# Tall Stature And Obesity

*ebook.ecog-obesity.eu/chapter-clinics-complications/tall-stature-obesity*

**Ewa Malecka-Tendera**
Department of Pediatrics, Pediatric Endocrinology and Diabetes
Medical University of Silesia, Katowice, Poland

Postnatal linear growth is controlled by genetic, endocrine and nutrition factors. Although adequate nutrition is essential for normal growth of the child, excessive fat tissue accumulation may cause abnormalities in the trajectory of linear growth. Obesity in children and adolescents has been long associated with tall stature. First studies presenting the hypothesis that overnutrition accelerates linear growth were published in 1960s [1]. On the other hand some studies suggest that taller children may be wrongly labelled as 'overweight' because body mass index (BMI) is dependent of height [2].

## Normal growth

Annual height velocity approximates 25 cm in the first year of life, and then decreases over time until a plateau-like phase of 5.5 cm is reached before the onset of puberty. Distinct sex-specific differences exist in annual height velocity in childhood and they are accentuated during puberty. Girls attain a peak height velocity of 8.3 cm per year at an average chronological age of 11.5 years. By contrast, boys gain height at the pre-pubertal rate until the mean age of 11 years and then experience a peak height velocity of 9.5 cm per year from approximately 13.5 years of age. The overall pubertal increment of stature in boys exceeds that of girls by only 3–5 cm, which means that the mean adult height difference of ~13 cm between the sexes is largely due to a more prolonged period of pre-pubertal growth in boys [3,4].

Growth during fetal life, infancy, childhood and adolescence is controlled by many factors such as genes, nutrition status and hormones. Fetal growth is mediated by insulin, insulin-like growth factor 1 (IGF-1), insulin-like growth factor 2 (IGF-2) and maternal nutrition. Growth hormone (GH) plays the main role in the post fetal life together with thyroid hormones and sex steroids are active growth stimulators during puberty [3,4].

GH acts mainly through IGF-1. IGF-1 is a single chain polypeptide involved not only in the regulation of growth but responsible for several metabolic actions. It interacts with insulin through the specific receptors in regulating body metabolism both in fasting and overnutrition state. It serves a role in beta-cell mass regulation in the pancreas, insulin secretion and insulin sensitivity, integrating lipolysis, proteolysis and insulin resistance [4-6]. On the other hand hyperinsulinemia was found to be associated with advanced bone age (BA) in obese children [7] so it also active in modulation of skeletal growth in humans. Increased insulin secretion is a normal feature in adolescence and it probably plays a role in activating the insulin receptor at the growth plate. At a given degree of obesity children may be either insulin sensitive or insulin resistant. In Pinhas-Hamiel et al study[7] hiperinsulinemia >30mIU/l was the strongest predictor of advanced BA.

## GH-IGF-1 axis in obesity

Intact GH/IGF-1 axis is essential for somatic growth in children. However overweight and obese children experience either normal or most often accelerated growth in spite of several abnormalities in GH and IGF-1 secretion. Compared to normal weight peers they have reduced GH secretion, decreased frequency of GH bursts and reduced GH half-life [6]. Moreover, GH response to several stimulation tests is blunted. However increased GH binding protein (GHBP) values have been found in obese children by Bouhours-Nouet et al.[10] suggesting increased GH receptor number in peripheral tissues. IGF-1 levels were found either normal or high, that may suggest an increased responsiveness to GH. GH responsiveness in

prepubertal children, as measured by the IGF-I increment in response to a single dose of GH, was increased in obese children compared with tall normal weight peers. It was also dependent on the fat mass percentage which suggests a link between the energy stores and the anabolic action of GH.

Kratzsch et al [9] have shown that obese girls have increased levels of growth hormone binding protein (GHBP) possibly reflecting elevated GH receptor tissue density. This mechanism could play a role in accelerating growth in obese children, as demonstrated by a significantly positive relationship between GHBP and height SDS. Wabitsch et al [10] have demonstrated that obese girls have increased IGF-I levels until maturity and suggested that the advanced development seen in overnutrition is due to increased IGF-I production. The large population-based Avon Longitudinal Study of Parents and Children (ALSPAC) showed that circulating IGF-1 levels in childhood were influenced by infant growth rate. The authors concluded that they may positively mediate the effects of early postnatal nutrition on later growth and maturation [11]. Denzer et al have found that IGF-I levels correlated with the degree of BA acceleration independently of gender and pubertal stage [12] .

The potential link between obesity and impaired GH secretion is leptin that is produced by the adipose tissue [13,14]. Serum leptin levels are elevated not only in simple obesity but also in other clinical conditions associated with increased body fat accumulation, such as Cushing's syndrome or adult GH deficiency. In rodents leptin had a stimulating effect on GH secretion and a similar effect has been hypothesized to occur in humans[15]. The coexistence of high leptin and low GH serum levels in obesity would suggest a status of leptin resistance. Animal models have shown that leptin can act as a skeletal growth factor, able to stimulate proliferation and differentiation of chondrocytes in the growth plate[15] .

## Growth in obese children

Obese children usually present with greater height than their normal weight peers although they do not tend to attain taller height as adults[16-18]. The increased linear growth is associated with accelerated skeletal maturation. In the study of Johnson et al [18] difference in skeletal age between obese and normal weight children was significant from 6 to 14 years of age in boys and from 7 to 16 years of age in girls. It reached its maximum at 14 years of age in girls and at 12 years in boys, bone age being approximately one year advanced with respect to normal weight peers. Large differences in stature were also found by Stovitz et al [14] in the cohort of 1375 boys and 1433 girls followed in CATCH study. According to them the difference peaked at approximately 11 years of age. Accelerated growth in childhood followed by reduced subsequent height gain was also reported by He and Karlberg in 3650 Swedish children[16]. These authors have calculated that each unit of increased BMI between two and eight years of age was associated with a 0.23 cm increase in height in boys and 0.29 cm increase in girls.

Interestingly, Johnson et al [20] have reported that advanced skeletal maturity preceded linear growth acceleration in overweight individuals. They suggested that factors involved in physical maturity are linked etiologically with the risk of becoming overweight. According to these authors early maturation combined with unrelated to mid-parental height tall stature in prepubertal children may herald obesity in young adulthood. The authors concluded that in children who are at risk to become obese or overweight adults increased BMI precedes the advancement in skeletal development and subsequently tall stature at puberty.

Belsky et al. measured polygenic risk of the obesity development using a multilocus genetic risk score derived from GWAS of obesity-related phenotypes [21]. In their 38-year prospective longitudinal study they found out that polygenic risk for obesity was partially mediated by rapid growth in the early childhood. Moreover, genetic associations with growth and obesity risk were independent of birth weight and the family history.

Differences in linear growth of obese children are due to the differences in the pace of maturation between overweight and normal weight children and adolescents. He and Kalberg [18] clearly shown that earlier age of puberty onset in obese children diminished the final height. In their study the impact of each BMI unit accelerated pubertal timing by 0.6 years in boys and by 0.7 years in girls. Therefore the temporary increase in height in childhood was compensated by a smaller gain in adolescence. These findings probably reflect growth plate maturation in response to early estrogenization. Despite acceleration of BA and decreased growth spurt during puberty, children with obesity generally attain expected adult height[16-20].

## Clinical implications

Tall stature or accelerated growth rate accompanied by early appearance of pubertal signs may raise the suspicion of hormonal pathology. Careful assessment of pubertal status and determination of bone age are helpful in prediction of adult height and reassurance of the patients and their guardians of normal growth pattern. Child's height should be always related to midparental height. However final height correction should be applied for height prediction in obese children at different bone age[17].

Nevertheless it is critical to identify situations in which tall stature or abnormal growth rate in overweight child are clinical manifestations of underlying pathology. Causes of statural overgrowth are listed in table 1.

***Table. 1 Pathology causing tall stature in children***

Syndromes associated with tall stature and overweight/obesity

1. Klinefelter's syndrome (XXY or other less common chromosomal aneuploidy)
2. Beckwith –Wiedeman syndrome
3. Sotos syndrome
4. Weaver's syndrome

Syndromes associated with tall stature and leanness

1. Marshall-Smith syndrome
2. Fragile X syndrome
3. Aromatase deficiency
4. Estrogen receptor deficiency
5. Marfan's syndrome
6. Homocystinuria
7. Androgen insensitivity

Endocrine causes of tall stature

1. GH excess (pituitary adenoma)

2. Hypogonadrotrophic hypogonadism
3. Precocious puberty (tallness at precocious growth spurt but reduced final height)
4. Hyperthyroidism (untreated may cause significant weight loss)

## Diagnosis of tall stature in obese children

Detailed family history including the measurement of parental height and physical examination of obese or overweight child with growth acceleration in most cased will exclude pathology and the need for further investigation[22,23]. Establishing a growth curve from serial height measurements and assessing pubertal status are useful in excluding hormonal pathology. Height and weight measurement, calculation of BMI together with plotting it on a BMI chart to calculate SD score is a helpful tool in discussion of the problem with parents or guardians. So is the final height prediction based on midparental height, pubertal stage and bone age advancement, however the standard error is always considerable.

If clinical examination suggests the need for subsequent investigation, the baseline studies should include;

1. Assessment of pubertal stage according to Tanner's scale
2. X-ray of the no dominating hand for bone age assessment
3. TSH and fT4 to exclude hyperthyroidism
4. IGF-1 and IGFBP3
5. Gonadotrophins (LH and FSH) and sex steroids if pubertal disturbances present
6. Magnetic resonance of the pituitary gland if IGF-1 level high
7. Karyotype if body disproportions, delayed puberty, psychosocial problems or mental retardation present
8. GH glucose suppression test to exclude pituitary adenoma
9. Plasma homocysteine if marfanoid features present

## Summary

Childhood obesity is related to the acceleration of the linear growth during prepuberty and early puberty with a subsequent trend toward a reduction of height velocity due to the less pronounced growth spurt as compared to the lean peers (Fig 1.). Therefore a vast majority of tall obese children will have a final height according to their genetic potential of growth. Nevertheless abnormal growth may be in some patients caused by an important pathological causes that need to be considered.

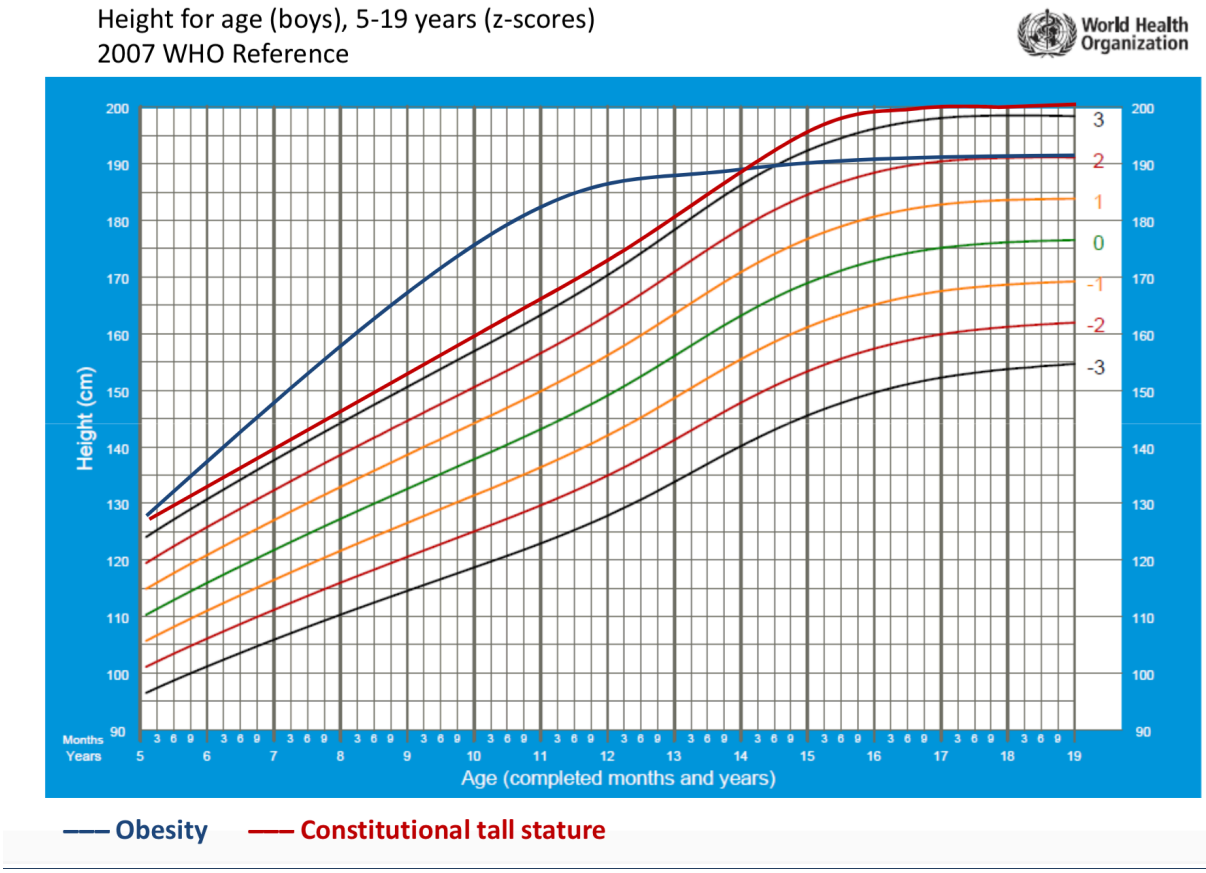


***Figure 1**: Tall Stature*

## References


1. Forbes GB. Lean body mass and fat in obese children. Pediatrics 1964;38:308-14
2. Metcalf BS, Hosking J, Fremeaux AE, Jeffrey AN, Voss LD, Wilkin TJ. BMI was right all along: taller children really are fatter (implications of making childhood BMI independent of height) EarlyBird 48. Int J Obes 2011;35:541-7
3. Nicol EL, Allen DB, Czernichow P, Zeiter P. Normal growth and growth disorders. In: Pediatric Practice Endocrinology ed Kappy MS, Allen DB et Geffner ME. McGraw Hill Medical 2010 pp.27-30
4. Patel I., Clayton P. Normal and disordered growth. In: Clinical pediatric endocrinology. Brook C, Calyton P, Brown R. ed Oxford: Blackwell; 2005.pp 90-112
5. De Leonibus Ch, Marcovecchio ML, Chiarelli F. Update on statural growth and pubertal development in obese children. Pediatr Reports 2012 doi:10.4081/pr.2012e135
6. Kreitschmann-Andermahr I, Suarez P, Jennings R, Evers N, Brabant G. GH/IGF-1 regulation in obesity- Mechanisms and practical consequences in children and adults. Horm Res Pediatr 2010;73:153-160.
7. Pinhas-Hamiel O, Benary D, Mazor-Aromovich K, et al. Advanced bone age and hyperinsulinemia in overweight and obese children. Endocr Pract 2013 doi:10.4158/EP13193.OR
8. Bouhurs-Nouet N, Gatelais F, Boux de Casson F, Rouleau S, Coutant R. The insulin-like growth factor response to growth hormone is increased in prepubertal children with obesity and tall stature. J Clin Endocrinol Metab 2007;92:629-35
9. Kratzsch J, Dehmel B, Pulzer F. et al. Increased serum GHBP levels in obese pubertal children and adolescents: relationship to body composition, leptin and indicators of metabolic disturbances. Int J Obes Relat Metab Disord 1997;21: 1130–1136.
10. Wabitsch M, Blum WF, Muche R, al. Insulin-like growth factors and their binding proteins before and after weight loss and their associations with hormonal and metabolic parameters in obese adolescent girls. Int J Obes Relat Metab Disord 1996;20: 1073–1080.
11. Ong K, Kratzsch J, Kiess W, Dunger D, and ALSPAC Team. Circulating IGF-1 levels in childhood are related to both current body composition and early postnatal growth rate. J Clin Endocrinol Metab 2002;87:1041-1044
12. Denzer C, Weibel A, Muche R, Karges B, Sorga W, Wabitsch M. Pubertal development in obese children and adolescents. Int J Obes 2007;31:1509-1519
13. Kasa-Vubu J, Ye W, Borer KT, Rosenthal A, Meckmongkol T. Twenty-four hour growth hormone and leptin secretion in active postpubertal adolescent girls: impact of fitness, fatness and age of menarche. J Clin Endocrinol Metab 2006;91:3935-3940
14. Shalitin S & Phillip M Role of obesity and leptin in the pubertal process and pubertal growth – a review. International Journal of Obesity and Related Metabolic Disorders 2003;27:869–874
15. Maor G, Rochwerger M, Segev Y et al. Leptin acts as a growth factor on the chondrocytes of skeletal growth centers. J Bone Miner Res 2002;17:1034-43.
16. Stovitz SD, Demerath EW, Hamman PJ et al Growing into obesity: patterns of height growth in those who become normal weight, overweight or obese as young adults. Am J Hum Biol 2011;23:635-641
17. Thodberg HH. Adult height prediction models. In Preedy VR (ed). Handbook of growth and growth monitoring in health and disease. Springer. Heidelberg.2012

18. He Q, Karlberg J. BMI in childhood and its association with height gain, timing of puberty and final height. Pediatr Res 2001;49:244-251
19. Fonnoy I. Effect of obesity on liner growth. Curr Opin Endocrinol Diabetes Obes 2013;20:44-49
20. Johnson W, Stovitz SD, Choh AC, Czerwinski SA, Towne B, Demerath EW. Patterns of linear growth and skeletal maturation from birth to 18 years of age in overweight young adults. Int J Obes (Lond) 2012;36:535-541
21. Belsky DW, Moffitt TE, Houts R, et al. Polygenic risk, rapid childhood growth and the development of obesity. Arch Pediatr Adolesc Med 2012;166:515-521
22. Kumar S. Tall stature in children: differential diagnosis and management. J Pediatr Endocrinol 2013 (suppl 1) 53
23. Davies JH, Cheetham T. Investigation and management of tall stature. Arch Dis Child 2014 doi: 1136/archdischild-2013-304830

## ~ About the Authors ~

# Ewa Malecka-Tendera

**Prof. Ewa Malecka-Tendera, MD, PhD**
Department of Paediatrics, Paediatric Endocrinology and Diabetes
Medical University of Silesia, Katowice, Poland
etendera@sum.edu.pl

Prof. Ewa Malecka-Tendera has been involved in the field of paediatric endocrinology since 1976. In 1983 she completed six-month endocrinology training at the Vanderbilt University in Nashville (USA). She received Board certification in Endocrinology in 1996 and in Diabetes in 2011. In 2001 she received the scientific title and a position of full professor. Currently she works as Head of the Department of Paediatrics, Paediatric Endocrinology and Diabetes at the Medical University of Silesia. This department is EASO accredited Collaborating Centre for Obesity Management (COM).

Since 1993 she is a member of Polish Society for Paediatric Endocrinology. From 2005 to 2009 has been serving in the capacity of President of this Society. She is a member of ESPE since 1996 and she was appointed its POC member. She was also a POC member of EFES/ECE in Gothenburg, Istanbul and Glasgow, of the European Congress of Obesity in Geneva and ICE in Rio de Janeiro. She was an invited speaker of symposia, MTE and Pro and Cons sessions at several international meetings and workshops and was also a lecturer at ESE Postgraduate Training Courses in Clinical Endocrinology. In 2010 she was nominated a Jury Member of EJE prize.

Prof. Ewa Malecka-Tendera is also active in the field of childhood obesity. Since 1992 has been a member of the European Childhood Obesity Group (ECOG). Between 1997 and 2003 she was a Scientific Advisor of the board of ECOG. She was a partner in EU project “PERISCOPE” and “BOYS AND GIRLS”. She was the founding fellow of SCOPE and EMA expert on Obesity in Children.

She published more than 200 papers in international and Polish peer-reviewed journals and several book chapters on peadiatric endocrine disorders as well as childhood and adolescent obesity prevalence, complications and management. Her current IF is around 96 with Hirsch Index 9.

## ~ How To Use This article ~

You are **free to use, share and copy this content** by quoting this article as follow:

*Malecka-Tendera E (2015). Tall Stature And Obesity. In M.L. Frelut (Ed.), The ECOG's eBook on Child and Adolescent Obesity. Retrieved from ebook.ecog-obesity.eu*

Also make sure to **give appropriate credit** when using this content. Please visit ebook.ecog-obesity.eu/terms-use/summary/ for more information.

## ~ Final Word ~

Thank you for reading this article.

If you have found this article valuable, please share it with someone that will be interested in.

Also make sure to visit ebook.ecog-obesity.eu to read and download more childhood obesity-related articles.