Somatic growth of lean children: the potential role of sleep

Yan-Rui Jiang, Karen Spruyt, Wen-Juan Chen, Xiao-Ming Shen, Fan Jiang
Shanghai, China

Background: **Despite the current obesity pandemic, childhood malnutrition remains an urgent, public health concern. Similar to the obesity pandemic, childhood malnutrition is influenced by genetic and a number of social, environmental and biological factors. In this study, we investigated the association between sleep duration and somatic growth in lean children.**

Methods: **A stratified, randomly clustered sampling design was used to select fifth grade students from 10 primary schools in Shanghai. Based on a body mass index below the 15th percentile a subsample of 143 lean children aged 10-11 years old was defined. Sleep duration and other potential confounders were surveyed through parental or self-report questionnaires. Body measurements were collected and used to calculate the *Z* score of weight, height, body mass index as well as body fat percentage.**

Results: **Compared with children who slept <9 hours, those who slept for ≥10 hours grew taller and gained more weight after adjusting for confounding factors. When children slept 9-10 hours, they had significantly higher *Z* score of weight and body mass index.**

Conclusions: **Prolonged sleep not only benefits weight gain but also improves height in lean children. Our findings might provide important public health advice such that prolonged sleep may be an effective modifier of nutritional problems in childhood.**

World J Pediatr 2014;10(3):245-250

Key words: **height;**
lean children;
sleep;
somatic growth;
weight

Author Affiliations: Department of Developmental and Behavioral Pediatrics, Shanghai Children's Medical Center, Shanghai Jiaotong University School of Medicine, Shanghai, China and MOE-Shanghai Key Laboratory of Children's Environmental Health (Jiang YR, Spruyt K, Chen WJ, Jiang F); Shanghai Institute for Pediatric Research, Xinhua Hospital, Shanghai Jiaotong University School of Medicine and MOE-Shanghai Key Laboratory of Children's Environmental Health, Shanghai, China (Shen XM)

Corresponding Author: Fan Jiang, Department of Developmental and Behavioral Pediatrics, Shanghai Children's Medical Center, Shanghai Jiaotong University School of Medicine, 1678 Dongfang Rd. Shanghai 200127, China (Tel: 86-21-38626012; Fax: 86-21-58706129; Email: fanjiang@shsmu.edu.cn)

doi: 10.1007/s12519-014-0500-2

Introduction

Increasing trends of childhood obesity have been noted in most regions of the world, ie, not only in developed countries but also in developing countries where children struggle with weight problems.[1] In contrast, data from the World Health Organization show that the prevalence of stunting and underweight in children younger than five years old is still high, that is 26.3% and 16.1% respectively.[2] Due to the health risks,[3,4] malnutrition in childhood remains a public health concern, which may be neglected in the current obesity pandemic.

Somatic growth can be assessed through single measurements such as height and weight, each defining health and nutrition of a developing child.[5] Growth is further influenced by genetic and a number of social, environmental and biological factors.[6-8] Recently, sleep duration has been proposed as a potential new factor.[9-11] Namely, in a meta-analysis of 12 studies including 30 002 children from different countries the pooled odds ratio for short sleep duration and obesity was 1.89.[12] Yet studies associating short sleep duration with weight gain primarily focus on the population in general, particularly in Western countries where the prevalence of obesity is high and may be skewed.[9-12] Consequently, the role of sleep in a lean population has not been well-documented. In addition, a non-linear association between sleep and weight has been suggested,[13-15] for instance, data of 30 451 adolescents from United States high schools indicated a significant quadratic (U-shaped) association between sleep duration and obesity.[13] The question remains to which advice should be provided to lean children.

Associations between growth hormone (GH) and sleep potentially lead to the hypothesis that prolonged sleep may improve height.[16-18] However, in contrast to weight, few epidemiological studies to date have reported a significant association between sleep

Original article

and height. Data of children aged 5 to 11 years old from England and Scotland showed a weak negative association between the child's height and the parental reported sleep duration.[19] A longitudinal study in 12 to 16 years old adolescents showed no association between sleep duration and linear growth velocity.[20] Also, a study conducted in 1 to 10 years old children showed that sleep duration did not correlate with height at any age nor when pooled over all ages.[21] Such non-significant results may be due to the large samples as well as to the broad age range, and because of the large variability in sleep duration during early and middle childhood.[21] Furthermore, these studies did not focus on lean subjects specifically. The only positive association between sleep and height was found in infants, which showed that prolonged night-time sleep and increased number of naps improved linear growth although the study consisted of 23 infants only.[22] Interestingly, lean subjects have been suggested to be more susceptible to the level of GH.[23]

Being in a dynamic developmental period marked by reduced sleep with increased daytime sleepiness,[24,25] our study focused on lean children aged 10-11 years old because in light of aforementioned their sleep duration might be an interesting factor towards somatic growth. We aimed to explore the association between sleep duration and somatic growth in lean children and hypothesize that longer sleep durations in lean children will improve height as well as weight indices.

Methods

Participants

The study was conducted from November to December 2009 in resident districts in Shanghai, China. A stratified, randomly clustered sampling design selected six urban districts, as well as four suburban and rural districts. Within each district, one primary school was randomly chosen and for each school, students of the fifth grade and their parents were recruited.[26] Of the children invited 1387 returned the questionnaires and 1649 took part in anthropometric assessments, resulting in 1309 children with complete data. Lean body weight was defined as children's body mass index (BMI) $<P_{15}$ (15th percentile) according to domestic data.[27]

Exclusionary criteria for participation in the study included chronic medical conditions, genetic or craniofacial syndromes, and developmental disorders. The study was approved by the Ethics Committee of Shanghai Children's Medical Center, and written informed consent was obtained from the parents or guardians.

Socio-demographic questionnaire

Parents were invited to fill out the socio-demographic questionnaire which surveyed family characteristics: age, gender, and parental BMI being calculated from reported weight and height. Appetite was obtained via self-report: more than peers, the same as peers, less than peers.

Sleep duration and sleep quality

The Children Sleep Habit Questionnaire (CSHQ) is a 33-item questionnaire to assess sleep quality of children aged from 4 to 12 years.[28] A Chinese version of the CSHQ was developed by translation and back-translation in 2005. Reliability, content validity and construct validity of the Chinese version of CSHQ in a general population of school-age children have been demonstrated.[29]

Parents were asked to report their child's sleep habits during the past month. Items were rated on a 3-point scale, i.e., usually (5 to 7 times per week), sometimes (2 to 4 times per week), and rarely (0 to 1 time per week). We also collected information about the child's evening bedtime, wake-up time for weekdays and weekends during the past month. The average reported night sleep time (hereafter sleep duration) was calculated as the weighted average of weekday and weekend sleep durations using the formula: ([weekday sleep duration×5]+[weekend sleep duration×2]) /7. The calculated sleep duration was then classified into 3 groups: <9 h (group 1), 9-10 h (group 2), and ≥10 h (group 3).

Anthropometric measurements

In each school, trained staff performed anthropometric measurements, i.e., weight, height, triceps and subscapular skinfold thicknesses, using a standardized procedure. Details can be found elsewhere.[26] In addition, Tanner stage (I to V) was determined based on visual inspection by an experienced pediatric endocrinologist.

BMI was calculated as weight (kg)/height squared (m^2). Body fat percentage (BF%) was calculated from the skinfold thickness according to the equations for Chinese children: Boy=6.931+0.428×(Triceps+Subscapular) and Girl=7.896+0.458×(Triceps + Subscapular).[30] Additionally, *Z* scores of weight, height, BMI and BF% were calculated.

Statistical analysis

Statistical descriptions were made using the mean and standard deviation for continuous variables, and percentage for categorical variables. Student's *t* test was applied to assess group differences. Partial correlation analyses adjusted for age were conducted to estimate the strength of associations of sleep duration with

the anthropometric measures. Analysis of variance (ANOVA) was used to assess group differences for the continuous variables and chi-square analyses for categorical variables. Multiple linear regression models were used to estimate the predictive associations of sleep duration with anthropometric characteristics while controlling for socio-demographic data, i.e., parental height/BMI, appetite and tanner stage. The level of statistical significance for all analysis was set at $P<0.05$. All statistical analyses were conducted using SPSS statistical software (version 17.0, SPSS Inc, Chicago).

Results

The lean sample consisted of 143 children, including 76 boys (53.1%) with a mean age of 10.85±0.47 years.

Table 1. Anthropometric measures and sleep duration by gender

Variables	Total (*n*=143)	Boys (*n*=76)	Girls (*n*=67)	*P* value
Weight, kg	28.49 ± 2.80	29.01 ± 2.64	27.90 ± 2.87	0.017
Height, cm	141.37 ± 5.78	141.21 ± 5.74	141.55 ± 5.86	0.73
BMI, kg/m^2	14.22 ± 0.62	14.52 ± 0.52	13.89 ± 0.56	<0.001
BF, %	13.79 ± 1.35	12.95 ± 0.92	14.75 ± 1.10	<0.001
Waist *Z* score	-1.21 ± 0.31	-1.20 ± 0.31	-1.22 ± 0.32	0.67
Height *Z* score	-0.70 ± 0.84	-0.73 ± 0.85	-0.68 ± 0.84	0.82
BMI *Z* score	-1.29 ± 0.20	-1.27 ± 0.22	-1.30 ± 0.18	0.19
Z score of BF%	-0.99 ± 0.21	-1.02 ± 0.21	-0.98 ± 0.22	0.27
Sleep duration, h	9.55 ± 0.57	9.51 ± 0.56	9.59 ± 0.57	0.38

BMI: body mass index; BF%: body fat percentage.

Table 1 shows the anthropometric characteristics and sleep duration of subjects stratified by gender. Children slept on average for 9.55±0.57 hours.

In general, positive associations were found between sleep with weight (r= 0.22, P=0.009) and sleep with height (r=0.20, P=0.015). It is suggested that the longer the sleep duration, the better the anthropometric measures (Fig.). Compared with children sleeping less than 9 hours, those sleeping ≥10 hours had a significantly higher weight *Z* score (-1.12±0.31 *vs.* -1.41±0.30, $F(2)$=4.13, P=0.014; Fig. A), but a marginally increased height *Z* score (-0.36±0.81 *vs.* -1.02±0.74, $F(2)$=3.57, P=0.050; Fig. B). Children sleeping between 9-10 hours only had a higher BMI *Z* score (-1.27±0.19 *vs.* -1.42±0.24, $F(2)$=3.52, P=0.027; Fig. C).There was a marginal difference in *Z* score of BF% between children sleeping between 9-10 hours and less than 9 hours (-0.98±0.23 *vs.* -1.12±0.15, $F(2)$=2.89, P=0.063; Fig. D).

A posterior analysis revealed that children who slept ≥10 hours, indeed had earlier bedtime (20:53±00:20) than children who slept <9 hours (22:17±00:36) and 9-10 hours (21:28±00:23) ($F(2)$=55.47, P<0.001). Furthermore, compared with short sleepers (group 1), longer sleepers (group 2 and group 3) had fewer sleep problems such as night waking with unconsolidated crying and sweating (group 3: 4.8%, group 2: 1.1%, group 1: 16.7%; $\chi 2(3)$=13.50, P=0.009) as well as bedtime resistance (group 3: 45%, group 2: 30%, group 1: 75%; $\chi 2(3)$=9.89, P=0.007).

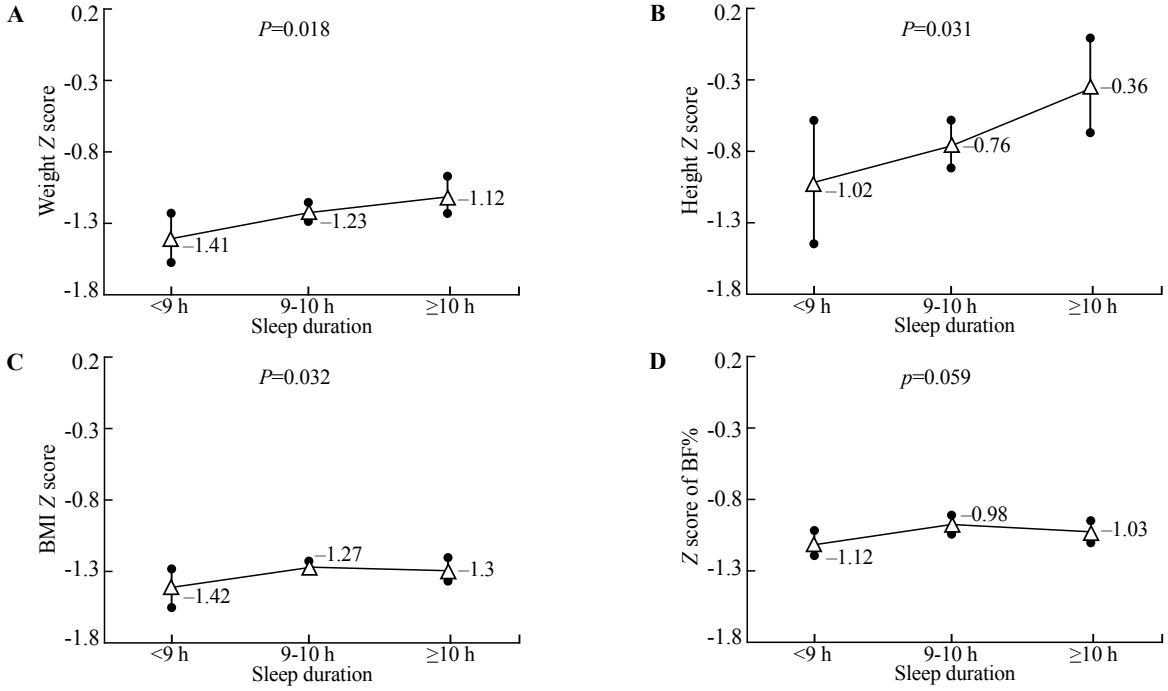

Fig. Sleep group differences in anthropometric measures (mean, 95% CI). BMI: body mass index; BF%: body fat percentage.

Table 2. Differences in sleep and anthropometric characteristics (adjusted models)

Z score	Sleep duration	Total		Boys		Girls	
		ß (se) *p*	Adjust R square	ß (se) *p*	Adjust R square	ß (se) *p*	Adjust R square
Height*			0.38		0.50		0.32
	<9 h	Ref		Ref		Ref	
	9-10 h	0.24 (0.19)		0.098 (0.23)		0.47 (0.31)	
		0.21		0.68		0.14	
	≥10 h	0.57 (0.22)		0.64 (0.28)		0.56 (0.36)	
		0.011		0.024		0.12	
Weight†			0.15		0.19		0.18
	<9 h	Ref		Ref		Ref	
	9-10 h	0.23 (0.083)		0.16 (0.11)		0.29 (0.14)	
		0.007		0.14		0.037	
	≥10 h	0.30 (0.096)		0.26 (0.13)		0.36 (0.15)	
		0.002		0.048		0.020	
BMI†			0.051		0.041		0.15
	<9 h	Ref		Ref		Ref	
	9-10 h	0.17 (0.057)		0.094 (0.081)		0.24 (0.079)	
		0.003		0.25		0.003	
	≥10 h	0.13 (0.066)		0.040(0.098)		0.21 (0.087)	
		0.044		0.69		0.019	
BF%†			0.027		0.050		0.13
	<9 h	Ref		Ref		Ref	
	9-10 h	0.12 (0.061)		0.13 (0.078)		0.060 (0.096)	
		0.045		0.10		0.54	
	≥10 h	0.087 (0.070)		-0.036 (0.094)		0.15 (0.11)	
		0.22		0.70		0.16	

* : adjust for parental height, appetite, tanner stage; †: adjust for parental BMI, appetite, tanner stage. ß (se): Beta (Standardized error); BMI: body mass index; BF%: body fat percentage.

After adjusting for potential confounders (Table 2), children sleeping between 9-10 hours (group 2) had higher weight and BMI *Z* scores when compared with those sleeping less than 9 hours (group 1). Similarly, when sleeping the amount of hours as clinically recommended (≥10 hours or group 3), children had a significantly higher *Z* score of height, weight and BMI *Z* scores. Of interest, BF% remains unaffected. As for confounding factors, mother's height (beta=4.49, *P*=0.002), father's height (beta=7.08, *P*<0.001) and tanner stage (beta=0.56, *P*<0.001) were predictive for height *Z* score in the adjusted model of height *Z* score. Appetite (beta=0.14, *P*=0.012) and tanner stage (beta=0.21, *P*<0.001) predicted weight *Z* score, whereas only appetite (beta=0.083, *P*=0.024) was related to higher BMI *Z* score in the adjusted models.

Stratified by gender (Table 2), longer sleep duration (group 3) was significantly associated with higher height and weight indices in boys. In girls longer sleep duration predicted improved anthropometry such as by weight and BMI *Z* scores.

Discussion

To our knowledge, this study is the first to explore the relationship between sleep and somatic growth in lean children specifically. Our findings suggested that compared with lean children who sleeping <9 hours, those sleeping ≥10 hours favored particularly height but also weight, whereas those sleeping 9-10 hours only gained weight. Body fat mass of the lean child was unaffected by more sleep. In other words, we found that lean children aged 10-11 years substantially improved height by sleeping the amount as clinically recommended (≥10 hours).

The positive association between sleep duration and height in lean children in our study is of importance in the global obesity debate, and extends our knowledge of the vital function of sleep in a child's development. Indeed, nocturnal GH secretion is dependent on sleep and is markedly secreted shortly after sleep onset, or in temporal association with the first period of slow-wave sleep (sleep stages 3 and 4).[16,17] A recent experimental study in adults indicated that the amount of growth hormone secreted during a 24-hour period was unchanged whether or not a person slept during the night, which produced a great deal of controversy in sleep-GH-height discussion.[31] Indeed, Van Cauter[32] highlighted that the total amount and the temporal distribution of GH release were strongly dependent on age, and characterized a pulsatile pattern and increased amplitudes of GH release in prepubertal and pubertal boys and girls. Our children with prolonged sleep duration (groups 2, 3) went to bed respectively 85 minutes and 52 minutes earlier than children in group 1, and had a better sleep quality. In other words,

the long sleepers also had an uninterrupted sleep, and hence both may have improved GH levels. Increased GH is necessary for the proliferation of cartilage cells at the epiphyseal plate permitting linear growth.[16] An inverse relationship has been shown between BMI and the peak GH in response to stimulation of GH in adults and children.[25,33] Namely, obese subjects typically had a decreased GH secretion as well as reduced or blunted GH responses to a variety of GH secretagogues, whereas the lean subjects were more susceptible to the level of GH.[25,33-35] Thus in our sample of lean children, a higher level of GH during prolonged sleep may have auxiliary promoted linear growth velocity.

In particular, we found that lean children who slept ≥10 hours have higher weight and BMI compared with those sleeping <9 hours, which may suggest that lean children need more sleep to gain weight. This finding is rather paradoxical in the obesity pandemic where short sleep is associated with weight gain,[9-12] yet it supports a potential U-shaped,[13] or more complex non-linear,[14,15] association between sleep and anthropometric status. As mentioned above, lean children with longer sleep may have a higher level of GH, which also has the function of promoting the synthesis of protein, subsequently benefiting weight gain.[36] Furthermore, an experimental study in rats showed that administered GH has differential effects on food intake in lean rats compared with obese rats, i.e., when GH was administered to these lean rats an uninterrupted stimulation of food intake was observed, whereas for obese rats they responded with a prompt suppression of food intake.[37] The different outcome, namely the stimulation or inhibition of appetite, is determined by the balance between two rather opposing metabolic events evoked by GH, i.e., one is the protein anabolic effect and the other is the lipolytic and calorigenic effect of GH.[36,38,39] Thus, likely GH stimulated food intake in a lean animal has an impact through the protein anabolic effect, whereas for an obese animal, the lipolytic and calorigenic effect of GH plays the primary role. They indeed found that the suppression of food intake in the obese animals was associated with significantly increased lipid oxidation and decreased hypothalamic galanin, but this was not true for lean animals.[37] Such functional pathways are in agreement with our results, suggesting that lean children with prolonged sleep may have a higher level of GH with subsequent weight gain. Finally, the discordant results in obese and lean children may also be ascribed to sleep having a different impact on the BMI status which potentially underpins the sleep-BMI controversy. In fact, few studies report on the distribution of underweight or lean subjects in their samples or their exclusion from the sample under investigation. Nevertheless, more studies are needed to explore possible mechanisms underlying this intriguing association of sleep with GH and other hormones, as well as with appetite and physical activity in different BMI or anthropometric conditions. Especially, given that the confounders in our final regression models aren't all that different from those reported in the literature.

There were several potential limitations to this study. Perhaps the most important limitation was the cross-sectional design of the study; as such, we are unable to determine the cause and effect relationship between sleep duration and somatic growth. Sleep duration was also determined according to parental report and not by an objective measure (for example, the polysomnogram). Furthermore, GH was not objectively assessed and therefore the underlying mechanisms remain speculative. In addition, the lean sample in our study is small, and a larger cohort study is required to investigate the association between sleep and somatic growth.

In conclusion, prolonged sleep may improve the growth in terms of weight and height in lean children. Our results underpin the vital function of sleep, and demonstrate that more sleep can improve lean children's anthropometry, which may have important public health implications.

Acknowledgments

The authors gratefully acknowledge the children and their families whose ongoing participation made this study possible.

Funding: The study was supported by grants from the Chinese National Natural Science Foundation (81172685), Ministry of Science and Technology (2010CB535000), Ministry of Health(201002006), Shanghai Science and Technology Commission (12411950405, 13QH1401800), Shanghai Municipal Committee of Education (11SG19, HJTY-2010-A09), Shanghai Key Discipline of Public Health; AFINS research project (AFINS-HOPE-2011025) and MOE New Century Excellent Talents (NCET-13-0362), Shengyuan Research Project.

Ethical approval: This study was approved by the Institutional Ethics Committee of Shanghai Children's Medical Center.

Competing interest: No benefits in any form have been received or will be received from any commercial party related directly or indirectly to the subject of this article.

Contributors: JYR collected data, carried out the final analyses and drafted the manuscript; SK carried out the final analyses and help drafted the manuscript; CWJ collected data and established the database; SXM and JF conceptualized and designed the study. All authors reviewed and revised critically for important intellectual content of manuscript, and approved the final manuscript as submitted.

References

1 Wang Y, Lobstein T. Worldwide trends in childhood overweight and obesity. Int J Pediatr Obes 2006;1:11-25.

2 WHO. http://www.who.int/nutgrowthdb/jme_unicef_who_wb.pdf (accessed October 27, 2012).
3 Stone R. Public health. Despite gains, malnutrition among China's rural poor sparks concern. Science 2012;336:402.
4 Caulfield LE, de Onis M, Blössner M, Black RE. Undernutrition as an underlying cause of child deaths associated with diarrhea, pneumonia, malaria, and measles. Am J Clin Nutr 2004;80:193-198.
5 de Onís M, Monteiro C, Akré J, Glugston G. The worldwide magnitude of protein-energy malnutrition: an overview from the WHO Global Database on Child Growth. Bull World Health Organ 1993;71:703-712.
6 Rogol AD, Roemmich JN, Clark PA. Growth at puberty. J Adolesc Health 2002;31:192-200.
7 Dekker LH, Mora-Plazas M, Marín C, Baylin A, Villamor E. Stunting associated with poor socioeconomic and maternal nutrition status and respiratory morbidity in Colombian schoolchildren. Food Nutr Bull 2010;31:242-250.
8 Zhou H, Wang XL, Ye F, Zeng XL, Wang Y. Relationship between child feeding practices and malnutrition in 7 remote and poor counties, P R China. Asia Pac J Clin Nutr 2012;21:234-240.
9 Chaput JP, Brunet M, Tremblay A. Relationship between short sleeping hours and childhood overweight/obesity: results from the 'Quebec en Forme' Project. Int J Obes (Lond) 2006;30:1080-1085.
10 Snell EK, Adam EK, Duncan GJ. Sleep and the body mass index and overweight status of children and adolescents. Child Dev 2007;78:309-323.
11 Guidolin M, Gradisar M. Is shortened sleep duration a risk factor for overweight and obesity during adolescence? A review of the empirical literature. Sleep Med 2012;13:779-786.
12 Cappuccio FP, Taggart FM, Kandala NB, Currie A, Peile E, Stranges S, et al. Meta-analysis of short sleep duration and obesity in children and adults. Sleep 2008;31:619-626.
13 Lowry R, Eaton DK, Foti K, McKnight-Eily L, Perry G, Galuska DA. Association of Sleep Duration with Obesity among US High School Students. J Obes 2012;2012:476914.
14 Knutson KL, Lauderdale DS. Sleep duration and overweight in adolescents: self-reported sleep hours versus time diaries. Pediatrics 2007;119:e1056-e1062.
15 Hassan F, Davis MM, Chervin RD. No Independent Association between Insufficient Sleep and Childhood Obesity in the National Survey of Children's Health. J Clin Sleep Med 2011;7:153-157.
16 Takahashi Y, Kipnis DM, Daughaday WH. Growth hormone secretion during sleep. J Clin Invest 1968;47:2079-2090.
17 Sassin JF, Parker DC, Mace JW, Gotlin RW, Johnson LC, Rossman LG. Human growth hormone release: relation to slow-wave sleep and sleep-walking cycles. Science 1969;165:513-515.
18 Van Cauter E, Plat L, Copinschi G. Interrelations between sleep and the somatotropic axis. Sleep 1998;21:553-566.
19 Gulliford MC, Price CE, Rona RJ, Chinn S. Sleep habits and height at ages 5 to 11. Arch Dis Child 1990;65:119-122.
20 Knutson KL. The association between pubertal status and sleep duration and quality among a nationally representative sample of U. S. adolescents. Am J Hum Biol 2005;17:418-424.
21 Jenni OG, Molinari L, Caflisch JA, Largo RH. Sleep duration from ages 1 to 10 years: variability and stability in comparison with growth. Pediatrics 2007;120:e769-e776.
22 Lampl M, Johnson ML. Infant growth in length follows prolonged sleep and increased naps. Sleep 2011;34:641-650.
23 Bonert VS, Elashoff JD, Barnett P, Melmed S. Body mass index determines evoked growth hormone (GH) responsiveness in normal healthy male subjects: diagnostic caveat for adult GH deficiency. J Clin Endocrinol Metab 2004;89:3397-3401.
24 Carskadon MA, Acebo C. Regulation of sleepiness in adolescents: update, insights, and speculation. Sleep 2002;25:606-614
25 Mercer PW, Merritt SL, Cowell JM. Differences in reported sleep need among adolescents. J Adolesc Health 1998;23:259-263.
26 Jiang YR, Chen WJ, Sun WQ, Wang Y, Li SH, Shen XM et al. Association between sleep duration and adiposity among Chinese preadolescents. Chin J Child Health Care 2012;20:787-790. [in Chinese]
27 Li H, Ji CY, Zong XN, Zhang YQ. Body mass index growth curves for Chinese children and adolescent aged 0-18 years old. Zhonghua Er Ke Za Zhi 2009;47:493-498. [in Chinese]
28 Owens JA, Spirito A, McGuinn M. The Children's Sleep Habits Questionnaire (CSHQ): psychometric properties of a survey instrument for school-aged children. Sleep 2000;23:1043-1051.
29 Li SH, Jin XM, Shen XM, Wu SH, Jiang F, Yan CH, et al. Development and psychometric properties of the Chinese version of Children's Sleep Habits Questionnaire. Zhonghua Er Ke Za Zhi 2007;45:176-180. [in Chinese]
30 Yao XJ, Liu CR, Chen Z, Zhang GR, Wang JH, Wang GL, et al. A study on body fat in children age 7-12. Zhonghua Yu Fang Yi Xue Za Zhi 1994;28:213-215. [in Chinese]
31 Brandenberger G, Gronfier C, Chapotot F, Simon C, Piquard F. Effect of sleep deprivation on overall 24 h growth-hormone secretion. Lancet 2000;356:1408.
32 Van Cauter E, Plat L. Physiology of growth hormone secretion during sleep. J Pediatr 1996;128:S32-37.
33 Stanley TL, Levitsky LL, Grinspoon SK, Misra M. Effect of body mass index on peak growth hormone response to provotative testing in children with short stature. J Clin Endocrinol Metab 2009;94:4875-4881.
34 Loche S, Guzzetti C, Pilia S, Ibba A, Civolani P, Porcu M, et al. Effect of body mass index on the growth hormone response to clonidine stimulation testing in children with short stature. Clin Endocrinol (Oxf) 2011;74:726-731.
35 Loche S, Cappa M, Borrelli P, Faedda A, Crinò A, Cella SG, et al. Reduced growth hormone response to growth hormone-releasing hormone in children with simple obesity: evidence for somatomedin C mediated inhibition. Clin Endocrinol (Oxf) 1987;27:145-153.
36 Møller N, Jørgensen JO. Effects of growth hormone on glucose, lipid, and protein metabolism in human subjects. Endocr Rev 2009;30:152-177.
37 Malmlöf K, Fledelius C, Johansen T, Theodorsson E. The anorectic response to growth hormone in obese rats is associated with an increased rate of lipid oxidation and decreased hypothalamic galanin. Physiol Behav 2011;102:459-465.
38 Scacchi M, Pincelli AL, Cavagnini F. Growth hormone in obesity. Int J Obes Relat Metab Disord 1999;23:260-271.
39 Wolthers T, Grøftne T, Møller N, Christiansen JS, Orskov H, Weeke J, et al. Calorigenic effects of growth hormone: the role of thyroid hormones. J Clin Endocrinol Metab 1996;81:1416-1419.

Received July 19, 2013
Accepted after revision December 10, 2013