Norms and Trends of Sleep Time Among US Children and Adolescents

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Abstract

Objectives—To develop national sleep norms conditional on age and to examine stratification by sex, race/ethnicity, and changes over time.

Design—Secondary analysis of a panel survey.

Setting—The 3 waves (1997, 2002, and 2007) of the Child Development Supplement of the Panel Study of Income Dynamics, a nationally representative survey.

Participants—Children from birth to 18 years with time-diary data were included: 2832 children in 1997, 2520 children in 2002, and 1424 children in 2007.

Main Exposure—Age.

Main Outcome Measures—Minutes of sleep for daytime and total sleep.

Results—The 10th, 25th, 50th, 75th, and 90th percentiles of the distribution of children's minutes of sleep conditional on age were estimated using a double-kernel estimator that incorporates sample weights. Total average sleep was estimated at more than 13 hours a day for infants, decreasing steadily throughout childhood and early adolescence, reaching about 9 hours a day for 14- to 18-year-olds. The estimated conditional percentiles were higher on weekends than on weekdays for older children. The conditional percentiles for the weekend sleep minutes were flatter with respect to age than the weekday sleep minutes. The interquartile ranges were greater for children younger than 6 years and for teenagers. The medians stratified by race/ethnicity and sex were similar for most ages. For different survey years, the estimated medians were within a few minutes of each other.

Conclusions—These estimates are consistent with the amount of sleep recommended for children, and no evidence was found of racial/ethnic differences.

Anecdotal evidence—frequently rehashed in popular media—indicates that too many children in the United States experience 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 attention-deficit/hyperactivity disorder, 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 duration norms based on random, representative samples of the population have been developed for some ages of children in Australia, Zurich, and Rome, there are few comparable data for the United States.[13–19]

This analysis uses time-diary data from the Child Development Supplement (CDS) of the Panel Study of Income Dynamics (PSID), a large, nationally representative survey, to develop national sleep norms for US children and adolescents. The primary aim of the study was to estimate the empirical distribution of minutes of sleep conditional on age in order to describe norms of sleep by age. Secondary aims included estimating age-conditional median sleep by sex and race/ethnicity and estimating changes over time in the median.

METHODS

STUDY SAMPLE

The PSID is a national sample of US individuals and families that originated in 1968 and is directed by the National Science Foundation.[20] Families have been followed up continually, and as the children in the original families have grown and created their own families, they, too, have been followed up. Low-income families were originally oversampled, and in 1997, an additional sample of post-1968 immigrant families was added to ensure adequate representativeness of these important groups.[21]

In 1997, the PSID added the CDS, funded by the National Institute of Child Health and Human Development.[22] During the 1997 wave, as many as 2 children from birth to 12 years old were randomly selected from 2705 PSID families; 88% of the families were successfully interviewed (3563 children).[23] These original respondents, aged 5 to 18 years in 2002, whose families were still active in the PSID (3480 children) were re-contacted, with 91% of families responding (2907 children).[23] By 2007, 1676 of the children who completed the 2002 wave were eligible for reinterview and 1506 children completed the third wave (90%).[23] The University of Michigan Survey Research Center developed weights for each child to account for the complex sampling of the PSID.[20] This study sample includes infants, children, and youth through age 18 with available time-diary data from the 1997, 2002, and 2007 waves of the CDS.

The CDS in 1997 was representative of the US population in 1997 when sample weights were used.[24] A 2012 assessment of the representativeness of the 2007 CDS sample, compared with the American Community Survey, found that it provided a good

representation of the corresponding populations and covered approximately 97% of the US population.[25]

This study was certified as exempt by the UCLA Institutional Review Board.

VARIABLES AND MEASUREMENT

The CDS covers a large array of developmental outcomes, demographic characteristics, and behavioral and cognitive assessments. In addition, it measures time spent in all of a child's activity, including sleeping, using time-diary data.[20] For each of 2 randomly chosen days (1 weekend and 1 weekday) in September and May, participants were asked to keep a prospective diary of their child's activity during a 24-hour period. Time-diary data have been used extensively in social scientific research,[26–32] have excellent validity compared with other methods,[28] and are less susceptible than direct observation to a Hawthorne effect.[29]

Sleep can be accurately measured using electroencephalography, polysomnography, and actigraphy, but these methods are not feasible in large-scale population surveys necessary to establish sleep norms.[33] A comparison of child- and adolescent-reported sleep time to actigraphy found high correlations of the 2 measures, but systematic overestimation of sleep through self-report, because self-report misses nighttime wakefulness captured by actigraphy.[34] It is expected that time-diary data would have similar strengths and weaknesses: high correlation but systematic overestimation of total sleep.

Including a weekday and a weekend day is important because there is some evidence that sleep duration differs in these 2 periods.[7] The primary outcome measures are the number of minutes of daytime and total sleep for weekdays and weekends. Daytime sleep was derived from time-diary entries for naps and resting, including activities such as "dozing."[22]

Children in the sample at least 12 years of age were asked to report their race/ethnicity, and the primary caregiver reported race/ethnicity for all children. Race/ethnicity was coded as white non-Hispanic, black non-Hispanic, Hispanic, or other. The "other" category was assigned when the child's self-report and that of the primary caregiver did not match.

STATISTICAL ANALYSIS

A weighted, double-kernel nonparametric quantile regression was used to estimate the conditional quantile functions, with sample weights incorporated in the local-linear kernel weights.[35–37] This method provides smoothed estimates of conditional quantiles, conditional on the child's age, sex, and race/ethnicity. The analysis used the automatic bandwidth selection procedures and median corrections described by Li et al.[35] All analyses were conducted using statistical code, written in R.[38] Bootstrapping was used to appropriately test the statistical significance of the differences in median, using the same bandwidth for each replicate that was chosen for the original data.[39]

The 10th, 25th, 50th, 75th, and 90th percentiles of the distribution of the number of minutes of sleep were estimated conditional on age for daytime and total sleep. Following previous analyses,[14] the conditional quantiles for daytime sleep were estimated only for those children with positive values. Conditional quantiles were estimated separately for weekday

and weekend sleep, and a weighted average of these values was calculated to get an estimate of overall sleep patterns for the entire week.

The medians of the distribution of the total number of minutes of sleep were then calculated separately for boys and girls and by racial/ethnic group. To test changes in sleep quantity over time, the conditional quantiles for the 1997, 2002, and 2007 waves of the CDS were estimated separately.

For the development of norms, it is important to have nationally representative estimates. Because the population itself changes over time, there is no single set of survey weights that will make individual survey waves representative 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. 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.[20] The approach taken here used sampling weights from the first wave of the CDS, inversely weighted by the number of times each child appears in the 1997, 2002, and 2007 waves.[39] Accordingly, these norms are valid for the US population as it existed in 1997. Although it would have been preferable to have norms representative of the 2007 US population, doing so would place more of the burden for representativeness on the post-sampling weights rather than on the randomized sampling scheme itself. Using the 2007 weights would have introduced bias to the extent that the attritted participants were unlike the continuing participants in their sleep patterns.

RESULTS

The Table presents the numbers of children in each survey wave with time-diary information, along with mean ages, age ranges, race/ethnicity, and sex. Because of the survey design, there are more observations of sleep duration in the middle of the age range, 2088 observations for 9- to 12-year-olds, than for other age ranges: 1083 for children aged birth to 4 years, 1478 for 5- to 8-year-olds, 1583 for 13- to 16-year-olds, and 541 for 17- to 19-year-olds.

Figure 1 shows the estimated 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 for the middle 95% of the age distribution, although the entire sample was used for estimation.

Sleep times are higher on weekends than on weekdays for older children (Figure 1A–B). Weekend sleep minutes are flatter with respect to age than the weekday sleep minutes (Figure 1A–B). The interquartile ranges are greater for children younger than 6 years and for teenagers than for children in the middle of the age range (Figure 1C). There are 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 1D–F). The amount of daytime sleep decreases sharply until approximately the age children enter school. The quantiles for daytime sleep for weekend and weekday sleep are similar, but

the amount of daytime sleep is higher on weekdays for children younger than 5 and generally higher on weekends for all but the 90th percentile for older children (Figure 1D–E). Figure 1D–F shows the quantiles of daytime sleep for children younger than 5. The proportion of infants who have at least some daytime sleep is 96.0%. This proportion decreases to 18.7% by age 10 but rises again to peak at 34.1% at age 17. Estimates of the duration of these naps for children older than 5 were highly unstable but generally varied from 30 to 90 minutes.

The medians by race/ethnicity are similar for most ages (Figure 2A). The median for blacks and whites tracks closely until approximately 5 years of age; then the median for black children dips below the median for white children by about 10 minutes, with a maximum difference of 15 minutes at age 7, until age 12 to 13 before rising slightly above the median for white children to a maximum difference of 10 minutes at age 16 (Figure 2A). The median for Hispanic children is higher than the medians for black and white children except for between the ages of 5 and 8 (Figure 2A). After age 9, Hispanic children average 19 more minutes per night of sleep than white children. Although this difference between whites and Hispanics is statistically significant for several years, it is quantitatively small. The estimated medians for Hispanic children and for all others are less smooth with respect to age than the other medians 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 2B). Again, the differences are not statistically significant.

The estimated medians for the different survey years are only 15 minutes apart at their widest gap (Figure 3). The medians for 2002 and 2007 are higher than the 1997 median for the overlapping age range by approximately 1 to 13 minutes; the range of difference between 2002 and 2007 is 1 to 15 minutes (Figure 3). These differences are not statistically significant.

COMMENT

Although the amount of sleep children need differs by child, recommendations cited by the Centers for Disease Control and Prevention are for 12 to 14 hours for children aged 1 to 3 years, decreasing to 11 to 13 hours for children aged 3 to 5, to 10 to 11 hours for children aged 5 to 10, and to $8^1/_2$ to $9^1/_2$ hours for adolescents.[40] The estimates presented here mirror this range quite well and suggest that children in the United States are getting an appropriate amount of sleep on average. There is no evidence of a decrease in sleep quantity during the 10-year period of these data and no evidence of clinically meaningful racial/ethnic differences 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 this symmetry suggests that it is plausible that there are no significant constraints on children's sleep time. One caveat to this conclusion is that there is no evidence of an overall increase in sleep time during adolescence, which some authorities have suggested would be appropriate.[41]

Both biological and social factors, such as school start times, may be responsible for the sleep patterns of adolescents.[41] Sleep timing is generally independent of sleep duration.[42–44] Consistent with previous research, this analysis does not find a sex difference in the age-conditional medians.[44,45]

Teenagers sleep longer on weekends, which is consistent with other research suggesting that adolescents catch up on sleep on non–school nights.[46] The decrease in total sleep until age 16 to 17 is consistent with research[45] finding a decrease in melatonin during puberty. These estimates are quite similar to a recent study[47] using 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.

Random-digit telephone surveys conducted by the National Sleep Foundation in 2004 and 2006 used a parental-report measure of typical sleep.[19] Compared with the results here, the National Sleep Foundation results suggested less sleep for those younger than 5, as well as for adolescents in grades 6 to 12.[19] The different sample, data collection instrument, and statistical methods may play a role in the different results.

The results here are broadly similar to those of a recent systematic review[48] that combined data across countries and estimated means and 95% CIs for infants and children aged birth to 12. One of the included studies[14] used data from participants in the Zurich Longitudinal Studies. These estimates are lower for very young children, closer for children approximately 8 years of age, and higher for older children. The difference in results may be attributable to their smaller sample size (453 children); to the fact that sleep duration in that study was calculated on the basis of maternal report of the child's usual bedtime and wake time, reported by 30-minute increments; to cross-country differences; or to change over time.[14,27,49] That study[14] also assumed a normal distribution of sleep duration in the data and estimated the mean (SD) of this distribution conditional on age and sex. 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[14] is reasonable and statistically efficient. At the same time, the method used here is more flexible and may have identified some subtler changes across ages.

Research using Internet-based surveys has found cross-country differences in sleep patterns. Young children from predominantly Asian countries got less sleep overall than young children from predominantly white countries.[48–52]

There have been a few other quantitative studies using US samples from earlier periods.[16–18] A study published by Terman and Hocking[16] in 1913 contained information on schoolchildren from California, Oregon, and Arizona. For young children, their estimates were longer than the estimates presented here by 45 minutes at most—but the gap narrowed to less than 2 minutes for children aged 14 to 15. For children at least 16 years of age, the Terman and Hocking estimates are slightly lower than those presented here. A study[17] using data from 1980 produced results similar to the 1913 Terman and Hocking estimates and also did not find a statistically significant difference between boys and girls.

Differences between the current analysis and studies conducted in the 20th century may arise for several reasons. The earlier estimates were not random samples and reflect white and generally more affluent populations than the United States as a whole. Because this analysis finds very small differences by racial/ethnic group, if the different sample makeup is driving the differences in result, it would most likely be related to unobserved, sleep-related attributes of the sample rather than to racial/ethnic differences. Previous samples were smaller so differences could be attributable to random variations. Finally, it is possible that sleep durations have shortened modestly for young children and lengthened even more modestly for older children compared with 1913 or 1980.

The trend data presented here focus on a relatively narrow time frame: from 1997 to 2007. The finding of no trend may reflect that the quantity of sleep that children receive is changing slowly enough that a 10-year period is insufficient to estimate these changes or that sleep is not decreasing over time.[1] The nationally representative estimates presented in this article provide a solid nationally representative baseline against which future estimates of child sleep may be assessed, helping to clarify any time trends in sleep duration.

There are several limitations to the current analysis. Self-report data tend to overestimate total sleep time, and it is expected that time diaries would have a similar weakness. These estimates should be interpreted in that light. For clinical communication, however, the estimates presented here may be more meaningful to parents and their children precisely because the kinds of bias from parental report during clinical encounters are similar to those present in these data. Data were collected during the school year and may not necessarily reflect sleep patterns during the summer.

In conclusion, the typical school-age child sleeps approximately 10 hours a night. Older children sleep a little less and younger children a little more. A typical toddler sleeps approximately $11^1/_2$ hours a night. These estimates are consistent with the amount of sleep recommended for children, and these results present no evidence of racial/ethnic differences or changes over time.

These results are presented as norms of sleep in the sense of what normally occurs, not necessarily what is healthy. These norms may have several uses.

The empirical conditional distribution of children's sleep presented here may be used by physicians and parents to determine when a child is far from the median of the distribution as a signal that that child's sleep patterns may need further assessment. They may also be used to guide further work about the amount of sleep that is optimal for children by providing a reference to how much sleep children in the United States are actually getting. Finally, these results may be used to inform research on trends in children's sleep over time.

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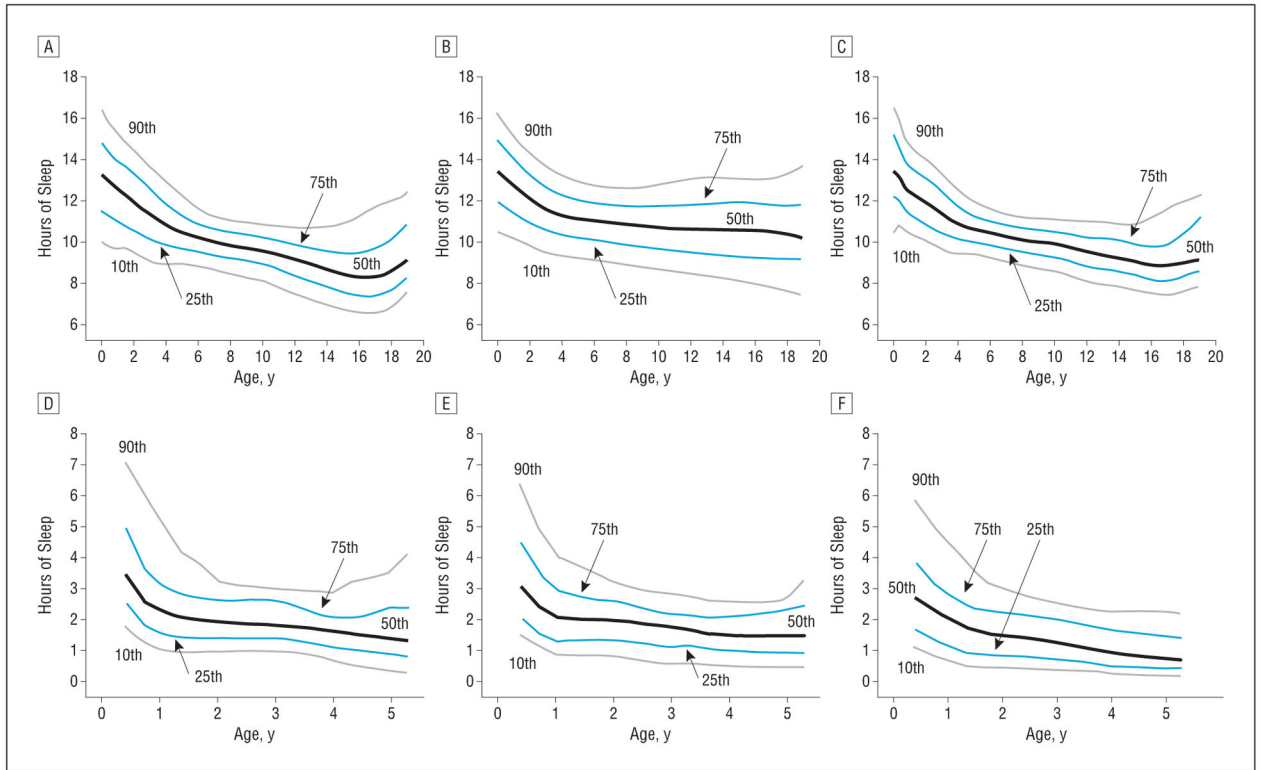
Figure 1.
Age-conditional 10th, 25th, 50th, 75th, and 90th percentiles of the distribution of children's number of minutes of sleep for weekdays, weekends, and overall. A, For weekday total sleep; B, for weekend total sleep; C, for overall sleep; D, for weekday daytime sleep through age 5; E, for weekend daytime sleep through age 5; F, for overall daytime sleep through age 5.
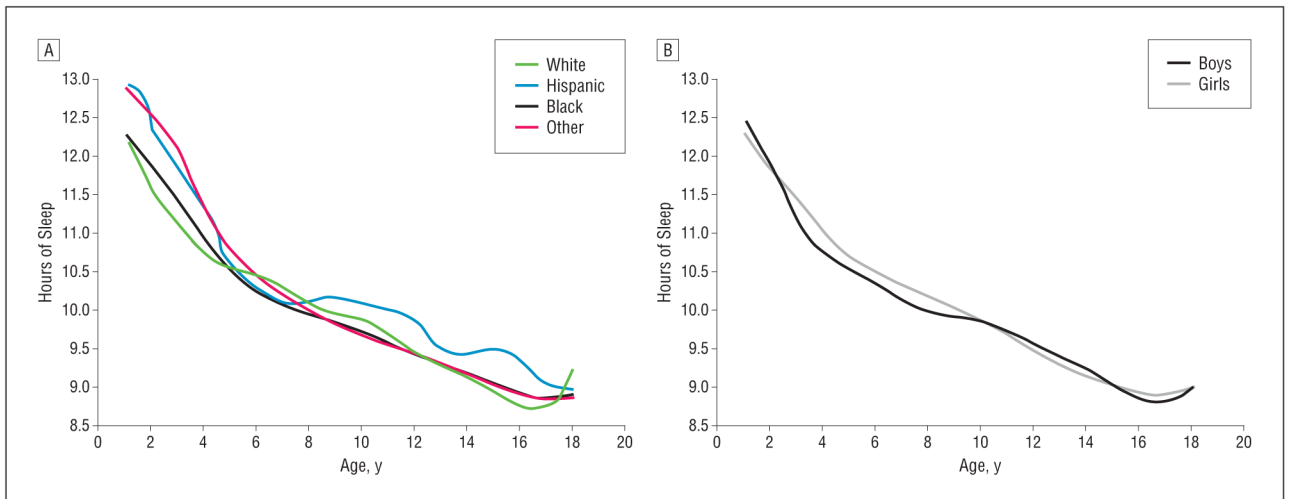
Figure 2.
Median comparisons of the distribution of children's sleep by race/ethnicity and sex. A, By race/ethnicity; B, by sex.
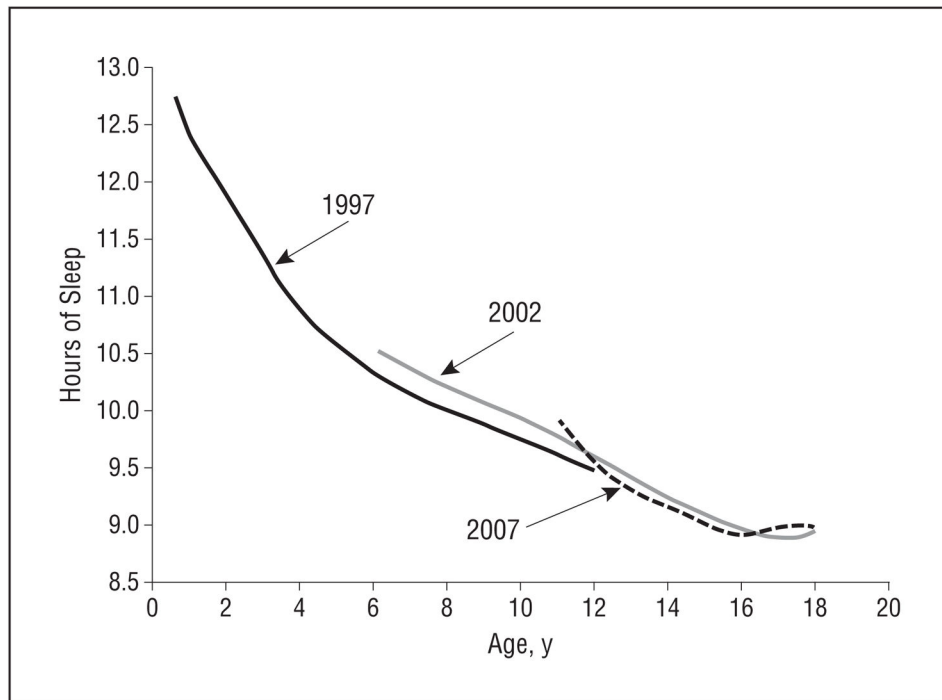
Figure 3.
Median comparison by survey year. This figure shows the age-conditional medians estimated by survey year for 1997, 2002, and 2007.

Table

Descriptive Statistics of Sample Children[a]

Variable	Survey Wave, y		
	1997	**2002**	**2007**
No.	2832	2520	1424
Age, mean (SD)	6.2 (3.8)	11.6 (3.7)	14.0 (2.2)
[range], y	[0–13][b]	[5–19]	[10–19]
Race/ethnicity, No. (%)			
White, non-Hispanic	1384 (48.9)	1204 (47.8)	688 (48.3)
Black, non-Hispanic	1088 (38.4)	1000 (39.7)	555 (39.0)
Hispanic	206 (7.3)	191 (7.6)	116 (8.1)
Other	149 (5.3)	118 (4.7)	63 (4.4)
Sex, No. (%)			
Girls	1454 (51.3)	1262 (50.1)	727 (51.1)
Boys	1378 (48.7)	1258 (49.9)	697 (48.9)

[a]This table gives descriptive statistics for children with reported time-diary data in the 3 waves of the Child Development Supplement I, II, and III.

[b]One child was 13 at the start of the survey process but turned 14 before it was completed.