Neuropsychological performance of a clinical sample of extremely obese individuals

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Abstract

Obesity is a leading cause of preventable death in America and its prevalence is increasing at an alarming rate. While it is known that individuals with specific obesity-related medical conditions perform poorly on neuropsychological tasks, recent evidence suggests that cognitive dysfunction in obese individuals may occur independently of medical co-morbidities. This study examined neuropsychological performance in a clinical sample of extremely obese patients. Individuals seeking surgical treatment of obesity (N=68) were administered cognitive tests as part of a standard pre-surgical evaluation. Results indicated significant differences in performances of extremely obese individuals on tests of executive functioning (planning, problem solving, mental flexibility) in comparison to normative data. No significant differences emerged between obese patients with and without co-morbid medical conditions of hypertension, type II diabetes, and obstructive sleep apnea on the neuropsychological tasks specific to executive functioning. Taken together, these results provide further evidence of specific cognitive dysfunction in extremely obese individuals.

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Obesity is now an epidemic in the United States. Recent estimates indicate that the majority of Americans are either overweight or obese (Hedley et al., 2004). Over the last two decades, the number of obese Americans has increased considerably, with the most rapid increase seen in those considered extremely obese (i.e. Body Mass Index ≥40). Excess body weight substantially increases the risk of morbidity from conditions such as type II diabetes, hypertension, cancer, stroke, and obstructive sleep apnea (Aronne, 2001). Ranking second only to smoking as a preventable cause of death, obesity contributes to over 300,000 deaths per year (Allison, Fontaine, Manson, Stevens, & VanItallie, 1999) and accounts for a significant percentage of national expenditures on health care in the U.S.

It is well known that certain medical co-morbidities are associated with adverse neurocognitive outcome. Neuropsychological investigations of patients with medical diagnoses including hypertension, diabetes, and obstructive sleep apnea have demonstrated deficits across a variety of cognitive domains, including attention, processing speed, memory, and executive functioning (Battersby et al., 1993; Manschot et al., 2006; Ostrosky-Solis, Mendoza, & Ardila, 2001; Salorio, White, Piccirillo, Duntley, & Uhlcs, 2002). While these medical conditions are often resultant from obesity or excess body weight, recent findings indicate that compromised neurocognition in obese individuals...
may exist independent of such medical conditions (Gunstad et al., 2007; Whitmer, Gunderson, & Barrett-Connor, 2005).

Elevated body mass index (BMI) has been associated with reduced cognitive performance in community samples of older adults, middle-age adults, and young adults, specifically in the areas of memory and executive function (Elias, Elias, Sullivan, Wolf, & D’Agostino, 2003; Gunstad et al., 2007). Further, studies of community-dwelling adults have found dysexecutive traits to be positively associated with disinhibited eating and greater food cravings (Spinella & Lyke, 2004), and decision making impairments to be positively associated with higher BMI’s (Davis, Levitan, Muglia, Bewell, & Kennedy, 2004).

To date, there is only one known study that has examined cognitive abilities in a clinical sample of obese individuals seeking primary treatment for obesity. Chelune, Ortega, Linton, & Boustany (1986) found executive function deficits in a substantial proportion of individuals seeking gastroplasty for the surgical treatment of obesity. Results from this study indicated that 21% of the sample scored in the impaired range on a measure of cognitive flexibility (Trail Making Test Part B), and that overall, the sample scored in the impaired range on a test of problem-solving (Category Test). As suggested by these authors, impaired performance on executive functioning measures may provide an early indicator of future difficulty complying with post-surgical recommendations and permanently incorporating appropriate lifestyle changes. However, follow-up data to the study is not available.

For the extremely obese, there is considerable evidence that traditional nonsurgical obesity treatments, such as diet, exercise, and pharmacotherapy, are ineffective for achieving long term, substantial weight loss (Buchwald et al., 2004). Due to the failure of such noninvasive treatments and excessive costs related to treatment of obesity-related medical co-morbidities, increasing numbers of extremely obese individuals are electing to have weight loss surgeries (termed “bariatric” surgeries). Bariatric surgeries modify the stomach and/or intestines to reduce the amount of food that can be eaten and absorbed. Although very effective in producing weight loss, continued success is contingent upon the patients’ ability to incorporate permanent lifestyle changes. These surgeries are currently the treatment of choice for persons with obesity who either: (a) have a BMI ≥ 40 or (b) have a BMI between 35 and 39.9 and secondary medical condition(s). Few controlled studies are available describing the neuropsychological characteristics of extremely obese individuals seeking primary treatment for obesity via bariatric surgery.

1. Rationale and hypotheses

Obesity is now considered a national public health agenda, as it is one of the most urgent and serious health threats confronting our nation. Obesity and its related medical co-morbidities are associated with adverse neurocognitive outcome, although few studies have examined cognition in clinical samples of extremely obese (BMI ≥ 40) individuals. The evidence from preliminary neuropsychological data consistently link cognitive dysfunction, specifically executive dysfunction, with obesity. The primary aim of this study is to further investigate the relationship between extreme obesity and specific neuropsychological performance. It was expected that overall, extremely obese individuals seeking primary treatment for obesity would show impairment in specific cognitive domains (e.g. executive functioning—including problem-solving, mental flexibility, and planning), independent of the medical co-morbidities of hypertension, diabetes, and obstructive sleep apnea. Further, it was predicted that patient BMI would negatively correlate with cognitive test performance.

2. Method

2.1. Participants and procedures

Participants included 68 patients (48 female, 20 male) seeking surgical treatment of obesity at a major medical center in the Southeast. Participants underwent a comprehensive psychological assessment, including brief neuropsychological testing, as part of the standard of care pre-surgical evaluation. Of these, 52 (76%) identified as Caucasian; the remaining 16 (24%) identified as African American. Mean age for the overall sample was 41 years (range 20–57 years; S.D. = 8.76), with 74% of the sample falling between the ages of 30–50. Mean education level for the overall sample was 14 (range 8–20 years; S.D. = 2.75) with 71% of the sample having completed between 12 and 16 years of education. Participant BMI averaged 51.18 k/m² (35.0–80.0 k/m²), which is well above the extremely obese cut-off score of BMI ≥ 40 k/m². The mean IQ of the sample was in the Average range of ability (mean Full Scale IQ = 96.54;
S.D. = 13.16) and the average reading level was at a high school level (range 4th grade–post-High School), with 78%
of the sample having at least a high school equivalent reading level.

Of note, 9 (13%; 2 males, 7 females) participants identified as having pre-existing learning problems (broadly
defined), 1 (1%; 1 female) participant reported history of seizure disorder (presently controlled without medication), 2
(3%; 2 females) participants reported history of CVA/TIA, and 2 (3%; 1 male, 1 female) participants reported remote
history (>20 years) of alcohol and drug abuse. The 2 individuals who reported a history of alcohol and drug abuse also
reported past head trauma with loss of consciousness (<5 min duration). No participants reported current substance
overuse, abuse, or dependence and no participants met diagnostic criteria for severe psychiatric disorder (including
schizophrenia or bipolar disorder).

Information regarding current medical conditions was obtained during a clinical diagnostic interview conducted
by a licensed clinical neuropsychologist (the second author of this study). Diagnosed medical conditions from patient
medical charts were unable to be obtained for all patients; thus, the self-reported data were used in the analysis. Based
on patient report, 44 individuals (64.71% of the sample) had a diagnosis of hypertension, 22 individuals (32.35% of
the sample) had a diagnosis of type II diabetes, and 29 individuals (42.65% of the sample) had been diagnosed with
obstructive sleep apnea.

Psychological evaluations are considered to be standard of care as a part of the clinical pre-surgical work-up for
bariatric surgery candidates. At this medical center, these evaluations follow a standard clinical protocol, which includes
evaluation of cognitive capacity, psychiatric status, health behavior compliance, current and past eating behavior, and
other psychosocial variables. Participants in this study underwent a comprehensive clinical diagnostic interview in
addition to psychological and neuropsychological testing. All testing was conducted on site in a private testing room
by a trained technician.

Data obtained from the evaluation was used to determine each candidate’s readiness for bariatric surgery from a
psychosocial perspective and was collected primarily for clinical purposes. For the present study, retrospective approval
was obtained from the local Institutional Review Board in order to include patient data in research.

2.2. Measures and materials

Neuropsychological domains assessed during the evaluation included intellectual and academic achievement, pro-
cessing speed, executive functioning, verbal fluency, and memory. Normative data was obtained from each test’s
 corresponding administration manual.

2.2.1. Wide range achievement Test-3 (WRAT-3; Wilkinson, 1993)

The Reading subtest of the WRAT-3 was used as a measure of reading ability. Predicted grade-equivalent scores
were calculated.

2.2.2. Wechsler adult intelligence Test-III (WAIS-III; Wechsler, 1997a)

Selected subtests of the WAIS-III (similarities, block design, digit span, and digit symbol) were administered to
estimate verbal, performance, and full scale intelligence quotients.

2.2.3. Rey complex figure test (CFT; Rey, 1941)

The CFT was used to measure perceptual and organizational skills and nonverbal memory. Scores were calculated

2.2.4. Trailmaking test (TMT, Parts A and B; Reitan, 1958)

The TMT was used to assess processing speed and cognitive flexibility.

2.2.5. Wisconsin card sorting test (WCST; Grant & Berg, 1948)

This task was used to assess problem-solving ability and ability to shift set.
2.2.6. Controlled oral word association test (COWA-T; Benton & Hamsher, 1983) and animal naming test (Goodglass & Kaplan, 1983)

These tests were used as measures of verbal fluency.

2.2.7. California verbal learning Test-II (CVLT-II; Delis, Kramer, Kaplan, & Ober, 2000)

The CVLT-II was used as a test of verbal learning and memory.

2.2.8. Logical memory subtest of the Wechsler memory scale-III (LM; Wechsler, 1997b)

This subtest was administered as a secondary measure of verbal memory to assess memory for contextual information.

2.2.9. Eating behavior questionnaires

Current and past eating behavior/eating pathology were evaluated through components of a semi-structured clinical diagnostic interview and the following self report questionnaires: the Questionnaire on Eating and Weight Patterns—Revised (Yanovski, 1995), and the Binge Eating Scale (Gormally, Black, Daston, & Rardin, 1982).

2.2.10. The center for epidemiological studies depression scale (CES-D; Radloff, 1977)

The CES-D was used as a measure of depressive symptoms.

3. Results

A series of one-sample t-tests was used to compare the performance of obese individuals on the neuropsychological tests with normative data. Normative data were obtained for each test from the corresponding scoring and assessment manual matching the average age (41 years) and education level (14 years) for the obese sample. On the TMT and CVLT-II, normative data are split by gender, and male participant data (mean age = 42, mean education level = 14) and female participant data (mean age = 41, mean education level = 14) were analyzed separately.

Although the tests measuring executive functioning (CFT, WCST, TMT Part B) are focal to this study, analyses on all of the tests administered were included in the analyses. To control for the increased risk of making Type I errors, Bonferroni adjustments were made to the alpha level of .05 for each analysis. Using the corrected significance level of .006 based on an alpha error rate of .05 and eight comparisons, t-tests revealed significant differences between extremely obese individuals in comparison to normative data on the CFT, WCST, and COWA-T. Specific analyses revealed that obese individuals scored significantly lower on CFT Copy (p < .001), 3 min delay (p < .001), and 30 min delay (p < .001) as compared to normative data matched on age (40–44 years) and made significantly more overall errors (p < .001) and more perseverative errors on the WCST (p < .001) in comparison to normative data corresponding to age and education level (ages 40–49 years with 13–15 years of education). On the COWA-T, the obese individuals performed significantly better (p < .001) as compared to normative data matched on age (31–44 years). There were no significant differences between the obese sample and normative data on the Animal Naming Test (p = .40) as compared to normative data matched on age (16–59 years) and education level (13–21 years), or between the obese sample and normative data based on age (35–44 years) for the LM-II Recall Total Score (p = .05) (see Table 1).

When normative data were split by gender (TMT and CVLT-II), an adjusted significance level of .005 (based on an error rate of .05 with ten comparisons) was used to determine whether there were differences between our clinical sample and normative data. Results indicated that there were no significant differences between males or females in our sample and normative data matched on age (40–44 years), gender, and education level (13–15 years) for TMT Part B (p’s > .005) or between males or females in our sample and normative data matched on gender and age (30–44 years) on the CVLT-II (p’s > .005).

In order to determine whether there were differences between males and females in our clinical sample on the neuropsychological tasks, a series of analyses of variance were conducted. These analyses indicated no differences between males and females on any of the neuropsychological variables.

As stated previously, a portion of the sample (n = 14) reported a history of learning problems (n = 9), head trauma and history of substance abuse (n = 2), seizure disorder (n = 1), or CVA/TIA (n = 2). Given that these types of conditions may be potential confounds in the present study, the results were analyzed excluding these individuals to determine whether differences in performance found between our clinical sample and normative data were influenced by the
Table 1
Performance of the obese sample (all subjects; n = 68) and normative data for executive functioning tests

<table>
<thead>
<tr>
<th>Variable</th>
<th>Normative Data</th>
<th>t-Score</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CFT copy</td>
<td>27.27 (5.89)</td>
<td>35.50</td>
<td>-11.52</td>
</tr>
<tr>
<td>CFT 3' delay</td>
<td>13.86 (5.21)</td>
<td>21.50</td>
<td>-12.10</td>
</tr>
<tr>
<td>CFT 30' delay</td>
<td>13.65 (5.32)</td>
<td>21.50</td>
<td>-12.37</td>
</tr>
<tr>
<td>WCST Psv. Errors**</td>
<td>18.36 (16.68)</td>
<td>9.00</td>
<td>4.49</td>
</tr>
<tr>
<td>WCST total errors</td>
<td>32.30 (23.89)</td>
<td>17.00</td>
<td>5.24</td>
</tr>
<tr>
<td>TMT B time (in s)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>89.80 (52.02)</td>
<td>66.00</td>
<td>1.94</td>
</tr>
<tr>
<td>Female</td>
<td>84.27 (59.03)</td>
<td>66.00</td>
<td>2.14</td>
</tr>
</tbody>
</table>

Note: *p < .006; **perseverative errors.

Table 2
Performance of the obese sample excluding participants who reported a history of learning problems, head injuries, CVA/TIA, seizures, or substance abuse problems (revised sample; n = 54) and normative data

<table>
<thead>
<tr>
<th>Variable</th>
<th>Normative Data</th>
<th>t-score</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CFT copy</td>
<td>28.29 (4.92)</td>
<td>35.50</td>
<td>-10.76</td>
</tr>
<tr>
<td>CFT 3' delay</td>
<td>14.63 (5.00)</td>
<td>21.50</td>
<td>-10.08</td>
</tr>
<tr>
<td>CFT 30' delay</td>
<td>14.46 (4.93)</td>
<td>21.50</td>
<td>-10.50</td>
</tr>
<tr>
<td>WCST Psv. errors**</td>
<td>16.76 (14.98)</td>
<td>9.00</td>
<td>3.81</td>
</tr>
<tr>
<td>WCST total errors</td>
<td>30.13 (23.75)</td>
<td>17.00</td>
<td>4.06</td>
</tr>
<tr>
<td>TMT B time (in s)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>88.47 (58.36)</td>
<td>66.00</td>
<td>1.59</td>
</tr>
<tr>
<td>Female</td>
<td>70.78 (38.16)</td>
<td>66.00</td>
<td>0.76</td>
</tr>
</tbody>
</table>

Note: *p < .006; **perseverative errors.

The performance of participants with the aforementioned conditions. With those individuals excluded from analyses, the results were similar to those obtained using the entire sample (see Table 2).

A series of one-way analyses of variance was conducted to determine the relationship between cognitive performance and the associated medical co-morbidities of hypertension, type II diabetes, and obstructive sleep apnea in our clinical sample. Results indicated that there were no significant differences between individuals with and without self-reported hypertension, type II diabetes, and obstructive sleep apnea on any of the neuropsychological variables using a corrected alpha of .003 based on nineteen comparisons. Table 3 includes data from those individuals with and without medical co-morbidities for the measures specific to executive functioning.

Table 3
Performance of obese individuals with and without self-reported medical conditions on executive functioning tests

<table>
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<tr>
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<tbody>
<tr>
<td>CFT copy</td>
<td>28.26 (5.12)</td>
<td>25.20 (6.92)</td>
<td>28.20 (5.15)</td>
<td>24.93 (6.97)</td>
<td>28.40 (4.81)</td>
<td>24.87 (7.94)</td>
</tr>
<tr>
<td>CFT 3' delay</td>
<td>14.19 (5.22)</td>
<td>13.16 (5.23)</td>
<td>14.33 (5.20)</td>
<td>13.24 (5.35)</td>
<td>14.07 (4.81)</td>
<td>13.17 (5.95)</td>
</tr>
<tr>
<td>CFT 30' delay</td>
<td>14.09 (5.44)</td>
<td>12.75 (4.76)</td>
<td>14.18 (5.47)</td>
<td>12.67 (4.86)</td>
<td>14.03 (5.38)</td>
<td>2.83 (5.50)</td>
</tr>
<tr>
<td>WCST total errors</td>
<td>29.83 (22.70)</td>
<td>37.71 (26.04)</td>
<td>30.33 (22.69)</td>
<td>37.65 (26.71)</td>
<td>28.40 (24.45)</td>
<td>33.14 (25.35)</td>
</tr>
<tr>
<td>TMT B time (in s)</td>
<td>89.89 (65.84)</td>
<td>77.55 (34.07)</td>
<td>90.93 (66.20)</td>
<td>76.90 (34.78)</td>
<td>87.40 (62.35)</td>
<td>81.40 (69.71)</td>
</tr>
</tbody>
</table>

Note: *perseverative errors. Information regarding current medical conditions was obtained during the clinical diagnostic interview conducted by a neuropsychologist. Diagnosed medical conditions from patient medical charts were unable to be obtained for all patients; thus, the self-reported data were used in the analysis.
Further analyses indicated that those individuals with reported hypertension, diabetes, and sleep apnea performed below normative levels on each of the executive functioning measures and the COWA-T (all p’s < .001), but did not perform worse than normative data on the CVLT-II, Animal Naming Test, or LM-II. Those individuals without hypertension and without type II diabetes did not perform significantly worse as compared to normative data on TMT Part B, although as a group, they performed significantly below normative levels on the other executive functioning measures (CFT and WCST). Participants with and without obstructive sleep apnea performed below normative levels on all of the tests.

Further, to determine whether patients reporting medical co-morbidities differed on demographic variables, a series of analyses of variance was conducted. Using a corrected alpha level of .013 based on an alpha error rate of .05 and four comparisons, there were no significant differences between patients with and without medical co-morbidities (hypertension, type II diabetes, and obstructive sleep apnea) on age, level of education, BMI, or reading grade level.

A series of bivariate correlations was performed to determine the relationship between calculated BMI, psychological factors, and cognitive factors. Results indicated a significant positive correlation between BMI and total score on the CES-D (r = .28, p = .05) and a significant negative correlation between CES-D and FSIQ (r = −.34, p < .05). No other significant correlations were found between CES-D and other neuropsychological variables. Significant negative correlations were found between BMI and FSIQ (r = −.35, p < .01), BMI and raw score of the Rey CFT Copy (r = −.30, p < .01), BMI and the Rey CFT 3 min delay (r = −.25, p < .05), and BMI and the Rey CFT 30 min delay (r = −.25, p < .05).

4. Discussion

As expected, extremely obese individuals performed poorly on a number of neuropsychological tests. This study represents one of the few investigations of neuropsychological performance of extremely obese (BMI ≥ 40) individuals, a segment of the population that is increasing at a rapid rate. This study offers further support to the growing body of evidence for a relationship between obesity and impaired neuropsychological performance. Results of this study suggest that obese individuals demonstrate impairments on specific neuropsychological measures, including the Rey CFT and the WCST. These tests are commonly used as measures of executive functioning, as they tap skills necessary for planning, mental flexibility, problem solving, and monitoring behaviors.

An unexpected finding indicated that our clinical sample performed significantly better in comparison to normative data on one measure, the COWA-T. Extremely obese individuals obtained a raw score of 38.6 (S.D. = 10.95), while normative data reflects a raw score of 31 words to be at the average range of ability. However, it is questionable whether this particular finding is of clinical significance.

Results from an increasing number of studies suggest a link between obesity and deficits in executive functioning. Executive dysfunction is associated with the inability to control aberrant behaviors, such as chronic overeating. Obese individuals often report great difficulties controlling eating behaviors, despite a desire to successfully lose weight. This deficit in inhibiting eating behaviors is a likely contributor to the extraordinarily high percentage of obese individuals who are unable to maintain weight loss with traditional weight loss interventions and may also be related to the difficulties many patients face in making permanent lifestyle changes after weight loss surgery.

Previous evidence also suggests a link between obesity-related co-morbidities (e.g., hypertension, diabetes, and obstructive sleep apnea) and impaired cognitive performance. Because obesity is associated with many diseases that in turn affect brain functioning, it is difficult to determine the specific relationship between obesity and cognitive functioning. However, there is evidence that obesity is an independent contributor to both cognitive functioning in general (Sorensen, Sonne-Holm, Christensen, & Kreiner, 1982), and executive dysfunction in particular (Gunstad et al., 2007). Moreover, increased BMI has been found to be associated with an increased risk of dementia (Gorospe & Dave, 2007).

Of note, the overall results from this study did not indicate a specific association between medical co-morbidities and cognitive dysfunction, offering preliminary evidence that obesity is an independent contributor to cognitive functioning above and beyond medical co-morbidities. When analyzing only those individuals in our sample with self-reported medical conditions (hypertension, type II diabetes, and obstructive sleep apnea), we found similar results to those when we analyzed the sample as a whole. However, a limitation to this study is that participant medical diagnoses were self-reported, although these diagnoses are likely to be accurate because each patient was undergoing medical testing as part of the pre-surgical work-up for weight loss surgery.
While there were no statistically significant differences between patients with and without medical co-morbidities on the neuropsychological measures, the results warrant a clinical interpretation. Given the results from previous studies suggesting a relationship between medical co-morbidities and cognitive dysfunction, we ran further analyses to more specifically determine the influence of medical co-morbidities on patient performance on the executive functioning measures. As is previously stated, there were no significant differences between patients with and without medical co-morbidities on the measures; however, post hoc analyses revealed that individuals without hypertension and without diabetes did not perform significantly worse as compared to normative data on one measure of executive functioning, TMT Part B. As a group, these individuals did perform significantly below normative levels additional executive functioning measures, the CFT and WCST. These results suggest that while those participants without hypertension and diabetes did not significantly differ from those with these medical conditions, they did not significantly deviate from normative data, suggesting that the conditions hypertension and diabetes may have had an influence on the results. Future research should further investigate the relationship between obesity and cognitive function in particular, while specifically controlling for medical conditions.

While the reasons underlying the association between obesity and cognitive dysfunction remain unclear, we offer speculative explanations. First, it is possible that since a larger body mass requires more blood flow for optimal functioning, the brain is deprived of blood flow that it normally receives under circumstances when the body is not as large. In turn, this lack of essential blood flow could be a contributing factor to poor cognitive performance in individuals with a larger body mass index. Alternatively, adipocytes, once thought only to store fat, are now known to secrete proteins (e.g., cytokines, leptin) that may alter cognitive functioning when present in abnormal levels (Harvey, 2007; Wilson, Finch, & Harvey, 2002). Again, these explanations are only speculative, and it remains unknown whether obesity is a cause or a result of executive dysfunction. While an increased number of studies now point to specific cognitive effects of obesity/increased BMI (Gunstad et al., 2007; Whitmer et al., 2005), the exact mechanism(s) underlying the relationship have yet to be determined.

Continued evaluations of cognitive deficits in extremely obese individuals, specifically in the area of executive functioning, will help to further explain the link between cognitive and neurobehavioral characteristics. In addition, future studies should use prospective neuropsychological data obtained prior to bariatric surgery to determine whether such information can serve as an early indicator of post-surgical outcome.

References


