Body Mass Index in Celiac Disease
Beneficial Effect of a Gluten-free Diet

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Background: There is concern about celiac disease patients being overweight and gaining more weight while on a gluten-free diet (GFD).

Aim: To investigate body mass index (BMI) and effect of GFD on BMI of celiac disease patients in the United States where obesity is a systematic problem.

Methods: BMI at diagnosis and after 2.8 years (mean) on a GFD were compared with national data.

Results: Among our patients (n = 369, 67.2% female), 17.3% were underweight, 60.7% normal, 15.2% overweight, and 6.8% obese. All patients were followed by a dietitian. Compared with national data, females had lower BMI (21.9 vs. 24.2, $P < 0.0001$) and fewer were overweight (11% vs. 21%, $P < 0.0001$); more males had a normal BMI (59.5% vs. 34%, $P < 0.0001$) and fewer were underweight (9.1% vs. 26.7%, $P < 0.0001$). Factors associated with low BMI were female sex, Marsh IIIb/c histology, and presentation with diarrhea. On GFD, 66% of those who were underweight gained weight, whereas 54% of overweight and 47% of obese patients lost weight.

Conclusions: A GFD had a beneficial impact on BMI, underweight patients gained weight and overweight/obese patients lost weight. The improvement in BMI adds to the impetus to diagnose celiac disease. Expert dietary counseling may be a major factor in the beneficial effects we noted.

Key Words: celiac disease, body mass index, NHANES III data, gluten-free diet

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Celiac disease is a genetically mediated autoimmune disease occurring as a result of a response to gluten, the storage protein of wheat, rye, and barley, in the diet.[1] Although celiac disease has been traditionally regarded as a malabsorption disorder with attendant diarrhea and weight loss, these presentations are now infrequently seen.[2] Patients have been noted to be overweight or even obese at presentation,[3] and there is concern that these patients gain more weight after adopting a gluten-free diet (GFD).[4]

There is little information about body mass index (BMI) and effect of GFD in patients with celiac disease in the United States. We therefore conducted this study in a large cohort of celiac disease patients to disclose the association of BMI and celiac disease, and to determine the impact of GFD on BMI in a US population. BMI of the population is considered important because it has been used as an assessment of mortality risk with an increased mortality seen in those with both high and low BMI.[5,6]

SUBJECTS AND METHODS

Our prospectively maintained database of celiac disease patients at the Celiac Disease Center of Columbia University (from 1981 to 2007) was analyzed. Inclusion criteria for this study included patients with biopsy-proven celiac disease, age ≥18 years with available baseline BMI. Another requirement was that the patient had been followed by our nutritionist and had been seen by her within the last 6 years. All patients were followed closely by the nutritionist, seen after diagnosis, at 3 months and at a year. Patients were seen at least annually after that. Visits with the nutritionist were typically for an hour duration. There were no specific plans for dietary guidance for weight control; however, it was frequently addressed by the nutritionist. We excluded patients who were considered to be poorly responsive to the diet and required evaluation for persistent or recurrent symptoms. Data regarding sex, age of diagnosis, baseline height and weight (before GFD), follow up weight on the GFD, and mode of disease presentation were collected. Mode of presentation, at the time of initial celiac disease diagnosis, was classified as classical (diarrhea predominant) and atypical (absence of diarrhea); atypical was further divided into anemia and those without anemia as the presentation. Duodenal biopsies for all patients were reviewed by an experienced pathologist and degree of villous atrophy was classified as Marsh I/II (no villous atrophy),[7] partial villous atrophy (Marsh IIIa), and subtotal/total villous atrophy (Marsh IIIb/c). We also reviewed follow-up biopsies when available. BMI defined as body weight (kg)/height (m^2) was recorded before and after gluten exclusion. BMI was further categorized into 4 groups according to World Health Organization criteria: BMI <18.5 as underweight, 18.5 to 24.9 as normal, 25 to 29.9 as overweight, and ≥30 as obese. Baseline and follow-up BMI in our study were compared with National Health and Nutrition Examination Survey (NHANES III; from 1988 to 1994) data. This data set was chosen to represent midpoints of our cohort data set. We also investigated possible factors associated with the baseline BMI and the impact of GFD on BMI. This study was approved by Columbia Institutional Review Board.

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TABLE 1. Clinical Characteristics of Patients With CD

	Total Patients, N = 369 (% of Total)	Female, N = 248	Male, N = 121	P*
Demographics				
Female patients (%)	248 (67.2)			
Male patients (%)	121 (32.8)			0.02
Mean age of CD diagnosis (y) (SD)	46.2 (15.5)	44.9 (15.3)	49.0 (15.6)	
Presentation				
Atypical with anemia (%)	44 (11.9)	32 (13.0)	12 (9.9)	
Diarrhea (%)	138 (37.9)	95 (38.8)	43 (36.4)	0.50
Atypical without anemia	187 (50.2)	120 (48.2)	66 (53.7)	
Histology				
Marsh I/II (%)	7 (2)	6 (2.6)	1 (0.86)	
Partial villous atrophy (%)	128 (36.8)	82 (35.3)	46 (39.7)	0.43
Total/subtotal villous atrophy (%)	213 (61.2)	144 (62.1)	69 (59.5)	
Body mass index				
<18.5	64 (17.3)	53 (21.3)	11 (9.1)	
18.5–24.9	224 (60.7)	152 (61.3)	72 (59.5)	0.002
25–29.9	56 (15.2)	28 (11.3)	28 (23.1)	
≥30	25 (6.8)	15 (6.1)	10 (8.3)	

*P value denotes the significance of comparison between female and male, and between groups.
CD indicates celiac disease.

Statistical analysis was performed using SAS software (SAS Institute Inc, Version 9.1, Cary, NC). Discrete variables were analyzed by the Pearson χ^2 test and continuous variables by the Student t test or generalized regression models. For all analyses, significance was determined at the $P < 0.05$ level (2-tailed).

RESULTS

Characteristics of the Cohort

In total 369 patients were included in this study. Their characteristics are shown in Table 1. Consistent with all the studies, females predominated (67.2%). Only 38% presented in the classical form with diarrhea, whereas the majority (61%) had the more severe villous atrophy. The mean (SD) BMI before GFD was 22.4 (4.5); median 21.4 and range: 14.8 to 42.4. The majority (60.7%) had a normal weight, whereas only 17.3% were underweight, 15.2% were overweight, and 6.8% were obese. Females had higher rate of a low BMI (21.3% vs. 9.1%) and more males were overweight (23.1% vs. 11.3%) with $P = 0.002$. No significant difference was detected regarding histology and mode of presentation between females and males.

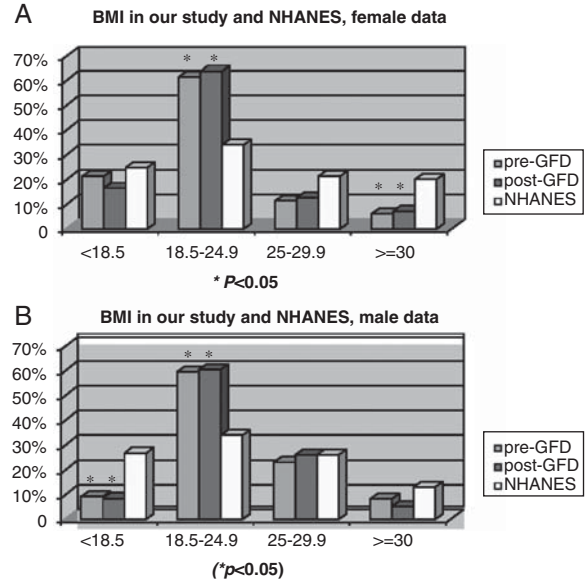

FIGURE 1. Comparisons of different body mass index (BMI) categories in patients with celiac disease and National Health and Nutrition Examination Survey (NHANES III) data, and effect of the gluten-free diet (GFD) among female (A) and male (B).

Comparisons With US Population Data

We compared the BMI of patients with celiac disease to that of the general US population (NHANES III data)[8] (Fig. 1). Females with celiac disease had significantly lower mean BMI (21.9 vs. 24.2, $P < 0.0001$) than the general population. Among males, 59.5% of those with celiac disease had a normal BMI compared with 34% of the general population and 9.1% with celiac disease were underweight compared with 26.7% of the general population ($P < 0.0001$). Similarly, among females, 61% of those with celiac disease had a normal BMI compared with 34% of general population and 11% with celiac disease were overweight compared with 21% of the general population ($P < 0.0001$).

Associations With BMI

The characteristics of the patients in different BMI groups are presented in Table 2. We noted a significant association between a low BMI (underweight) and female sex. There was no difference of age at diagnosis of celiac disease, mode of presentation, or histology among the 4 BMI groups. However, the underweight and normal weight groups had a significantly higher rate of more severe villous atrophy (Marsh IIIb/c) than Marsh IIIa. Patients with Marsh IIIa pathology had a significantly higher BMI than those with Marsh IIIb/c pathology (23.4 vs. 21.8, $P = 0.004$) and the overall effect is seen because of the influence of the female cohort.

Using the regression models, we found significant predictors for low BMI that included female sex, Marsh IIIb/c pathology (more severe), and presentation with diarrhea.

TABLE 2. Summary of Clinical Characteristics Among the 4 Categorized BMI Groups

BMI (kg/m^2)	<18.5	18.5–24.9	25–29.9	≥30	*P*
Total number of patients (% of total)	64 (17.3)	224 (60.7)	56 (15.2)	25 (6.8)	<0.0001
Demographics					
Female patients (%)	53 (82.8)	152 (67.9)	28 (50)	15 (60)	0.0016
Male patients (%)	11 (17.2)	72 (32.1)	28 (50)	10 (40)	
Mean age of celiac disease diagnosis, y (SE)	43 (1.9)	46.7 (1.0)	47.8 (2.1)	47.3 (3.1)	0.30
Presentation					
Atypical except anemia (%)	28 (43.7)	114 (50.9)	32 (57.1)	13 (52)	
Anemia (%)	6 (9.4)	27 (12)	9 (16.1)	2 (8)	0.44
Diarrhea (%)	30 (46.9)	83 (37.1)	15 (26.8)	10 (40)	
Histology					
Marsh I/II (%)	1 (1.7)	4 (1.9)	2 (3.7)	0	
Partial villous atrophy (%)	14 (24.1)	77 (36.2)	24 (44.4)	13 (56.5)	
Total/subtotal villous atrophy (%)	43 (74.2)	132 (61.9)	28 (51.9)	10 (43.5)	0.09
Follow-up length, y (Mean ± SD)	3.8 ± 6.6	2.7 ± 2.8	2.1 ± 1.8	1.7 ± 1.1	<0.0001
Pre-GFD BMI (Mean ± SD)	17.3 ± 0.9	21.4 ± 1.7	27.1 ± 1.3	33.8 ± 3.8	
Post-GFD BMI (Mean ± SD)	19.0 ± 2.7	21.7 ± 2.3	26.8 ± 2.4	33.3 ± 3.9	

BMI indicates body mass index; GFD, gluten-free diet.

Effect of the GFD on BMI

Overall, 54% gained weight and 38% lost weight. The change in BMI for each patient is shown graphically in Figure 2. The mean BMI in each category prediet and postdiet are presented in Table 2. BMI at follow up, while on a GFD, was assessed at a mean of 2.8 years (SD 2.7 y). The mean duration of follow-up for the 4 BMI groups is shown in Table 2. Change in BMI correlated significantly with the duration of follow-up, which was the longest for the underweight group ($r = 0.68$, $P < 0.0001$), and this significant association was because of the influence of the female cohort. There was no significant correlation between follow-up years and BMI change among normal, overweight, or obese groups. However, BMI change after the initiation of a GFD was significantly associated with baseline presentation of diarrhea (55.1% with a BMI increase vs. 40.5% with a BMI decrease and 4.4% of those who had no BMI change, $P = 0.0084$).

BMI at follow up was also compared with NHANES III data in Figure 1 and the pattern of weight change for each category is shown in Table 3. On the GFD, more than half of the underweight or normal weight groups gained weight, and more than half of the overweight and almost half of the obese group lost weight. A majority of the patients in each BMI category remained in the same category; however, the underweight group had the biggest changes. Among those initially underweight patients, 42.4% attained a normal weight, 3.4% became overweight, and 1.7% obese; among initially normal weight patients, 6.5% became underweight and 6.5% overweight; among initially overweight patients, 16.7% attained normal weight and 6.3% became obese; and among initially obese patients, 5.9% became overweight.

Effect of Duration of Follow-up on BMI

The underweight group had a significantly longer follow-up than the other 3 groups (1.1 y longer than the

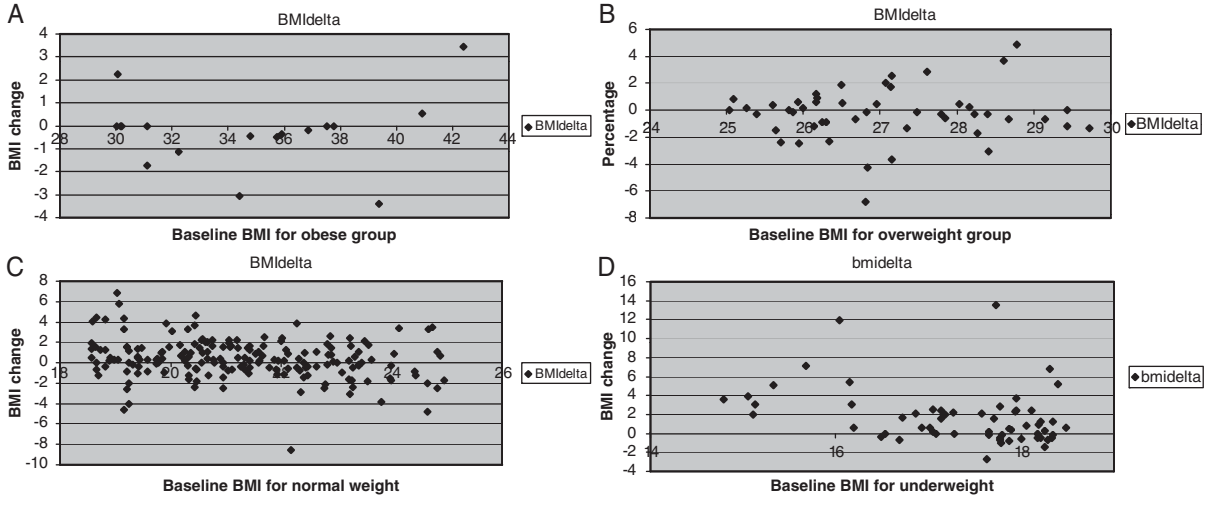

FIGURE 2. BMI change for individual patients among 4 baseline (A, obese baseline; B, overweight baseline; C, normal baseline; and D, underweight baseline) BMI groups. The change in BMI is plotted against the original BMI.BMI indicates body mass index.

TABLE 3. Follow-up BMI Changes and Weight Changes

		Follow-up Weight Change After Gluten-free Diet			Follow-up BMI After Gluten-free Diet			
Initial BMI	**Patients N (%)**	**Weight Gain (%)**	**Weight Loss (%)**	**No Change (%)**	**<18.5**	**18.5–24.9**	**25–29.9**	**≥30**
<18.5	64 (17.3)	39 (66.1)	16 (27.1)	4 (17.4)	31 (52.5)	25 (42.4)	2 (3.4)	1 (1.7)
18.5–24.9	224 (60.7)	107 (57.8)	68 (36.8)	10 (5.4)	12 (6.5)	161 (87)	12 (6.5)	
25–29.9	56 (15.2)	19 (39.6)	26 (54.2)	3 (6.3)		8 (16.7)	37 (77)	3 (6.3)
≥30	25 (6.8)	3 (17.7)	8 (47.1)	6 (35.3)			1 (5.9)	16 (94.1)

BMI indicates body mass index.

normal BMI group, $P = 0.04$; 1.7 y longer than the overweight group, $P = 0.02$; and 2.2 y longer than the obese group, $P = 0.03$).

To address the timing of the weight change we noted that, among the underweight group, increasing each 1 year of follow-up significantly increased BMI by 0.3 ($P < 0.0001$) and for the normal weight group, increasing each 1 year of follow-up significantly increased BMI by 0.08 ($P = 0.02$). In addition, for the overweight and obese groups, increasing each 1 year of follow-up decreased BMI by 0.06 and 0.3, respectively, but it was not statistically significant ($P = 0.2$ and $P = 0.5$). This latter result may be the result of the shorter follow-up period among these 2 groups. If we had longer follow-up data in these 2 groups, the BMI decrease may reach a statistical significant level. These results demonstrate that the duration of follow-up is an important factor and the weight change is an ongoing process.

Effect of Degree of Villous Atrophy on BMI

There was no significant association between BMI change on the GFD and baseline total villous atrophy ($P = 0.7$). We analyzed whether improvement in BMI was associated with change in the biopsy findings at follow up. The bulk of the patients had follow-up biopsies (n = 343). Overall, 60.6% improved their biopsy status with 44.3% in the normal/Marsh I/II category at follow-up versus 2% at baseline and 22.2% in the most severe degree of villous atrophy group at follow-up versus 61.5% at baseline. Histologic improvement occurred in each BMI group ($P = 0.09$). There was a significant association between biopsy change and BMI change ($P = 0.05$). Those in whom the BMI decreased had the greatest histologic improvement (50.48% vs. 7.21% for those with no change in BMI and 42.31% for those who increased their BMI).

DISCUSSION

It is now recognized that patients with celiac disease may be overweight or even obese.[4,9–13] There is however little data on the BMI of patients diagnosed with celiac disease in the United States and the effect of therapy with a GFD.[14] In our study of a large cohort of patients with celiac disease 60% had a normal BMI, whereas only 17.3% were underweight and 15.2% were in the overweight group with 6.8% obese. We found that female sex, diarrhea, and more severe degree of villous atrophy were independent predictors for a lower BMI.

When we looked at the BMI at the time of diagnosis of celiac disease, compared with the NHANES United States national data, differences were noted. The celiac patients of both sexes had a more favorable BMI than the national figures. There were fewer in categories of overweight and obese, whereas there was a greater rate of those with a normal weight in both male and female cohorts.

Our study compared with one from Minnesota in which 27% of the patients were overweight[3] and one from Ireland in which almost 40% were overweight or obese.[4] In the Irish study, only 5% were underweight at diagnosis and many (33% of women and 50% of men) were overweight, with 13% in the obese category. Our findings are similar to those from England, in which 6% were underweight, 66% were normal, and 28% were overweight (including 5% obese).[15]

The relative paucity of those with a low BMI (underweight category) emphasizes the fact that celiac disease should not be considered primarily as a malabsorption disorder in which patients may present underweight or malnourished. In fact, the majority of patients are of normal BMI though some may be overweight or even obese.

Because of the gain in weight of patients with celiac disease while on a GFD, the study from Ireland raised questions about the health benefit of the diagnosis of celiac disease and initiation of a GFD.[4] In contrast, our study demonstrated that the diagnosis of celiac disease and its treatment with a GFD resulted in improvement in an already favorable BMI pattern. The largest improvement in BMI (weight gain) was for the underweight group. Whereas weight loss was most pronounced in the patients who were overweight or obese at diagnosis. The number of follow-up years on a GFD significantly predicted the increase of BMI in the underweight and normal weight groups as well as predicted a BMI decrease in the overweight and obese groups, although the latter did not reach statistical significance, which may be caused by a shorter follow-up time. The overweight group was followed for a shorter period of time, so a longer observation may demonstrate a greater weight loss. Although many patients, especially in the normal BMI category gained weight, they usually did not change their BMI category. Similar favorable changes in BMI were noted in a smaller cohort of patients from the midwest of the United States.[14] Our study also demonstrated that the weight change is an on-going process and that BMI change was associated with improvement in biopsy status at follow-up biopsy.

Our findings are important because both low and high BMI are associated with increased morbidity and mortality, the so-called J or U shaped mortality curves associated with the different categories of BMI.[5,6,16,17] On the GFD, our patients shifted from both high and low BMI groups to the normal group.

The worsening of the BMI on the GFD in the large Irish study,[4] raised the question as to the wisdom of the quest to increase the diagnosis of the vast number of

patients who have undiagnosed celiac disease in the general population.[18,19] However, our study demonstrates an improvement in the BMI profile of patients with celiac disease and supports the benefit to the patient in the diagnosis and treatment of celiac disease.

An important aspect of our study is that the patients were seen in a Center dedicated to their care and followed by an experienced dietitian, an important factor in adherence to the GFD.[20–22] This may well have been the major factor in the excellent results noted by us and is impossible to dissect out the role of the dietitian as opposed to the diet from the data. In addition, there was no control group in our study. Of note, we excluded those who had persistent symptoms or refractory disease, despite the diet. This may have excluded noncompliant patients. The bulk of the patients in this study had follow-up biopsies of which 60% improved their biopsy grade of villous atrophy, indicating a strong dietary compliance factor.

Dietary management is the only therapy for celiac disease. Expert dietary counseling is important, because not only do patients need to be aware of what they have to avoid but they need to be able to make wise food choices among the gluten-free foods.[1] It is our practice to advise patients about a high quality GFD in which naturally gluten-free foods (eg, fruit and vegetables) and use of alternate, nongluten containing grains (eg, quinoa and buckwheat). There is unfortunately a paucity of dietitians available for the management of celiac disease.[23] The importance of expert dietary guidance is demonstrated in this study, for not only among our patients did the biopsy grade improve, reflecting gluten avoidance but BMI changed favorably indicating excellent dietary choices in the diet. In this light, there are actually sparse data on what those with celiac disease eat as part of the GFD and none in the United States. Although patients with celiac disease from Argentina have been shown to eat fewer calories,[24] and in Europe, consume less energy on the GFD.[25,26]

In conclusion, $< 20\%$ of celiac patients met the underweight criteria, the majority had a normal weight, however, for those who were either underweight or overweight/obese, treatment with a GFD resulted in a beneficial change in the BMI. This provides another reason to diagnose and treat those with celiac disease. Expert dietary counseling and patients being seen in a Center or clinic dedicated in managing the disease may be the most important factor in the management of celiac disease.

REFERENCES

1. Green PH, Cellier C. Celiac disease. *N Engl J Med*. 2007;357:1731–1743.
2. Rampertab SD, Pooran N, Brar P, et al. Trends in the presentation of celiac disease. *Am J Med*. 2006;119:355.e9–355.e14.
3. Murray JA, Van Dyke C, Plevak MF, et al. Trends in the identification and clinical features of celiac disease in a North American community, 1950 to 2001. *Clin Gastroenterol Hepatol*. 2003;1:19–27.
4. Dickey W, Kearney N. Overweight in celiac disease: prevalence, clinical characteristics, and effect of a gluten-free diet. *Am J Gastroenterol*. 2006;101:2356–2359.
5. Adams KF, Schatzkin A, Harris TB, et al. Overweight, obesity, and mortality in a large prospective cohort of persons 50 to 71 years old. *N Engl J Med*. 2006;355:763–778.
6. Willett WC, Dietz WH, Colditz GA. Guidelines for healthy weight. *N Engl J Med*. 1999;341:427–434.
7. Marsh MN. Gluten, major histocompatibility complex, and the small intestine. A molecular and immunobiologic approach to the spectrum of gluten sensitivity (“celiac sprue”). *Gastroenterology*. 1992;102:330–354.
8. Services USDoHH, (DHHS). National Center for Health Statistics, Centers for Disease Control & Prevention. Third National Health & Nutrition Examination Survey, 1988-1994, NHANES III Laboratory Data File. Volume Public Use Data File Documentation # 76200. Hyattsville, MD: U.S. Dept. of Health & Human Services, 1996:Public Use Data File Documentation Number 76200.
9. Owen DA, Thorlakson TK, Walli JE. Celiac disease in a patient with morbid obesity. *Arch Intern Med*. 1980;140:1380–1381.
10. Semeraro LA, Barwick KW, Gryboski JD. Obesity in celiac sprue. *J Clin Gastroenterol*. 1986;8:177–180.
11. Conti Nibali S, Magazzu G, De Luca F. Obesity in a child with untreated coeliac disease. *Helv Paediatr Acta*. 1987;42:45–48.
12. Czaja-Bulsa G, Garanty-Bogacka B, Syrenicz M, et al. Obesity in an 18-year-old boy with untreated celiac disease. *J Pediatr Gastroenterol Nutr*. 2001;32:226.
13. Franzese A, Iannucci MP, Valerio G, et al. Atypical celiac disease presenting as obesity-related liver dysfunction. *J Pediatr Gastroenterol Nutr*. 2001;33:329–332.
14. Murray JA, Watson T, Clearman B, et al. Effect of a gluten-free diet on gastrointestinal symptoms in celiac disease. *Am J Clin Nutr*. 2004;79:669–673.
15. West J, Logan RF, Card TR, et al. Risk of vascular disease in adults with diagnosed coeliac disease: a population-based study. *Aliment Pharmacol Ther*. 2004;20:73–79.
16. Romero-Corral A, Montori VM, Somers VK, et al. Association of bodyweight with total mortality and with cardiovascular events in coronary artery disease: a systematic review of cohort studies. *Lancet*. 2006;368:666–678.
17. Flegal KM, Graubard BI, Williamson DF, et al. Excess deaths associated with underweight, overweight, and obesity. *JAMA*. 2005;293:1861–1867.
18. James SP. National Institutes of Health consensus development conference statement on celiac disease, June 28-30, 2004. *Gastroenterology*. 2005;128:S1–S9.
19. Catassi C, Fabiani E, Iacono G, et al. A prospective, double-blind, placebo-controlled trial to establish a safe gluten threshold for patients with celiac disease. *Am J Clin Nutr*. 2007;85:160–166.
20. Bardella MT, Molteni N, Prampolini L, et al. Need for follow up in coeliac disease. *Arch Dis Child*. 1994;70:211–213.
21. Butterworth JR, Banfield LM, Iqbal TH, et al. Factors relating to compliance with a gluten-free diet in patients with coeliac disease: comparison of white Caucasian and South Asian patients. *Clin Nutr*. 2004;23:1127–1134.
22. Ciacci C, Cirillo M, Cavallaro R, et al. Long-term follow-up of celiac adults on gluten-free diet: prevalence and correlates of intestinal damage. *Digestion*. 2002;66:178–185.
23. Nelson M, Mendoza N, McGough N. A survey of provision of dietetic services for coeliac disease in the UK. *J Hum Nutr Diet*. 2007;20:403–411.
24. Smecuol E, Gonzalez D, Mautalen C, et al. Longitudinal study on the effect of treatment on body composition and anthropometry of celiac disease patients. *Am J Gastroenterol*. 1997;92:639–643.
25. Bardella MT, Fredella C, Prampolini L, et al. Body composition and dietary intakes in adult celiac disease patients consuming a strict gluten-free diet. *Am J Clin Nutr*. 2000;72:937–939.
26. Kinsey L, Burden ST, Bannerman E. A dietary survey to determine if patients with coeliac disease are meeting current healthy eating guidelines and how their diet compares to that of the British general population. *Eur J Clin Nutr*. 2008;62:1333–1342.