

Sleep Patterns and Sleep Disruptions in School-Age Children

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This study assessed the sleep patterns, sleep disruptions, and sleepiness of school-age children. Sleep patterns of 140 children (72 boys and 68 girls; 2nd-, 4th-, and 6th-grade students) were evaluated with activity monitors (actigraphs). In addition, the children and their parents completed complementary sleep questionnaires and daily reports. The findings reflected significant age differences, indicating that older children have more delayed sleep onset times and increased reported daytime sleepiness. Girls were found to spend more time in sleep and to have an increased percentage of motionless sleep. Fragmented sleep was found in 18% of the children. No age differences were found in any of the sleep quality measures. Scores on objective sleep measures were associated with subjective reports of sleepiness. Family stress, parental age, and parental education were related to the child's sleep-wake measures.

The critical role of sleep and sleep disturbances in child development has been repeatedly demonstrated. The causal relationships between sleep problems and children's well-being appear to be bidirectional (Dahl, 1996b; Sadeh, 1996; Sadeh & Gruber, 1998). Just as sleep could be a symptom of child psychopathology or a significant stressor in a child's life, psychopathology could result from or be exacerbated by insufficient sleep and consequent fatigue and sleepiness. Sleep problems are among the prominent clinical symptoms and diagnostic criteria of several emotional disorders such as affective disorders, posttraumatic stress disorder, and anxiety disorders (American Psychiatric Association, 1994; Dahl, 1996b; Dahl & Puig-Antich, 1990; Ford & Kamerow, 1989; Sadeh & Gruber, 1998; Sadeh, McGuire, et al., 1995; Wolfson & Carskadon, 1998). In early childhood, disturbed sleep has been associated with difficult temperament (Carey, 1974; Novosad, Freudigman, & Thoman, 1999; Owens et al., 1997; Sadeh, Lavie, & Scher, 1994; Schaefer, 1990; Van Tassel, 1985; Weissbluth & Liu, 1983; Zuckerman, Stevenson, & Baily, 1987).

Of particular interest is the relationship between sleep problems and neuropsychological functioning in children. Sleep disruptions have often been implicated in attention deficit hyperactivity disorder (ADHD) in children, because sleep deprivation and the resultant sleepiness could lead to ADHD-like symptoms (Chervin, Dillon, Bassetti, Ganoczy, & Pituch, 1997; Corkum, Tannock, & Moldofsky, 1998; Dahl, 1996b). Despite the disturbing lack of studies on the relationships between sleep and cognitive functioning in children, there are clear indications that learning and attention skills could be significantly compromised by insufficient sleep or sleep disruption (e.g., Dahl, 1996a, 1996b; Epstein, Chillag, & Lavie, 1998; Gozal, 1998; Hansen & Vandenberg, 1997; Marcotte

et al., 1998; Randazzo, Muehlbach, Schweitzer, & Walsh, 1998; Wolfson & Carskadon, 1998).

Despite the growing awareness in the scientific community of the need for normative developmental data on children's sleep and its disorders, such data are still lacking. Most of the sleep studies that have used objective measures to assess sleep (e.g., polysomnography) have focused on the periods of infancy and adolescence (Sadeh & Gruber, 1998). Furthermore, most of the research on children's and adolescents' sleep patterns has dealt with sleep disturbances. Few objective data exist on the normal development of the sleep-wake patterns in the school-age period (Wolfson, 1996). A solid research base on the normal developmental processes of the sleep-wake system in children is required for clinical assessment as well as for addressing educational and parental issues. Accurate and objective normative data with regard to questions such as how much sleep is sufficient at a certain age or how many night wakings constitute a significant sleep problem are still lacking. Therefore, our main purpose in this study was to establish normative data on the sleep-wake patterns of school-age children by using both objective and subjective methods.

Developmental Processes in Sleep

The development of the sleep-wake system is one of the first markers of early biobehavioral organization and adaptation (Sadeh & Anders, 1993; Thoman, 1975, 1990). This developmental process involves complex biological, physiological, and psychosocial mechanisms that commonly lead to the achievement of consolidated sleep-wake patterns. The vulnerability of these processes is manifested in the high prevalence of sleep disturbances in early childhood and later development (for reviews, see Anders & Eiben, 1997; Mindell, 1993; Sadeh & Anders, 1993; Sadeh & Gruber, 1998; Stores, 1996).

The development of the sleep-wake system involves two leading processes: (a) a shift from multiphasic sleep distributed across the day and the night to a monophasic event of consolidated sleep concentrated during the dark hours of the night and (b) a gradual reduction of sleep needs accompanied by a significant increase in waking time. The most dramatic shift along these lines occurs during the 1st year of life, when most infants achieve consolidated

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sleep throughout the night (Anders, 1979; Sadeh & Anders, 1993). Following this rapid developmental period, later development of the sleep-wake system manifests as a slow, gradual, and monotonic process associated with the disappearance of daytime naps (Weissbluth, 1995), delayed evening bedtime, and a resultant reduction in sleep time (Wolfson, 1996).

The first leading developmental process—sleep consolidation—is directly linked to night wakings, which constitute the most prevalent sleep problem in early childhood (Mindell, 1993; Richman, 1987; Sadeh & Anders, 1993). Developmentally, the night-waking phenomenon is expected to gradually subside with age, but substantial objective findings to support this expectation are still lacking. Because most of the research on infant night wakings has been based on parental reports, it is not clear if night wakings actually disappear with age or if children learn to soothe themselves and stop signaling to their parents (see Anders, 1979; Sadeh, 1994, 1996). Objective data on night waking beyond early childhood are still lacking, and therefore it is impossible to describe the night-waking phenomenon across the entire span of development.

The second developmental process—the normal tendency to delay sleep onset—is associated with difficulty falling asleep at bedtime and the clinical phenomenon of delayed sleep-phase syndrome (Thorpy, Korman, Spielman, & Glovinsky, 1988). From a developmental perspective, it has been argued that puberty is a critical maturational phase during which a major shift in sleep-wake organization occurs (Carskadon, 1990; Carskadon, Viera, & Acebo, 1993). Carskadon and colleagues have shown that there is an association between the sleep phase of the youngster and his or her pubertal status. In addition, they have demonstrated that daytime sleepiness has a developmental course peaking in adolescence (Carskadon, 1990; Carskadon & Dement, 1987; Wolfson & Carskadon, 1998).

Sleepiness and alertness are considered direct correlates of the sleep-wake system. Various models have been formulated to explain and predict sleepiness in humans as it relates to two common factors: the circadian rhythm and the sleep debt. The circadian rhythm influences daily fluctuations in alertness and leads to increased alertness during the morning and afternoon hours and reduced alertness during the nocturnal and noon hours. The sleep debt reflects the amount of sleep obtained, its quality, and the time elapsed from the last sleep episode (Borbely, 1994). Thus, the actual quantity and quality of the individual's sleep and their effects on his or her alertness are particularly relevant to the study of the developmental aspects of the relationships between sleep and sleepiness. Although a number of studies have documented the phenomenon of sleepiness in children and its relationships to sleep complaints, most of these studies have focused on the adolescent period or have relied on subjective sleep reports and global subjective sleepiness reports (Epstein et al., 1998; Tynjala, Kannas, & Levalahti, 1997; Wolfson & Carskadon, 1998). Therefore, there is still a lack of data on the subjective sleepiness of preadolescents and on the relationships between sleepiness and objective measures of sleep (e.g., true sleep duration, number of night wakings).

Sleep Problems in Children

On the basis of multiple surveys conducted in different countries, it has been estimated that 20% to 30% of children suffer from sleep disruptions (mainly night wakings) during the first 3 years of

life (for reviews, see Anders & Eiben, 1997; Mindell, 1993; Richman, 1987; Sadeh & Anders, 1993; Sadeh & Gruber, 1998). In school-age children, the prevalence of reported sleep problems appeared to drop to 1%–5% in early reports (Gass & Strauch, 1984; Richman, Stevenson, & Graham, 1982). However, it has been suggested that the frequency of these problems was underestimated because older children are less likely to alert their parents to their sleep problems (Anders, Carskadon, Dement, & Harvey, 1978). More recent studies have yielded higher prevalence rates. Kahn et al. (1989) surveyed preadolescents (aged 8 to 10 years) using parental reports and found a prevalence of 43% for a variety of sleep difficulties. "Poor sleep," a rough equivalent of the diagnosis of primary insomnia in the fourth edition of the *Diagnostic and Statistical Manual of Mental Disorders (DSM-IV;* American Psychiatric Association, 1994), was reported in 14% of the children. In adolescence, chronic or severe sleep difficulties have been self-reported by 11% to 33.4% of youth (Bearpark & Michie, 1987; Kirmil-Gray, Eagleston, Gibson, & Thorensen, 1984; Morrison, McGee, & Stanton, 1992; Price, Coates, Thorensen, & Grinstead, 1978). The confusing data persist even in the most recent studies. One study reported relatively high prevalence rates for specific sleep problems in school-age children—bedtime resistance, 27%; sleep-onset delays, 11%; morning wake-up problems, 17%; night waking, 6.5%; and fatigue complaints, 17% (Blader, Koplewicz, Abikoff, & Foley, 1997)—whereas another study reported very low prevalence rates, lower than 5% (Rona, Gulliford, & Chinn, 1998). Because these studies relied on subjective reports and often failed to provide detailed criteria to identify the exact nature of the problems (e.g., difficulty falling asleep owing to primary insomnia vs. delayed sleep phase), it is difficult to provide accurate estimates of the prevalence of specific sleep problems in this age group. In the present study we used objective measures to assess the prevalence of sleep disruption in school-age children.

Psychosocial Factors Influencing Sleep in Children

Sleep in children is sensitive to cultural and psychosocial influences. A review of the literature covering this topic is beyond the scope of this article. However, we can outline a number of dominant sources of psychosocial influences: (a) parental characteristics, personality, psychopathology, education, and parenting skills (Morrell, 1999; Rona et al., 1998; Sadeh & Anders, 1993; Van Tassel, 1985); (b) psychosocial stress and trauma (for reviews, see Moore, 1989; Sadeh, 1996); and (c) cultural and social demands and attractions, school, work, and entertainment (Carskadon, 1990; Wolfson, 1996; Wolfson & Carskadon, 1998).

We hypothesized that family stress resulting from stressful life events would be associated with poor sleep quality. In addition, we assessed the role of other family measures and health risk factors that had previously been associated with the quality of children's sleep (Anders & Eiben, 1997; Mindell, 1993; Sadeh & Anders, 1993; Sadeh & Gruber, 1998; Stores, 1996).

Methodological Issues in Children's Sleep Research

The research on sleep disruptions during childhood has been significantly hindered by two methodological impediments. The first impediment is related to the lack of a cost-effective and

nonintrusive method to study sleep in natural settings, which has led to an overreliance on subjective reports. The second impediment is related to the fact that in spite of many years of research on sleep problems throughout the life cycle, clear definitions for sleep disorders have yet to be devised.

With regard to the first impediment, a review of the literature reveals that, to date, most sleep-related studies in this field were based either on subjective data—parental reports or self-reports—or on polysomnographic studies (e.g., Kahn, Dan, Grosswasser, Franco, & Sottiaux, 1996). Sleep assessment based on subjective reports (either by the child or the parents) is by far the most commonly used method. Despite the informative value of subjective reports, it has been repeatedly demonstrated that these reports are limited by the restricted and biased knowledge that children and their parents have about their sleep (Sadeh, 1994, 1996). Polysomnography, on the other hand, provides detailed sleep information but seriously compromises the natural sleep settings of the child and is usually limited to 1 or 2 nights and to small samples owing to constraints of cost and compliance. It has been argued that for clinical or research purposes, sleep assessment should be conducted with complementary nonintrusive objective and subjective methods (Ferber, 1996; Sadeh, 1994, 1996; Wolfson, 1996).

During the last few years, actigraphy—activity-based sleep monitoring—has been established as a reliable method for naturalistic studies of sleep-wake patterns in adults and children (e.g., Cole, Kripke, Gruen, Mullaney, & Gillin, 1992; Sadeh, Acebo, Seifer, Aytur, & Carskadon, 1995; Sadeh, Hauri, Kripke, & Lavie, 1995; Sadeh, Lavie, Scher, Tirosh, & Epstein, 1991; Sadeh, Sharkey, & Carskadon, 1994). Actigraphy is based on a miniaturized wristwatch-like device that the child attaches to his or her wrist during the recording period. The device enables continuous recording for prolonged periods (more than a week) with no interference with the child's natural sleep environment. Validation studies that compared activity-based sleep-wake scoring with concomitant polysomnography or with direct observations have found agreement rates for sleep-wake states across 1-min epochs ranging between 85% and 95% for most normal and clinical samples (Sadeh, Acebo, et al., 1995; Sadeh, Hauri, et al., 1995; Sadeh et al., 1991; Sadeh, Sharkey, et al., 1994). We therefore conclude that actigraphy is an appropriate, cost-effective method for the assessment of children's natural sleep-wake patterns.

The second methodological problem is a lack of clear criteria for defining a sleep disruption. This lack is particularly conspicuous in light of the fact that most sleep problems are amenable to objective quantification. For example, in the *DSM-IV*, the two relevant criteria for primary insomnia (American Psychiatric Association, 1994) are (a) that the predominant complaint is difficulty initiating or maintaining sleep, or nonrestorative sleep, for at least 1 month and (b) that the sleep disturbance (or associated daytime fatigue) causes clinically significant distress or impairment in social, occupational, or other important areas of functioning (American Psychiatric Association, 1994). These criteria emphasize the subjective complaint but do not provide more precise criteria that would address the various components of the definition of a sleep problem, such as the number of wakings per night, the number of disturbed nights per week, or the duration of the night wakings that would constitute a clinically significant disorder.

In contrast to the clinical perspective of the *DSM-IV*, more precise definitions have been proposed for research purposes: for example, "if the child wakes at least two to four times a week" (Richman, 1987, p. 118) or (b) "if an infant [wakes] twice per night, six nights per week for more than a full year" (Johnson, 1991, p. 109). It appears that these definitions based on parental reports are inappropriate when objective measures of sleep are used (Kerr & Jowett, 1994; Minde et al., 1993). Because sleep schedule and sleep quality are amenable to objective measurement, we propose that new diagnostic criteria based on objective measures of sleep be used for developmental and clinical research.

Summary and Goals of the Study

Sleep plays an important role in child development and is related to other major components of a child's well-being. Significant developmental processes have been documented during the school-age period. However, objective normative data on sleep phenomena such as sleep schedule or night waking in large samples in this age group are still lacking. Our aim was to study natural sleep patterns with objective measures of sleep derived from actigraphy. Specific goals were to assess and document the following phenomena: (a) age differences in sleep schedule and sleep quality, (b) sleep disruptions in children as assessed by objective measures and precise definitions, (c) subjective sleepiness and its relationships with objective measures of sleep, and (d) the relationships between objective sleep measures and psychosocial measures.

Method

Participants

One hundred forty children, 72 boys and 68 girls, participated in the study. The children were sampled from three distinct age groups: second grade ($N = 50$, age range = 7.2–8.6 years, mean age = 7.9 years, $SD = 0.34$), fourth grade ($N = 37$, age range = 9.3–10.4 years, mean age = 9.7 years, $SD = 0.30$), and sixth grade ($N = 53$, age range = 9.9–12.7 years, mean age = 11.8 years, $SD = 0.45$). The children were mostly from two-parent families with middle-class or upper middle-class socioeconomic status, with highly educated and employed parents (see Table 1).

Table 1
Sample Characteristics

Characteristic	Range	$M \pm SD$	% of sample
Mother's age (in years)	28–53	39.7 \pm 4.7	
Father's age (in years)	24–68	42.6 \pm 5.7	
Mother's education (in years)	8–24	14.7 \pm 2.9	
Father's education (in years)	8–23	14.7 \pm 2.8	
No. of children in family	1–7	2.88 \pm 0.9	
No. of rooms at home	2–8	5.07 \pm 1.2	
Birth order of child			
Firstborn			38.1
Latest born			43.2
Parents employed full time			
Fathers			89.0
Mothers			44.5
Parents born in Israel			
Fathers			75.0
Mothers			76.3
Two parents in family			92.8

Most of the children were at least second-generation Israeli-born.

The study was approved and supported by the Tel Aviv University Institute Review Board, the National Ministry of Education, and the school authorities. It was defined by the school authorities as a school project, and informed consent was obtained from the children and their parents. Recruitment was focused on a target school in a district whose residents belong to middle and upper-middle socioeconomic classes. Each child was rewarded with a \$15 voucher (for an office and school supply store) for participating in the study. The recruitment efforts led to a consent rate of above 95% in all classes involved. Because our goal was to assess the full picture in total class samples of normal school children, only narrow exclusion criteria were used. Five children with acute (not chronic) physical illness or behavior problems were excluded from the study because of their inability to participate or to comply with the procedures. The Child Behavior Checklist (Achenbach & Edelbrock, 1983) was used to assess behavior problems. Although 4 children scored within the clinical range of behavior problems on the Child Behavior Checklist according to the Israeli norms (Zilber, Auerbach, & Lerner, 1994), they were fully integrated into their classes and were included in the sample. No other child- or family-related screening criteria were used.

Procedure and Instruments

Each child was monitored with an actigraph (AMA-32, Ambulatory Monitoring Inc., Ardsley, NY) for 4 to 5 consecutive nights. The actigraph was initialized to collect data in Mode 18, with 1-min epoch intervals. The children were instructed to attach the actigraph to their nondominant wrists. The children were monitored only during school nights (Sunday through Thursday). The study was performed during the period between the months of January and June. The different age groups were evenly divided between the various seasons covered by the study (winter, spring, and summer).

Actigraphic raw data were translated into sleep measures with the Actigraphic Scoring Analysis (ASA) program for an IBM-compatible PC. These sleep-wake measures have been validated against polysomnography with agreement rates for sleep-wake identification higher than 90% (Sadeh, Hauri, et al., 1995; Sadeh et al., 1991; Sadeh, Sharkey, et al., 1994).

Actigraphic sleep measures included (a) sleep onset time—defined as the first minute after reported bedtime that was identified as sleep by the ASA sleep-wake algorithm and that was followed by at least 15 min of uninterrupted sleep; (b) morning awakening time—defined as the last minute identified as sleep that was preceded by at least 15 min of uninterrupted sleep; (c) sleep period (the number of minutes from sleep onset time to morning awakening); (d) true sleep time (the number of minutes of sleep time excluding all periods of wakefulness); (e) sleep percentage—the percentage of the sleep period that was true sleep time; (f) number of night wakings (that lasted 5 min or longer and that were preceded and followed by at least 15 min of uninterrupted sleep); (g) longest sleep period—the longest period of continuous sleep without any wakefulness; and (h) motionless sleep percentage—the percentage of the sleep period in which there was no recorded activity.

In addition to the objective sleep measures, daily logs were used to obtain subjective information from the children, with parental help if needed. Subjective measures used for assessing the sleepiness and alertness of the children included the following scales: (a) morning drowsiness—a 4-point scale ranging from *very alert* (1) to *very drowsy* (4) and (b) evening sleepiness—a 4-point scale ranging from *very alert* (1) to *very sleepy* (4).

To supplement the daily information on daytime sleepiness with a more general overview of the child's sleep habits, we had each child and, independently, his or her parents complete the Sleep Habits Questionnaire, a 20-item 4-point Likert-type scale that includes items on sleep habits, sleepiness, and fatigue (Gruber, Sadeh, & Raviv, 1997). Separate factor analyses for the children's and parents' versions have yielded two comparable factors: (a) Sleepiness, composed of items related to the child's tendency to go to sleep very late, the child's tendency to sleep very little,

and the related daytime sleepiness and fatigue and (b) Sporadic Daytime Sleep, which includes items on daytime naps and uncontrollable sleep episodes. These two factors were calculated separately for the children and the parents. Measures of internal consistency (Cronbach's alpha) for these four calculated scales ranged between .72 and .82.

Results

Psychometric Qualities of the Sleep Measures

The raw actigraphic data of 4 children are presented in Figure 1. To assess the reliability (or stability) of the sleep measures, we calculated reliability estimates for repeated measures (5 nights) for each measure (Acebo et al., 1999; Winer, 1971). The reliability estimates for the actigraphic measures for each age group and for the total sample are presented in Table 2. In general, most of the reliability estimates were found to be adequate (>.70) or better (Acebo et al., 1999).

Age Differences in Sleep Measures

For most statistical analyses, scores on each of the measures from the actigraphic and the daily log data were averaged across the 5 nights of monitoring. Thus, scores on the measures represent the calculated means.

To assess age differences in scores on the actigraphic sleep measures while controlling for the multiple comparisons, we used a multivariate analysis of variance (MANOVA) with age (age groups according to grade level) and gender as the independent variables and the eight actigraphic sleep measures as the dependent variables. The MANOVA revealed significant main effects for age, Wilks's lambda $F(14, 256) = 8.27, p < .0001$, and gender, Wilks's lambda $F(7, 128) = 2.14, p < .05$. Analyses of variance (ANOVAs) were used to assess the distinct effect for each dependent measure (see Table 3). Significant age differences were manifested in the sleep-wake schedule measures. Older children had delayed sleep onset times, shorter sleep periods, and shorter true sleep times than younger children (see Figure 2 for the distribution of sleep periods by age groups). Significant gender differences were also found. Girls obtained longer true sleep times, and their sleep was characterized by greater percentages of motionless sleep.

Assessment of "Poor Sleep" Prevalence

To identify children with fragmented sleep patterns, we defined *poor sleep* as sleep that is characterized by either (a) a sleep percentage lower than 90 (i.e., the child spends more than 10% of the sleep period, after sleep onset, in wakefulness) or (b) waking three times or more per night on average (with each night waking being 5 min long or longer). We used these criteria, which are stricter than those commonly used in the field, because the criteria used by most studies are based on parental reports and are not appropriate for actigraphic data. A similar approach was adopted for video-based sleep assessment (Minde et al., 1993). Twenty-five children (17.9%) met our criteria and therefore could be considered poor sleepers (see Figure 3). There were no significant age or gender differences in the representation of these children.

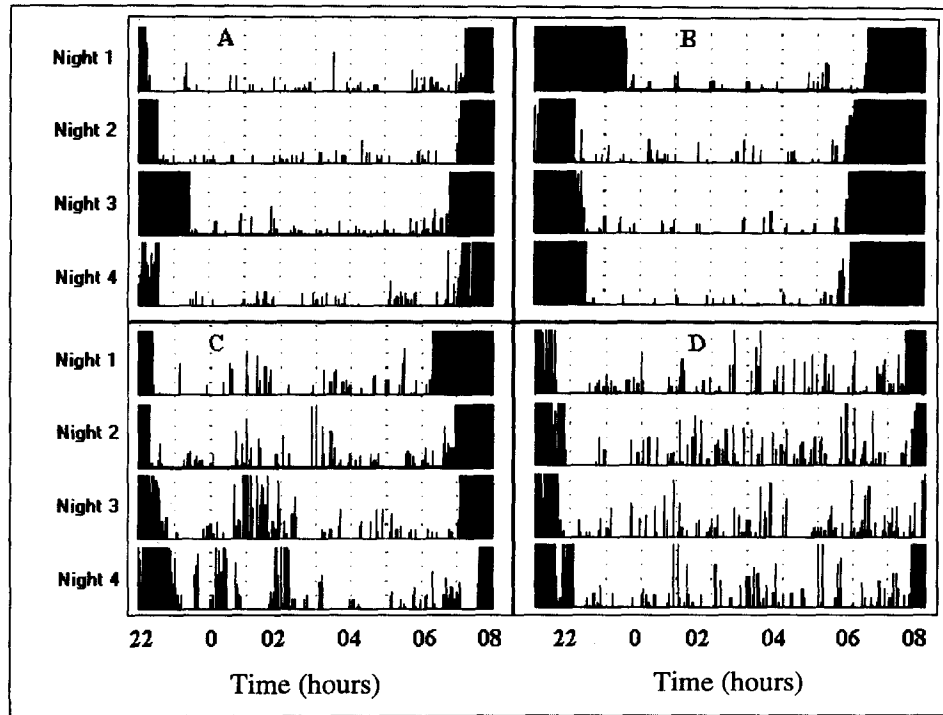


Figure 1. Raw nocturnal activity data of 4 children. Each panel (A, B, C, and D) represents the raw activity data of 1 child for 4 consecutive nights. Dark areas represent increased activity level associated with wakefulness (prior to sleep onset, after morning awakening time, and during night wakings). Children A and B exhibit consolidated sleep with very little activity and no extended or multiple night wakings, whereas Children C and D exhibit fragmented sleep, with increased activity throughout the night identified as multiple and/or prolonged night wakings.

Subjective Sleepiness

A MANOVA was performed on the subjective sleepiness measures derived from the daily logs and the Sleep Habits Questionnaire. Significant age differences were found, Wilks's lambda $F(12, 208) = 3.98, p < .0001$. ANOVAs were used to assess the distinct age differences for each independent measure. Significant age differences were found on the subjective sleepiness measures. Older children reported significantly increased morning drowsi-

Table 2
Actigraphic Sleep Measures: Reliability Estimates for Aggregated Values Over 5 Successive Nights of Recording, by Age Group

Sleep measure	2nd grade	4th grade	6th grade	Total sample
Sleep onset time	.73	.83	.77	.86
Morning wake time	.59	.84	.66	.68
Sleep period	.63	.67	.66	.81
Sleep percentage	.75	.77	.83	.79
True sleep time	.74	.78	.72	.82
No. of night wakings	.71	.60	.75	.71
Longest sleep period	.72	.71	.82	.76
Motionless sleep percentage	.87	.89	.91	.89

Note. All values are significant at $p < .0001$.

ness, $F(2, 134) = 7.94, p < .001$, and their parents reported them to have a significantly increased tendency for unplanned daytime sleep episodes, $F(2, 134) = 6.98, p < .005$.

After controlling for age differences, we found modest but significant correlations between the actigraphic sleep measures and subjective sleepiness. Morning drowsiness was significantly correlated with sleep onset time ($r = .26, p < .005$). The tendency of the child toward sporadic and unplanned daytime sleep episodes, as reported by the child and the parents, was significantly correlated with the sleep period after age was controlled for (for child report, $r = .25, p < .005$; for parental report, $r = .27, p < .005$).

Psychosocial Variables Associated With Sleep Measures

We selected a multivariate approach to assess our hypothesis regarding the relationships between family stress and the child's sleep patterns, as well as the predictive power of other family variables and health risk factors. We used stepwise regression analysis with actigraphic sleep schedule and sleep quality measures as the criteria and with demographic and background measures as predictors. The selected demographic and background measures included the child's age and gender, the parents' age (average of the mother's and the father's ages), parents' education (average of the mother's and the father's years of education), the socioeconomic status score, the number of siblings, and birth

Table 3
Age Differences in Actigraphic Sleep Measures: Means (\pm SDs), F Values, and Statistically Significant Scheffé Post Hoc Comparisons

Sleep measure	2nd grade	4th grade	6th grade	F(2, 136)		Scheffé comparisons
				Gender	Age	
Sleep onset time (in min)				0.01	46.65****	6th > 4th > 2nd
Boys	21.6 \pm 0.5	22.3 \pm 0.5	22.7 \pm 0.6			
Girls	21.7 \pm 0.6	22.0 \pm 0.5	22.7 \pm 0.6			
Morning wake time (in hr)				1.43	0.12	
Boys	6.86 \pm 0.3	6.90 \pm 0.4	6.81 \pm 0.4			
Girls	6.92 \pm 0.3	6.85 \pm 0.3	6.98 \pm 0.4			
Sleep period (in min)				0.54	63.40****	2nd > 4th > 6th
Boys	554 \pm 28	514 \pm 25	487 \pm 28			
Girls	555 \pm 30	534 \pm 19	494 \pm 35			
Sleep percentage				2.45	1.03	
Boys	92.5 \pm 4.3	93.7 \pm 3.5	93.8 \pm 4.0			
Girls	93.8 \pm 3.0	94.7 \pm 2.5	94.2 \pm 3.9			
True sleep time (in min)				4.68*	34.62****	2nd > 4th > 6th
Boys	513 \pm 36	481 \pm 30	457 \pm 35			
Girls	520 \pm 36	505 \pm 24	465 \pm 33			
No. of night wakings				1.23	1.80	
Boys	2.09 \pm 1.3	1.77 \pm 1.3	1.78 \pm 1.3			
Girls	2.05 \pm 1.1	1.50 \pm 1.0	1.52 \pm 1.3			
Longest sleep period (in min)				0.47	0.45	
Boys	203 \pm 76	172 \pm 76	184 \pm 82			
Girls	187 \pm 67	196 \pm 50	195 \pm 92			
Motionless sleep percentage				9.71***	2.71	
Boys	62.7 \pm 9.4	68.4 \pm 7.3	67.0 \pm 9.6			
Girls	69.1 \pm 7.2	71.1 \pm 6.7	70.3 \pm 7.7			

* $p < .05$. *** $p < .005$. **** $p < .0001$.

order. In addition, two composite scores were calculated. The first composite score was related to early life risk factors (pregnancy and birth complications and stressors and postdelivery complications). The second composite score was related to recent and present family stress factors (loss, illness, hospitalizations, relocation, and emotional turmoil within the family). These risk factors were calculated in accordance with the paradigm suggested by Sameroff and colleagues (Sameroff & Fiese, 1990; Sameroff, Seifer, Barocas, Zax, & Greenspan, 1987). We chose this set of selected variables to test our specific hypothesis about the relationships between stress and sleep in children as well as to assess

and control for the variance explained by other measures that had been associated with sleep in previous research.

The results of the stepwise regression are presented in Table 4. Variables with no significant contribution to the explained variance are not included in the table (although they were included in the analysis). The sleep onset time and sleep period measures were best explained by the child's age, and additional variance was independently explained by the parents' age. Older children and children of older parents went to sleep later and slept less than did younger children or children of younger parents. However, the

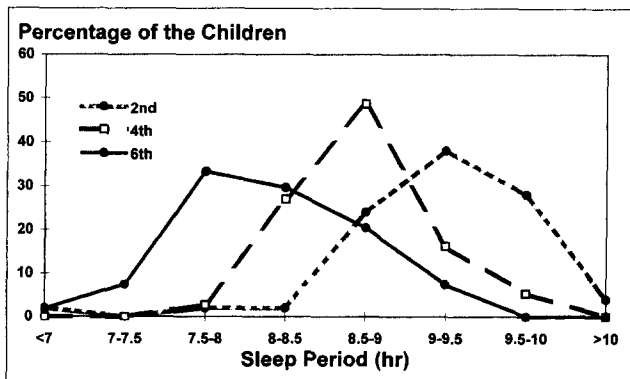


Figure 2. Distribution of sleep period in the three age groups (2nd, 4th, and 6th grades).

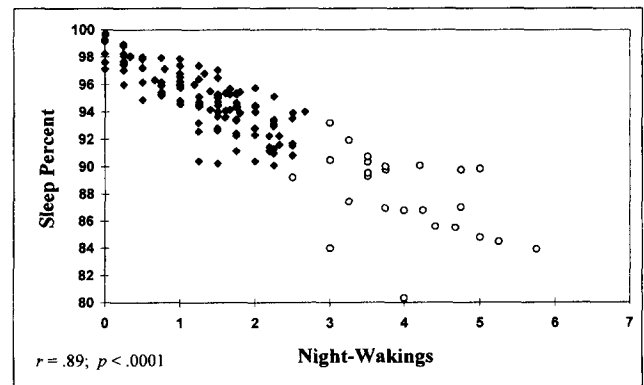


Figure 3. Scatter plot of sleep percentage and number of night wakings. Open circles denote children identified as "poor sleepers" (sleep percentage lower than 90 or waking three or more times per night).

Table 4
Stepwise Regression Analysis With Selected Objective Sleep Measures as Criteria and Background and Demographic Measures as Predictors

Criteria	Predictors	β	Partial R^2	Model R^2	F
Sleep onset time	Child's age	.24	.41	.41	86.9****
	Parents' age	.03	.04	.45	9.1***
Sleep period	Child's age	-15.0	.48	.48	116.7****
	Parents' age	-1.43	.03	.51	6.8**
Sleep percentage	Family stress	-.62	.05	.05	7.7*
	Parents' education	.31	.04	.10	6.5**
No. of night wakings	Parents' education	-.10	.05	.03	4.4*
	Family stress	.15	.03	.07	4.0*

Note. Only variables making a significant contribution to the explained variance are included in the table. Partial R^2 refers to the unique contribution of each variable. Model R^2 refers to the accumulated variance explained by the model (by all entered predictors). F refers to the significance of the contribution of each specific variable.

* $p < .05$. ** $p < .01$. *** $p < .005$. **** $p < .0001$.

sleep quality measures (sleep percentage and number of night wakings) were best explained by the parents' education and family stress. The parents' higher education level was associated with improved sleep quality. In line with our hypothesis, increased family stress was associated with poorer sleep quality (sleep percentage and number of night wakings explained 3% and 5%, respectively, of the variance).

Discussion

Our study used objective measures to examine the sleep-wake patterns of school-age children in their natural sleep environments. The methodology we used enabled us to assess 140 children for 5 nights each and provided a unique data set that is rare in this field. In addition, our ability to define the study as a school project and the very high consent rate we obtained (above 95%) guarantee that the results are not skewed by selection or consent biases.

Our results highlight significant developmental processes in the sleep-wake system during the school-age period and provide normative data on sleep patterns and sleep disruptions. The results also shed light on the relationship between sleep and subjective daytime sleepiness. The new set of findings includes clear indications that although sleep schedule and sleep quantity vary with age, sleep quality remains remarkably stable within this age group. In addition, significant gender differences were identified, and the prevalence of sleep disruptions was assessed with the use of a new definition based on objective measures of sleep quality.

Reliability and Stability of the Sleep Measures

The relatively high (>.70) reliability estimates obtained for most of the objective sleep measures suggest that these measures are both reliable and quite stable within these age groups. These results are similar to those obtained for younger (12-60 months of age) and older (adolescent) participants by Acebo et al. (1999). It should be emphasized that our assessment of stability was limited to school days, whereas other studies have emphasized the dramatic fluctuations between weekdays and weekends as a major source of instability in the adolescent period (e.g., Wolfson & Carskadon, 1998). Future studies should further examine this stability-instability dimension in the sleep-wake system because it

may have important repercussions for biobehavioral regulatory systems.

Age Differences

As expected, age differences were found in scores on both the objective and the subjective sleep measures. Sleep onset time in second grade (21.6) was more than 1 hr earlier than that in sixth grade (22.7), whereas sleep period and true sleep time were reduced accordingly, because morning awakening time was quite stable and determined by the fixed school schedule. Despite these variations in sleep schedule and sleep duration, sleep quality appears to remain stable across this age range because no age differences were found on any of the objective sleep quality measures.

The subjective daily sleepiness ratings indicate that the older children (sixth grade) reported increased morning drowsiness compared with the younger children. These findings suggest that the age-related significant delay in sleep onset and the shortening of sleep lead to chronic partial sleep deprivation and increased daytime sleepiness even in this age group preceding adolescence, where such a tendency has already been established (Carskadon, 1990; Carskadon & Dement, 1987; Carskadon et al., 1993; Tynjala et al., 1997; Wolfson & Carskadon, 1998). Evidence of increased daytime sleepiness was also found in both the children's and the parents' sleep questionnaire data. It has been well documented that a developmental biobehavioral shift that has been associated with puberty occurs in the early adolescent period (Carskadon, 1990; Carskadon & Dement, 1987; Carskadon et al., 1993; Tynjala et al., 1997; Wolfson & Carskadon, 1998). Our findings suggest that there is an ongoing and gradual process of sleep-phase "drift" occurring earlier than has been previously reported. The extreme of this biobehavioral shift—that is, the delayed sleep phase—is also related to the clinical manifestation of delayed sleep-phase disorder, which appears to rise in prevalence during adolescence (Alvarez, Dahlitz, Vignau, & Parkes, 1992; Thorpy et al., 1988). The significant reduction in sleep duration coupled with the significant increase in daytime sleepiness found in our study suggests that the sleep behavior of the older children may not be in accordance with their physiological needs. These children are thus at

risk of being chronically sleep deprived, which may have adverse cognitive, behavioral, and emotional consequences.

Assessment of Sleep Disruptions

The issue of sleep fragmentation, or night wakings, during the school-age period merits special attention. The average of close to two night wakings per night remains quite stable across the school-age period and is strikingly similar to that found with the use of the same methodology in normal infants and toddlers (Sadeh et al., 1991). Notwithstanding the fact that data are missing for various age groups, our findings suggest that the night-waking phenomenon remains remarkably stable across development from infancy to early adolescence.

The identification of poor sleepers in our study was based on objective definitions. We propose that these measures and definitions serve as the standard criteria for future research. Following Minde et al. (1993), we chose relatively strict criteria that nevertheless led to the finding that almost every fifth child in our sample experienced significant sleep difficulties. In most of these children, no sleep problem was identified or reported by the parents or the children themselves even after a follow-up inquiry. This finding explains the relatively low prevalence of night-waking problems reported in earlier questionnaire-based studies (Blader et al., 1997) and suggests that many children may experience significant sleep disruption even though neither they nor their parents are aware of it. These disturbances may nevertheless be clinically significant and have adverse behavioral and cognitive consequences. The fact that subjective sleepiness and fatigue have been significantly linked to fragmented sleep suggests that impaired arousal level is indeed one of the direct implications of these sleep problems. Similar results were found in a recent study of asthmatic school-children who, when compared with healthy control children, demonstrated lower sleep quality even when their asthma was controlled and they were in a stable and nonsymptomatic period (Sadeh, Horowitz, Wolach-Benodis, & Wolach, 1998). The asthmatic children were identified as significantly sleepier and less alert than the healthy controls despite the fact that their sleep disruptions were relatively subtle.

Gender Differences

The issue of gender differences in sleep patterns is complex, and the related literature is quite confusing. Our findings indicate that girls spend more time than boys in true sleep and that they have higher percentages of motionless sleep. Our findings that girls spend more time in sleep support recent findings from a large questionnaire survey of 572 fifth-grade Israeli children, which found that girls slept longer than boys (Epstein et al., 1998). However, other studies have yielded contradictory results (e.g., Gau & Soong, 1995). Additional studies using objective measures are needed to determine whether these differences are culturally determined or represent a universal gender-specific phenomenon.

Our findings that girls sleep more and spend more time in motionless sleep are an extension of the findings of earlier studies in which actigraphy was used with infants and young children (Sadeh et al., 1991). However, such gender differences were not found when the same technique was used with newborns during the first 2 days of life (Sadeh, Dark, & Vohr, 1996). This discrep-

ancy raises the issues of the source of gender differences in motor activity during waking and sleep states and their maturational onset (Anders, Halpern, & Hua, 1992; Cornwell, 1993; Eaton & Enns, 1986; Eaton & Yu, 1989; Feldman, Brody, & Miller, 1980). The gender- and age-related differences in the structure of sleep throughout the night during this age period should be further explored and linked to physiological and psychosocial pubertal changes.

Predictors of Sleep Patterns

The multivariate analysis of the demographic and environmental factors predicting the sleep measures indicated that the sleep schedule (sleep onset time and sleep duration) is best predicted by the child's age and, in addition, by the parents' age (independent of the child's age). This finding suggests that younger parents are more likely to enforce an earlier bedtime (and the resultant extended sleep duration). The best predictors of sleep quality measures were the parents' education and family stress. Although it is not entirely clear why the children of parents with a higher education level sleep better, this finding is consistent with a recent report correlating poor sleep with lower maternal education (Rona et al., 1998).

Our hypothesis that family stress is associated with poor sleep in children was supported by our findings (see Sadeh, 1996, and Sadeh & Gruber, in press, for reviews). The family stress index (composite score) explained 3%–5% of the variance in the sleep quality measures (sleep percentage and the number of night wakings). Although the statistical power of this finding is limited, nevertheless, to the best of our knowledge, it is the first documentation of such a relationship between family stress and objective sleep quality measures in a nonclinical community sample of school-age children. It has been repeatedly demonstrated that the sleep of infants, children, and adolescents is sensitive to environmental stress. Increased stress and the anxiety associated with it are likely to activate an alarm response that triggers the activity of the adrenocortical system and facilitates hypervigilance (Field & Reite, 1984; Fisher & Rinehart, 1990; Gunnar, Maone, & Fisch, 1985; Selye, 1983). On the basis of an experimental study, it has also been suggested that stress-related physiologic reactivity may be an individual trait of the child, which could explain the susceptibility of certain children to sleep disorders (Fisher & Rinehart, 1990). To the best of our knowledge, our study is the first to demonstrate a relationship between objective measures of sleep quality and a composite score of family stress in normal school-age children. This finding also supports the use of a composite score of family risk factors, as suggested by Sameroff and colleagues (Sameroff & Fiese, 1990; Sameroff et al., 1987).

The variance of the sleep measures accounted for by the predictive variables, although statistically significant, was modest, which might have resulted from the fact that the range of the predictive demographic variables was narrow in our relatively homogeneous target sample.

Limitations of the Study and Future Research

It is important to highlight the methodological limitations of the study. The use of a cross-sectional design precludes the possibility of analyzing individualized developmental processes and enables

only age-group comparisons. Important issues such as the stability of the sleep schedule or the persistence of poor sleep quality during individual child development from the second to the sixth grade cannot be addressed until our follow-up data collection and analysis are completed. Another limitation is our focus on school days only, which precludes analyzing important issues related to the variations in sleep-wake patterns from school to nonschool days. The third important limitation of our study is the lack of additional physiological and psychosocial measures that would enable the disentangling of biological and psychosocial sources that could account for the age and gender differences documented in this study. Finally, although the use of activity-based sleep assessment enables relatively large-scale studies with multiple nights and minimal variations to children's sleep ecology to be conducted, when sleep disruptions are detected on the basis of actigraphy, the actual causes for the disruptions remain unclear.

Future research should address questions such as the following: What happens to individual children during development in the school-age period? How stable is the sleep-wake system across development? Do children identified as poor sleepers in second grade maintain their poor sleeper status at later ages? These questions and others warrant a longitudinal study covering this age period that would relate changes in the sleep-wake system to the child's environmental and functional characteristics.

As we emphasized before, actigraphy provides information on the behavioral aspects of sleep but is limited in its capacity to provide more detailed information on the internal structure of sleep and the underlying physiologic systems. Nevertheless, we believe that this methodology facilitates large-scale studies on children's sleep in their natural sleep settings for extended periods. These studies have special informative value and should be further applied to explore normal and impaired sleep, to accumulate normative data, to establish solid definitions for specific childhood sleep disorders, and to further investigate the relationships between sleep and the multiple facets of child development.

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Developmental Psychology will publish a special issue in 2002 on the topic of Violent Children: Bridging Development, Prevention, and Policy. The problem of chronic violence in children has reached a new level of public awareness. Developmental science has much to contribute to the understanding of this problem and how it can be addressed in the public domain. This special issue will highlight original empirical research that contributes to this understanding.

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