PEDIATRICS®
OFFICIAL JOURNAL OF THE AMERICAN ACADEMY OF PEDIATRICS

Sleep Duration From Ages 1 to 10 Years: Variability and Stability in Comparison With Growth

Oskar G. Jenni, Luciano Molinari, Jon A. Caflisch and Remo H. Largo

Pediatrics 2007;120;e769-e776
DOI: 10.1542/peds.2006-3300

ARTICLE

Sleep Duration From Ages 1 to 10 Years: Variability and Stability in Comparison With Growth

Oskar G. Jenni, MD, Luciano Molinari, PhD, Jon A. Caflisch, MD, Remo H. Largo, MD

Child Development Center, Department of Pediatrics, University Children's Hospital Zurich, Zurich, Switzerland

The authors have indicated they have no financial relationships relevant to this article to disclose.

ABSTRACT

OBJECTIVE. Our goal was to describe the variability of sleep duration (time in bed per 24 hours) in healthy children from 1 to 10 years of age in comparison with growth measures.

METHODS. A total of 305 children were followed with structured sleep-related interviews and measurements of height and weight 12, 18, and 24 months after birth and then at annual intervals until 10 years of age. SD scores were calculated, and smooth curves were fitted by smoothing splines through the SD scores. The long-term variability channel within children (units SD score) was defined as the difference between the maximum and the minimum of the smooth curves and the short-term variability channel (units SD score) as the difference of the largest and the smallest deviations of the original SD scores from the smooth curve.

RESULTS. Sleep duration remained within a long-term variability channel <0.5 SD score in 21% of the children (34% for height, 21% for weight). Nearly every second child (46%) stayed within a long-term variability channel <1.0 SD score (76% for height, 64% for weight). Sleep duration of ~90% of all children ran within a long-term variability channel of <2.0 SD score (corresponding, eg, to the range between the 2nd and the 50th percentile). No single child's sleep duration remained within a short-term variability channel <0.5 SD score, indicating fluctuations from year to year (60% for height, 53% for weight). An association between aspects of sleep duration and somatic growth was not observed at any age.

CONCLUSIONS. Sleep duration during early and middle childhood shows large variability among children, as well as trait-like long-term stability and state-like yearly fluctuations within children. An individual approach to the child's sleep behavior is needed; expectations in terms of appropriate sleep duration of the child should be adjusted to the individual sleep need.

www.pediatrics.org/cgi/doi/10.1542/peds.2006-3300

doi:10.1542/peds.2006-3300

Key Words
sleep duration, growth, longitudinal, intraindividual stability, interindividual variability

Abbreviations
ZLS—Zurich Longitudinal Studies
SDS—SD score
STV—short-term variability
LTV—long-term variability

Accepted for publication Feb 23, 2007

Address correspondence to Oskar G. Jenni, MD, Child Development Center, Department of Pediatrics, University Children's Hospital, Steinwiesstrasse 75, CH-8032 Zurich, Switzerland. E-mail: oskar.jenni@kispi.uzh.ch

PEDIATRICS (ISSN Numbers: Print, 0031-4005; Online, 1098-4275).

Numerous epidemiologic and school-based studies indicate that 20% to 30% of the pediatric population has sleep problems, which are frequently associated with significant psychological and social consequences.[1–8] A thorough history-taking by the health care professional and the use of sleep diaries are the first steps in identifying the type and the source of the sleep problem.[9] Among the sleep variables collected are the timing and the duration of sleep, the regularity of sleep–wake periods, the frequency and type of night wakings, and the presence of sleep-onset difficulties or bedtime struggles.

There is little consensus, however, about which sleep behaviors should be considered as typical developmental changes and which sleep amount is normal for a given age. In fact, the 2003 National Sleep Disorders Research Plan highlighted the need for more knowledge about normal sleep behaviors in children as a central basis to identify whether and what kind of interventions are advisable (see Hunt[10]). We recently published percentile curves for parent-reported sleep duration (ie, time in bed per 24 hours) in a normal, healthy population of children who were followed longitudinally from birth through adolescence (in the Zurich Longitudinal Studies [ZLS][11,12]). Sleep duration declined across childhood and showed a large variability between children (interindividual variability); for example, at 1 year of age, 96% of all children slept between 11.4 hours and 16.5 hours per 24 hours and at 5 years of age between 9.5 hours and 13.3 hours. We concluded from these findings that there is no optimal amount of sleep for the entire population of children, for instance that all children sleep for 12 hours. In contrast, some children may sleep for long hours, whereas others are considered as short sleepers. These findings raise the question about whether sleep duration of individual children remains stable with respect to the changing population distribution across age (intraindividual stability): do short sleepers remain short sleepers when they grow older? Do long sleepers also sleep long hours later in life?

It is common knowledge that growth varies between individual children; some children are short, whereas others are tall. Longitudinal studies have shown that stature remains relatively stable during early and middle childhood; in other words, that children's height generally stays within growth or percentile channels (growth canalization[13,14]). The stability of growth across age suggests that short children remain short and tall children remain tall when they grow older. These findings are acknowledged by pediatricians, who routinely use growth charts to screen for abnormalities in growth; when a child's height crosses percentile lines, the health care professional may suspect a growth or developmental abnormality.

In the ZLS, a variety of child variables have been longitudinally assessed from birth through adulthood, which allow an examination of the intraindividual variability of developmental variables across age and specifically a comparison of patterns of sleep duration and somatic growth. The purpose of this longitudinal analysis of the ZLS is twofold: (1) to describe sleep patterns in the first 10 years of life in normal, healthy children with respect to the variability within children and (2) to compare this intraindividual variability of sleep duration with that of height and weight.

METHODS

Subjects and Study Design

Reference values for sleep duration from birth through adolescence and for bed-sharing behavior and sleep problems across childhood have been reported in 2 previous publications,[8,11] whereas the growth variables for these children have not been published before. The subjects for the analysis of this article are a subset of the previously reported 493 children.[8,11] Data from 160 children were excluded because of >1 missing data point of sleep variables (data were interpolated when 1 data point was missing), and data of 13 children were excluded because of missing data in either height or weight. Moreover, 15 twin-born children were excluded (ie, the higher child number = later born twin). Finally, data of 305 children (83 preterm and 222 term infants, 151 boys and 154 girls) were used for this analysis. Average sleep duration of the previously published sample (n = 493[11]) and the subset reported here (n = 305) was practically identical. The children were followed with comprehensive neurodevelopmental and anthropometric assessments and with structured interviews 12, 18, and 24 months after birth and at annual intervals thereafter until 10 years of age (11 waves of data, time limits for follow-up: for the age of 12–18 months ± 1 week, for ≥2 years ± 2 weeks). Subject enrollment began in 1974 and continued over a 19-year period. The subjects were born between October 1974 and September 1978 (Second ZLS; n = 147) and between September 1978 and 1993 (Zurich Generational Study; n = 158). Correction of preterm birth was made by calculating the ages of examination from term. Ninety-seven percent of the maximum number of possible visits were conducted at appropriate ages. The study was performed according to the Declaration of Helsinki. Informed consent was obtained from the parents.

Measures

Sleep Variables

Structured face-to-face interviews with parents (primarily mothers) were performed for various sleep-related habits (for complete questionnaires developed in 1953 for the European Collaborative Studies, see Falkner[15]). Bedtime, wake time, and daytime sleep duration were asked for the 3 months preceding the consultation using the following wording: When does the child go to bed usually? Categories of rating: 17:00, 18:00, 18:30, 19:00, 19:30, 20:00, 20:30, 21:00, 21:30, 22:00, 22:30, 23:00, 23:30, 24:00. When does the child wake up usually? 05:00, 05:30, 06:00, 06:30, 07:00, 07:30, 08:00, 08.30, 09:00, 9:30, 10:00, 10:30. How long does the child sleep during daytime? Nighttime sleep duration was calculated from bedtime and wake time. Total sleep duration was the sum of nighttime and daytime sleep duration (time in bed per 24 hours). Only 2 research assistants used the same procedures and completed the same questionnaires with face-to-face parental interviews during the past 30 years since the beginning of data acquisition in 1974. A comparison of both interviewers' data sets did not reveal any significant differences in sleep variables. An analysis of variance at each age indicated that there was no significant difference in sleep duration between boys and girls. We found no significant differences between term- and preterm-born children (published by Iglowstein et al[16]).

Growth Variables

The details of the anthropometric measurements and techniques of assessment were previously reported in detail by Prader et al[17] for the ZLS. Briefly, at age 12 and 18 months, children were weighted on a balance-beam–type scale, whereas at later ages, weight assessments were done on a standing-beam scale. Supine length was measured up to 2 years of age on a supine measuring table; after that age, standing height was taken by a stadiometer (Harpenden, Crymych, United Kingdom).

Statistical Analysis

The statistical analysis was performed using S-PLUS 2000 for Windows (Insightful Corp, Seattle, WA). The percentiles for sleep duration presented in Figs 1 and 2, top, are those published by Iglowstein et al.[11] For height and weight, empiric percentiles are presented, based on all available data of the second LS and the Zurich Generational Study (~500 subjects, evenly distributed between boys and girls).

For sleep duration and height, which follow approximately a Gaussian distribution, SD scores (SDSs) were calculated as SDS = $[x(a) - m(a)]/s(a)$, where $x(a)$ is the measurement of a child (sleep duration or height) at age (a) years, and $m(a)$ and $s(a)$ are the corresponding sample mean and SD, respectively. Because the distribution of weight was non-Gaussian, weight SDSs were calculated after the LMS method, which is roughly equivalent, in this case, to a square-root transformation of the original values.[18]

Short-term variability (STV) and long-term variability (LTV) of individual longitudinal patterns for any variable was determined by the following steps. A smooth curve was first fitted by smoothing splines through the SDSs. The degrees of freedom of the smoothed curve were determined automatically by the smoothing algorithm (S-Plus function smooth.spline) but bounded between 2 and a parameter-dependent upper bound d, corresponding roughly, for integer d, to a straight line and a polynomial of degree $d - 1$. The upper bound was 4 for sleep duration, 4.5 for height, and 5 for weight. The justification for a different upper bound in smoothing the SDSs for sleep duration, height, and weight was as follows: weight can be measured precisely; therefore, we may assume that observed variations are real (apart perhaps from diurnal effects), which should therefore not be smoothed out. In contrast, information on sleep duration may contain several sources of measurement errors (eg, biased parental report; see discussion); therefore, we may smooth more. Measurement errors of height are assumed to be between errors of weight and sleep duration. However, the effect of this choice on the numeric results with respect to using a common number of degrees of freedom (eg, 4.5) was minimal. Pearson correlations between SDSs of sleep duration, height, and weight were calculated to examine the relationship between sleep duration and growth measures.

Definition of Variables

Gray areas in Fig 3 illustrate the definition of intraindividual LTV and STV of sleep duration. The LTV channel (unit SDS) was defined as the difference between the maximum and the minimum of the smooth curve. A small LTV channel (ie, low intraindividual variability) indicated high stability across age, whereas a large LTV channel (ie, high intraindividual variability) pointed to low stability in the course of development. The example (child 651) shows low stability of sleep duration across age (LTV channel width of 2.57 SDS). The STV channel (unit SDS) was defined as the difference of the largest and the smallest deviations (with sign) of the original SDS from the smooth curve. Child 651 shows an STV channel width of 1.43 SDS.

RESULTS

Table 1 shows the average and the SD of sleep duration per 24 hours during the first 10 years of life as well as the corresponding values of height and weight for both boys and girls ($n = 305$). Mean sleep duration declined, whereas height and weight increased across age. Interindividual variability was different between measures; the average SD of sleep duration was 8% of the population mean, whereas it was 4% for height and 14% for weight (Table 1).

Figures 1 and 2 illustrate sleep and growth patterns of 4 selected children (2 girls and 2 boys) across the first 10 years of life. Individual sleep duration, height, and weight are annually plotted across age within the corresponding percentile curves for sleep duration[11] (see "Methods"). The SDS trends are presented below these panels. Sleep duration of children 3 and 203 (Fig 1)

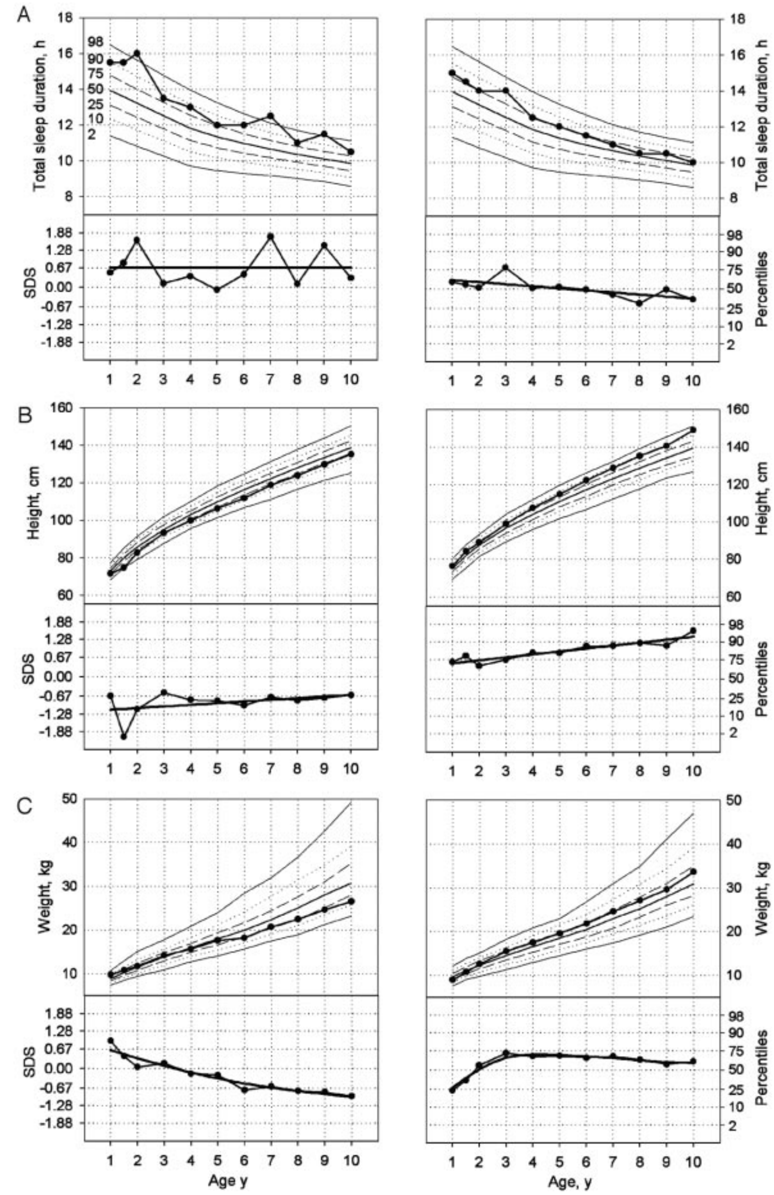

FIGURE 1
Individual sleep and growth patterns of a girl (subject 3 [left]) and a boy (subject 203 [right]). The reference (percentiles) of sleep duration was from ref 11, and that of height/weight was calculated on the basis of the second Zurich Longitudinal Study and the Generational Study. Note that the percentile curves of sleep duration (upper panels) were corrected for birth year 1990 (as published by Iglowstein et al[11]), because sleep duration was shown to decrease with birth cohort, and do not correspond exactly to the SDS lines (lower panels). For example, female subject 3 born in 1977 appears to sleep more according to the percentiles than to her SDS. A, Sleep; B, height; C, weight.

remained within a narrow LTV channel, reflecting substantial long-term stability of sleep amount (small LTV). However, the children differed considerably in their STV channel. Sleep duration of child 3 crossed the percentile curves several times and showed intermittent increases and drops across age (large STV). In contrast, sleep amount of child 203 closely followed the long-term trend (small STV). The age course of height in both children showed small LTV, indicating relatively stable growth patterns across age. In contrast, weight seemed to be less stable across age than height in both children. By and large, height and weight followed closely the long-term trend, indicating small STV in these variables.

Children 651 and 152 (Fig 2) exhibited substantial instability in the long-term trends of sleep duration compared with the children presented in Fig 1; the long-term trend of child 651 crossed 4 percentiles across age by increasing sleep amount from the 10th to the 90th percentiles relative to the reference population (see also Fig 3), and child 152 showed a curvilinear long-term trend with an initial decline and a consecutive rise in sleep duration. Sleep duration of child 651 exhibited a large STV channel, whereas sleep duration of child 152 followed closely the curvilinear trend. Again, growth patterns were relatively stable across age with small LTV and STV (Fig 2).

Figure 4 summarizes the width of the LTV and STV channels of all 305 children in cumulative frequency curves (unit SDS). Sleep duration remained within an LTV channel <0.5 SDS in 21% of the children (34% for height; 21% for weight). Nearly every second child (46%) stayed within an LTV channel <1.0 SDS (76% for

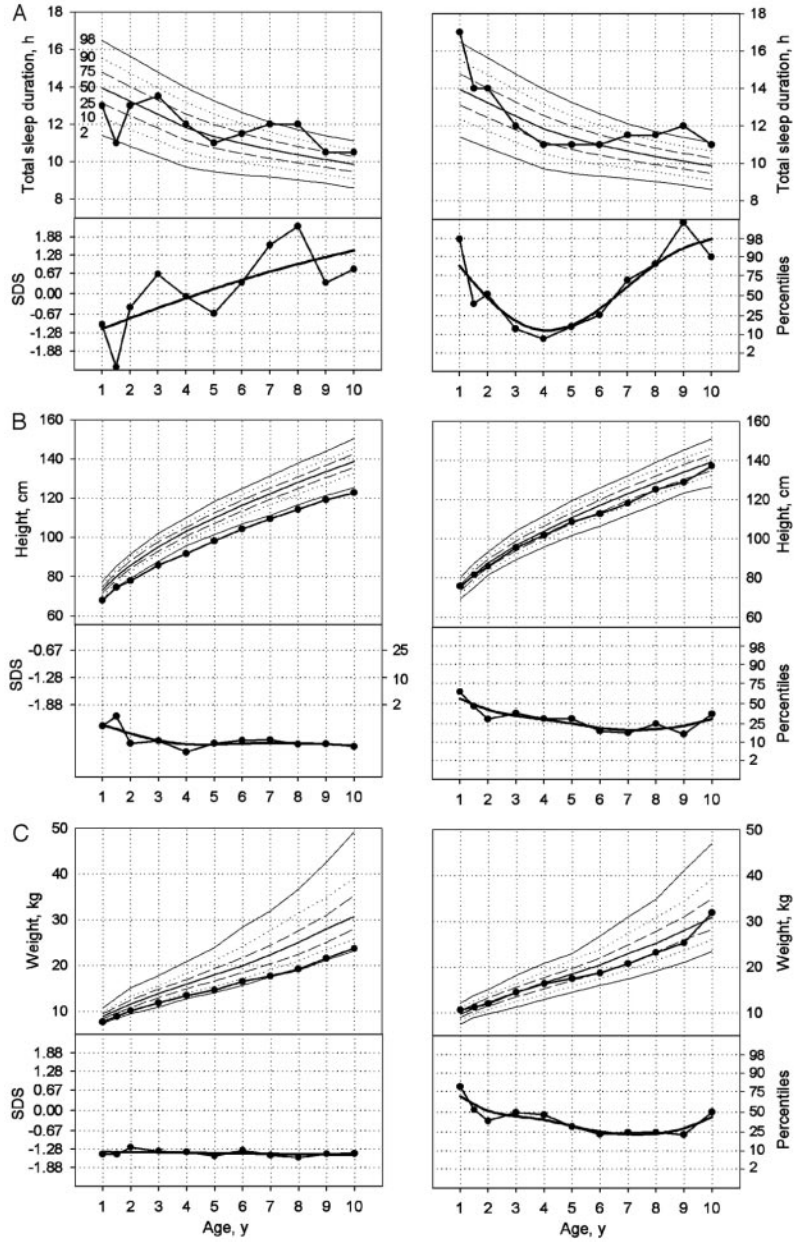

FIGURE 2
Individual sleep and growth patterns of a girl (subject 651 [left]) and a boy (subject 192 [right]). A, Sleep; B, height; C, weight.

height; 64% for weight). Sleep duration of ~90% of all children ran within an LTV channel of <2.0 SDS (corresponding, eg, to the range between the 2nd and the 50th percentiles or the 98th and the 50th percentiles). In contrast, no single child's sleep duration remained within an STV channel <0.5 SDS, indicating fluctuations from year to year (60% for height, 53% for weight). A cumulative frequency curve of STV channels in a series of independent random values (simulation; data not shown), however, were more variable than STV of sleep duration. STV of weight and height differed only marginally and not significantly. No gender differences in LTV and STV were found for sleep duration, weight, and height.

An association between aspects of sleep duration and somatic growth was not observed at any age. SDSs of sleep duration did not correlate with SDSs of height or weight at any age or when pooled over all ages ($r = 0.03$ for sleep duration/height, $r = -0.03$ for sleep duration/weight; $P > .05$). As expected, height and weight were strongly correlated ($r = 0.75$; $P < .001$). Also sleep duration variability, as expressed by LTV and STV, did not correlate with the corresponding parameters of growth in height or weight.

DISCUSSION

The main goal of the analysis presented in this article was to explore the intraindividual variability of sleep duration (time in bed per 24 hours) in the first 10 years of life in comparison with that of growth variables. For

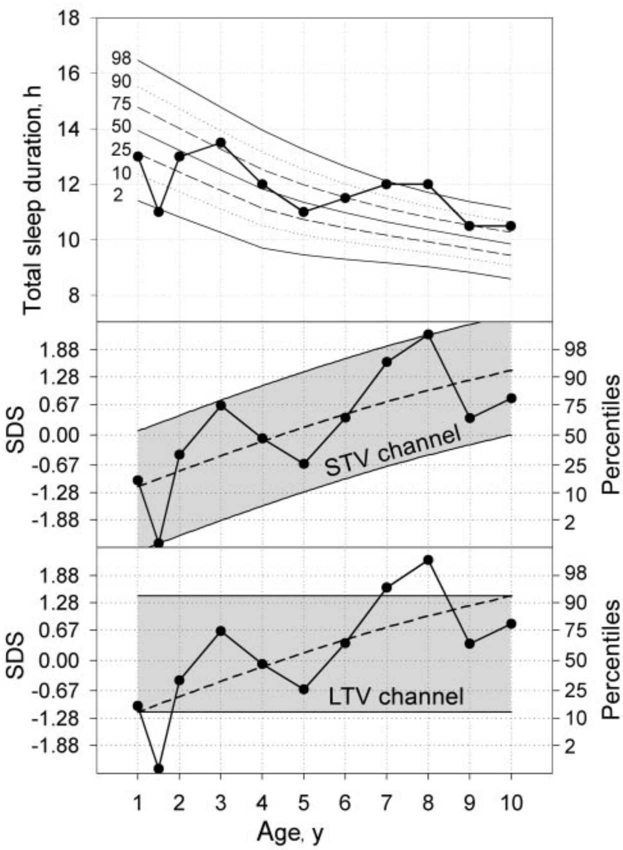

FIGURE 3
Definition of variables. The gray areas indicate the STV (middle) and LTV (lower) channels of individual 651 (see also Fig 2 left; STV channel width: 1.43 SDS; LTV channel width: 2.57 SDS). The dashed line illustrates the smoothed curve. See "Methods" for more details.

TABLE 1 Average and SD of Sleep Duration Per 24 Hours During the First 10 Years of Life and the Corresponding Values of Height and Weight for Boys and Girls (n = 305)

Age, y	Sleep Duration, Mean (SD), h	Height, Mean (SD), cm		Weight, Mean (SD), kg	
		Boys	Girls	Boys	Girls
1	14.6 (1.4)	74.8 (2.5)	73.0 (2.3)	9.6 (1.1)	8.8 (0.8)
1½	14.2 (1.2)	81.9 (2.9)	80.0 (2.7)	11.1 (1.3)	10.3 (1.0)
2	13.8 (1.1)	87.6 (3.0)	85.8 (3.0)	12.3 (1.4)	11.5 (1.2)
3	13.0 (1.2)	96.6 (3.5)	95.1 (3.4)	14.6 (1.7)	13.8 (1.6)
4	12.1 (1.2)	104.0 (3.8)	102.8 (3.7)	16.5 (2.0)	15.9 (1.9)
5	11.6 (1.0)	110.8 (4.2)	109.7 (4.1)	18.5 (2.4)	18.0 (2.4)
6	11.3 (0.8)	117.0 (4.6)	116.1 (4.3)	20.7 (2.9)	20.3 (3.0)
7	11.1 (0.7)	123.0 (5.0)	122.2 (4.5)	23.0 (3.4)	22.8 (3.6)
8	10.6 (0.6)	128.7 (5.3)	127.9 (4.8)	25.6 (3.9)	25.9 (4.2)
9	10.5 (0.6)	134.3 (5.5)	133.5 (5.1)	28.5 (4.6)	28.7 (5.1)
10	10.1 (0.6)	139.2 (5.9)	138.9 (5.6)	31.9 (5.7)	32.1 (5.9)

Mean sleep duration declined whereas height and weight increased across age. Interindividual variability was different between measures; the average SD of sleep duration was 8% of the population mean, whereas it was 4% for height and 14% for weight.

this purpose, we used data of the ZLS, one of the largest and most complete birth-to-maturity cohorts on growth and development ever collected.[19] The analysis was restricted to early and middle childhood (ages 1–10 years), because during infancy and adolescence, major maturational changes in sleep regulatory processes do occur, and, therefore, instability of sleep behavior may be observed.[20–22] We found that sleep duration of ~90% of all children ran within an LTV channel of <2.0 SDS (corresponding, eg, to the range between the 2nd and the 50th percentiles or the 98th and the 50th percentiles). The intraindividual stability of height was higher than that of weight, which in turn was higher than for sleep duration.

Serial measurements of individuals over time are useful to quantify the degree of stability of a specific variable.[23,24] We know that height and weight remain relatively stable across childhood, indicating that growth can be reliably determined and is predictable over time.[13,14] We also found a high stability of growth variables over both short-term and long-term intervals in our sample (small STV and LTV). Taken together, most short children remained short and most tall children remained tall when they grew older. These findings support current guidelines to monitor growth in children by growth charts for determining growth abnormalities.

Similarly, we also found a moderately stable long-term trend of sleep duration with respect to the changing population distribution (ie, most children stay within an LTV channel <2.0 SDS), indicating that the interindividual variability of sleep duration in part reflects trait-like characteristics of the individual; in other words, intrinsic biological factors. In fact, a growing body of evidence suggests that specific sleep regulatory processes (determining the sleep timing and duration on a neurologic[25,26] and genetic basis[27]) greatly vary among individuals.[26]

In our study, sleep duration varied from year to year (ie, large STV or low short-term stability). These yearly fluctuations may represent state-like effects and indicate short-term developmental spurts or delays of the child, intermittent illnesses or other stresses, changes in psychosocial environment or child-rearing attitudes, seasonal effects, and measurement errors. We note that the sleep data were based on subjective parental reports and not on objective methods (eg, actigraphy, polysomnography). Subjective reports may be incomplete because of biased parental information about children's sleep, and parent-reported sleep duration may more represent a measure for time in bed than for actual sleep time. Sadeh and colleagues,[28,29] however, showed that reports by caregivers are reliable in terms of bedtime and nocturnal interactions, sleep-onset time, and sleep duration but not for sleep quality measures or night wakings. Sadeh[30] recently also demonstrated that his sleep questionnaire for infants corresponded well with actigraphy and daily parental sleep logs. We also found in an ongoing study of our center (with n = 53) that parent-reported bedtime and wake time correlate well with sleep diary information and actigraphy in healthy children.

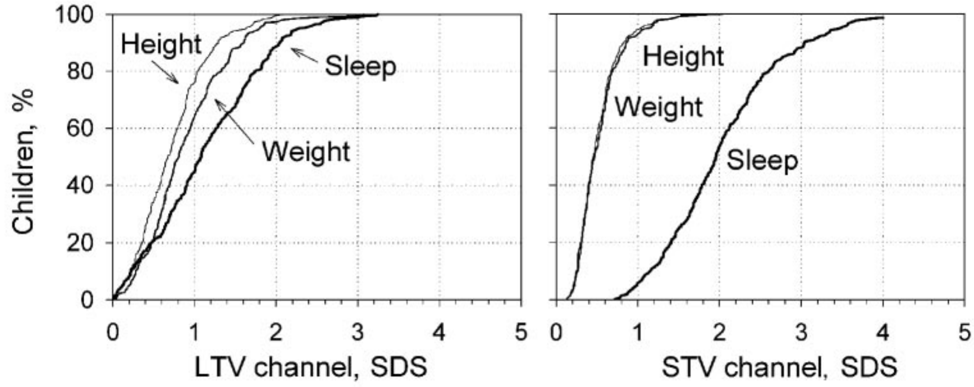

FIGURE 4
Cumulative frequency curves of STV (right) and LTV (left) channel widths ($n = 305$). A steeper curve reflects a more stable variable.

Several studies reported a relationship between sleep physiology and growth hormone secretion.[31–34] We did not, however, find any evidence to support an association between parent-reported sleep duration and growth variables, confirming 2 similar studies in 5- to 11-year-old children[35] and 12- to 16-year-old adolescents.[36] We agree with these authors that the variation of sleep duration among children does not seem to have an effect on growth. Whether sleep disorders in children can inhibit growth by decreasing the diurnal growth hormone release remains to be established. A recent experimental study in adults challenged this view[37]; the growth hormone peak at night was compensated for during the day when individuals were prevented from sleep for 24 hours and the total amount of secreted growth hormone per 24 hours remained constant during sleep loss.

What are the clinical implications of our findings? We need to recognize that some children sleep less than others and vice versa. Knowledge about the long-term stability of sleep duration may help to develop realistic expectations in regard to individual sleep needs of the child. Health care professionals commonly find that parents overestimate the time in bed required by their children.[38,39] Some families set a specific "children's bedtime" without taking into account that each child has different sleep needs or gets different amounts of daytime sleep.[39] Parental expectations and assumptions may be based on what friends or family members say or parental magazines and expert books recommend. Percentile curves for sleep duration are useful to demonstrate to parents that their child's sleep duration lies within the reference range at a given age. When the child is expected to stay in bed for more hours than he or she can sleep, difficulties falling asleep, waking too early, or extended periods of wakefulness during the night may occur.[38,39] In theses cases, bedtime needs to be adjusted to the individual sleep need by correcting the timing and distribution of sleep during the day and at night. Sleep diaries are a reliable clinical tool for such purposes.

Percentiles for sleep duration are also helpful to detect either short or prolonged sleep compared with the normal population. Sleep diaries or actigraphy may be used to verify short or long sleep duration. If the child does not demonstrate signs of sleepiness in the course of the day, wakes up spontaneously in the morning, and shows age-appropriate behavior during daytime, then no additional actions are required in clinical practice. The child with an intrinsically short sleep duration (short sleeper), however, must be distinguished from the child who gets insufficient sleep and shows sleepiness and behavioral abnormalities during the day that may significantly affect cognitive, academic, and behavioral functioning.[40–43] In contrast, the impact of prolonged sleep duration on children's health is less clear. Prolonged sleep duration is a *Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition* diagnostic criterion for depression,[44] has been associated with depressive symptoms in adults, and occurs more frequently in individuals of low socioeconomic status.[45] However, whether the same association can also be found in children is unknown.

CONCLUSIONS

Sleep duration shows considerable long-term stability; in ~90% of all children, sleep duration remains within an LTV channel of <2.0 SDS (eg, between the 2nd and the 50th percentiles), indicating that interindividual variability of sleep duration in part reflects trait-like characteristics of the child. In other words, many young children who sleep only short periods compared with their contemporaries do so also later during childhood, and the same is true for long sleepers. The percentile curves for sleep duration published in 2003 in this journal[11] are useful in clinical practice for counseling parents, developing appropriate expectations in regard to the individual sleep needs of the child, and detecting short and prolonged sleep duration. The findings of the Zurich Longitudinal Studies in terms of the large variability among children in developmental measures indicate that we should consider age-specific needs and characteristics of the individual child.[46]

ACKNOWLEDGMENTS

This study was supported by Swiss National Science Foundation grant 3200B0-112324.

We are grateful to the participants and their families for continuing participation and cooperation.

REFERENCES

1. Lozoff B, Wolf A, Davis N. Sleep problems seen in pediatric practice. *Pediatrics.* 1985;75:477–483
2. Zuckerman B, Stevenson J, Bailey V. Sleep problems in early childhood: continuities, predictive factors, and behavioral correlates. *Pediatrics.* 1987;80:664–671
3. Blader J, Koplewicz H, Abikoff H, Foley C. Sleep problems of elementary school children: a community survey. *Arch Pediatr Adolesc Med.* 1997;151:473–480
4. Mindell JA, Owens JA, Carskadon MA. Developmental features of sleep. *Child Adolesc Psychiatr Clin N Am.* 1999;8:695–725
5. Thunström M. Severe sleep problems among infants in a normal population in Sweden: prevalence, severity and correlates. *Acta Paediatr.* 1999;88:1356–1363
6. Owens JA, Spirito A, McGuinn M, Nobile C. Sleep habits and sleep disturbance in elementary school-aged children. *J Dev Behav Pediatr.* 2000;21:27–36
7. Halbower AC, Marcus CL. Sleep disorders in children. *Curr Opin Pulm Med.* 2003;9:471–476
8. Jenni OG, Zinggeler Fuhrer H, Iglowstein I, Molinari L, Largo RH. A longitudinal study of bedsharing and sleep problems among Swiss children in the first 10 years of life. *Pediatrics.* 2005;115 233–240
9. Mindell J, Owens JA. *A Clinical Guide to Pediatric Sleep: Diagnosis and Management of Sleep Problems in Children and Adolescents*. Philadelphia, PA: Lippincott Williams & Wilkins; 2003
10. Hunt CE. *2003 National Sleep Disorders Research Plan*. Bethesda, MD: National Center on Sleep Disorders Research; 2003
11. Iglowstein I, Jenni OG, Molinari L, Largo RH. Sleep duration from infancy to adolescence: reference values and generational trends. *Pediatrics.* 2003;111:302–307
12. Jenni OG. Sleep onset insomnia during childhood or poor fit between biology and culture: comment on van der Heijden et al. "Prediction of melatonin efficacy by pre-treatment dim light melatonin onset in children with idiopathic chronic sleep onset insomnia." *J Sleep Res.* 2005;14:195–197; discussion 197–199
13. Prader A, Tanner JM, von HG. Catch-up growth following illness or starvation. An example of developmental canalization in man. *J Pediatr.* 1963;62:646–659
14. Tanner JM. *Growth at Adolescence*. Oxford, United Kingdom: Blackwell Scientific; 1962
15. Falkner F. *Child Development: An International Method of Study*. Basel, Switzerland: Karger; 1960
16. Iglowstein I, Latal Hajnal B, Molinari L, Largo RH, Jenni OG. Sleep behavior in preterm children from birth to age 10 years: a longitudinal study. *Acta Paediatr.* 2006;95:1691–1693
17. Prader A, Largo RH, Molinari L, Issler C. Physical growth of Swiss children from birth to 20 years of age. First Zurich Longitudinal Study of Growth and Development. *Helv Paediatr Acta.* 1989;52:1–125
18. Cole TJ, Green PJ. Smoothing reference centile curves: the LMS method and penalized likelihood. *Stat Med.* 1992;11:1305–1319
19. Tanner JM. A brief history of the study of human growth. In: Ulijaszek SJ, Johnston FE, Preece MA, eds. *The Cambridge Encyclopedia of Human Growth and Development*. Cambridge, United Kingdom: Cambridge University Press; 1998:3–12
20. Jenni OG, Achermann P, Carskadon MA. Homeostatic sleep regulation in adolescents. *Sleep.* 2005;28:1446–1454
21. Jenni OG, Borbély AA, Achermann P. Development of the nocturnal sleep electroencephalogram in human infants. *Am J Physiol.* 2004;286:R528–R538
22. Jenni OG, Carskadon MA. Spectral analysis of the sleep electroencephalogram during adolescence. *Sleep.* 2004;27:774–783
23. Sheehy A, Gasser T, Largo R, Molinari L. Short-term and long-term variability of standard deviation scores for size in children. *Ann Hum Biol.* 2002;29:202–218
24. Goldstein H. Measuring the stability of individual growth patterns. *Ann Hum Biol.* 1981;8:549–557
25. Saper CB, Scammell TE, Lu J. Hypothalamic regulation of sleep and circadian rhythms. *Nature.* 2005;437:1257–1263
26. Aeschbach D, Sher L, Postolache TT, Matthews JR, Jackson MA, Wehr TA. A longer biological night in long sleepers than in short sleepers. *J Clin Endocrinol Metab.* 2003;88:26–30
27. Tafti M, Maret S, Dauvilliers Y. Genes for normal sleep and sleep disorders. *Ann Med.* 2005;37:580–589
28. Sadeh A, Raviv A, Gruber R. Sleep patterns and sleep disruptions in school-age children. *Dev Psychol.* 2000;36:291–301
29. Tikotzky L, Sadeh A. Sleep patterns and sleep disruptions in kindergarten children. *J Clin Child Psychol.* 2001;30:581–591
30. Sadeh A. A brief screening questionnaire for infant sleep problems: validation and findings for an Internet sample. *Pediatrics.* 2004;113(6). Available at: www.pediatrics.org/cgi/content/full/113/6/e570
31. Takahashi Y, Kipnis DM, Daughaday WH. Growth hormone secretion during sleep. *J Clin Invest.* 1968;47:2079–2090
32. 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
33. Finkelstein JW, Anders TF, Sacher EJ, Roffwarg HP, Hellman LD. Behavioral state, sleep stage and growth hormone levels in human infants. *J Clin Endocrinol Metab.* 1971;32:368–371
34. Van Cauter E, Plat L, Copinschi G. Interrelations between sleep and the somatotropic axis. *Sleep.* 1998;21:553–566
35. Gulliford M, Price C, Rona R, Chinn S. Sleep habits and height at ages 5 to 11. *Arch Dis Child.* 1990;65:119–122
36. 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
37. 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
38. Ferber R. *Solve Your Child's Sleep Problems*. New York, NY: Simon & Schuster; 2006
39. Largo RH, Hunziker UA. A developmental approach to the management of children with sleep disturbances in the first three years of life. *Eur J Pediatr.* 1984;142:170–173
40. Fallone G, Acebo C, Seifer R, Carskadon MA. Experimental restriction of sleep opportunity in children: effects on teacher ratings. *Sleep.* 2005;28:1561–1567
41. Dahl RE. The impact of inadequate sleep on children's daytime cognitive function. *Semin Pediatr Neurol.* 1996;3:44–50
42. Wolfson AR, Carskadon MA. Understanding adolescents' sleep patterns and school performance: a critical appraisal. *Sleep Med Rev.* 2003;7:491–506
43. Jenni OG, Dahl RE. Sleep, cognition and emotion: a developmental view. In: Nelson CA, Luciana M, eds. *Handbook of Developmental Cognitive Neuroscience*. Cambridge, MA: MIT Press; In press
44. American Psychiatric Association. *Diagnostic and Statistical Manual of Mental Disorders, 4th ed.—Text Revision (DSMIV-TR)*. Washington, DC: American Psychiatric Publishing; 2000
45. Patel SR, Malhotra A, Gottlieb DJ, White DP, Hu FB. Correlates of long sleep duration. *Sleep.* 2006;29:881–889
46. Jenni OG, O'Connor BB. Children's sleep: an interplay between culture and biology. *Pediatrics.* 2005;115:204–216