19.1%
Completed High School		25.0%
Some College		16.7%
Completed College		29.8%
Graduate School		8.3%
Baseline Clinical Characteristics		
Hypertension		48.8%
Type 2 Diabetes		23.8%
Sleep Apnea		40.5%

Table 2

Baseline Cognitive Test Performance

Baseline Cognitive Test Performance	Mean ± SD	% Impaired
Verbal Learning/Memory		
Verbal Learning	30.19± 4.40	2.5%
Short Verbal Free Recall	7.31 ± 2.02	14.3%
Long Verbal Free Recall	6.89 ± 2.07	11.9%
Verbal Recognition	10.37 ± 1.17	15.5%
Attention/Executive Function		
Digit span—Forward	7.31 ± 2.33	6.0%
Digit span—Backward	4.20 ± 2.69	4.9%
Switching of Attention—Numbers	21.05 ± 9.34	0.0%
Switching of Attention—Numbers/Letters	46.43 ± 18.56	6.0%
Maze Overrun Errors	23.83 ± 27.41	15.5%

Table 3

Predicting Body Mass Index (BMI) at 12 Week Follow-Up in Bariatric Surgery Patients.

	β	*t*	*p*
Attention/Executive Function			
Block 1			
Baseline BMI	0.94	20.66	<.001 *
Surgery Type	−0.11	−2.45	.02 *
Sex	0.05	1.05	.30
Block 2			
Baseline BMI	0.95	20.79	<.001 *
Surgery Type	−0.09	−1.97	.05
Sex	0.07	1.40	.17
Digit Span	0.04	0.83	.41
Switching of Attention—Numbers	−0.05	−0.92	.35
Switching of Attention—Numbers/Letters	0.14	2.04	.05 *
Maze Overrun Errors	−0.01	−0.22	.82
Memory			
Block 1			
Baseline BMI	0.94	20.66	<.001 *
Surgery Type	−0.11	−2.45	.02 *
Sex	0.05	1.05	.30
Block 2			
Baseline BMI	0.96	19.83	<.001 *
Surgery Type	−0.12	−2.46	.02 *
Sex	0.10	1.95	.06
Learning	−0.06	−0.81	.42
Short Free Recall	0.07	0.66	.52
Long Free Recall	−0.12	−1.38	.17
Recognition	−0.02	0.29	.78

Note.

* indicates significance at $p \leq .05$ level.

Table 4

Predicting % Excess Weight Loss (%EWL) at 12 Week Follow-Up in Bariatric Surgery Patients.

	β	*t*	*p*
Attention/Executive Function			
Block 1			
Baseline BMI	−0.56	−5.70	<.001 *
Surgery Type	0.28	2.91	<.01 *
Block 2			
Baseline BMI	−0.56	−5.70	<.001 *
Surgery Type	0.28	2.91	.01 *
Digit Span	−.05	−0.43	.67
Switching of Attention—Numbers	0.13	1.04	.30
Switching of Attention—Numbers/Letters	−0.26	−1.76	.08
Maze Overrun Errors	0.02	0.19	.85
Memory			
Block 1			
Baseline BMI	−0.56	−5.70	<.001 *
Surgery Type	0.28	2.91	.01 *
Block 2			
Baseline BMI	−0.58	−5.41	<.001 *
Surgery Type	0.30	2.81	.01 *
Learning	−0.01	−0.09	.93
Short Free Recall	−.07	−.30	.77
Long Free Recall	0.17	0.86	.31
Recognition	−0.00	−0.01	.99

Note.

* indicates significance at $p \leq .05$ level.

BMI = Body Mass Index.

Table 5

Predicting Body Mass Index (BMI) at 12 Month Follow-Up in Bariatric Surgery Patients.

	β	*t*	*p*
Attention/Executive Function			
Block 1			
Baseline BMI	0.60	8.84	<.001 *
Surgery Type	−0.45	−6.59	<.001 *
Sex	−0.08	−1.22	.23
Block 2			
Baseline BMI	0.59	8.86	<.001 *
Surgery Type	−0.43	−6.34	<.001 *
Sex	−0.12	−1.71	.09
Digit Span	0.00	0.01	.99
Switching of Attention—Numbers	0.15	1.77	.08
Switching of Attention—Numbers/Letters	−0.12	−1.40	.17
Maze Overrun Errors	0.18	2.26	.03 *
Memory			
Block 1			
Baseline BMI	0.60	8.84	<.001 *
Surgery Type	−0.45	−6.59	<.001 *
Sex	−0.08	−1.22	.23
Block 2			
Baseline BMI	0.67	9.90	<.001 *
Surgery Type	−0.46	−6.54	<.001 *
Sex	0.00	0.00	.99
Learning	0.04	0.36	.72
Short Free Recall	−0.29	−2.14	.04 *
Long Free Recall	0.01	0.05	.96
Recognition	0.01	.15	.88

Note.

*indicates significance at $p \leq .05$ level.

Table 6

Predicting % Excess Weight Loss (%EWL) at 12 Month Follow-Up in Bariatric Surgery Patients.

	β	*t*	*p*
Attention/Executive Function			
Block 1			
Baseline BMI	−0.27	−3.03	.003 *
Surgery Type	0.52	582	<.001 *
Block 2			
Baseline BMI	−0.28	−3.11	.003 *
Surgery Type	.51	5.73	<.001 *
Digit Span	−0.09	−0.91	.37
Switching of Attention—Numbers	−0.21	−1.90	.06
Switching of Attention—Numbers/Letters	0.10	0.86	.39
Maze Overrun Errors	−0.15	−1.12	.16
Memory			
Block 1			
Baseline BMI	−0.27	−3.03	.003 *
Surgery Type	0.52	5.82	<.001 *
Block 2			
Baseline BMI	−0.35	−3.91	<.001 *
Surgery Type	0.56	6.06	<.001 *
Learning	−0.11	−0.79	.43
Short Free Recall	0.46	2.60	.01 *
Long Free Recall	−0.11	−0.69	.49
Recognition	−0.06	−0.63	.53

Note.

* indicates significance at $p \leq .05$ level.

BMI = Body Mass Index.