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The Role of Cognitive Function in Postoperative Weight Loss Outcomes: 36 Month Follow-Up

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Abstract

Introduction/Purpose—Cognitive dysfunction is associated with reduced postoperative weight loss up to two years following surgery, though the role of cognition at more extended follow-up is not yet understood. Thirty-six months following bariatric surgery, we retrospectively compared obese and non-obese patients on12-week postoperative cognitive performance. We hypothesized that early postoperative cognitive dysfunction would predict higher body mass index (BMI) and lower percent weight loss (%WL) in the total sample at 36 month follow-up.

Materials and Methods—Fifty-five individuals undergoing bariatric surgery completed cognitive testing at preoperative baseline and serial postoperative timepoints, including 12 weeks and 36 months. Cognitive test scores were normed for demographic variables. Percent weight loss (%WL) and body mass index (BMI) were calculated at 36-month follow-up.

Results—Adjusting for gender, baseline cognitive function, and 12-week %WL, 12-week global cognitive test performance predicted 36 month postoperative %WL and BMI. Partial correlations revealed recognition memory, working memory, and generativity were most strongly related to weight loss.

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Conflict of Interest Statement

Mary Beth Spitznagel: No conflict of interest
Michael Alosco: No Conflict of Interest
Rachel Galioto: No conflict of interest
Gladys Strain: No conflict of interest
Michael Devlin: No conflict of interest
Robyn Sysko: No conflict of interest
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Conclusion—Cognitive function shortly after bariatric surgery is closely linked to extended postoperative weight loss at 36 months. Further work is necessary to clarify mechanisms underlying the relationship between weight loss durability and cognitive function, including contribution of adherence, as this may ultimately help identify individuals in need of tailored interventions to optimize postoperative weight loss.

Keywords

memory; cognition; executive function; adherence

Introduction

Although high rates of weight loss typically result from bariatric procedures, [1] a substantial proportion of patients do not realize optimal weight loss at extended follow-up.[2] For example, recent work shows that following gastric bypass, average weight loss at year 2 is approximately 35%, but by year 6 it drops to less than 28%, representing 7% weight regain.[3] One recently identified contributor to reduced weight loss following bariatric surgery is cognitive impairment. Within the bariatric surgery population, clinically significant impairment in at least one aspect of cognition is present in up to 23% of patients, and subclinical cognitive difficulties are present in approximately 40%. [4] Emerging evidence from our group demonstrates that cognitive function is directly related to weight loss outcomes in this population. A subset of patients enrolled in the Longitudinal Assessment of Bariatric Surgery (LABS) parent project underwent cognitive testing at preoperative baseline and serial postoperative timepoints; preoperative executive function and memory performance predicted 12-month postoperative BMI, and memory performance predicted 12-month percent excess weight loss.[5] Although this initial work did not elucidate how cognitive performance and weight loss outcomes are linked, it suggests a possible role of cognitive ability in postoperative adherence. Patients receive much of the necessary education regarding postoperative guidelines for lifestyle changes during the preoperative planning stage. Deficits in memory or executive function could interfere with a patient's ability to plan for and follow postoperative guidelines. However, given that cognition has been demonstrated to improve shortly following bariatric surgery[3], in examining long term weight loss outcomes, it is appears to be as (or perhaps more) important to consider the predictive ability of cognitive performance not just at baseline, but following that initial improvement as well. Supporting this notion, we recently demonstrated that 12 week postoperative cognitive ability predicted 24 month follow-up; after accounting for baseline levels of cognitive function 12 weeks following surgery, poorer cognitive test performance predicted reduced weight loss outcomes 24 months after surgery.[6]

Although cognitive function predicts weight loss at 12 and 24 months, most patients are still losing weight or maintaining loss at these times, whereas later timepoints may capture weight regain.[3,7] Examination of later timepoints may thus show different patterns in the relationship between cognitive function and postoperative outcomes, and would better reflect durability of weight loss following bariatric procedures. The current study examined how cognitive function contributes to weight outcomes postoperatively at 36 months. We hypothesized that poorer cognitive function at 12 weeks (controlling for baseline cognition) would predict lower %WL and greater BMI 36 months following surgery.

Materials and Methods

Study Design and Participants

Study methods have been previously published[6] and are summarized here. Fifty-five bariatric surgery patients were recruited into a multi-site prospective study examining the neurocognitive effects of bariatric surgery as part of the Longitudinal Assessment of Bariatric Surgery (LABS) parent project. The current sample represents individuals that had complete data at preoperative baseline, as well as postoperative 12-week and 36-month timepoints. Nearly the entire sample underwent Roux-en-Y; as just a single patient underwent a gastric banding procedure, no comparisons for type of surgery were conducted. See Table 1 for baseline demographic and clinical characteristics.

Procedures

This study is registered with clinicaltrials.gov, all procedures were approved by the appropriate Institutional Review Boards, and all participants provided written informed consent prior to study involvement. Participants completed measures at preoperative baseline (within 30 days prior to surgery), and postoperative follow-up at 12 weeks (± 5 days) and 36 months (± 30 days) after surgery. Weight and height were measured in the research office with shoes removed. Medical records were reviewed by research staff to corroborate and supplement participant self-report. The Integneuro cognitive test battery was utilized to assess cognition; this battery demonstrates high sensitivity to cognitive difficulties observed in obese individuals[8,9] and bariatric surgery patients.[4] This battery assesses performance in multiple cognitive domains and can be completed in 45–60 minutes. Specific tests used reflect cognitive domains of Attention/Executive Function and Memory:

Attention/Executive Function

Digit Span Backward: This test assesses working memory, or focused concentration. The task presents a series of numbers on a touch-screen, separated by a one-second interval. At the end of each series, the participant enters the numbers in backward sequence on a keypad. Each sequence of numbers gradually increases from 3 to 9, with two sequences at each level. Total number correct was used in the current analyses.

Switching of Attention (SOA): This test measures cognitive flexibility and psychomotor speed. The first task (SOA-A) presents participants with an array of 25 numbers randomly placed on a touch-screen, which the participant then taps in ascending order as quickly as possible. The second task (SOA-B) presents 13 numbers (1–13) and 12 letters (A-L), which participants tap in alternating and ascending order (i.e., 1-A-2-B-3-etc…) as quickly as possible. Completion time was used as the dependent variable.

Verbal Interference: This test taps inhibition of an automatic and irrelevant response. The task presents names of colors printed in a different color ink (e.g., the word "red" presented in blue ink). Below each word is a response pad with the four possible choices displayed in

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black and in fixed format. The participant taps the word choice that reflects color of the ink of the target word, rather than the meaning of the word written, assessing cognitive inhibition. Total number of correctly identified words was the dependent variable used in this study.

Verbal Fluency: Verbal fluency tasks of phonemic (letter) and semantic (animal) fluency were conducted to assess generativity, or ability to fluidly produce new ideas meeting specific criteria. Letter fluency asks participants to generate words beginning with a given letter of the alphabet, and animal fluency asks participants to generate animal names. Trials last 60 seconds; letter fluency combines three trials, whereas animal fluency is a single trial. Total number of words generated in each of these conditions was used as the dependent variable.

Maze Task: This task assesses planning. Participants are presented with a grid (8×8 matrix) of circles and asked to identify a hidden path through the grid. Distinct auditory and visual cues are presented for correct and incorrect responses. The trial ends when the subject completes the maze twice without error or after 10 minutes has elapsed. Total number of errors made on this task was used as the dependent variable.

Memory

Verbal List-Learning and Memory: Participants are 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 20 minutes (during which the participant completes other tasks), participants are again asked to recall target words. Finally, a recognition trial comprised of target words and foils is completed. Total Learning, Short Delay Free Recall, Long Delay Free Recall, and Recognition of these verbal list items were used to assess memory.

Data Analyses

To facilitate clinical interpretation and maintain directionality among measures, all raw scores of neuropsychological measures assessing cognitive function were transformed to t-scores (a distribution with a mean of 50 and a standard deviation of 10) using existing normative data to standardize scores for demographic characteristics including age and gender, as well as estimated premorbid intelligence. Consistent with clinical interpretation, a t-score < 35 (i.e., 1.5 SD below the mean) was used to define cognitive impairment in the current sample. A global cognitive function composite score consisting of mean t-scores for each cognitive task was computed for preoperative baseline and 12-week postoperative timepoints. Higher scores reflect better performance. BMI and %WL were calculated using the standard formulas.

Repeated measures analysis of variance (ANOVA) was first conducted to determine whether cognitive function improved from baseline to 12 weeks following surgery. Post-operative cognitive improvements at 12 weeks have been previously shown[3] and we sought to determine whether cognition function following surgery is associated with long-term weight loss success. Consistent with our most recent work in this area[6] we wished to consider the predictive ability of initial postoperative improvements in cognition, while still controlling for cognitive performance from preoperative baseline. Thus, to characterize how cognitive function contributes to weight loss outcomes, a series of multivariable hierarchical regression analyses were conducted to determine the predictive validity of the 12-week global cognitive composite score on %WL and BMI at 36 months following bariatric surgery, controlling for confounding variables. For the regression model examining %WL at 36 months as the dependent variable, the baseline global cognitive composite, baseline BMI, %WL at 12 weeks, and gender (1 = male; 2 = female) were entered in block 1; the global cognitive composite at 12 weeks was entered in block 2. These same analyses were performed for BMI at 36 months, with baseline global cognitive composite, baseline BMI, and gender entered in block 1. Follow-up partial correlations controlling for gender and baseline variables were conducted to clarify the specific cognitive tests at the 12 week timepoint that were most closely associated with 36-month %WL and BMI.

Results

Pre- and Postoperative BMI and %WL

The average preoperative baseline BMI of the sample is classified as very severely obese (M (SD) = 45.11 (5.11) kg/m^2. At 12 weeks ($F(1,54) = 564.61$, $p < 0.001$) and 36 months ($F(1,54) = 57.50$, $p < 0.001$) the sample BMI significantly decreased and fell within the severely obese (M (SD) = 37.23 (4.76)) kg/m^2 and moderately obese (M (SD) = 31.69 (5.84)) kg/m^2 classification, respectively. Significant increases were also noted in %WL from 12 weeks to 36 months ($F(1,54) = 50.80$, $p < 0.001$). Of note, approximately 69% of participants exhibited greater than 25% WL at the 36-month follow-up. None of the patients in our sample demonstrated failure to lose weight at the 12 week timepoint, and only 5.5% of the sample (3 patients) showed weight loss less than 2 standard deviations below average (M (SD) = 17.47 (5.05). Percentage of individuals who regained weight between postoperative timepoints was 16.2% (9 patients); of these, only 3% (2 patients) gained more than 7%.

Baseline and 12-Week Cognitive Test Performance

Using a t-score cutoff of 35, many participants exhibited baseline impairments across cognitive domains. The most common baseline impairments were found in learning/ memory, with 21.8% of participants exhibiting impairment in Learning and 16.4% in Recognition. Within baseline attention/executive function, 12.7% of the sample exhibited impairments in both the Maze and Verbal Fluency tasks, and 9.1% demonstrated impairments in Switching of Attention tasks. Impairments on the other tasks of attention/ executive were less common. Using the global cognitive composite, repeated measures ANOVA showed significant improvements in cognitive function from baseline to postoperative week 12 ($F(1,54) = 69.33$, $p < 0.001$). See Table 2 for a full summary of cognitive test performance at baseline, 12 weeks, and 36 months following surgery.

Predictive Validity of 12 Week Cognitive Function for 36 Month Post-Operative %WL and BMI

See Tables 3 and 4 for a summary of regression analyses examining the predictive validity of 12-week cognitive function on %WL and BMI 36 months following surgery. After adjusting for baseline global cognitive function, 12-week %WL, baseline BMI, and gender, the 12-week global cognitive composite demonstrated significant predictive validity for 36-month postoperative %WL ($\beta = .59$, $p < .01$). A similar pattern emerged for BMI ($\beta = -.55$, $p = .01$), even after controlling for baseline cognitive function, baseline BMI, and gender. In each case, poorer cognitive function at 12 weeks predicted reduced %WL and higher BMI 36 months following bariatric surgery.

Correlations between 36-Month %WL and BMI with Specific Cognitive Domain Scores

Partial correlations controlling for gender, baseline cognitive test performance, and 12-week %WL showed poorer performance in Recognition ($r(40) = 0.30$, $p = 0.05$) was associated with reduced 36-month %WL. There was a similar trend for Digit Span Backwards ($r(40) = 0.28$, $p = 0.07$). No such pattern emerged between 36-month %WL and any of the other cognitive tests ($p > 0.05$). In terms of BMI, partial correlations adjusting for gender, baseline BMI, and baseline cognitive test performance revealed poorer performances in Digit Span Backwards ($r(40) = -0.32$, $p = 0.04$) and Animal Fluency ($r(40) = -0.32$, $p = 0.04$) were associated with higher BMI postoperatively at 36 months. There was also a trend for Recognition ($r(40) = -0.27$, $p = 0.09$). BMI at 36 months did not demonstrate associations with any other specific cognitive measures ($p > 0.05$).

Discussion

The current study reveals that early postoperative cognitive dysfunction predicts reduced bariatric postoperative weight loss 36 months following surgery. The elements of cognition that appear to be most consistently linked to weight loss outcomes are specific aspects of executive function (i.e., working memory, generativity) and memory (i.e., recognition memory). This study extends past findings which showed cognitive function predicts weight loss outcomes at 12 and 24 months. As previously reviewed, postoperative weight loss is typically ongoing at 12 months and 24 months.[3,6] By examining the role of early postoperative cognitive function in predicting weight loss 3 years following surgery, the current study begins to address how cognitive function relates to weight loss durability.

A likely mechanism by which cognitive dysfunction leads to reduced long-term weight loss outcomes is poor adherence. Successful postoperative weight loss has been linked to adherence, including attending follow-up appointments[10] and following guidelines for postoperative diet and eating behavior[11,12] as well as physical activity.[12,13] Recent work from our group demonstrates that cognitive function is directly linked to adherence behavior in bariatric surgery patients,[14] implicating adherence as a potential mediator of the relationship between cognitive function and postoperative weight loss. It appears likely that impaired memory and executive function could contribute to difficulty incorporating exercise into a daily routine, planning ahead for healthy meals, or resisting tempting foods.[6,14] The present findings lend further support to the notion that cognitive function plays a role in the bariatric surgery patient's ability to adhere to postoperative recommendations and in sustained weight loss outcomes. In the current study, the cognitive abilities that best predicted weight loss outcomes included memory (specifically recognition memory) as well as executive functions (specifically working memory and generativity). These cognitive functions could impact the daily functioning of a postoperative patient in a variety of ways. For example, a deficit in recognition memory could lead to difficulty remembering and selecting optimal food choices when presented with an array of options, as occurs in a grocery store or restaurant. Difficulty in executive functions such as generativity could impact ability to problem-solve and develop new alternatives if prior dietary or physical activity choices become less feasible or are inconsistent with postoperative lifestyle recommendations. Moreover, in the context of poor working memory skills, any behavior requiring concentration, such as following steps in a new recipe, could be affected. Although such specific links between cognition and behavior in the bariatric postoperative patient are at this point still speculative in nature, they suggest areas in which further research is needed. For example, prospective work is needed to determine if outcomes can be improved utilizing organizing and reminding interventions to specifically target executive function and memory weaknesses in individuals with these cognitive deficits.

Prior work suggests that the relationship between cognitive function and weight loss varies during the postoperative course; the relationship is not significant in the earliest months (i.e., 12 weeks) after surgery, but emerges strongly at 12 and 24 months.[5,6] The current findings of a continued significant relationship between cognition and weight loss outcomes at 36 months fall in line with a pattern suggesting that the association between cognitive function and weight loss is greater at later timepoints. This is perhaps not surprising, given that the natural course of surgical effects in bariatric procedures includes robust early weight loss, but greater variability at later timepoints,[7] when behavioral factors may play a larger role in the patient's ultimate weight loss outcome. Replication in other samples will help to clarify the role of cognitive dysfunction over time in adverse outcomes; this may be particularly important in populations at high risk for cognitive impairment (e.g. older adults).

Similar to past work from our group,,[4,5,6] the current study does not find global cognitive impairment in bariatric surgery patients, but identifies clinical impairment only in a subset. Memory deficits were the most common, with 21.8% of participants exhibiting clinical impairment in ability to learn new verbal information, and 16.4% demonstrating impaired ability to recognize newly learned verbal information. Within tasks of attention/executive functions, 12.7% of the sample exhibited impairment in a maze task, as well as verbal fluency, while 9.1% demonstrated impairment in cognitive flexibility. Given the strength of the association between cognitive performance and weight loss outcomes, cognitive function should be considered in pre- and postoperative clinical screening of bariatric surgical candidates/patients. While the current research does not demonstrate that poor cognitive function will inevitably lead to weight loss failure, this type of cognitive screening may help detect individuals who could benefit from greater intervention, especially if tailored to address individual cognitive impairment. Particularly if occurring during other scheduled visits (e.g., initial psychological appointment; 12 week postoperative appointment), pre- and early postoperative brief cognitive screening could provide a low cost way to increase the treatment team's understanding of an individual patient's needs, which may in turn lead to more positive weight loss outcomes.

The primary limitation of this study is the small sample size. To understand the impact of cognitive function on postoperative weight loss, direct comparison of individuals with and without cognitive impairment would be necessary, though the current sample is underpowered to complete such analyses. Retrospective comparison of cognitive performance in individuals who regain weight at later timepoints relative to those who were successful at maintaining weight loss would also be of interest in more fully understanding durability of weight loss; however, within the current sample, too few individuals with significant weight regain returned at the 36 month timepoint, precluding this type of analysis. Similarly, while the present results do account for initial 12-week weight loss, the sample does not include adequate numbers of individuals with poor initial weight loss to determine if these individuals might have different cognitive responses and weight loss. Such variability in postoperative weight loss outcomes could have important clinical implications for degree or timing of postoperative cognitive improvement, which in turn may impact weight loss outcomes. Additionally, it is likely that the individuals lost to follow-up may be both those with greater cognitive impairment and poorer weight loss outcomes, further emphasizing the need to study this phenomena in larger samples with optimized retention.

Consistent with this notion, future studies should focus on the factors underlying the manner in which cognitive function contributes to durability of weight loss, with particular emphasis on behavioral adherence. The current study suggests that the most common cognitive deficits in this sample are in learning and memory, followed by planning, generativity, and cognitive flexibility. The areas of cognition most closely related to weight loss outcomes similarly reflect memory (specifically recognition memory) and attention/executive function (i.e., working memory, generativity). These findings provide the base for future work to examine specific cognitive predictors of postoperative failure or success in adherence, as well as the foundation for creative interventions to address specific cognitive impairments and optimize weight loss.

Conclusions

Results of the current study indicate that 36 months postoperative weight loss is predicted by cognitive test performance 12 weeks after surgery. Although further work is needed in this area, cognitive screening before and shortly after surgery could serve as an objective method for detection of individuals potentially in need of intervention to optimize weight loss. Future research should clarify how cognitive function impacts postoperative adherence to diet, eating behavior, and physical activity, how cognitive function and ability to adhere to lifestyle changes interact to predict weight loss, and if interventions targeted to specific cognitive deficits might improve long term weight loss outcomes.

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Table 1

Demographic and Clinical Characteristics of 55 Bariatric Surgery Patients

DEMOGRAPHIC CHARACTERISTICS	
Age, mean (SD)	45.00 (10.28)
Female (%)	87.3
Race (% Caucasian)	83.6
BASELINE MEDICAL CHARACTERISTICS (%)	
Hypertension	56.4
Diabetes	21.8
Sleep Apnea	34.5

Table 2

Neuropsychological Test Performance in Bariatric Surgery Patients at Baseline, 12-weeks, and 36-months

	Baseline M(SD)	**12-week M(SD)**	**36-month M(SD)**
Attention/Executive Function			
Digit Span Backward	48.84 (8.12)	50.38 (10.30)	53.22 (13.29)
SOA-A	55.74 (15.32)	61.91 (12.47)	54.25 (12.59)
SOA-B	54.89 (13.56)	59.22 (12.36)	60.06 (10.49)
Verbal Interference	54.64 (12.10)	62.75 (13.62)	65.62 (10.50)
Maze Errors	51.25 (13.32)	56.76 (12.62)	56.52 (12.67)
Letter Fluency	45.88 (9.69)	46.82 (9.77)	48.11 (9.59)
Animal Fluency	49.85 (10.44)	51.40 (9.99)	50.29 (12.15)
Memory			
Learning	42.92 (9.78)	46.93 (10.63)	47.14 (14.75)
SDFR	45.67 (8.17)	48.73 (10.48)	52.32 (13.14)
LDFR	44.90 (8.54)	47.93 (11.39)	51.95 (11.99)
Recognition	42.06 (8.11)	52.64 (9.24)	54.83 (8.23)

Note. Averages were based on complete data for each time point.

Abbreviations—SOA = Switching of Attention; SDFR = Short Delay Free Recall; LDFR = Long Delay Free Recall

Table 3

Predictive Validity of Cognitive Function at 12 Weeks on 36-month %WL (*N* = 55)

	36-Month %WL β (*SE b*)
Block 1	
Baseline Cognitive Function	−.10(.30)
%WL 12-weeks	.26(.34)
Baseline BMI	.24(.34)
Gender	.12(5.00)
R^2	.11
F	1.60
Block 2	
Cognitive Function 12-weeks	.59(.43)*
R^2	.24
F for ΔR^2	8.44*

Note.

* $p < .01$;

WL = Weight Loss; BMI = Body mass index

β = Standardized Beta Coefficient; *SE b* = standard error of unstandardized beta coefficient

Table 4

Predictive Validity of Cognitive Function at 12 Weeks on 36-month BMI (*N* = 55)

	36-Month BMI β (*SE b*)
Block 1	
Baseline Cognitive Function	.01(.13)
Baseline BMI	.45(.15)**
Gender	−.09(2.16)
R^2	.21
F	4.59**
Block 2	
Cognitive Function 12-weeks	− .55(.19)**
R^2	.32
F for ΔR^2	8.26**

Note.

* $p < .05$;

** $p < .01$;

BMI = Body Mass Index

β = Standardized Beta Coefficient; *SE b* = standard error of unstandardized beta coefficient