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Obesity and Overweight Problems Among Individuals 1 to 25 Years Following Acute Rehabilitation for Traumatic Brain Injury: A NIDILRR Traumatic Brain Injury Model Systems Study

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Objective: Examine the prevalence of weight classifications and factors related to obesity/overweight among persons 1 to 25 years following traumatic brain injury (TBI) using the Traumatic Brain Injury Model Systems national database. **Design:** Multicenter, cross-sectional, observational design. **Setting:** Traumatic Brain Injury Model Systems inpatient rehabilitation facilities. **Participants:** Persons ($N = 7287$) 1, 2, 5, 10, 15, 20, or 25 years after TBI who required inpatient acute rehabilitation. **Main Outcome Measures:** Body mass index, demographic characteristics, functional, health, satisfaction with life, and global outcomes. **Results:** Overall postinjury weight prevalence rates were 23% obese, 36% overweight, 39% normal, and 3% underweight. Higher rates for obesity and overweight problems were associated with increasing time since injury. Younger (18-19 years) and older (80+ years) age, those in a vegetative state, and those reporting excellent health were less likely to be obese. Individuals with a history of hypertension, heart failure, or diabetes were more likely to be obese. **Conclusions:** Being obese or overweight presents a health risk in the years following rehabilitation for TBI. The findings support the need for longitudinal studies and highlight the advisability of monitoring weight and promoting healthy lifestyle behaviors over time in survivors of TBI. **Key words:** *health behaviors*, *lifestyle*, *obesity*, *overweight*, *traumatic brain injury*, *weight*

OBESITY IN THE UNITED STATES has become a significant public health problem.[1] Being overweight or obese is associated with greater health risks such as cardiovascular diseases, type 2 diabetes, hyperlipidemia, hypertension, cerebral vascular accidents, sleep apnea, respiratory problems, depression,

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some forms of cancer, lowered cognition, and even mortality.[2,3] In general, people with disabilities are more vulnerable to problems with weight management. According to the Behavioral Health Risk Factor Surveillance System, obesity rates for adults with disabilities are 58% higher than for adults without disabilities, with annual health care costs estimated at approximately $44 billion.[4] Secondary health conditions associated with obesity/overweight among adults with disabilities can compromise recovery and limit opportunities for community engagement in work, leisure, and physical activity.[5]

Adults with a moderate or severe traumatic brain injury (TBI) often experience changes in neurocognitive functioning, emotional well-being, sleep/fatigue, pain, motor functioning, balance, and/or seizures that can negatively affect weight and participation in weight management behaviors (eg, physical activity; healthy diet).[6,7] Other factors may also limit physical functioning (eg, orthopedic injuries; surgeries) and dietary intake (eg, medications; dysphagia; hypothalamic disorder compromising endocrine control),[8,9] thereby affecting weight.

Achieving and maintaining a healthy diet and engaging in regular physical activity following a TBI are critical goals for recovery.[10] Immediately after injury, nutrition and level of physical activity often drastically change,[11,12] influenced in part by disruption of anatomical, biochemical, and endocrine pathways in the central nervous system.[8,9,13,14] Early in recovery, weight loss is often evident related to hypermetabolism, hypercatabolism, reduced caloric intake, and/or altered gastrointestinal function.[14] In later phases of recovery, increased oral intake and calories, coupled with reduced mobility and physical activity, promote weight gain. This trend may continue over the course of long-term recovery, given problems with sleep, pain, sedentary lifestyles, depression, medication side effects, and limited transportation. Thus, it is reasonable to suspect that people experiencing TBI are at risk for unhealthy weight gain and associated health problems. However, research examining weight/obesity issues among persons with TBI is scarce. Of the few studies to date, findings indicate greater complications and mortality among patients with TBI who are obese at the time of injury,[7,15,16] higher prevalence of obesity at the time of inpatient rehabilitation (13.2%),[6] and initial weight loss/gain over the first year post-TBI.[14,17] Further research is needed to better understand problematic weight among patients with TBI. Therefore, the purpose of this study was to assess the relations between the prevalence of weight classifications (obesity, overweight, normal, underweight) at postinjury years 1, 2, 5, 10, 15, 20, and 25 and demographic and injury characteristics, as well as functional, life satisfaction, and health outcomes using a large-scale database of TBI survivors.

METHODS

Participants

The sample was drawn from the Traumatic Brain Injury Model Systems (TBIMS) National Database (NDB) sponsored by the National Institute on Disability, Independent Living, and Rehabilitation Research. The study design and procedures were approved by all participating TBIMS Center's institutional review boards. Participants were at least 16 years of age, incurred a moderate or severe TBI, and received inpatient rehabilitation at a TBIMS center. Inclusion criteria are available from the TBIMS National Data and Statistical Center Web site (www.tbindsc.org). For the current study, participants or their proxies were interviewed at any of the regularly scheduled TBIMS follow-up time points (1, 2, 5, 10, 15, 20, or 25 years postinjury). If more than 1 interview was conducted for a participant during the study window, only data from his or her most recent interview were used. The TBIMS participants provided informed consent directly or by proxy, and the study was overseen by each TBIMS centers' institutional review board. Overall follow-up rate for all years in the TBIMS National Database is 82.5%. The TBIMS data collection protocol uses a best source policy for interviewing a proxy when the individual is not able to provide valid information.

There were 7702 participants with follow-up interviews conducted during the study window. Of these, 7287 (94.6%) had self-reported height and weight data to compute body mass index (BMI); 388 participants did not have recorded height or weight, and 27 participants had an arm or leg amputation (see Figure 1).

Measures

Weight categories

Body mass index (BMI) was calculated as weight/height (kg/m^2). Height and weight were measured by participants' self-report, similar to other national surveillance studies.[18] Weight categorization was defined using the Centers for Disease Control and Prevention guidelines[19] as follows: BMI score of 18.5 or below =

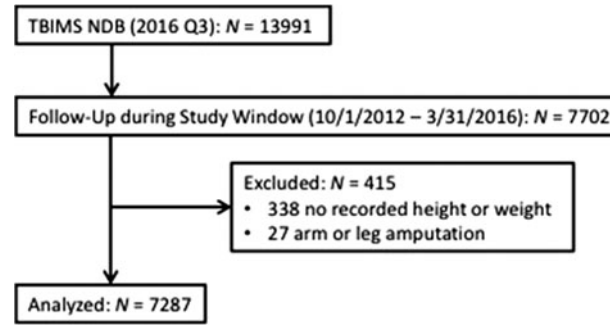

Figure 1. Sample flowchart. TBIMS indicates Traumatic Brain Injury Model Systems; NDB, National Database.

Underweight, 18.5 to 24.9 = *Normal or Healthy Weight*, 25 to 29.9 = *Overweight*, and 30 or greater = *Obese*.

Sociodemographic variables

Information concerning age, gender, race/ethnicity (white, black, Hispanic, other), education level (less than high school, high school/GED, beyond high school), marital status (married, not married), person living with (alone, spouse/significant other, other family, other), and employment (gainful employment, homemaker, retired, unemployed, other) was obtained from the most recent follow-up.

Injury variables

Duration of posttraumatic amnesia (PTA) (mild [less than a day], moderate/severe [1-7 days], very severe [8-28 days], extremely severe [28+ days]), acute care length of stay (1-9, 10-17, 18-27, and 28+ days), and rehabilitation length of stay (0-12, 13-19, 20-31, and 32+ days) at the time of injury were used in the analyses.

Health variables

Participants were asked whether a physician had ever informed him or her of the presence of the following medical conditions: hypertension, seizures, myocardial infarction/heart attack, heart failure liver disease, stroke, cancer, chronic obstructive pulmonary disease, and diabetes. Participants also rated on a 5-point scale their current overall health and whether physical and emotional health were better or worse since the last contact. There were also queries about alcohol and drug use, with the answers recoded into a single variable designating problem substance use.

Functional Independence Measure

The Functional Independence Measure (FIM)[20] is composed of 18 items designed to operationally measure level of independence in self-care, mobility, and cognition. Performance on each item is scored 1 to 7, with 7 representing the highest level of independence. The 2 subcomponents of the FIM focusing on motor (13 items) and cognitive (5 items) functioning were employed in this study.

Disability Rating Scale

The Disability Rating Scale (DRS)[21] is an 8-item scale that incorporates the Glasgow Coma Scale and items assessing cognitive capability for feeding, toileting, and grooming. Separate items rate the need for assistance/supervision and potential for employment. Higher scores (maximum = 30) represent a greater level of disability.

Satisfaction With Life Scale

The Satisfaction With Life Scale (SWLS)[22] is a 5-item measure of a subject's well-being. Each item is scored on a scale of 1 to 7 on the basis of agreement with statements about the individual's quality of life. A total score is obtained by summing the 5 subscores (range: 5-35), with higher scores representing greater satisfaction with life.

Extended Glasgow Outcome Scale

The Extended Glasgow Outcome Scale[23] measures outcome in 8 categories: Dead, Vegetative State, Lower Severe Disability, Upper Severe Disability, Lower Moderate Disability, Upper Moderate Disability, Lower Good Recovery, and Upper Good Recovery.[23] Questions focus on independence in the home and community, work activities, social/leisure activities, and family/social relationships.

Participation Assessment With Recombined Tools–Objective

The Participation Assessment With Recombined Tools–Objective (PART-O)[24,25] comprises 17 items measuring community participation including activities outside the home, social engagement, and productivity. The FIM cognitive, DRS, SWLS, and PART-O were dichotomized using the 50th percentile (median) of the data. The 25th percentile was used for FIM motor due to the high ceiling effect (median = 90, maximum = 91).

Analyses

As a consequence of the large sample size, the authors anticipated that a number of comparisons would be statistically significant but not necessarily clinically meaningful. Therefore, it was decided a priori that standardized effect sizes would be used to determine the relative importance of findings rather than performing statistical tests. Effect sizes were computed using Cohen *h* on the basis of the arcsine transformation of proportions[26] to compare the prevalence of each BMI category (eg, obese) between groups. For groups defined by 2 categories (eg, sex), effect sizes represented differences between the groups (eg, difference in obese prevalence between males and females). For groups defined by more than 2 categories, effect sizes represented the difference in prevalence rates between the reference group and the null of the reference group (eg, difference in obese prevalence between whites and nonwhites). Effect sizes less than 0.10 were considered immaterial, those between 0.10 and 0.20 were considered "modest," 0.20 and 0.30 "important," 0.30 and 0.40 "very important," and 0.40

or more "substantial." These thresholds were chosen because they correspond to nonstandardized differences the authors felt were clinically meaningful.

RESULTS

Sample characteristics

The demographic characteristics of the sample at their most recent follow-up are summarized in Table 1. The sample comprised 73.4% males with 68.2% white, 16.7% black, 10.4% Hispanic, and 4.6% all other racial/ethnic categories; these are generally consistent with the ranges for the TBIMS National Data Base. Average age was 46.0 years at the most recent follow-up (SD = 17.8).

BMI, weight categories, and most recent follow-up

The distribution of BMI and weight categories is summarized in Table 2. The mean BMI at follow-up was 26.8 (SD = 5.5). Approximately 2.5% (n = 179) of the participants had BMI scores classified as "underweight," 38.7% (n = 2,823) as "normal weight," 36.2% (n = 2,639) as "overweight," and 22.6% (n = 1,646) as "obese". There was a significant relation between weight category and year of follow-up ($\chi^2 = 51.0$, $df = 15$, $P < .0001$). On average, 2.5% of the participants were classified as underweight; however, the rate was higher for those 1 to 5 years postinjury (2.6%-3.2%) and lower for those 10 years postinjury or more (1.1%-1.9%). Similarly, while 38.7% of the sample was classified as normal weight, the rate was higher for those 1 to 2 years postinjury (41.7%-42.3%) and lower for those 5 years or more postinjury (33.8%-37.5%). A total of 36.2% of the sample was classified as overweight with little variation among the participants at different follow-up year (35.0%-37.9%). Conversely, while 22.6% of the sample was classified as obese, this rate was lower for those 1 to 2 years postinjury (18.6%-19.8%) and higher for those 5 years or more postinjury (23.6%-28.5%).

TABLE 1 *Demographic characteristics of the sample at most recent follow-up*

Variables at most recent follow-up	Mean	SD
Age at most recent follow-up	46.0	17.8
	Count	**Percentage**
Sex		
Male	5,347	73.4
Female	1940	26.6
Race/Ethnicity		
White	4971	68.2
Black	1217	16.7
Hispanic	760	10.4
Other	338	4.6
Education		
Less than HS/GED/Trade	1123	15.5
HS/GED/Trade	2364	32.6
More than HS/GED/Trade	3773	52.0
Employment status		
Employed	2524	34.7
Homemaker	179	2.5
Retired	3158	43.5
Unemployed	995	13.7
Other	410	5.6
Mode of transportation		
Drives vehicle	3633	51.2
Rides with someone else	2438	34.3
Public transit	725	10.2
Special bus or van service	305	4.3

BMI and demographic characteristics at most recent follow-up

The distribution of BMI at most recent follow-up for subgroups defined by demographic characteristics is shown in Table 3. There were several "important" and

TABLE 2 *Mean BMI and weight category prevalence by most recent follow-up*[a]

	BMI				Weight category			
	N	**Mean**	**SD**	**Range**	**Under**	**Normal**	**Over**	**Obese**
All Participants	7287	26.8	5.48	11.8–60.6	2.5%	38.7%	36.2%	22.6%
1 y postinjury	963	26.1	4.99	15.8–54.8	3.2%	41.7%	36.4%	18.6%
2 y postinjury	1879	26.3	5.18	12.6–55.5	2.9%	42.3%	35.0%	19.8%
5 y postinjury	1978	26.9	5.47	11.8–60.6	2.6%	37.5%	36.3%	23.6%
10 y postinjury	1399	27.4	5.81	15.8–59.7	1.8%	35.6%	37.9%	24.7%
15 y postinjury	805	27.3	5.69	16.1–55.6	1.9%	36.9%	35.5%	25.7%
20+ y postinjury	263	28.1	6.16	16.9–54.7	1.1%	33.8%	36.5%	28.5%

Abbreviation: BMI, body mass index.

[a]Only the most recent follow-up BMI score was used for each participant included in the overall sample.

TABLE 3 *Demographic variables by weight category at most recent follow-up*

	BMI category			
	Underweight (2.5%)	**Normal weight (38.7%)**	**Overweight (36.2%)**	**Obese (22.6%)**
Age (at most recent follow-up), y				
16–19	5 (5.4%)[a]	65 (70.7%)[b]	17 (18.5%)[b]	5 (5.4%)[b]
20–29	51 (3.5%)	719 (48.8%)[c]	461 (31.3%)[a]	243 (16.5%)[a]
30–39	26 (1.7%)	606 (39.2%)	551 (35.6%)	364 (23.5%)
40–49	21 (1.7%)	394 (32.6%)[a]	440 (36.5%)	352 (29.2%)
50–59	23 (1.8%)	406 (32.2%)[a]	524 (41.5%)[a]	309 (24.5%)
60–69	20 (2.3%)	285 (32.4%)[a]	359 (40.8%)[a]	216 (24.5%)
70–79	10 (2.2%)	163 (36.3%)	179 (39.9%)	97 (21.6%)
≥80	23 (6.1%)[a]	184 (49.1%)[c]	108 (28.8%)[a]	60 (16.0%)[a]
Sex				
Male	91 (1.7%)[a]	1927 (36.0%)[c]	2129 (39.8%)[c]	1200 (22.4%)
Female	88 (4.5%)[a]	896 (46.2%)[c]	510 (26.3%)[c]	446 (23.0%)
Race				
White	115 (2.3%)	1927 (38.8%)	1824 (36.7%)	1105 (22.2%)
Black	30 (2.4%)	458 (37.6%)	392 (32.2%)[a]	337 (27.7%)[a]
Hispanic	18 (2.4%)	268 (35.3%)	313 (41.2%)[a]	161 (21.2%)
Other	16 (4.7%)[a]	169 (50.0%)[c]	110 (32.5%)	43 (12.7%)[c]
Primary person living with				
Alone	33 (2.6%)	497 (38.9%)	456 (35.7%)	290 (22.7%)
Spouse/Significant other	41 (1.4%)[a]	975 (34.4%)[a]	1132 (39.9%)[a]	688 (24.3%)
Other family	75 (3.2%)	1003 (42.2%)[a]	785 (33.0%)[a]	516 (21.7%)
Other	30 (3.8%)	343 (43.5%)[a]	264 (33.5%)	151 (19.2%)
Marital status				
Married	35 (1.5%)	774 (32.9%)[a]	953 (40.5%)[a]	591 (25.1%)
Not married	144 (2.9%)	2046 (41.5%)[a]	1684 (34.2%)[a]	1055 (21.4%)
Education				
Less than HS/GED/Trade	27 (2.4%)	441 (39.3%)	394 (35.1%)	261 (23.2%)
HS/GED/Trade	59 (2.5%)	838 (35.4%)	890 (37.6%)	577 (24.4%)
More than HS/GED/Trade	93 (2.5%)	1529 (40.5%)	1347 (35.7%)	804 (21.3%)

Abbreviation: BMI, body mass index.
[a]Modest effect size: $0.1 \leq h \leq 0.2$.
[b]Substantial effect size: $0.4 < h$.
[c]Important effect size: $0.2 < h \leq 0.3$.

"substantial" differences in postinjury BMI associated with age at follow-up. Participants 16 to 19 years of age were more likely to be of normal weight and less likely to be overweight or obese than those not 16 to 19 years of age; participants 20 to 29 years of age were more likely to be of normal weight than those not 20 to 29 years of age; participants 80 years of age or older were more likely to be of normal weight than those not 80 years of age or older. There were also "important" differences in postinjury BMI associated with sex and race/ethnicity. Females were more likely to be of normal weight and less likely to be overweight than males. Participants who were "other" races and ethnicities (eg, Asian/Pacific Islander, Native American) were more likely to be of normal weight and less likely to be obese than those who were white, black, or Hispanic.

BMI and injury characteristics

The distribution of BMI categories for subgroups defined by injury characteristics is shown in Table 4. There were only "modest" differences in postinjury BMI associated with PTA duration. Acute length of stay and rehabilitation length of stay were "immaterial."

BMI and global outcomes at most recent follow-up

Table 5 shows the distribution of BMI at last follow-up for subgroups defined by global outcomes. There were "substantial" differences in BMI associated with the Extended Glasgow Outcome Scale. Participants in a vegetative state at most recent follow-up were more likely to be underweight or normal weight and less likely to be overweight or obese than participants who were nonvegetative.

BMI and health characteristics at most recent follow-up

The distribution of BMI at last follow-up for subgroups defined by health and medical characteristics is shown in Table 6. There were "very important"

TABLE 4 *Injury characteristics by weight category*

	BMI category			
	Underweight (2.5%)	**Normal weight (38.7%)**	**Overweight (36.2%)**	**Obese (22.6%)**
Posttraumatic amnesia				
Mild (0 d)	20 (4.5%)[a]	163 (36.5%)	161 (36.1%)	102 (22.9%)
Moderate/Severe (1–7 d)	36 (3.5%)	419 (40.8%)	375 (36.5%)	196 (19.1%)
Very severe (8–28 d)	59 (2.2%)	1095 (41.0%)	943 (35.3%)	574 (21.5%)
Extremely severe (>28 d)	61 (2.1%)	1028 (36.0%)	1058 (37.1%)	706 (24.7%)
Acute length of stay				
0–9 d	60 (3.2%)	789 (42.0%)	670 (35.7%)	358 (19.1%)
10–17 d	44 (2.3%)	785 (40.3%)	698 (35.9%)	419 (21.5%)
18–27 d	39 (2.2%)	647 (36.9%)	650 (37.0%)	419 (23.9%)
≥28 d	36 (2.1%)	602 (35.2%)	62 (36.3%)	450 (26.3%)
Rehabilitation length of stay				
0–12 d	46 (2.5%)	741 (40.3%)	650 (35.3%)	402 (21.9%)
13–19 d	47 (2.7%)	701 (39.9%)	652 (37.1%)	357 (20.3%)
20–31 d	40 (2.2%)	686 (37.9%)	649 (35.8%)	437 (24.1%)
≥32 d	44 (2.5%)	653 (36.8%)	648 (36.5%)	429 (24.2%)

Abbreviations: BMI, body mass index.
[a]Modest effect size: $0.1 \leq h \leq 0.2$.

differences in BMI associated with hypertension, heart failure, diabetes, and general health status, as well as "important" differences in postinjury BMI associated with number of seizures in the prior year and general health status. Participants with 5 to 20 seizures in the past year were more likely to be of normal weight and less likely to be overweight than those with fewer than 5 or more than 20 seizures. Participants with a history of hypertension, heart failure, or diabetes were less likely to be of normal weight and more likely to be obese than those without such a history. Participants reporting excellent general health at last follow-up were more likely to be of normal weight and less likely to be obese than all others, whereas participants reporting poor general health were more likely to be obese than all others.

DISCUSSION

To our knowledge, this is the first report of the relations between weight and long-term outcomes following moderate-severe TBI. The large-scale, cross-sectional method employed, along with representation of patients with TBI from 16 TBIMS centers across the United States, provides insight into this important issue. This was not a longitudinal study in which changes at the individual level were observed. Nonetheless, the current results indicate that those who were further out postinjury had higher proportions of overweight and obese classifications.

Fifty-five percent of individuals 1 to 2 years postinjury were either overweight or obese, and 67% of those 20 to 25 years postinjury were classified in these 2 categories. Of the entire cohort, 59% were overweight or obese. However, the rate of overweight/obesity in the TBI sample did not reach levels reported by the Centers for Disease Control and Prevention using data from the National Health and Nutrition Examination Survey, which indicates that 70.7% of US adults are overweight or obese.[1] It is not clear why the TBI sample differed from the national sample, even when the same age ranges were examined. One explanation for the discrepancy may be related to higher rates of mortality and complications associated with obesity at the time of TBI compared with those who are nonobese.[7,15,16] This may have led to a selection bias among those with TBI who were captured in this study. Also, rehabilitation patients are expected to participate in several hours of therapy daily, and this may have precluded some people with obesity from being referred for inpatient rehabilitation, thus eliminating them from recruitment into the TBIMS sample. To date, there are no comparable data on obesity/overweight prevalence post-TBI. However, in a prior study using the TBIMS data from a single center that examined obesity/overweight prevalence at the time of inpatient rehabilitation alone, only 13% of patients were obese and 26.9% overweight (40.1% combined), which is also below the national population as well as the current findings at 1-year postinjury.[6] The discrepancy between overweight/obesity classifications obtained in national samples versus those in this study may also reflect that frequent follow-up in this study, as well as clinical appointments, may promote a stronger focus on healthy lifestyle choices in the TBI sample. Nonetheless, it is

TABLE 5 *Global outcomes by weight category at most recent follow-up*

	BMI category			
	Underweight (2.5%)	**Normal weight (38.7%)**	**Overweight (36.2%)**	**Obese (22.6%)**
Employment				
Employed	37 (1.5%)[a]	998 (39.5%)	940 (37.2%)	549 (21.8%)
Homemaker	6 (3.4%)	78 (43.6%)[a]	52 (29.1%)[a]	43 (24.0%)
Retired	90 (2.8%)	1138 (36.0%)	1150 (36.4%)	780 (24.7%)
Unemployed	30 (3.0%)	410 (41.2%)	349 (35.1%)	206 (20.7%)
Other	15 (3.7%)	190 (46.3%)[a]	140 (34.1%)	65 (15.9%)[a]
Mode of transportation				
Drives vehicle	46 (1.3%)[a]	1339 (36.9%)	1397 (38.5%)	851 (23.4%)
Rides with someone else	81 (3.3%)	958 (39.3%)	850 (34.9%)	549 (22.5%)
Public transit	30 (4.1%)[a]	332 (45.8%)[a]	239 (33.0%)	124 (17.1%)[a]
Special bus or van service	11 (3.6%)	103 (33.8%)[a]	97 (31.8%)[a]	94 (30.8%)[a]
Follow-up GOSE				
Vegetative state	4 (18.2%)[b]	13 (59.1%)[b]	3 (13.6%)[b]	2 (9.1%)[b]
Lower severe disability	44 (4.4%)[a]	379 (38.1%)	351 (35.3%)	221 (22.2%)
Upper severe disability	19 (2.5%)	292 (38.6%)	246 (32.5%)	200 (26.4%)
Lower moderate disability	25 (2.7%)	306 (32.9%)[a]	342 (36.7%)	258 (27.7%)[a]
Upper moderate disability	35 (2.1%)	625 (37.5%)	614 (36.9%)	391 (23.5%)
Lower good recovery	23 (2.5%)	345 (38.1%)	325 (35.9%)	212 (23.4%)
Upper good recovery	23 (1.3%)[a]	767 (42.9%)[a]	678 (37.9%)	321 (17.9%)[a]
Follow-up FIM motor				
<25th percentile (84)	60 (3.6%)	611 (37.1%)	575 (34.9%)	403 (24.4%)
≥25th percentile (84)	108 (2.0%)	2099 (39.1%)	1971 (36.7%)	1195 (22.2%)
Follow-Up FIM cognitive				
<50th percentile (30)	56 (3.7%)	590 (38.5%)	545 (35.5%)	343 (22.4%)
≥ 50th percentile (30)	113 (2.1%)	2129 (38.7%)	2006 (36.4%)	1259 (22.9%)
Follow-up PART out and about				
<50th percentile (1.57)	111 (3.1%)	1368 (38.8%)	1228 (34.8%)	818 (23.2%)
≥ 50th percentile (1.57)	68 (1.8%)	1424 (38.5%)	1385 (37.5%)	819 (22.2%)
Follow-up PART productivity				
<50th percentile (1)	106 (3.3%)	1197 (37.2%)	1200 (37.3%)	717 (22.3%)
≥50th percentile (1)	73 (1.8%)	1604 (39.9%)	1424 (35.4%)	923 (22.9%)
Follow-up PART social				
<50th percentile (2.29)	122 (3.2%)[a]	1468 (39.1%)	1323 (35.2%)	841 (22.4%)
≥50th percentile (2.29)	56 (1.6%)[a]	1300 (38.0%)	1279 (37.4%)	786 (23.0%)
Follow-up satisfaction with life				
Less satisfied (SWLS <20)	53 (2.4%)	830 (36.8%)	775 (34.4%)	597 (26.5%)[a]
More satisfied (SWLS ≥20)	70 (1.9%)	1423 (38.8%)	1384 (37.8%)	787 (21.5%)[a]

Abbreviations: BMI, body mass index; FIM, Functional Independence Measure; GOSE, Extended Glasgow Outcome Scale; PART, Participation Assessment With Recombined Tools; SWLS, Satisfaction With Life Scale.
[a]Modest effect size: $0.1 \leq h \leq 0.2$.
[b]Substantial effect size: $0.4 < h$.

clear that the proportion of those exhibiting weight problems increases with time since TBI, along with associated health problems; this represents a significant problem that could have great consequences for those with a history of moderate-severe TBI.

In the current study, there was a substantial relation between excess weight and age at follow-up. Specifically, those younger than 30 years or those older than 80 years had relatively less excess weight than all other age groups. This pattern resembles that of the US population as a whole.[1] Those interviewed (younger than 30 years) were injured more recently and potentially have not been followed long enough to display weight gain or have a higher activity level, even in the presence of their injury. The decrease in weight problems after 80 years of age may reflect a survivorship issue; those who are overweight/obese may be less likely to survive to this age, given their associated health problems.

Significant associations were found between excess weight and several chronic health conditions including hypertension, heart failure, and diabetes. Furthermore,

TABLE 6 *Health/medical variables by weight category at most recent follow-up*

	BMI category			
	Underweight (2.5%)	**Normal weight (38.7%)**	**Overweight (36.2%)**	**Obese (22.6%)**
Number of seizures in the past year				
None	153 (2.3%)	2504 (38.1%)[a]	2408 (36.6%)	1508 (22.9%)
1	6 (3.0%)	86 (42.4%)	67 (33.0%)	44 (21.7%)
2–4	10 (3.9%)	114 (44.2%)[a]	92 (35.7%)	42 (16.3%)[a]
5–20	6 (4.3%)[a]	70 (50.4%)[b]	36 (25.9%)[b]	27 (19.4%)
>20	2 (3.4%)	25 (43.1%)	16 (27.6%)[a]	15 (25.9%)
Hypertension/High BP				
Yes	58 (2.3%)	702 (28.2%)[c]	927 (37.3%)	801 (32.2%)[c]
No	118 (2.5%)	2095 (44.2%)[c]	1691 (35.7%)	833 (17.6%)[c]
Myocardial infarction/Heart attack				
Yes	11 (3.9%)	88 (31.1%)[a]	106 (37.5%)	78 (27.6%)[a]
No	167 (2.4%)	2715 (39.0%)[a]	2518 (36.2%)	1559 (22.4%)[a]
Heart failure				
Yes	9 (4.7%)[a]	53 (27.6%)[b]	58 (30.2%)[a]	72 (37.5%)[c]
No	169 (2.4%)[a]	2750 (39.0%)[b]	2567 (36.4%)[a]	1563 (22.2%)[c]
Liver disease				
Yes	11 (3.8%)	89 (30.4%)[a]	124 (42.3%)[a]	69 (23.5%)
No	167 (2.4%)	2713 (39.1%)[a]	2498 (36.0%)[a]	1567 (22.6%)
Stroke				
Yes	14 (2.7%)	169 (33.0%)[a]	197 (38.5%)	132 (25.8%)
No	163 (2.4%)	2631 (39.1%)[a]	2428 (36.1%)	1505 (22.4%)
Cancer				
Yes	17 (3.5%)	176 (36.7%)	173 (36.1%)	113 (23.6%)
No	160 (2.4%)	2625 (38.8%)	2452 (36.3%)	1524 (22.5%)
COPD				
Yes	29 (3.3%)	337 (38.8%)	281 (32.4%)	221 (25.5%)
No	149 (2.3%)	2468 (38.7%)	2346 (36.8%)	1416 (22.2%)
Diabetes				
Yes	12 (1.4%)	210 (25.4%)[c]	301 (36.4%)	305 (36.8%)[c]
No	164 (2.6%)	2593 (40.4%)[c]	2323 (36.2%)	1334 (20.8%)[c]
General health				
Excellent	17 (2.0%)	406 (46.9%)[b]	335 (38.7%)	108 (12.5%)[c]
Very Good	28 (1.7%)	704 (41.5%)	637 (37.6%)	327 (19.3%)[a]
Good	40 (2.0%)	690 (34.8%)[a]	722 (36.4%)	533 (26.9%)[a]
Fair	25 (2.1%)	404 (33.9%)[a]	430 (36.1%)	332 (27.9%)[a]
Poor	16 (5.2%)[a]	98 (31.7%)[a]	88 (28.5%)[a]	107 (34.6%)[b]
Physical health				
Much better	34 (2.3%)	615 (40.9%)	557 (37.1%)	296 (19.7%)[a]
Slightly better	25 (1.7%)	552 (38.5%)	525 (36.6%)	331 (23.1%)
About the same	40 (1.8%)	852 (37.3%)	838 (36.7%)	553 (24.2%)
Slightly worse	16 (2.4%)	222 (33.3%)[a]	240 (36.0%)	189 (28.3%)[a]
Much worse	10 (6.5%)[b]	56 (36.6%)	50 (32.7%)	37 (24.2%)
General emotional health				
Much better	24 (1.9%)	485 (37.8%)	459 (35.7%)	316 (24.6%)
Slightly better	22 (1.8%)	438 (36.3%)	476 (39.4%)	271 (22.5%)
About the same	51 (2.1%)	960 (39.0%)	884 (35.9%)	564 (22.9%)
Slightly worse	18 (2.3%)	291 (37.8%)	278 (36.1%)	183 (23.8%)
Much worse	11 (3.6%)	122 (39.6%)	110 (35.7%)	65 (21.1%)
Follow-up smoked cigarettes				
Not at all	108 (2.2%)	1821 (36.5%)[a]	1866 (37.4%)	1190 (23.9%)
Some days	21 (3.6%)	232 (39.9%)	200 (34.4%)	129 (22.2%)
Everyday	50 (3.0%)	754 (44.7%)[a]	559 (33.1%)	324 (19.2%)[a]
Drug use				
Yes	20 (2.2%)	416 (46.8%)[a]	309 (34.8%)	144 (16.2%)[a]
No	159 (2.5%)	2385 (37.6%)[a]	2310 (36.4%)	1495 (23.5%)[a]

(*continues*)

TABLE 6 *Health/medical variables by weight category at most recent follow-up (Continued)*

	BMI category			
	Underweight (2.5%)	**Normal weight (38.7%)**	**Overweight (36.2%)**	**Obese (22.6%)**
Drinking category				
Abstaining	111 (2.8%)	1486 (37.2%)	1432 (35.9%)	961 (24.1%)
Light	34 (2.3%)	585 (39.4%)	522 (35.2%)	343 (23.1%)
Moderate	17 (1.3%)[a]	521 (40.1%)	510 (39.3%)	250 (19.3%)[a]
Heavy	16 (3.8%)	186 (43.7%)[a]	145 (34.0%)	79 (18.5%)[a]
Substance problem use				
Yes	40 (2.4%)	718 (42.6%)[a]	606 (35.9%)	323 (19.1%)[a]
No	137 (2.5%)	2064 (37.6%)[a]	1993 (36.3%)	1299 (23.6%)[a]

Abbreviations: BMI, body mass index; BP, blood pressure; COPD, chronic obstructive pulmonary disease.
[a]Modest effect size: $0.1 \leq h \leq 0.2$.
[b]Important effect size: $0.2 < h \leq 0.3$.
[c]Very important effect size: $0.3 < h \leq 0.4$.

general health was rated as poorer among those overweight and obese. These findings are consistent with those in the general population. In a 2013 evidence-based review published by the National Heart, Lung, and Blood Institute, the Obesity Expert Panel found that the higher the BMI, the greater the risk for combined fatal and nonfatal coronary heart disease or stroke, type 2 diabetes, and all-cause mortality.[27] Hypertension has also been found to be associated with high BMI in studies using the National Health and Nutrition Examination Survey database.[28] Thus, persons with TBI are not immune to the development of health conditions typically associated with obesity; it remains to be determined whether those with TBI are more susceptible to the negative effects of these conditions and how to best intervene to address the problem.

In terms of injury characteristics, those in a persistent vegetative state were significantly less likely to be at risk for obesity. Unfortunately, lower weight in these individuals, especially the 1 in 5 who were underweight, may not be an indicator of health. Muscle wasting associated with persistent vegetative state and reliance on supplemental nutrition, such as via gastrostomy, may combine to undermine weight gain.

Implications

The increased prevalence of hypertension, diabetes, heart failure, and overall poor health among those who are obese or overweight points to potential adverse health implications related to excess weight. As we did not assess the timing of the development of weight problems and health conditions, we could not determine whether elevated weight contributed to or caused the health conditions. However, these findings do highlight the potential importance of surveillance, prevention, and management of weight and related health conditions during the years postinjury. Overweight/obesity following TBI is likely multifactorial and therefore a complex issue to address. Nutrition and exercise recommendations for the general population apply while needing to consider the unique obstacles often caused by brain injury. Contributing issues may include medical conditions (neuroendocrine dysfunction) and medications that promote weight gain or increased appetite; cognitive impairment; impulsivity and poor self-control; decreased balance; spasticity; and lack of transportation or other resources.

To properly address the issue of problematic weight following TBI, rehabilitation providers should routinely monitor weight, identify potential causes of weight gain, and assess knowledge of and obstacles to healthy lifestyle behaviors. Many tools exist to promote self-management in the area of weight management and healthy living.

Limitations

Recruitment was conducted at specialized centers for TBI inpatient rehabilitation. Thus, the findings may not generalize to individuals with TBI who do not receive inpatient rehabilitation. Similarly, results cannot be generalized to the full spectrum of the severity of TBI, as those whose injuries were not severe enough to necessitate inpatient rehabilitation were not eligible. As this study was cross-sectional in nature, it could not be determined whether weight status at follow-up represented a change from preinjury weight or compared

with the previous follow-up. In this cross-sectional design, data from a participant's most recent follow-up interview were used in the analyses. This procedure created 2 sources of potential confound–historical and survival. Data from more recent follow-ups were obtained more recently in time; thus, any societal attitudes that could affect weight would have had a differential impact as a function of time postinjury. Survival bias was risked by the later follow-up time points underrepresenting participants who were first injured when they were older, as they would be less likely to survive to later follow-up years. It is unlikely that either source of bias substantially affected the current findings. The cross-sectional nature of this study also limits the ability to assess unmeasured potential contributing causes of weight gain and the directionality of these associations (eg, whether health factors prevent adequate exercise, resulting in weight gain, or whether weight gain limits the mobility needed for adequate exercise). Follow-up studies that assess pre- and postinjury weights across time in the same individuals would provide valuable information regarding the risk factors for progression to unhealthy weight categories and the time-course of weight change trajectories after TBI. Given unequal distribution of age at TBI, there may be more factors at play to explain the relation of age and weight problems, such as the year of injury and effects of aging. It should also be noted that while BMI is a measure used clinically and is the most frequently used measure or estimate of weight classification in similar research, it has limitations, even when reported accurately. Body mass index does not take into account the percentage of lean body mass compared with adipose tissue and this may account for the proportion of participants not only in the vegetative state but also in the overweight and obese categories (eg, higher percentages of lean body mass accounting for their categorization), thus affecting outcomes and conclusions. Finally, these findings may represent an underestimate of problem weight in this sample, given the potential bias inherent in self-report versus objective data.[7,15,29] However, this is a common practice in population-based studies.

CONCLUSION

Being overweight/obese is a potentially significant health problem for people who experience a moderate-severe TBI and require acute rehabilitation. A majority of survivors have excess weight with associated chronic disorders. Those who are overweight/obese rate their health as poor. These findings also highlight the potential importance and benefits of surveillance, prevention, and management of weight and related health conditions following TBI. Lifestyle and health behaviors related to weight gain will need to be a component of any proactive approach to managing TBI as a chronic health condition.[8,30]

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