Norms and Trends of Sleep Time Among U.S. Children and Adolescents

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Abstract

Objective: To develop national sleep norms conditional on age and to examine stratification by gender, race/ethnicity, and changes over time.

Design: Secondary analysis of a panel survey.

Setting: The three waves (1997, 2002, and 2007) of the Child Development Supplement of the Panel Study of Income Dynamics, a nationally representative survey.

Participants: Children from age 0 to 18 were included. After excluding children without time diary data, we were left with 2,832 children in 1997, 2,520 children in 2002, and 1,424 children in 2007.

Main Exposure(s): Age.

Outcome Measures: Minutes of sleep for daytime and total sleep.

Results: We estimate the 10th, 25th, 50th, 75th and 90th percentiles of the distribution of childrens' minutes of sleep conditional on age using a double-kernel estimator that incorporates sample weights. Total average sleep is over 13 hours a day for infants, declining steadily throughout childhood and early adolescence until it reaches about 9 hours a day for 14 to 18-year-olds. The estimated conditional percentiles are higher on weekends than on weekdays for older children. The conditional percentiles for weekend sleep minutes are flatter with respect to age than the weekday sleep minutes. The interquartile ranges are greater for children younger than 6 and for teenagers. The medians stratified by race/ethnicity and gender similar for most ages. For different survey years, the estimated medians are also quite similar.

Conclusion: Our estimates are consistent with the amount of sleep recommended for children,

and we find no evidence of racial/ethnic disparities.

Introduction

Anecdotal evidence—bruited about broadly in popular media—indicates that too many children in the US suffer from inadequate sleep, and that this problem is worsening over time. However, little empirical evidence exists to support this claim.[1] Poor sleep has been associated with behavioral problems including aggression and ADHD, as well as with poor sociability, learning disabilities, and obesity.[2-12] Yet despite the tremendous importance of adequate sleep to child health and development, and notwithstanding the intense interest of parents and pediatricians about what constitutes normal sleep and what are the determinants of inadequate sleep, far more remains to be learned about this topic than is reliably understood at present. Although sleep norms have been developed for some ages of children in Australia, Zurich, and Rome, there aren't representative sleep norms available in the U.S. context except for some estimates from the early 1980s, and little data are available to assess trends over time in sleep quantity.[13-18]

We used time-diary data from the Child Development Supplement of the Panel Study of Income Dynamics, a large, nationally representative survey, to develop national sleep norms for U.S. children and adolescents. We estimated norms for daytime and total sleep and examined stratification by gender and race/ethnicity and changes over time.

Methods

Study Sample

Panel Study of Income Dynamics (PSID) is a representative sample of U.S. individuals and families that originated in 1968 and is directed by the National Science Foundation.[19] Two independent samples made up the core 1968 sample.[20] Both were national in scope, a cross-sectional sample and a sample of low-income families. The cross-sectional sample was an equal probability sample of households from the 48 contiguous states.[20] The second sample, of low-income households, was selected from the Survey of Economic Opportunity that was conducted by the Bureau of the Census for the Office of Economic Opportunity.[20] In 1997, the instrument was changed to biennial data collection with a reduction in the core sample and an additional sample of post-1968 immigrant families.[20]

In 1997, the PSID added a component survey, the Child Development Supplement (CDS), funded by the National Institute of Child Health and Human Development.[21] Longitudinal data are available for these children in 2002 and 2007. The University of Michigan Survey Research Center, Ann Arbor, developed weights for each child to account for the complex sampling of the PSID.[19] This study sample includes infants, children, and youth through age 18 of both sexes and all of the racial/ethnic groups available in the CDS data file with available time diary data. We pooled the data from the CDS waves to develop the average daytime and nighttime sleep durations normalized by age and gender.

Variables and Measurement

The CDS covers a large array of developmental outcomes, demographics, behavioral and cognitive assessments and time-use diary data. Time-use diary data covers one randomly chosen week day and one randomly chosen weekend day between September and May in each survey

year.[19] Both primary and secondary activities are recorded for children for each 24-hour period. Having a week day and a weekend day are important because there is some evidence that sleep duration differs in these two periods.[7] When compared to direct observation, time-use diary data have been shown to have excellent validity.[22, 23] The primary outcome measures are the number of minutes of daytime and total sleep for weekdays and weekends.

We estimated the conditional medians for children by race/ethnicity to test whether there are disparities. Only children in the sample at least 12 years of age were asked to report their own race/ethnicity. The primary caregiver reported race/ethnicity for younger children. The categories were somewhat different, with children being asked to choose from the following: African-American, White, Hispanic, Asian/Pacific Islander, American Indian or Alaskan Native, Multi-racial, don't know or refused (in 2002 and 2007). When primary care givers were asked in 1997, they were able to choose from the following categories: White non-Hispanic, Black non-Hispanic, Hispanic, Asian or Pacific Islander, American Indian or Alaskan Native, other, don't know, and refused. We use consistent measures of race, using the "Multi-racial" category for cases where the child's self-reported and the report of the primary care giver do not match. We used the categories of White, Black, Latino and all others because there were too few observations for the Asian/Pacific Islander, American Indian, Alaskan Native, and Multi-racial categories for us to separately estimate these conditional medians.[24]

Statistical Methods

We used a weighted, double-kernel non-parametric quantile regression to estimate the conditional quantile functions, incorporating sample weights in the local-linear kernel weights.[24-

[26] This method provides smoothed estimates of conditional quantiles, conditional on the child's age, gender and race/ethnicity. We used the automatic bandwidth selection procedures and median corrections described in Li, Graubard, and Korn 2010. This technique allows for nonparametric estimation of the conditional quantiles while also allowing us to incorporate the sample weights—crucial for the development of national norms. We obtained the statistical code, written in R, from Yan Li's personal webpage.[27] We used bootstrapping to gauge the statistical significance of the differences in median, using the same bandwidth for each replicate that was chosen for the original data.[28]

We estimate the 10th, 25th, 50th, 75th and 90th percentiles of the distribution of the number of minutes of sleep conditional on age for daytime and total sleep. Following other analyses[14], we estimate the conditional quantiles for daytime sleep only for those children with positive values. We estimate the conditional quantiles separately for weekday and weekend sleep and used a weighted average of these values to get an estimate of overall sleep patterns for the entire week. We also compute the medians of the distribution of the average total number of minutes of sleep for boys and girls and by racial/ethnic group. To test changes in sleep quantity over time we separately estimate the conditional quantiles for the 1997, 2002, and 2007 waves of the CDS, and test the differences in results for same-age children at different survey waves.

For the development of norms, in which it is important to have nationally representative estimates, the analysis will use sampling weights from the 1st wave of the Child Development Supplement weighted by the number of times each child appears in the 1997, 2002, and 2007 waves.[28] Because the population itself changes over time, there is no single set of survey weights

that will make individual survey waves representative both of the population at the time they were sampled and of the population at the time of analysis. Any attrition in the sample over time will exacerbate this problem. The original sampling in the PSID oversampled African Americans and the poor.

Attrition since that time has been relatively uniform across all groups, but has been slightly higher among male-headed households and among those in the South.

Results

Sleep-time diary data for at least one weekday or one weekend day was available for 2,832 children in 1997, 2,520 children in 2002, and 1,424 children in 2007. The decline in sample size is primarily due to children aging out of the sampling window (up to age 13, 18, or 19 depending on the survey wave).[19] The response rate was 88% of eligible children in 1997; 91% of eligible children in 2002; and 90% of eligible children in 2007.[19] Table 1 presents the numbers of children in each survey wave with time-diary information, along with average ages, age ranges, race/ethnicity, and gender.

Figure 1 shows the weighted estimated conditional percentiles of sleep for weekdays, weekends, and overall. Because of the relatively few observations for the ends of the age distribution as well as the poor performance of kernel smoothers at the ends of data distributions, figures show the results only for the middle 95%, although the entire sample was used for estimation.

The estimated conditional percentiles for sleep time are higher on weekends than on weekdays

for older children (Figure 1, panels A and B). The conditional percentiles for weekend sleep minutes are flatter with respect to age than the weekday sleep minutes (Figure 1, panels A and B). The interquartile ranges are greater for children younger than 6 and for teenagers than for children in the middle of the age range (Figure 1, panel C).

There are very few children in the sample with no daytime sleep at very young ages.
The estimated conditional percentiles for daytime sleep are much higher for infants (Figure 1, panels D, E and F). The amount of daytime sleep falls sharply until approximately the age children enter school. The estimated conditional quantiles for daytime sleep for weekend and weekday sleep are very similar but the amount of daytime sleep is higher on weekdays for children under 5 and generally higher on weekends for all but the 90^{th} percentile for older children (Figure 1, panels D and E). Panels D-F of Figure 1 report daytime sleep across all children, including those who engage in none. The proportion of infants who have at least some daytime sleep is approximately 95%. This figure falls throughout the first 5 years of life, until it reaches 14% by age 10, thereafter it rises again, reaching 28% by age 14. Estimates of the quantity of these naps were highly unstable, but generally varied from 30-90 minutes.

The medians by race/ethnicity are similar for most ages (Figure 2, panel A). The median for African-Americans and Whites tracks very closely till about 5 years of age; then the median for African-American children dips below the median of white children by about 10 minutes, with a maximum difference of 15 minutes at age 7, until age 12-13 before rising slightly to a maximum difference of 10 minutes at age 16 (Figure 2, panel A). The median for Latino children is higher than the medians for African-American and white children except for between the ages of 5-8

(Figure 2, panel A). After around age 9, Latino children average about 19 more minutes per night of sleep than White children. While this difference between whites and Latinos is statistically significant for several years, it is not clinically meaningful. The estimated medians for Latino children and for all others are less smooth than the other median because the sample size is smaller. The medians for girls and boys are virtually identical for the entire range and cross each other a few times (Figure 2, panel B). Again, the differences are not statistically significant.

The estimated medians for the different survey years are also quite close (Figure 3). The medians for 2002 and 2007 are higher than the 1997 median for the overlapping age range by about 1-13 minutes; the range of difference between 2002 and 2007 is 1-15 minutes (Figure 3). These differences, too, are not statistically significant.

Comment

While the amount of sleep children need differs by child, recommendations cited by the Centers for Disease Control and Prevention are for 12-14 hours for children age 1-3 years, declining to 11-13 hours for children age 3-5, to 10-11 hours for children age 5-10, and 8.5-9.5 for adolescents.[29, 30] The estimates presented here mirror this range quite well and suggest that children in the US are getting an appropriate amount of sleep on average. We find no evidence of a decrease in sleep quantity over the 10-year period of these data, and no evidence of clinically meaningful racial/ethnic disparities in the amount of sleep among children and youth.

Across all ages, the range of estimates is relatively symmetric around the median, which is what

one would expect from biological differences in need, and suggests that it is plausible that there are no significant constraints on children's sleep time. One caveat to this conclusion is that we find no evidence of an increase in sleep time during adolescence, which some authorities have suggested would be appropriate.

Our estimates provide a slightly different picture of the sleep duration of children than previous studies, including the Iglowstein et. al. 2003 study that used data from participants in the Zürich Longitudinal Studies.[14] Our estimates of the age-conditional quantiles are flatter than those estimated in Iglowstein et. al. so our estimates are lower for very young children, closer for children around 8 years of age and higher for older children. The difference in results may be attributable to their smaller sample size (453 children) or to the fact that sleep duration in that study was calculated based on maternal report of the child's "usual" bedtime and wake time, reported by 30-minute increments. That study also assumed a normal distribution of sleep duration in the data and estimated the mean and standard deviation of this distribution conditional on age and gender. Given that those data, as well as the data used here, do indeed exhibit a symmetric, normal distribution, the method used by Iglowstein et al is both reasonable and statistically efficient. At the same time, the method used here is more flexible, and may have identified some subtler changes across ages.

The Zürich study found a decrease in total sleep quantity over time that varied with child age. From 1974 to 1986 total sleep time of 2-year-olds was estimated to have decreased by approximately 40 minutes per day. This differential was steadily smaller for older children, and non-existent for 16-year-olds. This difference between this result and the result reported here of

no change over time may be due to differences between Zürich and the U.S., to differences in the time period assessed, or to differences in study methodology.

A U.S. study published in 2004 used a stratified random sample of births at a few hospitals in Cleveland, Ohio and sleep journals and questionnaires to assess sleep duration in children from 8 to 11 years old.[31] The authors found that mean sleep time decreased with age, with 10-11 year olds sleeping about 18 minutes less than 8 year olds.[31] Despite using very different methods, our estimates of the median of total sleep for 10-11 year olds was about 16-26 minutes less than our estimate of the median for 8 year olds. While the conditional median for boys was lower than for girls from ages 8-10 in our study, we did not find that this difference was statistically significant at the 5% level—unlike the results of the Cleveland study which showed a statistically significant difference between the mean sleep times of boys and girls with boys getting less sleep.[31]

There have been a few other quantitative studies using U.S. samples from earlier time periods.[16-18] A study published by Terman and Hocking in 1913 contained information on school children from age 6-18 from California, Oregon, and Arizona.[16] These authors looked at average sleep durations for children attending school and also did not find differences in the average sleep durations of boys and girls.[16] Their estimates differed from our estimates of the median at earlier ages—they had longer durations by 45 minutes at most—but the gap narrowed to less than 2 minutes for children 14-15. Our durations were slightly longer for children at least 16 years of age. A study using data from 1980 used a sample of parents visiting 3 general practitioners and was predominantly white.[17] For children age 0-16, the means estimated in the Weissbluth et al.

were greater than the estimated median from our study (by at most one hour). The gap narrowed at older ages. Weissbluth et al. matched our results in that they also did not find a statistically significant difference between boys and girls.

Part of the differences in the results of our study from historical studies is due to the difference in our estimation of the median instead of the mean and that our sample is derived from a survey designed to be representative sample of the U.S. in 1968. The earlier estimates that span most of our age range are not random samples and were taken for very different populations in very different times. It is also possible that sleep durations have shortened for young children and lengthened for older children compared to 1913 data or have generally shortened for most children compared to 1980 data.

The trend data presented here focus on a relatively narrow time frame: from 1997 to 2007. It may be that the quantity of sleep that children receive has changed over a longer time horizon, or is changing slowly enough so that a 10-year period is insufficient to adequately estimate these changes. If so, we hope that these estimates will provide a solid baseline against which future estimates of child sleep may be assessed.

We are aware that there are several dedicated sleep questionnaires that have been developed and validated for children.[32] The use of time diary data will not be as valid *for individuals* as one of these dedicated sleep screeners. However, the time diary data do permit accurate estimate of the median values of sleep, since the errors in time diary data should be randomly distributed. Data were collected during the school year and may not necessarily reflect sleep patterns during the

summer.

The typical school-age child sleeps about 10 hours a night. Older children sleep a little less; younger children a little more. A typical toddler sleeps about 11.5 hours a night. These estimates are consistent with the amount of sleep children typically need, and we find no evidence of racial/ethnic disparities or changes over time. Although sleep is a cause of anxiety for parents, who often overestimate their children's sleep requirements,[33] the evidence suggests that in fact parents may be more competent than perhaps they realize.

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Figures

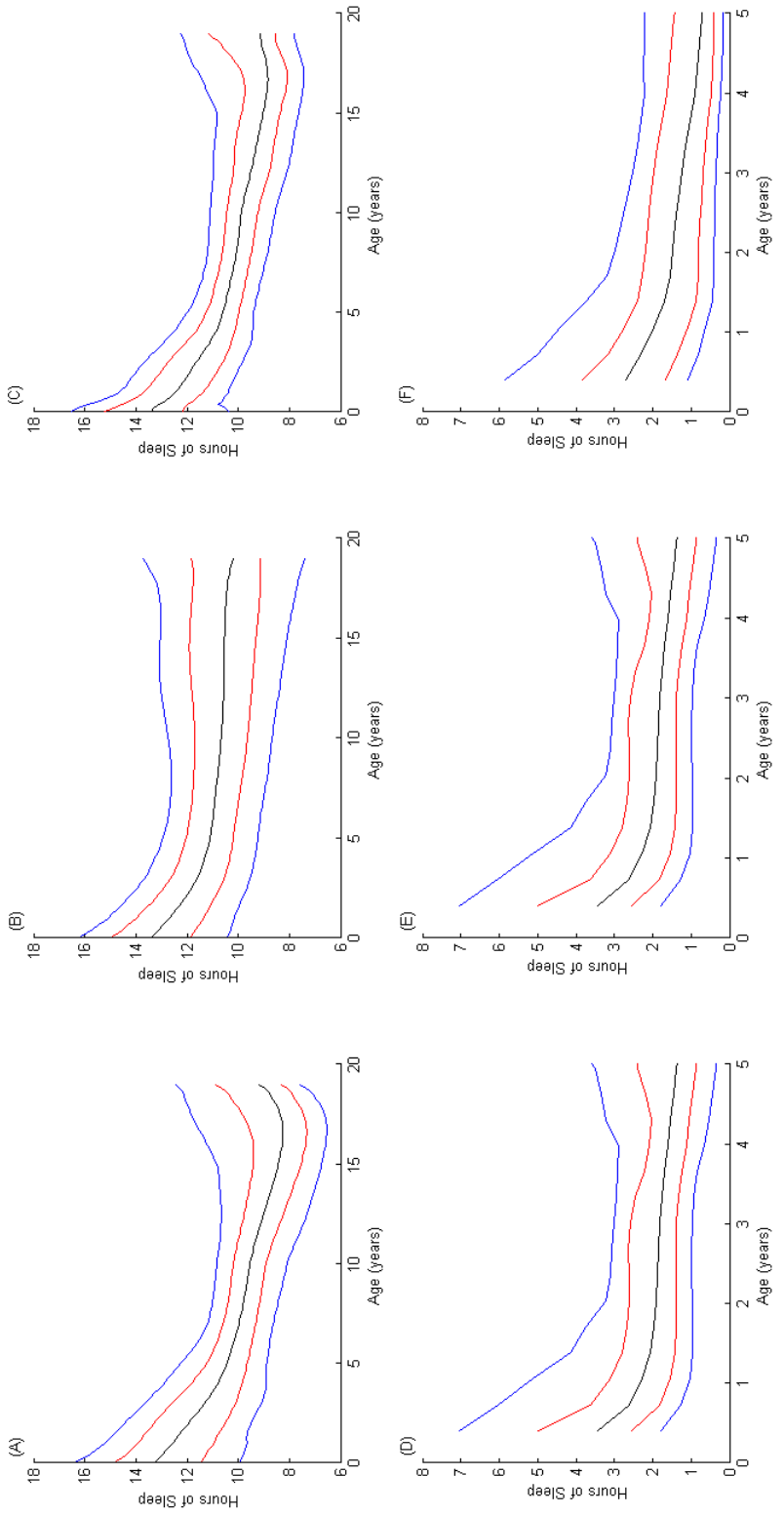

Figure 1, Age-conditional 10th, 25th, 50th, 75th and 90th percentiles of the distribution of childrens' number of minutes of sleep for weekdays, weekends, and overall (A) Conditional percentiles for weekend total sleep. (B) Conditional percentiles for weekday total sleep. (C) Conditional percentiles for overall sleep. (D) Conditional percentiles for weekend daytime sleep through age 5. (E) Conditional percentiles for weekday daytime sleep through age 5. (F) Conditional percentiles for overall daytime sleep through age 5.

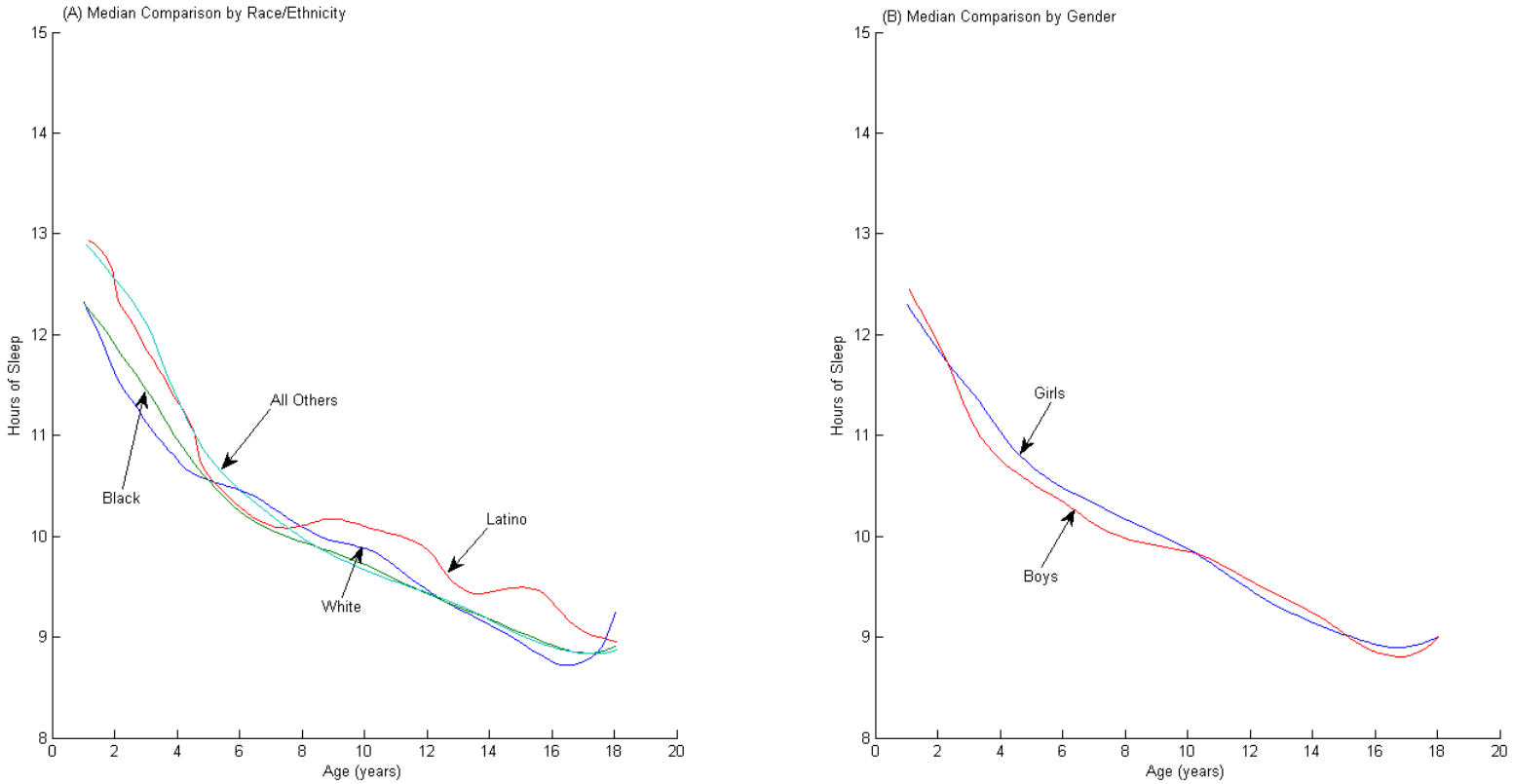

Figure 2: Median Comparisons by Race/Ethnicity and Gender

(A) Medians of the distribution of childrens' sleep by race/ethnicity. (B) Medians of the distributions of childrens' sleep by gender.

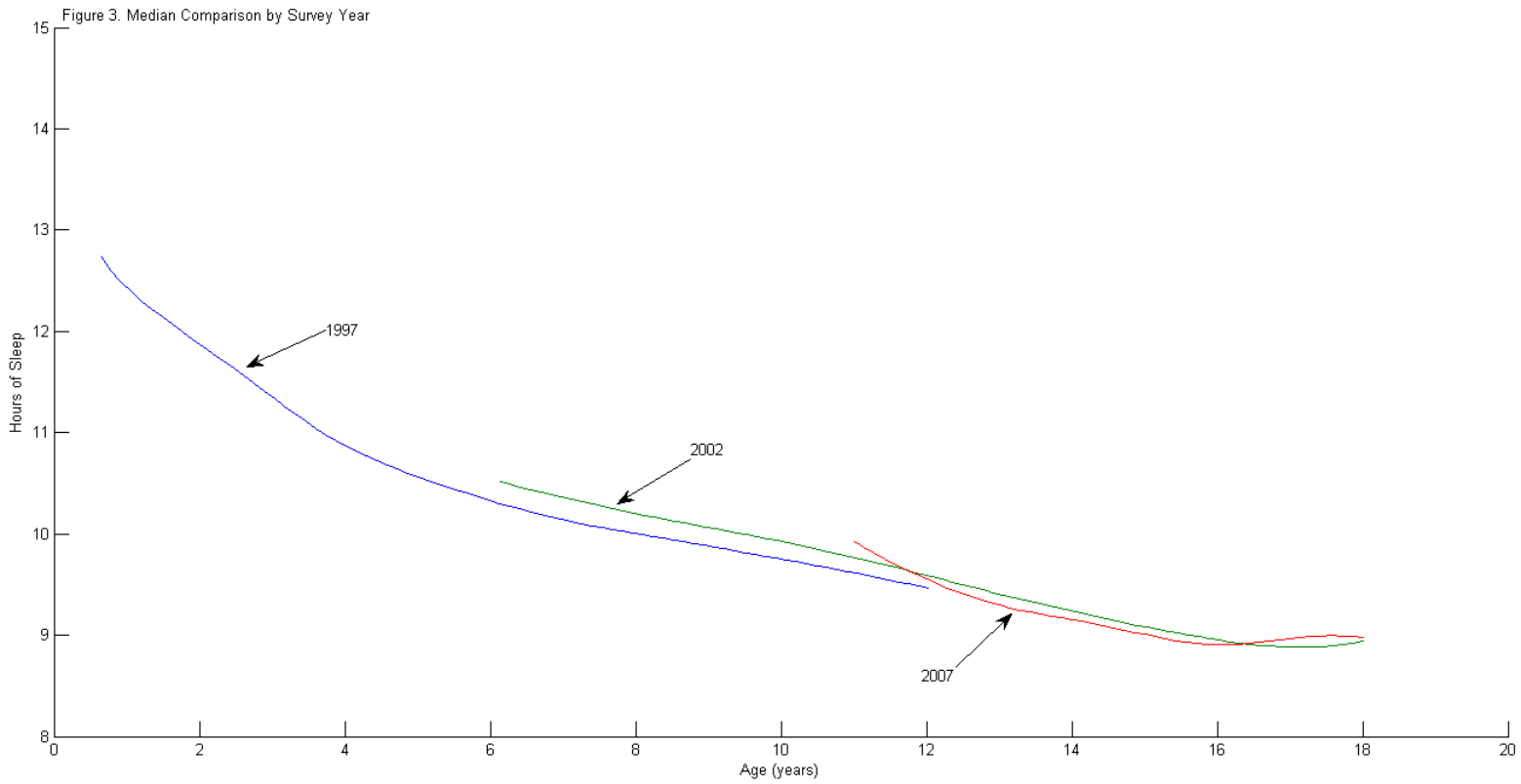

Figure 3: Median Comparison by Survey Year

This figure shows the age-conditional medians estimated by survey year for 1997, 2002, and 2007

Table 1: Descriptive Statistics of Sample Children

	Survey Wave Year		
	1997	**2002**	**2007**
N	2,832	2,520	1,424
Age, mean ± SD	6.21 ± 3.75	11.62 ± 3.73	14.01 ± 2.19
Age, range [max – min]	13.92	14	9
Race/Ethnicity			
White, N (%)	1,384 (48.96)	1,204 (47.91)	688 (48.38)
Black, Non-Hispanic, N (%)	1,088 (38.49)	1,000 (39.79)	555 (39.03)
Latino, N (%)	206 (7.29)	191 (7.6)	116 (8.16)
Other, N (%)	149 (5.27)	118 (4.7)	63 (4.43)
Gender			
Girls, N (%)	1,454 (51.34)	1,262 (50.08)	727 (51.05)
Boys, N (%)	1,378 (48.66)	1,258 (49.92)	697 (48.95)

This table gives descriptive statistics for children with reported time diary data in the three waves of the CDS I, II, and III.