ABSTRACT—Daytime fatigue and lack of sleep seem to increase throughout adolescent years. Several environmental, psychological, and biological factors have been associated with the development of sleep across adolescence. The aim of the present article is to summarize these factors and to give examples of various outcomes in sleep patterns among adolescents studied in different cultural settings. It is obvious from earlier work that many adolescents have displaced circadian rhythms and lack of adaptation to school hours due to an early school start or additional burdens for work. Several interventions have aimed to help the adaptation process by supporting sleep processes and changing scheduling, in this way promoting classroom alertness. In summary, adolescents worldwide shorten their sleep due to schoolwork hours and additional work, especially by disturbing their sleep due to circadian misalignment.

INTRODUCTION

Insufficient sleep and daytime sleepiness are commonly increasing during the preadolescent and adolescent years (Tynjälä, Kannas, & Valimaa, 1993). It has been suggested that environmental, psychosocial, and biological factors might underlie changes in sleep patterns across adolescence (Crowley, Acebo, & Carskadon, 2007). There are reasons to believe that limitations in sleep recovery are widespread among adolescents and affect negatively school and work performance. It is therefore of great importance to highlight possible solutions as to how to promote effective sleep behavior in relation to school- and work-related demands.

There are indications that at least some of the reduction of sleep in adolescence can be attributed to school scheduling hours and the typical early start (approximately 08:00 hr) of school. Moreover, the differences in sleep onset between weekdays and weekends among adolescents as a result of school timing are well known (O’Brien & Mindell, 2005). An example of a biological factor is hormonal influence on sleep behavior at pubertal development. This phase of life is recognized to be related to a phase delay of the circadian timing system (Andrade, Benedito-Silva, Domenice, Arnhold, & Menna-Barreto, 1993; Carskadon, Vieira, & Acebo, 1993).

Although individuals differ in sleep patterns, some general sleep characteristics are age dependent. The drastic shortening of sleep needs from a daily average of 16 hr at birth to 10.5 hr at age 7 sums to around three fourth of an hour reduction for each year of growth (Roffwarg, Muzio, & Dement, 1966). After this, the reduction continues but at a slower pace. The next 7-year period between ages 7 and 14 shows a reduction from 10.5 to 8.5 hr (close to a reduction of 15 min for each year). During the next 7-year period from adolescence through adulthood (14–21 years), sleep need is further reduced down to 7.75 hr (reduction of 10 min each year). Deviations from a normal sleep length are typically initiated in adolescent years, but other sleep-related phenomena are also occurring.

Longitudinal research designs have shown that subjective daytime sleepiness is more common in late puberty, suggesting that a greater sleep depth is found in this age group.
Internal and External Time Conflicts in Adolescents

SLEEP IN ADOLESCENTS WITH NORMAL EARLY SCHOOL STARTING TIMES

In a large international collaboration study including 11 European countries, each country studying a representative group, 40,202 students between 11 and 16 years of age gave questionnaire data on sleep habits (Tynjälä et al., 1993). The results demonstrated a significant difference in sleep length during a school week of about 1 hr within the European student population. The experience of morning tiredness was very common (on at least four school mornings in a week) in about 20%–37% of students in most countries. This study showed that the inability to fall asleep was a common sleep complaint among European adolescents. The 11- to 12-year-old age group slept 9–10 hr, the 13- to 14-year-olds slept 8.6–9.6 hr, and the 15- to 16-year-olds slept 8.3–9.2 hr. Occurrence of difficulty in falling asleep (26%–34%) has also been reported in Canada (Laberge et al., 2001).

A Dutch study addressed 449 schoolchildren with fixed morning start times while in seventh and eight grades in elementary schools (mean age 11 years). It was demonstrated that 43% of the responders had difficulty getting up in the morning, 15% of them reported sleep problems, and 25% did not feel rested at school (Meijer, Habekotte, & Van den Wittenboer, 2000).

Another significant development of adolescent sleep—apart from reductions of sleep length—is the increasing difference between sleep lengths taken during school days and nonschool days (Carskadon & Dement, 1987). The difference can be related to environmental factors such as the demands of schoolwork (including early starts) and adolescents taking more power over their life and sleep scheduling. The outcome of such sleep scheduling is a significant shortening of sleep during most part of the week and a possible recuperation at weekends. The discrepancy between weekend sleep and weekday sleep has been shown in several studies to be 1–1.5 hr (Carskadon & Dement, 1987; Laberge et al., 2001). Thus, there are strong indications that short sleep in connection to school scheduling elevates sleepiness at school and likely also has a negative effect on learning (Fallone, Seifer, Acebo, & Carskadon, 2002). From the outcome of adolescent sleep studies, we can conclude that sleep duration is closely associated with school scheduling hours. This was further demonstrated in a study by Szymczak, Jasinska, Pawlak, and Zwierzykowska (1993), where children were followed over a year. They found that sleep in children increased during vacations. If we consider mean sleep length during school nights, the sleep outcome is much shorter than the sleep need, and the reduction of sleep would resemble about 1 hr in every 3 years during school years (Fallone et al., 2002).

Individual differences play an important role in shaping sleep habits. It is apparent that the effect of morningness—eveningness is significant in all age groups, also among adolescents, and that particularly eveningness is associated with less time in bed, more sleep debt, later bedtimes, more irregular sleep habits, and higher consumption of alerting stimulants such as coffee (Giannotti, Cortesi, Sebastiani, & Ottaviano, 2002; Taillard, Philip, & Bioulac, 1999). Carskadon et al. (1993) have shown that morningness—eveningness preferences are related to pubertal development and are geared mainly by biological changes rather than mediated through psychosocial factors.
Gender difference studies are scarce in chronotype reports (Giannotti et al., 2002) as well as in studies reporting sleep habits among adolescents (Fallone et al., 2002; Tynjälä, Kannas, & Levalahti, 1997). However, the weekend delay of sleep is closely related to pubertal changes. Because girls show a more rapid development, they also show later bedtime habits than boys at least in early adolescence (10–13 years old; Laberge et al., 2001).

In summary, we can conclude that adolescents around the world shorten sleep according to age mainly by delaying timing of sleep due to biological and psychosocial reasons and that they are subjected to premature forced awakenings in connection to school days.

SLEEP AND DAYTIME FUNCTIONING OF ADOLESCENTS ON A TWO-SHIFT SCHOOL SCHEDULE

As we can see from the previous section, school schedule is one of the external factors that has been named responsible for some sleep characteristics of adolescents and their daytime functioning. Much attention has been paid to research of sleep restriction imposed by early school start in single-shift schools. In contrast, there are few studies reporting data on sleep of adolescents who attend double-shift schools, even though double-shift schools are common in many countries (Bray, 1990). In a double-shift system, one group of students usually attends school in the morning and the other in the afternoon. Students can attend classes on a fixed shift schedule, that is, at the same time every school day, or can change shifts, in some cases, on a weekly basis. A double-shift school system quite differently impacts patterns of sleep and wakefulness as compared to a single-shift system, giving different opportunities for sleep and putting different constraints on the students.

The National Sleep Foundation (2000) recommendations for healthy sleep state that optimal daytime functioning with minimal sleepiness in adolescents requires from 8 hr 30 min to 9 hr 25 min of sleep every night. Further, it is recommended that adolescents should avoid large irregularities of sleep pattern and duration. Therefore, it was of interest to determine what happens with sleep in adolescents on a two-shift school schedule with respect to those recommendations for healthy sleep.

A diary study of 17-year-old adolescents on fixed shifts (Valdez, Ramirez, & García, 1996) found that, on weekdays, adolescents who attended school in the afternoon slept on average longer (8 hr 35 min) than adolescents who attended school in the morning (6 hr 40 min). However, in a study which analyzed actigraphic sleep data of 13-year-old adolescents on fixed morning and afternoon shifts, a difference in sleep duration between adolescents attending the morning shift and those attending the afternoon shift was not confirmed (Louzada & Menna-Barreto, 2004).

The studies of adolescents who attend school 1 week in the morning and the other in the afternoon indicate that adolescents prolong their sleep on school weeks with afternoon shifts. Namely, a large survey study found that 11- to 18-year-old Croatian adolescents on average get a recommended amount of sleep when on the afternoon shift (Radosovic-Vidacek & Koscec, 2003). This finding was further confirmed in a diary study of sleep in 16-year-old Croatian adolescents (Koscec, Radosovic-Vidacek, & Bakotic, 2006). Adolescents reported on average 8 hr 35 min of sleep on an afternoon schedule, in comparison to 6 hr 30 min of sleep throughout the week of morning schedule. On the first weekend night following the morning schedule, adolescents extended their sleep, which was not the case on the weekend following the afternoon schedule. This study also pointed to the advantage of an afternoon schedule regarding sleepiness upon waking. Beneficial effect of afternoon shifts for fulfillment of adolescents’ sleep need was found also in a questionnaire study of 15- to 18-year-old Greek adolescents who slept on average 8 hr 49 min when on afternoon shifts, in comparison to 7 hr 35 min when on morning shifts (Lazaratou, Dikeos, Anagnostopoulos, Sbokou, & Soldatos, 2005).

Two-shift school systems, in which students change shifts, facilitate irregularities of sleep pattern and sleep duration, which is not consistent with recommendations stating that adolescents should avoid large delay of bedtime and wake time as well as large extension of sleep. However, with regard to irregularity of sleep duration, the results indicate that extension of main sleep when on afternoon shifts is used to pay off insufficient sleep from morning shift days (Radosovic-Vidacek, Koscec, & Bakotic, 2006). On the other hand, there is still a question of whether sleep irregularity has negative impact on daytime functioning of adolescents. Pronounced sleep delay and sleep extension observed between morning and afternoon shifts were not found to be important predictors of daytime sleepiness, depressed mood, school grades, or injuries of adolescents (Radosovic-Vidacek & Koscec, 2004a). Therefore, irregularity of sleep on afternoon shifts with respect to morning shifts may not be viewed as a negative aspect of two-shift school schedules. Bedtime delay on weekends with respect to morning shifts was the only measure of sleep irregularity that predicted sleepiness and injuries of adolescents in a two-shift system. Sleep duration on morning shifts attained small predictive value for measures of daytime functioning. Morningness–eveningness preference was a consistent predictor of self-reported measures of daytime functioning in adolescents (Radosovic-Vidacek & Koscec, 2004a).

In families that were shifting their rhythms of sleep and wakefulness due to engagement of parents in shift work and engagement of adolescents in a two-shift school schedule,
EFFECTS OF WORKING AND STUDYING ON SLEEP AND SLEEPINESS AMONG STUDENTS

Young adults undergo intense physical, emotional, and cognitive development, aggravated by such factors as college admission, establishment of important relationships, independence from their parents, and the beginning of a labor life. During the past years, worries about the double journey of studying and working have been discussed. The double journey (work and study) may result in or aggravate health problems, including sleep problems, as observed in previous studies with high school students.

Machado, Varella, and Andrade (1998) compared female evening college students who worked and did not work. It was observed that female students who did not work went to bed and woke up later than those who did work. The latter had shorter sleep duration and more regular sleeping times during weekdays than those who did not work.

Fischer, Oliveira, Teixeira, Teixeira, and Amaral (2003) studied fundamental and high school students, attending morning and evening classes, from 14 to 18 years old, living in two small towns located in the countryside of the State of Sao Paulo. The students were interviewed and answered a comprehensive questionnaire on sociodemographic items, working and living conditions, and health symptoms, including sleep duration during working days and days off. This study showed that working teens reported shorter sleep duration during the week when compared to their colleagues who did not work. During the weekend, those who worked reported longer sleep times suggesting a building up of a sleep debt.

Several other factors are associated with sleep duration among working teens. A study carried out among high school students in Sao Paulo, Brazil, using actigraphy showed that some factors significantly associated with shorter sleep duration were as follows: age entering the labor force, workplace and job title, wages, and quality of working conditions. Work control is also included as an important variable affecting sleep duration as well as high psychological demands, ability to perform tasks, and support from coworkers (Fischer et al., 2005).

Teixeira et al. (2007) showed that the sleepiness patterns of working teens were significantly different from nonworkers, as they were sleepier on early mornings and late evenings. Working teens face more difficulties in arriving at school on time and in remaining in school during the school hours. A U-shaped pattern of sleepiness was probably due to the circadian influence, and the rapid rise of sleepiness toward the evenings reflected the sleep debt because students woke up early in the morning (around 06:00 a.m.). Along the working week (Monday–Friday), sleepiness showed an additional afternoon peak, a so-called “postlunch dip.” On Mondays, sleepiness among teenage workers was likely to be associated with changes in bed times and waking up times, as well as extracurricular activities during the prior weekend.

In the same study, Teixeira et al. (2007) showed that students who did not work could follow the free expression of their sleep–wake cycle, as they did not have to wake up early during the weekdays for work. Thus, they express the phase delay of sleep that is characteristic of puberty. As observed by the wrist actigraphy assessments and diary data, the working students went to bed almost immediately upon arriving home at night, as they had to wake up early the next day to go to work.

The working students had shorter sleep periods during all school days by about 2 hr/day compared to nonworking students. The data support a cumulative loss of sleep across weekdays in young workers. This seems to explain the differences in sleep patterns on weekends between the two groups: workers went to sleep earlier than nonworkers, thus making an advanced waking time possible.

Individuals submitted to more strict work hours and/or school schedules tend to express more regular sleep–wake cycles. In summary, school/work duties during workdays seem to force working students to follow a stricter sleep–wake routine than nonworkers.

INTERVENTIONS

Interventions on School Time Scheduling

To help adolescents to obtain enough sleep in connection with school days with the standard early start, one solution could be to impose sleep schedules that would optimize sleep. One such attempt was made by Fallone et al. (2002) by asking children 6–12 years of age to either lengthen or reduce their
sleep mainly by altering time for initiating sleep. Actigraphs were used to evaluate sleep. The alterations of sleep averaged 3.5 hr and successfully demonstrated that children may be able to change sleep by initiating bedtime earlier in the evening. Unfortunately, this experiment lasted only for 1 week for each condition, and there was a lack of report on sleep quality and how difficult the new sleep times were to follow, and there were no reports on daytime sleepiness. But it has been shown in similar sleep manipulations of children 9–12 years old that a lengthening of sleep of an hour also shows positive effects on neurobehavioral functioning as opposed to 1-hr reduction (Sadeh, Gruber, & Raviv, 2003). A few studies have shown that a reduction of sleep in children will increase daytime sleepiness. For example, in one study, children’s sleep was restricted to 4 hr, and the results showed that more sleepiness was detected (Fallone, Acebo, Arnedt, Seifer, & Carskadon, 2001).

One other obvious way of treating sleep reductions in adolescence is to alter school start time. This type of intervention has rarely been investigated although many schools, particularly in the United States, have decided to introduce a later start (Fallone et al., 2002).

Carskadon, Wollson, Acebo, Tzischinsky, and Seifer (1998) followed a group of 25 students in the United States that during high school years were subjected to a 65-min earlier start of their normal school day schedule (from 8.25 hr in Grade 9 to 7.20 hr in Grade 10). The results demonstrated that, despite an earlier start, students did not go to bed earlier, and also the dim light onset of melatonin phase in saliva was delayed. It was concluded that adolescents show limits when trying to make adjustments to an earlier scheduling of school days. A number of cross-sectional studies have demonstrated that an earlier start of the school day results in worse sleep and that also there is a negative influence on daytime functioning as well as grades (Epstein, Chillag, & Lavie, 1998; Wollson & Carskadon, 2003). But there still seems to be a lack of published studies evaluating a delay of school start times in a robust interventional longitudinal design.

Interventions Using Bright Light
Some attempts to use light treatment during the morning hours have been explored in order to advance the circadian rhythm, promoting earlier bedtimes and sound sleep as well as to elevate alertness in school and promote learning. One such attempt was recently reported by Hansen, Janssen, Schöff, Zee, and Dubocovich (2005) using bright light treatment (1,800 lux) during morning school hours in a high school during November and February. A total of 60 students were studied and they normally slept 7.0 hr in connection with school days. The bright light treatment did not significantly affect sleep length or timing according to sleep diary measures, either on school days or at weekends. Also, performance and mood were very little affected. The lack of positive results can possibly be associated with the strong delay of sleep rhythms at weekends, academic pressure, or lack of control of individual overall daily exposures of light.

Interventions Dealing With Nutrition
Because a rhythmic misalignment with school scheduling does not only affect sleep cycles, it is important to also consider other circadian influences such as feeding behavior and metabolic consequences for school performance. For example, the study by Saarinpää-Heikkilä et al. (2000) found a clear link between late bedtimes, daytime sleepiness, and irregular breakfast habits in adolescent years. Similar findings have been reported in a sample of Japanese children between 12 and 14 years of age (Arakawa et al., 2001), where skipped breakfast/later bedtimes also contributed to lowered mood and elevated daytime sleepiness. Obesity has also been associated with habitual short sleep episodes (Vioque, Torres, & Quiles, 2000), and skipping breakfast and fast-food consumption are connected to weight gain in the transition period from adolescence to adulthood (Niemeier, Raynor, Lloyd-Richardson, Rogers, & Wing, 2006). To receive breakfast at school would delay the timing of nutritional intake to a later circadian phase when both appetite and the intestinal systems are activated, making it possibly to ingest larger and possible more nutritional meals (Lowden, Holmbäck, Åkerstedt, Forslund, & Lennernäs, 2001). It has also been demonstrated that students involved in school breakfast programs show favorable and improved school functioning on both psychosocial and academic variables (Kleinman et al., 2002).

Intervention on Educational Programs
An educational program on sleep seems to give adolescents with little knowledge about sleep some long-lasting effects (Cortesi, Giannotti, Sebastiani, Bruni, & Ottaviano, 2004). A sleep hygiene education program was presented to 58 adolescent students and the effects on self-reported sleep (diary), sleepiness, and mental states were evaluated (de Sousa, Arafujo, & de Azevedo, 2007). The interventions were introduced during 1 week and contained several parts including posters, interactive sleep education, lectures, a survey, and a quiz. The program was evaluated before the intervention and 1 month after. Daytime napping was shown to be initiated earlier with possible positive effects on sleep latency at night, but no significant effects were obtained on sleep timing, sleep quality, and alertness despite the very high occurrence of sleep-related problems in the studied group. The authors conclude that there is a need to further evaluate a more intensive and long-lasting interventional program with use of a larger group of students and with the possibility of including control groups.
CONCLUSIONS

In summary, adolescents around the world shorten sleep according to age mainly by delaying timing of sleep due to biological and psychosocial reasons and that they are subjected to forced awakenings in connection with school days. However, in some countries, double-shift school schedules seem to have beneficial effects regarding the fulfillment of sleep needs of adolescents.

More research is needed on adolescents to evaluate the effects on promoting sufficient sleep on school days by various interventions, such as educational programs on sleep hygiene, bright light treatment, breakfast programs, and so forth, that can be of use in trying to alter sleep habits by either self-selection or the influence of parental control. The lack of positive results in intervention attempts may be associated with several factors such as the strong delay of sleep rhythms at weekends, academic pressure and extra timework, and increased degrees of freedom in social life.

Governmental policies to prevent work injuries and implement health promotion programs among working teens should take into account the negative factors associated with the double journey of work and study.

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REFERENCES


