Body Mass Index and Alcohol Use

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SUMMARY. *Background*. Obesity, inactivity, and being overweight are leading causes of morbidity and mortality in the United States. The relationship between eating, overeating, and addiction have been discussed, debated, and more recently investigated. We have hypothesized that drugs of abuse compete with food for brain reward sites. Overeating and obesity may act as protective factors reducing drug reward and addiction.

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Methods. In the first part of this study, 374 charts of all active weight management patients in a 12-month period were examined. Demographic information, laboratory testing, psychiatric diagnostic interview, alcohol and drug history were reviewed. A detailed alcohol use, abuse, dependence history was present in 298 charts as part of the pre-bariatric evaluation. The relationship between BMI and alcohol use among female patients (n = 298) was then analyzed.

Results. We found a significant ($p < .05$) inverse relationship between BMI and alcohol consumption. The more obese the patient was, the less alcohol they consumed. The percentage of women who consumed alcohol in the past year decreased as BMI level increased. These results confirmed our surgeons' perception that it is rare to find a morbidly obese patient excluded for bariatric surgery because of excessive alcohol consumption.

Conclusions. Obese patients have lower rates of alcohol use than found in the general population of women. As BMI increases, lower rates of alcohol consumption are found. Overeating may compete with alcohol for brain reward sites, making alcohol ingestion less reinforcing.

KEYWORDS. Alcohol, BMI, obesity, eating, addiction

INTRODUCTION

Obesity is a multi-factorial disease that is escalating in epidemic proportions nationally and internationally.[1] Recently, obesity has been identified as the most chronic health problem in the Western world.[2] According to the CDC, in 2000 nearly 39 million adults in the U.S. met the criteria for a diagnosis of obesity, defined as having a Body Mass Index score of 30 or more[3] (Table 1). From 1960 to1999, there was a significant increase in the number of overweight and obese adult Americans, increasing from 44% to 61%.[4,5] Moreover, the prevalence of obesity during this time more than doubled from 13% to 27%.[4,5]

These escalating rates have made obesity and being overweight leading causes of morbidity and mortality in the United States, second only to tobacco in the number of attributable deaths each year. The medical complications associated with obesity are significant and vast, including, but not limited to sleep apnea, hypertension, osteoarthritis, diabetes

TABLE 1. Body mass index table.

Body Mass Index Table

	Normal						Overweight					Obese										Extreme Obesity															
BMI	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**	**45**	**46**	**47**	**48**	**49**	**50**	**51**	**52**	**53**	**54**
Height (inches)	**Body Weight (pounds)**																																			
58	91	96	100	105	110	115	119	124	129	134	138	143	148	153	158	162	167	172	177	181	186	191	196	201	205	210	215	220	224	229	234	239	244	248	253	258
59	94	99	104	109	114	119	124	128	133	138	143	148	153	158	163	168	173	178	183	188	193	198	203	208	212	217	222	227	232	237	242	247	252	257	262	267
60	97	102	107	112	118	123	128	133	138	143	148	153	158	163	168	174	179	184	189	194	199	204	209	215	220	225	230	235	240	245	250	255	261	266	271	276
61	100	106	111	116	122	127	132	137	143	148	153	158	164	169	174	180	185	190	195	201	206	211	217	222	227	232	238	243	248	254	259	264	269	275	280	285
62	104	109	115	120	126	131	136	142	147	153	158	164	169	175	180	186	191	196	202	207	213	218	224	229	235	240	246	251	256	262	267	273	278	284	289	295
63	107	113	118	124	130	135	141	146	152	158	163	169	175	180	186	191	197	203	208	214	220	225	231	237	242	248	254	259	265	270	278	282	287	293	299	304
64	110	116	122	128	134	140	145	151	157	163	169	174	180	186	192	197	204	209	215	221	227	232	238	244	250	256	262	267	273	279	285	291	296	302	308	314
65	114	120	126	132	138	144	150	156	162	168	174	180	186	192	198	204	210	216	222	228	234	240	246	252	258	264	270	276	282	288	294	300	306	312	318	324
66	118	124	130	136	142	148	155	161	167	173	179	186	192	198	204	210	216	223	229	235	241	247	253	260	266	272	278	284	291	297	303	309	315	322	328	334
67	121	127	134	140	146	153	159	166	172	178	185	191	198	204	211	217	223	230	236	242	249	255	261	268	274	280	287	293	299	306	312	319	325	331	338	344
68	125	131	138	144	151	158	164	171	177	184	190	197	203	210	216	223	230	236	243	249	256	262	269	276	282	289	295	302	308	315	322	328	335	341	348	354
69	128	135	142	149	155	162	169	176	182	189	196	203	209	216	223	230	236	243	250	257	263	270	277	284	291	297	304	311	318	324	331	338	345	351	358	365
70	132	139	146	153	160	167	174	181	188	195	202	209	216	222	229	236	243	250	257	264	271	278	285	292	299	306	313	320	327	334	341	348	355	362	369	376
71	136	143	150	157	165	172	179	186	193	200	208	215	222	229	236	243	250	257	265	272	279	286	293	301	308	315	322	329	338	343	351	358	365	372	379	386
72	140	147	154	162	169	177	184	191	199	206	213	221	228	235	242	250	258	265	272	279	287	294	302	309	316	324	331	338	346	353	361	368	375	383	390	397
73	144	151	159	166	174	182	189	197	204	212	219	227	235	242	250	257	265	272	280	288	295	302	310	318	325	333	340	348	355	363	371	378	386	393	401	408
74	148	155	163	171	179	186	194	202	210	218	225	233	241	249	256	264	272	280	287	295	303	311	319	326	334	342	350	358	365	373	381	389	396	404	412	420
75	152	160	168	176	184	192	200	208	216	224	232	240	248	256	264	272	279	287	295	303	311	319	327	335	343	351	359	367	375	383	391	399	407	415	423	431
76	156	164	172	180	189	197	205	213	221	230	238	246	254	263	271	279	287	295	304	312	320	328	336	344	353	361	369	377	385	394	402	410	418	428	435	443

Source: Adapted from *Clinical Guidelines on the Identification, Evaluation, and Treatment of Overweight and Obesity in Adults: The Evidence Report.*

mellitus, gall bladder disease, heart disease, and other degenerative conditions including certain types of cancer.[6-19] Not surprisingly, the health-care costs directly associated with obesity and these complications have also significantly increased and are presently estimated to be $70 billion or 9.4% of all health care costs.[20]

In order to comprehend this "so-called" epidemic, the relationship between eating, overeating, and addiction has been explored. Interestingly, some striking similarities have been discovered.[21] These findings suggest that eating for pleasure is distinct from eating when hungry and that in this way, food has the potential to act as a controlling substance. Consequently, we hypothesize that drugs of abuse can compete with food for brain reward sites, both ultimately providing the experience of pleasure. We have also noted that as a result of this relationship, overeating and obesity may act as protective factors reducing drug reward and addictions.

METHODS

In the first part of this study, charts of all weight management patients in a 12-month period were examined. Demographic data, BMI and substance use history were collected from 374 charts. We found severely obese patients with a Body Mass Index (BMI) of 55 or more were significantly less likely than those with a BMI of 45 or less to consume alcohol in the past year.[22] We then analyzed the relationship between BMI and alcohol use among female patients (n = 298) referred for weight management.

RESULTS

Mean age was 40.6 ± 11.64 years (range, 16 to 79). Mean BMI was 46.1 ± 11.8 kg/m^2 (range, 27 to 107) and mean initial weight was 276.4 ± 70 pounds (range 154 to 611). Analysis was done to compare four groups, those with BMI less than or equal to 29, those with a BMI from 30 through 39, from 40 through 49, and those with a BMI of 50 or more. We found an inverse relationship between BMI and alcohol consumption, such that the percentage of women who consumed alcohol in the past year decreased as BMI level increased. While 62.5% of the sample with BMI $\leq$ 29 (n = 8) used alcohol in the past year, only 47.6% of

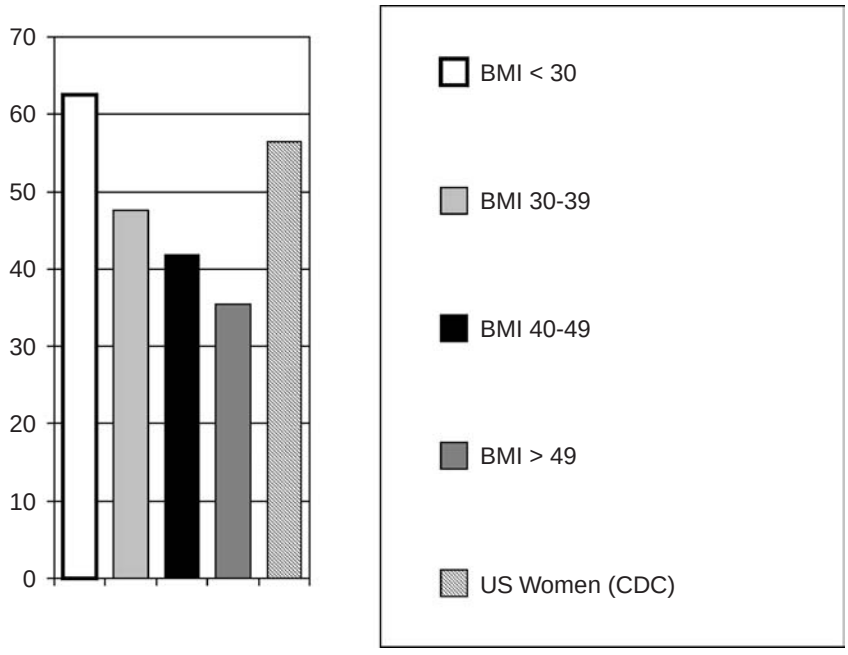
those with BMI 30-39 (n = 84), 41.8% of those with BMI 40-49 (n = 110), and only 35.4% (n = 96) of those with BMI ≥ 50 used alcohol in the past year. Pearson's correlation was −.115, p-value < .05. We concluded that alcohol use was significantly decreased for severely obese patients compared with previously collected telephone survey data within Florida and also national prevalence data (Figure 1).

DISCUSSION

Addiction

Addiction is a chronic disease that involves both biological and environmental variables.[23] Specifically it is characterized by compulsive self-administration without apparent regard to the consequences of consuming the addictive substance. The process of addiction is mediated

FIGURE 1. Past year alcohol use among obese women.



through brain mechanisms underlying reward or reinforcement. Reinforcement itself can be accomplished through both positive and negative mechanisms.

Addiction and the Human Brain

Recently, attempts to understand addiction and the way in which the biological and environmental factors interact have relied heavily on imaging studies such as positron emission tomography (PET) and functional magnetic resonance imaging (fMRI). Specifically these studies involve examining the neurochemical and functional changes in the brains of drug-addicted subjects.[24] The most impressive findings have shown that the reinforcing effects of frequently abused drugs are associated with large and rapid increases in dopamine.[24] Moreover, during drug withdrawal, the brain of an addict has significant deficits in dopamine function associated with deficits in the prefrontal regions. Since dopamine is additionally involved in the reinforcing effects of natural reinforcers, it has been suggested that this fluctuation in brain dopamine function subsequently decreases the sensitivity of natural reinforcers. Additionally, disruption in the frontal cortical functions may transpire which ultimately may result in disturbance in inhibitory control.

The functional imaging studies have proven that it is both drug craving and drug intoxication that cause direct dopaminergic activation of the brain circuitry involved in the reward (nucleus accumbens) pathway. The motivation (orbitofrontal cortex), memory (amygdala and hippocampus), and cognitive control (prefrontal cortex and cingulated gyrus) pathways also reveal some activation.[24] Thus, the consequence of chronic drug use is modification of multiple brain circuits in addition to loss of inhibitory control. This is believed to be the underlying mechanism which makes drugs of abuse addicting substances.[25,26]

Animal studies indicate that neurobiological mechanisms, which are involved in reinforcement, do in fact promote certain behaviors. Dopamine D2 receptor levels mediate reinforcing responses to drugs of abuse such that there is a decrease in the reinforcing effects of alcohol and morphine in mice that lack dopamine D2 receptors.[27,28] Moreover, the animal studies have shown a decrease in the reinforcing effects of cocaine in animals whose dopamine D2 receptors are blocked.

The human studies, however, are not as transparent. For example, whereas the mice show a reduction in self-administration of alcohol when given a dopamine agonist, humans show no effect when given

long-acting bromocriptine, a D(2) agonist. This suggests the complexity of dependence-related behaviors in humans.[29]

Neurobiological Theories of Etiology of Obesity

Eating for Pleasure

Like many illicit drugs, anticipation and ingestion of food causes an increase in the extracellular level of dopamine in the nucleus accumbens, a major target of the mesolimbic dopaminergic system.[30-35] It is in this way that eating behaviors can mimic addiction behaviors. In effect, the brain does not seem to differentiate whether the reward is provoked by licit or illicit drugs or extreme environmental manipulations or fasting.

There is a significant amount of research suggesting that it is this reinforcing dopaminergic neurotransmission that may be involved in obesity. Specifically, there is a high prevalence of the Taq I A allele for the dopamine D2 receptors in obese subjects.[36] This Taq I A allele has itself been linked with lower levels of dopamine D2 receptors.[37] Thus individuals with the A1 allele may use food to elevate dopamine stimulation and subsequently, the reinforcement desired.[38] These findings suggest that this is the likely mechanism by which low dopamine brain activity may contribute to dysfunctional eating behaviors.

Additional research supporting this theory has been provided by positron emission tomography (PET) and [11^{c}]raclopride, which both measure dopamine D2 receptor levels. Studies have shown that obese subjects have significantly lower amounts of striatal dopamine D2 receptor availability than control subjects.[39] Given that dopamine D2 receptors mediate reinforcing responses, these findings suggest that obesity reflects a "reward deficiency syndrome."[40] Since dopamine has a role in regulating food intake by modulating food reward via the meso-limbic circuitry and nucleus accumbens, it is suspected that dopamine D2 receptors regulate compulsiveness in pathological eaters. Additional studies are needed to determine if low dopamine D2 levels are associated with obesity due to the fact that they contribute to a higher vulnerability for addictive behaviors or if there is another neurobiological mechanism at play.

Animal studies have further demonstrated the similarities and relationship between illicit drugs and food. Carroll[41] and Specker and colleagues[42] showed that rats self administer drugs too a much greater extent when they are food deprived.[41,42] Furthermore, studies using rhesus monkeys have revealed that non-drug alternative reinforcers, such

as saccharin, reduce drug self-administration.[43] These findings have been replicated with phencyclidine (PCP)[41,44-46] ethanol,[47] and smoked cocaine base.[48] Human studies have noted that other non-drug reinforcers, such as material items and money, work in a similar fashion and, when available, result in a reduction in drug self-administration.[49-52]

PET and 2-deoxy-2[^{18}F]fluro-D-glucose have also been used in human subjects to assess whether or not obese subjects have an enhanced sensitivity in the brain region associated with sensory processing of food.[53] It was found that, in fact, obese subjects did have significantly greater glucose metabolism in the postcentral gyrus of the left and right parietal cortex.[53] This is where the somatosensory maps of the mouth, lips, and tongue are located and it is also the area in which taste perception occurs. The increased activity in these regions may explain how food is more rewarding and thus, more salient to obese individuals.

Several laboratory animal and human studies have examined factors that influence the choice between eating or engaging in alternative behaviors.[54-58] These studies have shown that, like other reinforcers, eating is subject to the same factors such as the amount of work required to obtain the reinforcer, the quantity and timing of consumption of the reinforcer, and the alternative activities available other than eating.[54-58]

The relative reinforcing value of eating food as opposed to engaging in alternative activities can be determined by providing subjects the opportunity to work for access to the alternatives. The relative reinforcing value is determined based on the amount of work done to obtain one vs. another alternative. Overwhelmingly, the studies show that whichever alternative the subject works harder for, the more rewarding that alternative is. Johnson found that obese subjects consumed more calories and worked harder to obtain food than non-obese subjects when food cues were visible during a food-directed reinforcement task.[59] Similar findings include that overweight adults reporting a higher reinforcement value for eating on reinforcement surveys compared to adults who were not overweight.[59,60]

Eating Due to Hunger

Neuropeptide Y (NPY), agouti related peptide (AgrP) and γ-aminobutyric acid (GABA) are other neuromodulators that promote feeding behavior. These substances, however, seem to be related to the appetitive drive due to hunger as opposed to pleasure. Nevertheless, disturbances

in these substances, may also play a role in the pathological eating behaviors that lead to obesity.

NPY stimulates food intake by activation of NPY Y1 and Y5 receptors in the medial paraventricular nucleus.[61] Studies show that hyperphagia, increased rates of body weight gain, and ultimately morbid obesity result when there is continuous stimulation of NPY receptors.[61,62] Moreover both fasting and dieting readily increased NPY synthesis in the arcuate nucleus (ARC) and release in the paraventricular nucleus (PVN) to sustain the appetitive drive needed for energy replenishment.[62,63] Interestingly, reduction in NPY availability at target sites in the PVN and possibly in the ARC enhanced NPY Y1 receptor sensitivity resulting in hyperphagia among these rats and overt obesity.[62,64] Thus, it appears that an imbalance in NPY signaling locally in the ARC and PVN results in unregulated phagia involving distinctive molecular sequalae.[65]

GABA has been shown to stimulate feeding via $GABA^A$ receptor activation or locally in the ARC itself, which reduces anorexigenic melanocortin signaling to the PVN, resulting in enhanced feeding.[66]

AgrP, an endogenous antagonist at melanocortin 4 (MC4) receptors, stimulates feeding by a distinct mode of signal relay in the PVN. The MC4 receptors mediate the tonic restraint on feeding.[61,67,68]

Additionally, the neuromodulators α-MSH and cocaine-and-amphetamine regulating transcript (CART) are involved in promoting satiety and inhibiting feeding, and therefore, disturbances of these also have the potential to be involved in obesity. These peptides are released in the PVN where they act to inhibit feeding.[61,66,69] The inhibitatory effects of α-MSH are mediated by MC4 receptors, the same receptors which normally mediate the tonic restraint on feeding. In fact, studies have shown that mice with a null mutation for MC4 receptors develop hyperphagia and obesity.[61,66,70]

It is important to note that Pirola and Lieber reported on the hypermetabolic effect of alcohol more than thirty years ago, however this applies only to higher consumption rates.[71,72] In their study, Pirola and Lieber found that when a group of alcoholics had fifty percent of carbohydrate calories replaced with ethanol, a small but significant decrease in body weight was noted.[71] They also compared adding 2000 kcal/day of ethanol or chocolate to the diet. The additional calories from chocolate resulted in significant weight gain (approximately six pounds in two week), however mean change in weight with the additional calories from ethanol, even after 30 days, was less than half a pound.[71] In a later

paper, they describe the possible role of hepatic microsomal enzymes in the energy wastage found in alcoholism.[72]

CONCLUSIONS

Obese female patients (BMI $\geq$ 30) have lower rates of alcohol use than found in the general population of women (56.4% recently reported by the CDC).[73] As BMI increases, lower rates of alcohol consumption are found. Conversely, BMI increases during supervised abstinence.[74] Overeating may compete with alcohol for brain reward sites and result in reduced alcohol intake and dependence rates. Drugs of abuse may hijack existing reward pathways as suggested by Volkow and others,[24] but of these pathways, the food pathways are primary.

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