Sleep Duration From Infancy to Adolescence: Reference Values and Generational Trends

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ABSTRACT. *Objective.* **The main purpose of the present study was to calculate percentile curves for total sleep duration per 24 hours, for nighttime and for daytime sleep duration from early infancy to late adolescence to illustrate the developmental course and age-specific variability of these variables among subjects.**

Methods. **A total of 493 subjects from the Zurich Longitudinal Studies were followed using structured sleep-related questionnaires at 1, 3, 6, 9, 12, 18, and 24 months after birth and then at annual intervals until 16 years of age. Gaussian percentiles for ages 3 months to 16 years were calculated for total sleep duration (time in bed) and nighttime and daytime sleep duration. The mean sleep duration for ages 1 to 16 years was estimated by generalized additive models based on the loess smoother; a cohort effect also had to be included. The standard deviation (SD) was estimated from the loess smoothed absolute residuals from the mean curve. For ages 3, 6, and 9 months, an alternative approach with a simple model linear in age was used. For age 1 month, empirical percentiles were calculated.**

Results. **Total sleep duration decreased from an average of 14.2 hours (SD: 1.9 hours) at 6 months of age to an average of 8.1 hours (SD: 0.8 hours) at 16 years of age. The variance showed the same declining trend: the interquartile range at 6 months after birth was 2.5 hours, whereas at 16 years of age, it was only 1.0 hours. Total sleep duration decreased across the studied cohorts (1974–1993) because of increasingly later bedtime but unchanged wake time across decades. Consolidation of nocturnal sleep occurred during the first 12 months after birth with a decreasing trend of daytime sleep. This resulted in a small increase of nighttime sleep duration by 1 year of age (mean 11.0 ± 1.1 hours at 1 month to 11.7 ± 1.0 hours at 1 year of age). The most prominent decline in napping habits occurred between 1.5 years of age (96.4% of all children) and 4 years of age (35.4%).**

Conclusions. **Percentile curves provide valuable information on developmental course and age-specific variability of sleep duration for the health care professional who deals with sleep problems in pediatric practice.** ***Pediatrics*** **2003;111:302–307;** ***sleep duration, naps, generational trends, infants, children, adolescents.***

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ABBREVIATION. SD, standard deviation.

Epidemiologic studies have demonstrated in various age groups from infancy to adolescence a high prevalence of sleep disturbances that are associated with significant medical, psychological, and social consequences (see review[1]). They range from frequent night wakings or difficulties in falling asleep in early childhood to more medically or biologically based disorders in school-aged children and adolescents, such as obstructive sleep apnea, parasomnia, or excessive sleepiness.[1] Knowledge of sleep characteristics, such as the amount of sleep and the timing of bedtime and daytime naps, is of importance in assessing sleep complaints and in providing preventive advice.

It is a common clinical experience that parents are frequently concerned that children do not get enough hours of sleep for their age. They tend to overestimate children's sleep requirements.[2,3] Unrealistic or rigid parental expectations of sleep need without taking the child's age into account have been shown to be a significant cause for bedtime difficulties and for frequent night and/or early morning wakings.[2,3] If the time that a child spends in bed exceeds his or her actual sleep need, then he or she may struggle at bedtime, awaken during the night, or awaken too early in the morning.[4] A successful and effective approach to the management of these interactive sleep problems is to adjust the time in bed to the real sleep requirement.[2]

Sleep duration as an indicator for sleep need declines considerably from the newborn period to late adolescence, but substantial individual variability remains at all ages. Studies with age-specific reference values from infancy through adolescence with large study populations are scarce. Most studies examined a small number of children, were focused on limited age groups, or did not analyze the interindividual variability.[5–13] Thus, complete normative data on children's sleep duration as a function of chronological age do not exist.[14] However, such data are necessary to deal accurately with sleep problems in children and to reassure distressed parents.[2]

The aim of this study was to present percentile curves for total sleep duration per 24 hours, for nighttime and for daytime sleep duration. These data provide valuable information for the health care professional who deals with sleep disorders in pediatric practice.

METHODS

A total of 493 subjects from the Zurich Longitudinal Studies (141 preterm and 352 term infants, 261 boys and 232 girls) were followed by comprehensive neurodevelopmental assessments and with structured interviews at 1, 3, 6, 9, 12, 18, and 24 months after birth and at annual intervals thereafter (time limits: for the age of 3–18 months ± 1 week, for 2 years and above ± 2 weeks) until 16 years of age. The subjects were born between October 1974 and September 1978 (Second Zurich Longitudinal Study, $n = 213$) and between September 1978 and 1993 (Zurich Generational Study, $n = 280$). All children were of Swiss origin and formed a representative selection of the Swiss urban population. 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 subjects of the Second Zurich Longitudinal Study were not seen at the ages of 11, 12, 13, 15, and 16 years. The main characteristics of the Zurich Longitudinal Studies have been described previously.[15]

Structured interviews with the parents (mostly with the mother) were performed for various sleep-related habits (see complete questionnaires[16]). Bedtime, wake time, and daytime napping habits (duration and frequency) 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, and 22:00. When does the child wake up usually? 04:00, 05:00, 05:30, 06:00, 06:30, 07:00, 07:30, 08:00, and 09:00. How many times and how long does the child sleep during daytime? Number of naps per day; duration: 0 minutes, 15 minutes, 30 minutes, 1 hour, 2 hours, 3 hours, 4 hours, 5 hours, and 6 hours.

Nighttime sleep duration was calculated from bedtime and wake time. Total sleep duration was the sum of nighttime and daytime sleep duration. During the entire study period, only 2 interviewers using the same interview procedures completed the questionnaires. A comparison of both interviewers' data sets did not reveal any significant differences in sleep duration and napping habits. A preliminary analysis by analysis of variance at each age indicated that there was no significant difference with respect to these sleep characteristics either between preterm and term infants or between boys and girls. Therefore, we used the entire study population to calculate percentiles.

Statistics

A preliminary analysis showed that the distribution of total sleep duration and nighttime sleep duration for all ages, as well as of daytime sleep duration up to the age of 4 years, did not in terms of skewness and kurtosis strongly deviate from a Gaussian (normal) distribution, with the exception of the data for age 1 month. Gaussian percentiles, defined as $m(a) + c_\alpha \times s(a)$, with m(a) the mean sleep duration at age a years, s(a) the standard deviation (SD) of the sleep duration at the same age, and c_α a constant taken from tables of the standard Gaussian distribution (eg, $c_\alpha = 2.05$ for the 98th percentile) were therefore used. Gaussian percentiles are more precise, when appropriate, than empirical ones, and the availability of m(a) and s(a) allows a simple calculation of SD scores, useful for comparisons across age and subgroups. The preliminary analysis also showed a clear reduction in average sleep duration with cohort (birth year), which had to be taken into account in the subsequent modeling of m(a) and s(a).

For estimating m(a), the mean sleep duration by age, generalized additive models were used,[17,18] based on the loess smoother,[19] including a linear interaction of age and birth year. This means that at any given age, sleep duration decreases, within the cohorts under study, linearly with birth year, with an age-dependent slope. The SD of sleep duration depended on age but only weakly, if at all, on birth year; it was estimated by applying the loess smoother to the absolute residuals from the birth year–dependent mean curve. This procedure was used in the age range 1 to 16 years. The data for the first year of life did not fit well, particularly with respect to their variability and especially for the first month of life, with the later trends. For this reason, we fitted a very simple model, linear in age and without birth effect, for ages 3, 6, and 9 months and calculated empirical percentiles for age 1 month.

For daytime sleep duration, data from age 1 month to 4 years, limited to those subjects who actually slept (day sleep duration >0), were included in the calculation of the percentiles by the same procedure described above. The percentage of subjects who slept during the day as well as the number of naps per day at any given age are also provided. Daytime sleep is generally indicated by the parents as a multiple of half hour. At later ages (beyond age 4), only a few values occur and Gaussian percentiles are not appropriate (eg, at age 4, 64% of the subjects do not sleep at all during the day, whereas 11% sleep for 1 and 17% for 2 hours; the corresponding figures at age 5 are 83%, 7%, and 7%, respectively.)

RESULTS

The main results are illustrated in Figs 1 to 3, which provide percentile curves for total sleep duration, nighttime sleep duration, and daytime sleep duration. Numeric values are given in Table 1.

Total Sleep Duration per 24 Hours

Total sleep duration decreased from an average of 14.2 hours (SD: 1.9 hours) at 6 months of age to an average of 8.1 hours (SD: 0.8 hours) at 16 years of age. In addition, the variance showed the same declining trend: the interquartile range at 6 months after birth was 2.5 hours, whereas by 16 years of age, it was reduced to 1.0 hours. For example, at 2 years of age, 96% of all children presented in this report showed a total sleep duration between 10.8 and 15.6 hours and at 12 years of age between 8.0 and 10.7 hours (Fig 1).

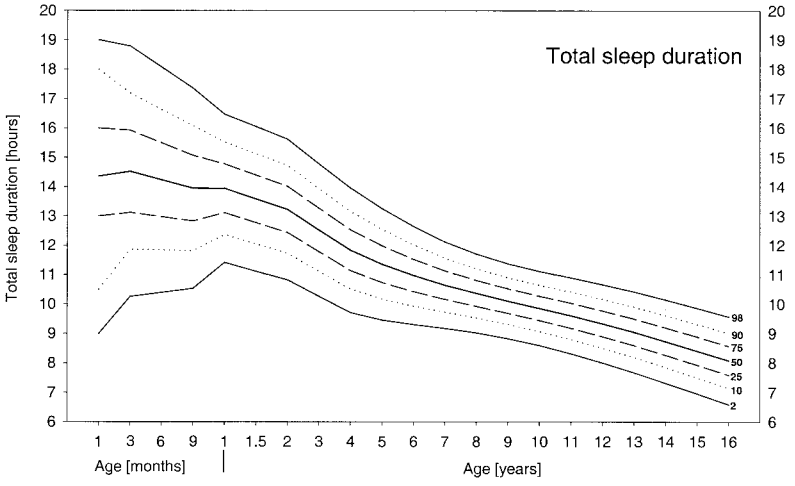

Fig 1. Percentiles for total sleep duration per 24 hours from infancy to adolescence.

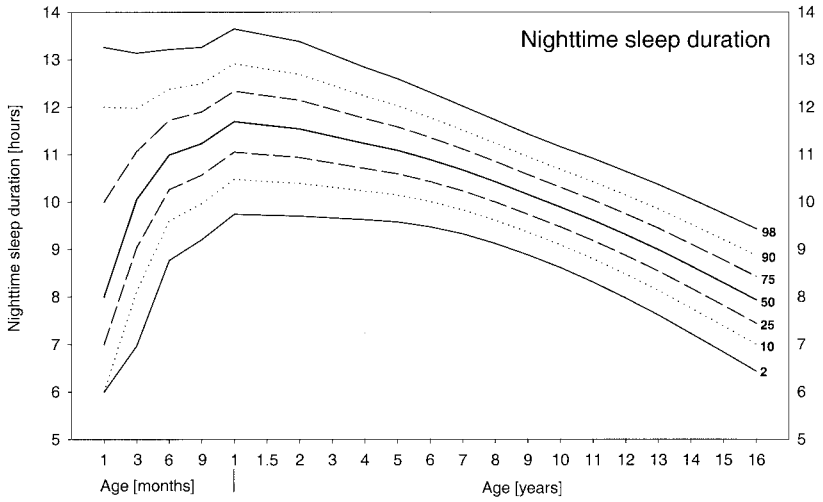

Fig 2. Percentiles for nighttime sleep duration per 24 hours from infancy to adolescence.

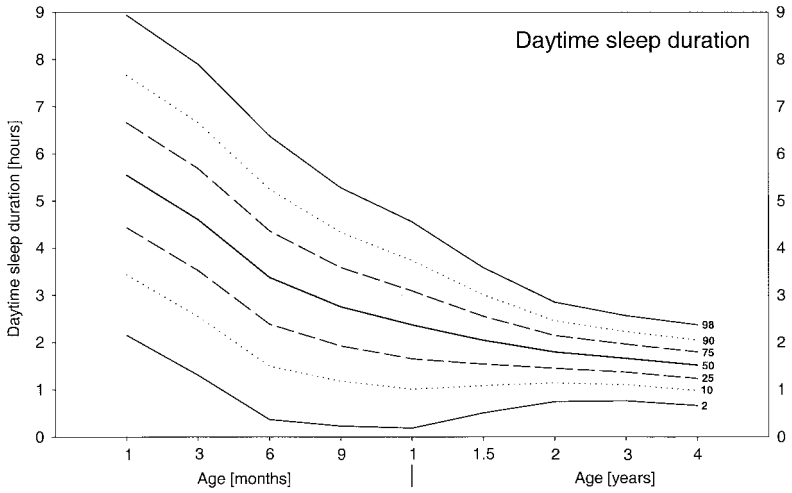

Fig 3. Percentiles for daytime sleep duration per 24 hours.

TABLE 1. Numeric Percentile Values*

Age (Years)	*n*	Total Sleep Duration				Nighttime Sleep Duration				Daytime Sleep Duration				Daytime Napping Children (%)
		Mean	SD	2%	98%	Mean	SD	2%	98%	Mean	SD	2%	98%	
0.5	456	14.2	1.9	10.4	18.1	11.0	1.1	8.8	13.2	3.4	1.5	0.4	6.4	100
0.75	458	13.9	1.7	10.5	17.4	11.2	1.0	9.2	13.3	2.8	1.2	0.2	5.3	100
1	458	13.9	1.2	11.4	16.5	11.7	1.0	9.7	13.6	2.4	1.1	0.2	4.6	100
1.5	452	13.6	1.2	11.1	16.0	11.6	0.9	9.7	13.5	2.0	0.7	0.5	3.6	96
2	460	13.2	1.2	10.8	15.6	11.5	0.9	9.7	13.4	1.8	0.5	0.7	2.9	87
3	450	12.5	1.1	10.3	14.8	11.4	0.8	9.7	13.1	1.7	0.4	0.8	2.6	50
4	464	11.8	1.0	9.7	14.0	11.2	0.8	9.6	12.8	1.5	0.4	0.7	2.4	35
5	447	11.4	0.9	9.5	13.3	11.1	0.7	9.6	12.6					8
6	452	11.0	0.8	9.3	12.6	10.9	0.7	9.5	12.3	Children without daytime				5
7	448	10.6	0.7	9.2	12.1	10.7	0.7	9.3	12.0	napping excluded				1
8	439	10.4	0.7	9.0	11.7	10.4	0.6	9.1	11.7					
9	426	10.1	0.6	8.8	11.4	10.2	0.6	8.9	11.4					
10	416	9.9	0.6	8.6	11.1	9.9	0.6	8.6	11.2					
11	196	9.6	0.6	8.3	10.9	9.6	0.6	8.3	10.9					
12	186	9.3	0.6	8.0	10.7	9.3	0.7	8.0	10.6					
13	164	9.0	0.7	7.7	10.4	9.0	0.7	7.6	10.4					
14	336	8.7	0.7	7.3	10.1	8.6	0.7	7.2	10.1					
15	125	8.4	0.7	7.0	9.9	8.3	0.7	6.8	9.7					
16	100	8.1	0.7	6.6	9.6	7.9	0.7	6.4	9.4					

* From age 11 to 13 and then from 15 to 16, sleep variables were assessed only in the Zurich Generational Study (1978–1993, $n = 280$).

Duration of Nighttime Sleep

Consolidation of nocturnal sleep occurred during the first 12 months after birth with a decreasing trend of daytime sleep duration. This resulted in an increase of nighttime sleep duration by age 1 year (mean: 10.0 ± 1.5 hours at 3 months to 11.7 ± 1.0 hours at 1 year of age). Thereafter, a marked reduction of nighttime sleep duration was demonstrated.

Because of the discrete nature of the raw data, the empirical 2nd and 10th percentiles coincide at age 1 month. After the age of 7 years, small differences between nighttime and total sleep duration on the order of a few minutes (see the corresponding Table 1) were attributable to fitting procedures (Fig 2).

Duration of Daytime Sleep (Napping Habits)

Daytime sleep duration gradually declined in the first years of life, illustrating increasing concentration of sleep in the nighttime hours. In the first 12 months after birth, all infants in our study population napped (Fig 4, Table 1). Napping frequency decreased from birth to 7 years when only 0.9% of the children still slept during the daytime. At 18 months of age, there was a significant change from 2 or more naps to only 1 nap per day. At the age of 3 years, 50.4% of the children still napped once per day (Figs 3 and 4).

Cohort Effect

As indicated in "Methods," the mean sleep duration for age, m(a), depended on cohort but not the SD for total, nighttime, and daytime sleep duration. This dependence of m(a) on birth year was modeled by a linear interaction between age and birth year. For illustration, the mean total sleep duration for the cohorts 1974, 1979, and 1986 are presented in Fig 5. The trend of sleep duration diminished with age across cohorts; at 2 years of age, the decrease between 1974 and 1986 was from an average of 14.2 hours to 13.5 hours for total sleep duration, whereas at 14 years of age, it was from 9.0 hours to 8.8 hours. This cohort effect was analyzed in more detail with regard to bedtime and wake time. In younger children, the evening bedtime was increasingly delayed across cohorts. Although in the mid-1970s the mean bedtime in children 2 years old was at 19:08 (±0:38), in the 1990s, bedtime was delayed to 19:46 (±0:50). The cohort effect in wake time was much smaller, not systematical, and limited to the first 3 years. Thus, the shift in the evening bedtime across cohorts accounted for the substantial decrease in sleep duration in younger children between the 1970s and the 1990s (Table 2).

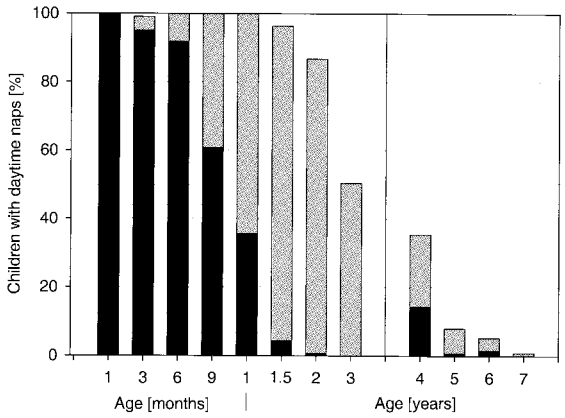

Fig 4. Percentage of children who napped during the first 7 years after birth. For 1 month to 3 years: dark bars represent 2 or more naps per day, and light bars represent only 1 nap per day. For 4 to 7 years: dark bars represent napping every day, and light bars represent napping occasionally.

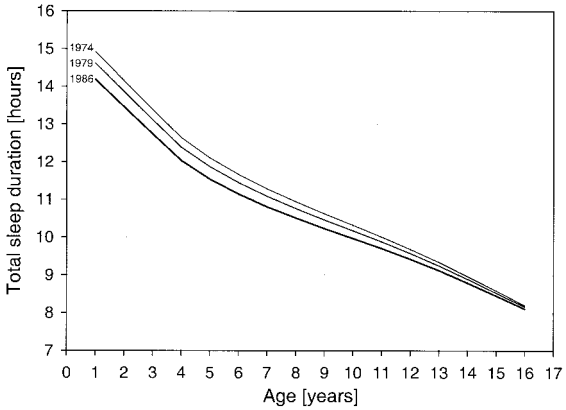

Fig 5. Time trend of mean total sleep duration across 3 birth cohorts for birth years 1974, 1979, and 1986.

DISCUSSION

To our knowledge, this is the first publication of percentile curves for sleep duration from early infancy to late adolescence. It may help the clinician to evaluate sleep problems in the pediatric age group and may reassure parents of the normality of their child's sleep duration.

In general, the length of the child's sleep is individually assessed by the parents or the child him- or herself. However, because sleep onset and wake-up time in the morning may be difficult to define by subjective assessment, the sleep duration reported here should in general be interpreted as time spent in bed. The reliability of parental reports for sleep duration, obtained from daily sleep logs, was demonstrated by comparisons with objective actigraphic measures.[20,21] Sadeh[21] reported that parents overestimated sleep duration on average by only 14 minutes. The correlation between actigraph and parental report was in general higher for schedule-related measures such as sleep onset time and sleep duration compared with number of night wakings. Data on the reliability of structured interviews as used in this study are currently not available.

The mean total sleep duration reported here is in good agreement with values given by others. In a large longitudinal study, Klackenberg[5,6] found a mean total sleep duration in 1-year-old infants of 13.2 hours (13.9 hours, values in brackets refer to the results of the present study), at 3 years of 12 hours (12.5 hours), at 6 years of 11 hours (11 hours), and at 12 years of 9.5 hours (9.3 hours).[5,6] In the first year of life, Bamford et al[11] showed the mean total sleep duration to decrease from 14.3 hours (14.2 hours) at 6 months of age to 13.6 hours (13.9 hours) at 1 year of age.[11] In preschool children, Jacklin et al[12] described a total sleep duration of 13.3 hours (13.6 hours) at 18 months, 12.7 hours at 26 months, and 11.8 hours at 33 months of age. Gulliford et al[10] reported an average sleep duration in school-age children of 11.2 hours (11.4 hours) at 5 years and of 10.5 hours (10.4 hours) at 8 years. In the early adolescent age group, we confirmed the study by Szymczak et al,[13] who ob-

TABLE 2. Bedtime and Waketime (in hours:minutes) Across 3 Cohorts (1974–1978, 1979–1985, 1986–1993) at Selected Ages

	Cohort	6 Months	1 Year	3 Years	5 Years	10 Years	14 Years
Bedtime	74–78	19:18 (0:49)	19:08 (0:38)	19:35 (0:35)	19:46 (0:29)	20:45 (0:32)	21:43 (0:41)
	79–85	19:41 (0:51)	19:35 (0:39)	19:53 (0:41)	19:56 (0:38)	20:50 (0:36)	21:47 (0:37)
	86–93	20:16 (1:08)	19:46 (0:50)	20:07 (0:42)	20:11 (0:38)	20:59 (0:40)	22:02 (0:37)
	P	<.0001	<.0001	<.0001	<.0001	.01	.1
Wake time	74–78	6:55 (0:57)	7:16 (0:50)	7:18 (0:44)	7:16 (0:35)	6:56 (0:20)	6:41 (0:23)
	79–85	7:16 (0:55)	7:34 (0:50)	7:27 (0:46)	7:17 (0:38)	6:56 (0:23)	6:39 (0:24)
	86–93	7:13 (0:13)	7:19 (0:52)	7:35 (0:50)	7:20 (0:39)	6:56 (0:29)	6:30 (0:20)
	P	.0004	.005	.005	NS	NS	NS
N		461	458	455	448	416	335

NS indicates not significant.
* Mean values and SD (in parentheses) are presented. One-way analysis of variance with factor "cohort."

tained a total sleep duration of 10.2 hours (9.9 hours) in 10-year-olds and of 8.7 hours (8.7 hours) in 14-year-olds. It is interesting that Laberge et al[9] found mean values from 10 to 14 years of age that were consistently 0.5 hours higher compared with what we found. In our study, the parents were also asked about the duration of daytime sleep and napping habits from the period of birth to 7 years of age. For the most part, our results are in accordance with previous findings of Weissbluth.[22] All of these studies were conducted in countries with similar child-rearing practices and cultural influences (in North America, Continental Europe, and United Kingdom). Therefore, we propose that the percentile curves presented in this study can be applied to children in all Western societies.

As mentioned above, age-specific reference values for several sleep characteristics have been collected either by parental estimation or by more objective methods such as polysomnography.[5–12,23,24] Although sleep electroencephalographic studies may provide true physiologic values,[7,8] they have some significant methodological limitations, such as increased wakefulness during the night or lack of 24-hour recordings.[25] Thus, total sleep time determined by polysomnography is generally shorter than total sleep duration estimated by the time spent in bed. In 9-month-old infants, the mean nocturnal sleep time was 611 ± 52 minutes (672 ± 60 minutes in our study), whereas in 2-year-old infants 571 ± 79 minutes (690 ± 54 minutes) were obtained.[23] In school-age children, the mean total sleep time was 564 minutes at 9.5 years of age.[26]

Because it was not the principal objective to study gender differences or variations between term and preterm infants, the results of these comparisons are not illustrated. However, we could confirm previous reports, which found no differences in sleep duration between these groups.[6,11,13,27] For this reason, we included the entire study population to calculate percentiles.

The subjects in this longitudinal study were recruited from 1974 until 1993. A comparison of 3 birth cohorts (1974, 1979, and 1986) revealed a decreasing trend of the mean total sleep duration across cohorts (Fig 5). The cohort trend had to be taken into account during the modeling procedure of the percentile curves. It was most pronounced in infants and young children and decreased continuously up to adolescence. During the last decades, young children went to sleep later and later, but wake time remained unchanged. As a consequence, time spent in bed became shorter across cohorts. In preschool children, the parents determine bedtime, whereas with age, bedtime is increasingly self-determined by the child. Therefore, a more liberal parental attitude toward evening bedtime in the past decades is most likely responsible for the bedtime shift and for the decline of sleep duration across cohorts.

For simplicity, the percentile curves and the corresponding tables given in this report apply formally for children born approximately in 1990. Whether bedtime and therefore time spent in bed will continue to change across generations will depend on child-rearing practices in the future.

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HYPOCRISY OF GLOBALIZATION

"Since 1990, the number of people living on <$2 a day has risen by more than 100 million, to 3 billion. The gap between rich and poor countries has turned into a chasm. Even relatively prosperous parts of the developing world, such as Southeast Asia and Eastern Europe, have fallen into unprecedented slumps. 'Globalization today is not working for many of the world's poor'. . . It is not working for much of the environment. It is not working for the stability of the global economy. . . [for example] extension of patent agreements have guaranteed high profits for Western pharmaceutical companies like Pfizer and Merck while depriving African governments of the drugs they need to fight an AIDS epidemic. The critics of globalization accuse Western countries of hypocrisy. . . and the critics are right."

Joseph Steiglitz, quoted in Cassidy J. Master of disaster. *New Yorker Magazine.* July 15, 2002

Submitted by Student

Sleep Duration From Infancy to Adolescence: Reference Values and Generational Trends

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