10-1-2013

The relationship between adiposity and stature in prepubertal children with celiac disease

Benjamin U. Nwosu
University of Massachusetts Medical School

Rachel I. Snook
University of Massachusetts Medical School `

Louise S. Maranda
University of Massachusetts Medical School

DOI 10.1515/jpem-2012-0312 — J Pediatr Endocr Met 2013; 26(9-10): 819–824

Benjamin Udoka Nwosu*, Rachel I. Snook and Louise Maranda

The relationship between adiposity and stature in prepubertal children with celiac disease

Abstract

Background and aim: The pathogenesis of short stature in celiac disease (CD) is unknown. Obese children are generally taller than their non-obese peers; however, the role of adiposity on stature in CD is unclear. Our aim was to determine the association between adiposity and stature in CD.

Subjects and methods: We compared the anthropometric characteristics of prepubertal children of ages 3–12 years, with biopsy-proven CD (n=40) and who were not on gluten-free diet, to same aged, prepubertal non-CD children (n=50). Body mass index (BMI) was calculated using the formula weight/height^2. Sex-adjusted midparental target height (MPTH) standard deviation score (SDS) was calculated using National Children Health Statistics data for 18-year-old adults. Data were expressed as mean±standard deviation.

Results: CD subjects had significantly lower BMI SDS than controls (0.61±1.22 vs. 1.28±1.60, p=0.027) but were not significantly shorter than the controls (−0.05±1.21 vs. 0.21±1.71, p=0.41). When the patients were subdivided into the normal-weight and overweight/obese groups, the normal-weight CD patients were of similar height as the normal-weight controls (p=0.76) but were significantly shorter than both the overweight/obese controls (p<0.001) and overweight/obese CD children (p<0.001). Interestingly, the overweight/obese CD children were significantly taller than the normal-weight controls (p=0.003). The MPTH SDS did not differ between the groups.

Conclusions: Overweight/obese prepubertal children with CD were taller than both their normal-weight CD peers and the normal-weight controls, but were of similar height as the overweight/obese control subjects.

Keywords: celiac disease; obesity; stature.

***Corresponding author: Benjamin U. Nwosu**, MD, Associate Professor, Division of Endocrinology, Department of Pediatrics, University of Massachusetts Medical School, 55 Lake Avenue North, Worcester, MA 01655, USA, Phone: +508-334-7872, Fax: +508-856-4287, E-mail: Benjamin.Nwosu@umassmemorial.org
Rachel I. Snook and Louise Maranda: University of Massachusetts Medical School, 55 Lake Avenue, North, Worcester, MA 01655, USA

Introduction

Celiac disease (CD) is an autoimmune enteropathy that affects 0.5%–1% of the population (1). Untreated CD is associated with malnutrition in 67% of patients (2). However, recent studies indicate that CD and obesity can coexist in children and adolescents (3–6) at a reported frequency of 5%–6% (6, 7) for obesity alone, and up to 19% for both overweight and obesity (6). Extraintestinal features such as short stature, delayed puberty, and dental enamel defects may occur as monosymptomatic manifestations of CD (8). In one study, short stature was the leading extraintestinal symptom of CD in 30% of 485 children (9). The pathogenesis of short stature in CD is unknown (10). Some studies report that nutritional deficits lead to impaired growth in children with untreated CD (10, 11), whereas others demonstrate evidence for growth hormone (GH) deficiency (12, 13) and GH resistance (14–16) in some patients with CD.

Despite the description of obesity in patients with CD (3–6, 17–22), the role of adiposity on stature in prepubertal children with CD is unknown. In general, obese or overweight children are taller than normal-weight children (23). The mechanism of this height differential is unknown. The proposed mechanisms for the tall stature include insulin stimulation of the insulin-like factor-I receptor (24) and the stimulatory effects of leptin on the hypothalamic-pituitary-gonadal axis (25–27), skeletal growth centers (28), and the activity of enzymes essential for the synthesis of adrenal androgens (29). Obese children have increased adrenal androgen levels (30), and this may be involved in the accelerated growth of these children before puberty (31).

The aim of this study was to determine the role of adiposity on stature in untreated, prepubertal children with CD. Our hypothesis was that overweight/obese prepubertal children with CD would be significantly taller than normal-weight CD children.

Subjects and methods

Subjects

Medical records of prepubertal children aged 3–12 years with CD at the Children's Medical Center of the UMass Memorial Medical Center

were reviewed and compared with a cohort of healthy prepubertal children without CD who participated in a prospective cross-sectional study of the role of vitamin D in the protection of bone mineral content in prepubertal children. The study protocol was approved by the University of Massachusetts Institutional Review Board. Study subjects (n=40; 26 females and 14 males) were included if they had a diagnosis of CD by intestinal biopsy and if they were not on a gluten-free diet (GFD). All children who carried a diagnosis of CD had undergone an endoscopic examination of the upper gastrointestinal tract with a variable number of biopsies of the distal duodenal mucosa (32, 33). Infiltrative changes (Marsh type I), crypt hyperplasia (Marsh type II), and villous atrophy (Marsh type III) were considered characteristic histopathological features of CD (34). Patients were excluded if they had disorders of the thyroid or adrenal glands, or other autoimmune diseases such as type 1 diabetes. Subjects were also excluded if they had syndromic short stature, GH deficiency, or were in puberty as determined by Tanner 2 breast development or greater in girls or a testicular volume of ≥4 cm^3 in boys. Subjects were categorized into either normal weight or overweight and obese using a body mass index (BMI) of 5th to <85th percentile for normal weight, >85th but <95th percentile for overweight, and ≥95th percentile to define obesity (35). An age-matched group of healthy prepubertal children who participated in a cross-sectional study entitled 'The Relationship between Vitamin D Deficiency and Low Bone Mineral Content in Children', ClinicalTrails.gov Identifier: NCT0075689, at the Children's Medical Center of the UMass Memorial Medical Center, served as normal controls. All subjects in the control group were prepubertal (Tanner 1 breast for girls and testicular volume of <4 cm^3 for boys), not on vitamin D or calcium supplementation, and had no medical diseases affecting calcium or vitamin D metabolism. All controls were negative for CD-associated autoantibodies and had no diagnosis of CD. This group consisted of 29 overweight/obese (17 males, 12 females) and 21 normal-weight (12 males, 9 females) subjects.

Anthropometry

Height was measured to the nearest 0.1 cm using a wall-mounted stadiometer (Holtain Ltd., Crymych, Dyfed, UK) that was calibrated daily. Weight was measured to the nearest 0.1 kg using an upright scale. BMI was derived using the formula weight/height^2 (kg/m^2), and expressed as standard deviation score (SDS) for age and sex based on National Center for Health Statistics (NCHS) data (36). Sex-adjusted midparental target height (MPTH) SDS was calculated for 18-year-old adults using NCHS data and the standard formula for MPTH (37). The MPTH is a child's projected adult height based on the heights of his or her parents and is calculated as follows: for girls, the father's height minus 13 cm (5 in) is averaged with the mother's height; for boys, the mother's height plus 13 cm is averaged with the father's height (37). Anthropometric data were expressed as mean±SD.

Statistics

Statistical analyses were performed using the SPSS Predictive Analytics Software v.19 (IBM Corporation, Somers, NY). Means and standard deviations were calculated for descriptive summary statistics. Anthropometric measurements were compared using Student's t-test. BMI and sex-adjusted MPTH were expressed as SDS. All data were normally distributed.

Results

The baseline characteristics of the study patients and controls are shown in Table 1. The CD subjects were predominantly of modified Marsh III classification (n=36; 90%), with only three subjects (7.5%) classified as Marsh I and one subject (2.5%) as Marsh II. Their modes of presentation were as follows: diarrhea alone (5%), diarrhea in conjunction with other gastrointestinal complaints (32.5%), abdominal pain (27.5%), short stature (5%), asymptomatic but detected through family screening for CD and other disorders (17.5%), and other (including flatulence, abdominal distension, hematochezia, and weight loss) (12.5%). Family history of CD was present in nine (22.5%) of the CD patients. Of the nine affected families, only two fathers and two mothers had CD, whereas the rest of the affected family members were either the patients' siblings or grandparents.

Statistical analysis showed that CD subjects had significantly lower BMI SDS than controls (0.61±1.22 vs. 1.28±1.6, p=0.027) but were not significantly shorter than the controls (−0.05±1.21 vs. 0.21±1.71, p=0.41). However, when the patients were subdivided into the

Table 1 Comparison of the anthropometric characteristics of prepubertal children with celiac disease and normal controls.

Parameter	Celiac disease (n=40)	Normal (n=50)	p-Value
Age, years	7.52±2.66	8.02±2.66	0.38
Height SDS	−0.05±1.21	0.21±1.71	0.41
Weight SDS	0.322±1.53	1.08±1.96	0.042
BMI SDS	0.61±1.22	1.28±1.60	0.027
MPTH SDS	0.02±0.95 (n=17)	−0.01±0.93 (n=26)	0.91
Child Ht SDS-MPTH SDS	−0.53±1.12 (n=17)	−0.18±1.54 (n=26)	0.40

SDS, standard deviation score; BMI, body mass index; MPTH, midparental target height.

normal-weight and overweight/obese groups (Figure 1), the overweight/obese CD patients (n=17) were taller than the normal-weight CD subjects (n=23) (0.67±0.95 vs. −0.58±1.11, p<0.001), and the overweight/obese controls (n=29) were taller than the normal-weight controls (n=21) (0.88±0.42 vs. −0.71±1.66, p=0.001). The normal-weight CD patients were of similar height as the normal-weight controls (−0.58±1.11 vs. −0.71±1.66, p=0.76), but were significantly shorter than both the overweight/obese controls (−0.58±1.11 vs. 0.88±0.42, p<0.001) and the overweight/obese CD children (−0.58±1.11 vs. 0.67±0.95, p<0.001). The overweight/obese CD children and overweight/obese controls had similar height SDS (0.67±0.95 vs. 0.88±0.42, p=0.56). The MPTHs did not differ between these two groups. There was no age difference between the normal-weight and overweight/obese CD patients (7.0±2.26 vs. 8.22±3.06, p=0.18), nor between the normal-weight and overweight/obese controls (7.28±2.42 vs. 8.56±2.74, p=0.0.08).

Interestingly, the overweight/obese CD patients had a significantly lower BMI SDS than the overweight/obese controls (1.71±0.45 vs. 2.37±0.89, p=0.002), as well as a significantly lower weight SDS (1.63±0.69 vs. 2.36±1.08, p=0.008), but had similar height SDS (0.67±0.95 vs. 0.88±0.42, p=0.56). There was no difference in BMI SDS between the normal-weight controls and the normal-weight CD children (−0.23±1.03 vs. −0.21±0.93, p=0.93). As expected from the study design, the overweight/obese controls had significantly greater BMI SDS than both the normal-weight controls (2.37±0.89 vs. −0.23±1.03 p<0.001) and the normal-weight CD patients (2.37±0.89 vs. −0.21±0.93, p<0.001).

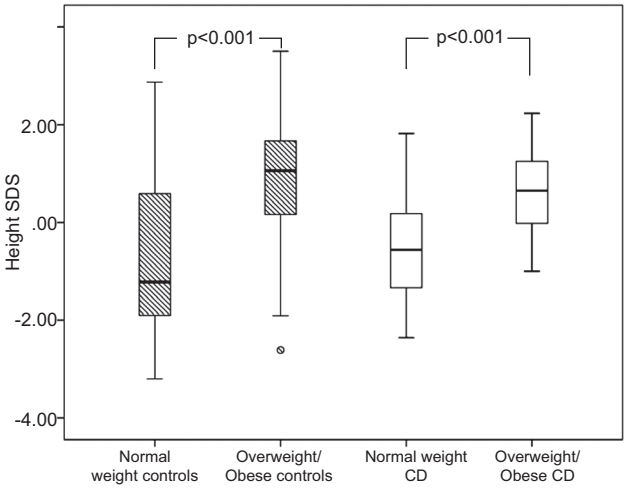

Figure 1 Box plots of the comparison of height standard deviation scores of patients with celiac disease and normal controls stratified by body mass index. This figure shows that the overweight/obese controls and overweight/obese children with celiac disease were significantly taller than their respective normal-weight peers.

Further analysis for the associations between tissue transglutaminase IgA antibody level and BMI SDS, height SDS, and weight SDS, separately, showed no linear relationships between transglutaminase antibody level and these anthropometric parameters. The non-significant β coefficients were as follows: BMI (β=−0.22, p=0.21), height SDS (β=−0.12, p=0.31), and weight SDS (β=−0.25, p=0.15). The adjusted R^2 was <0.035 for all three parameters, which was consistent with the absence of linear relationships between tissue transglutaminase IgA antibody and the anthropometric parameters.

Discussion

This study showed that overweight/obese prepubertal children were taller than their normal-weight peers irrespective of whether they had CD or were healthy. The normal-weight CD children had similar height as the normal-weight controls, but were significantly shorter than both the overweight/obese controls and the overweight/obese CD children. The overweight/obese CD patients had significantly lower BMI and weight SDS than the overweight/obese controls. Height SDS was similar between the overweight/obese CD children and the overweight/obese controls. The MPTHs were similar for the CD and non-CD children.

The findings from this study on the association between height and adiposity in children are similar to earlier studies carried out in healthy children in the US (38, 39), Australia (40), and Japan (41). Despite the cross-cultural reproducibility of these findings in normal children, this phenomenon of height difference based on the degree of adiposity in children has not been studied in prepubertal children with CD. Freedman et al. (42) employed a cross-sectional study to investigate the relationships between height and BMI, skin fold thickness, and percentage body fat determined by dual-energy X-ray absorptiometry in 5–18-year-old subjects (n=1180) and found that obesity was substantially higher among 5–11-year-old subjects who were relatively tall for their age than among shorter children. Among 5–8-year-old boys, each SD increase in height-for-age was associated with a 4.6-fold increase in the prevalence of obesity (p<0.001), and the subjects' heights were correlated with BMI, skinfold thickness, and percentage body fat.

Cheng et al. (43) investigated the effect of the degree of villous atrophy on BMI and reported that the underweight and normal-weight CD patients had a significantly higher rate of more severe villous atrophy (Marsh III b/c) than Marsh IIIa. Patients with a Marsh IIIa pathology had a significantly higher BMI than those with a Marsh IIIb/c pathology (p=0.004). Thus, it is possible that less severe degrees of villous atrophy could enhance the accumulation or the preservation of body fat. Reilly et al. (6) studied the effects of GFD on anthropometric characteristics of patients with CD and followed the patients for a mean duration of 35.6 months. They found that 75% of patients with elevated BMI at diagnosis experienced a significant decrease in their BMI SDS, with 44% of subjects achieving normal BMI status. In contrast, patients with normal BMI SDS at diagnosis experienced a significant increase in BMI SDS, with 13% of the subjects becoming overweight. A remarkable finding from our study was that the overweight/obese CD patients had a significantly lower BMI and weight SDS than the overweight/obese controls. This is suggestive of relative malabsorption in the overweight/obese CD patients at diagnosis. Although the serum concentrations of transglutaminase IgA antibody have been correlated with the degree of intestinal injury in CD, we found no relationships between tissue transglutaminase IgA antibody levels and anthropometric parameters such as height, weight, and BMI. However, our finding may be applicable to only Marsh III category disease, as 90% of our CD patients had modified Marsh III score.

The mechanism of the height difference between normal-weight and overweight/obese children is unclear. One proposed mechanism involves the stimulation of the insulin-like factor-I receptor by elevated levels of circulating insulin in obese children (24). Leptin is also believed to play a central role in the effect of adiposity on stature (23). Ertekin et al. (44) found that in children with CD, leptin levels were not only correlated with baseline BMI but were also significantly reduced in active CD, and increased significantly following GFD, in parallel with increasing BMI (44). Studies that reported increased adrenal androgen levels in obese children (30) also showed that these children frequently show an increase in height velocity with tall stature for age (31) despite low or variable levels of GH, insulin-like growth factor-I, and GH binding protein (45).

The unique strength of this study is that it was conducted exclusively in prepubertal children. Studies in prepubertal children are a better guide to potential causal associations than studies in pubertal or postpubertal subjects because associations in childhood are less prone to confounding physiologic and lifestyle factors, such as the different stages of pubertal maturation and the effects of fluctuations in pubertal hormone levels on adiposity. This prepubertal cohort represents the youngest group of subjects in whom the association between adiposity and height in CD could be demonstrated. The robust group of healthy prepubertal children in the control group ensured the validity of the anthropometric comparisons. Furthermore, the results were adjusted for MPTH to exclude the effects of genetic causes of short stature.

This study has some limitations. First, the cross-sectional study design limited causal inference about the effects of adiposity on stature in CD. The relatively small sample size could have precluded the detection of subtle differences between the groups. Bone age data were not available for our cohort. It is possible that obesity could lead to bone age advancement and possibly contribute to the height differential between normal-weight and overweight/obese children. However, this is unlikely in a cohort of prepubertal children. Our cohort predominantly had modified Marsh III disease; therefore, our results may not be generalizable to patients with the less severe forms of the disease.

In conclusion, this study showed that overweight/obese prepubertal children with CD were taller than their normal-weight peers with CD. This finding, which has previously been demonstrated in healthy children, suggests that less severe forms of CD could permit the accumulation of fat tissue, which promotes statural growth. Further studies examining the roles of leptin, insulin, and adrenal androgens on stature in CD are warranted.

Acknowledgements: This study was supported in part by a grant to Benjamin U. Nwosu from the Department of Pediatrics and the Faculty Diversity Scholars Program, University of Massachusetts Medical School, Worcester, MA. BUN is a member of the UMass Diabetes and Endocrine Research Center (DK32520). We thank Mr. Francis M. Wanjau for his help with data management.

Received October 4, 2012; accepted April 15, 2013; previously published online May 24, 2013

References

1. Fasano A. Should we screen for coeliac disease? Yes. Br Med J 2009;339:b3592.
2. Corazza GR, Di Sario A, Sacco G, Zoli G, Treggiari EA, et al. Subclinical coeliac disease: an anthropometric assessment. J Intern Med 1994;236:183–7.
3. Valletta E, Fornaro M, Cipolli M, Conte S, Bissolo F, et al. Celiac disease and obesity: need for nutritional follow-up after diagnosis. Eur J Clin Nutr 2010;64:1371–2.
4. Telega G, Bennet TR, Werlin S. Emerging new clinical patterns in the presentation of celiac disease. Arch Pediatr Adolesc Med 2008;162:164–8.
5. Venkatasubramani N, Szabo S, Werlin SL. Autoimmune hepatitis in a child with chronic hepatitis B virus infection. J Pediatr Gastroenterol Nutr 2009;49:639–41.
6. Reilly NR, Aguilar K, Hassid BG, Cheng J, Defelice AR, et al. Celiac disease in normal-weight and overweight children: clinical features and growth outcomes following a gluten-free diet. J Pediatr Gastroenterol Nutr 2011;53:528–31.
7. Venkatasubramani N, Telega G, Werlin SL. Obesity in pediatric celiac disease. J Pediatr Gastroenterol Nutr 2010;51:295–7.
8. Verkasalo M, Kuitunen P, Leisti S, Perheentupa J. Growth failure from symptomless celiac disease: a study of 14 patients. Helv Paediatr Acta 1978;33:489–95.
9. Bottaro G, Cataldo F, Rotolo N, Spina M, Corazza GR. The clinical pattern of subclinical/silent celiac disease: an analysis on 1026 consecutive cases. Am J Gastroenterol 1999;94:691–6.
10. Meazza C, Pagani S, Laarej K, Cantoni F, Civallero P, et al. Short stature in children with coeliac disease. Pediatr Endocrinol Rev 2009;6:457–63.
11. Assiri AM. Isolated short stature as a presentation of celiac disease in Saudi children. Pediatr Rep 2010;2:e4.
12. Vanderschueren L, Wolter R, Molla A, Eggermont E, Eeckels R. Plasma growth hormone in coeliac disease. Helv Paediatr Acta 1973;28:349–57.
13. Peracchi M, Molteni N, Cantalamessa L, Bardella MT, Peracchi G, et al. Abnormal growth hormone responsiveness to stimuli in women with active celiac sprue. Am J Gastroenterol 1992;87:580–3.
14. Lecornu M, David L, Francois R. Low serum somatomedin activity in celiac disease: a misleading aspect in growth failure from asymptomatic celiac disease. Helv Paediatr Acta 1978;33: 509–16.
15. Bresson JL, Prevot C, Rappaport R, Czernichow P, Schmitz J, et al. [Circulating somatomedin activity and growth hormone secretion: changes during late diagnosed celiac disease and effects of treatment]. Arch Fr Pediatr 1979;36:XIII–VIII.
16. Federico G, Favilli T, Cinquanta L, Ughi C, Saggese G. Effect of celiac disease and gluten-free diet on growth hormone-binding protein, insulin-like growth factor-I, and insulin-like growth factor-binding proteins. Horm Res 1997;48:108–14.
17. Dickey W, Kearney N. Overweight in celiac disease: prevalence, clinical characteristics, and effect of a gluten-free diet. Am J Gastroenterol 2006;101:2356–9.
18. Owen DA, Thorlakson TK, Walli JE. Celiac disease in a patient with morbid obesity. Arch Intern Med 1980;140:1380–1.
19. Semeraro LA, Barwick KW, Gryboski JD. Obesity in celiac sprue. J Clin Gastroenterol 1986;8:177–80.
20. Conti Nibali S, Magazzu G, De Luca F. Obesity in a child with untreated coeliac disease. Helv Paediatr Acta 1987;42:45–8.
21. Czaja-Bulsa G, Garanty-Bogacka B, Syrenicz M, Gebala A. Obesity in an 18-year-old boy with untreated celiac disease. J Pediatr Gastroenterol Nutr 2001;32:226.
22. Franzese A, Iannucci MP, Valerio G, Ciccimarra E, Spaziano M, et al. Atypical celiac disease presenting as obesity-related liver dysfunction. J Pediatr Gastroenterol Nutr 2001;33:329–32.
23. Shalitin S, Phillip M. Role of obesity and leptin in the pubertal process and pubertal growth – a review. Int J Obes Relat Metab Disord 2003;27:869–74.
24. Lustig RH, Weiss, R. Pediatric endocrinology, 3rd ed. Philadelphia: Saunders, 2008.
25. Jin L, Burguera BG, Couce ME, Scheithauer BW, Lamsan J, et al. Leptin and leptin receptor expression in normal and neoplastic human pituitary: evidence of a regulatory role for leptin on pituitary cell proliferation. J Clin Endocrinol Metab 1999;84:2903–11.
26. Lebrethon MC, Vandersmissen E, Gerard A, Parent AS, Junien JL, et al. In vitro stimulation of the prepubertal rat gonadotropin-releasing hormone pulse generator by leptin and neuropeptide Y through distinct mechanisms. Endocrinology 2000;141:1464–9.
27. Yu WH, Kimura M, Walczewska A, Karanth S, McCann SM. Role of leptin in hypothalamic-pituitary function. Proc Natl Acad Sci USA 1997;94:1023–8.
28. Maor GR, Segev Y, Phillip M. Leptin acts as a growth factor on the chondrocytes of skeletal growth centers. J Bone Miner Res 2002;17:1034–43.
29. Biason-Lauber A, Zachmann M, Schoenle EJ. Effect of leptin on CYP17 enzymatic activities in human adrenal cells: new insight in the onset of adrenarche. Endocrinology 2000;141:1446–54.
30. Genazzani AR, Pintor C, Corda R. Plasma levels of gonadotropins, prolactin, thyroxine, and adrenal and gonadal steroids in obese prepubertal girls. J Clin Endocrinol Metab 1978;47:974–9.
31. De Simone M, Farello G, Palumbo M, Gentile T, Ciuffreda M, et al. Growth charts, growth velocity and bone development in childhood obesity. Int J Obes Relat Metab Disord 1995;19:851–7.
32. Ravelli A, Bolognini S, Gambarotti M, Villanacci V. Variability of histologic lesions in relation to biopsy site in gluten-sensitive enteropathy. Am J Gastroenterol 2005;100:177–85.
33. Kav T, Sivri B. Is enteroscopy necessary for diagnosis of celiac disease? World J Gastroenterol 2012;18:4095–101.
34. Hill ID, Dirks MH, Liptak GS, Colletti RB, Fasano A, et al. Guideline for the diagnosis and treatment of celiac disease in children: recommendations of the North American Society for Pediatric Gastroenterology, Hepatology and Nutrition. J Pediatr Gastroenterol Nutr 2005;40:1–19.
35. Barlow SE. Expert committee recommendations regarding the prevention, assessment, and treatment of child and adolescent overweight and obesity: summary report. Pediatrics 2007;120(Suppl 4):S164–92.
36. Kuczmarski RJ, Ogden CL, Guo SS, Grummer-Strawn LM, Flegal KM, et al. 2000 CDC Growth Charts for the United States: methods and development. Vital Health Stat 11 2002:1–190.

37. Wales JK, Wit J-M, Rogol AD. Pediatric endocrinology and growth, 2nd ed. New York: Saunders Scientific Publications, 2002.
38. Killeen J, Vanderburg D, Harlan WR. Application of weight-height ratios and body indices to juvenile populations – the National Health Examination Survey Data. J Chronic Dis 1978;31: 529–37.
39. Himes JH, Roche AF. Subcutaneous fatness and stature: relationship from infancy to adulthood. Hum Biol 1986;58: 737–50.
40. Lazarus R, Baur L, Webb K, Blyth F. Adiposity and body mass indices in children: Benn's index and other weight for height indices as measures of relative adiposity. Int J Obes Relat Metab Disord 1996;20:406–12.
41. Hattori K, Hirohara T. Age change of power in weight/height(p) indices used as indicators of adiposity in Japanese. Am J Hum Biol 2002;14:275–9.
42. Freedman DS, Thornton JC, Mei Z, Wang J, Dietz WH, et al. Height and adiposity among children. Obes Res 2004;12:846–53.
43. Cheng J, Brar PS, Lee AR, Green PH. Body mass index in celiac disease: beneficial effect of a gluten-free diet. J Clin Gastroenterol 2010;44:267–71.
44. Ertekin V, Orbak Z, Selimoglu MA, Yildiz L. Serum leptin levels in childhood celiac disease. J Clin Gastroenterol 2006;40:906–9.
45. Maccario M, Ramunni J, Oleandri SE, Procopio M, Grottoli S, et al. Relationships between IGF-I and age, gender, body mass, fat distribution, metabolic and hormonal variables in obese patients. Int J Obes Relat Metab Disord 1999;23:612–8.