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Chapter 9

SLEEP PROBLEMS DURING ADOLESCENCE: LINKS WITH DAYTIME FUNCTIONING

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ABSTRACT

Sleep-wake patterns undergo significant changes during adolescence. The most prominent changes are an increased delay in sleep phase and a reduction in nocturnal sleep time. These changes are caused by different psychosocial and physiological factors. In about ten percent of adolescents, these patterns may develop into a delayed sleep phase syndrome (DSPS), which is characterized by consistent reported sleep onset times and waking times that are considerably delayed relative to societal demands. Adolescents may suffer from other common sleep problems such as insomnia, which is shortly described in this chapter as well. Other potential medical sleep-related disorders (e.g., sleep disordered breathing, restless leg syndrome, Klein-Levine Syndrome), are not covered in this chapter. The second part of the chapter, describes the negative consequences of adolescents' chronic insufficient sleep. Sleepiness, poor academic performance and neurobehavioral functioning, emotional difficulties and increased risk taking behavior are all closely related to adolescents' typical sleep patterns (i.e. decreased nocturnal sleep, irregular sleep-wake schedule, late bedtime and rise time, poor perceived sleep quality). In the conclusion part we will describe among others the main methodological shortcomings of the research in this field with guidelines for healthy sleep in adolescents.

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CHARACTERISTICS OF ADOLESCENTS' SLEEP PATTERNS

There is substantial evidence suggesting that the development of adolescents is accompanied by considerable changes in sleep and wakefulness patterns. The most extensive changes in sleep patterns manifest themselves in the timing and duration of sleep (i.e. sleep schedule patterns).[1-3] Carskadon [1], a central researcher in the domain of adolescents' sleep, and her colleagues, have documented the following main characteristics of adolescents' sleep: 1.During adolescence, there is a significant delay in sleep phase, manifested in markedly later bedtime and sleep onset time during the weekdays. Because sleep onset time is usually determined by school start time, adolescents show a significant shortening of nocturnal sleep duration. Whereas young adolescents (11-13 years old) sleep on average between 8.5 and 9.5 hours, during the high school years the average duration declines to around 7.5 hours [1-4]. 2. When allowed to sleep, adolescents will not only delay bedtime, but rise time will be shifted as well. As a result, there is an increasingly large discrepancy between sleep schedule during the weekdays and weekends. During weekends, the delay in sleep onset may be even more prominent, and many adolescents sleep into the late morning or noon hours as a way to compensate for the sleep deficit accumulated during the week. The gap in bedtime between school days and weekends averages between one and two hours and usually increases with age [1-4]. The difference in rise time is even larger and is estimated to be 1.5-3 hours in younger adolescents and 3-4 hours in high school students [2].

It is important to emphasize that the reduction in adolescents' sleep duration is not a result of decreased sleep needs. In fact, longitudinal studies carried out by Carskadon and colleagues demonstrated that when given the opportunity to sleep, adolescents would sleep approximately 9.2 hours across all pubertal stages and that optimal alertness in adolescents requires over 9 hours of nocturnal sleep [5, 6].

Different psychosocial and biological factors seem to be responsible for the profound changes in adolescents sleep patterns. Psychosocial factors include academic demands, social activities, sports, internet, television viewing, part-time employment, and use of mobile phone at night. In addition, parents are less involved in deciding about bedtime and social pressure may play a role as well[1-4, 7-9]. Moreover, increased emotional and sexual arousal accompanying adolescent development may lead to sleep onset difficulties and to delayed sleep [10,11]. Studies conducted by Carskadon and colleagues in the last 30 years highlighted the possibility that in addition to the well known influence of environmental factors, biological factors also play a role in delaying the timing of sleep during adolescent development[1,5,12-15]. In particular, Carskadon and colleagues proposed that during adolescent development the intrinsic circadian system changes in a way that contributes to the delay in sleep schedule.[13] The circadian clock is a physiological system that regulates, among other behaviors, sleep/wake behavior. Naturally, the circadian rhythms fluctuate with a period slightly greater than 24 hours. Therefore, under free running clock conditions, most individuals would fall asleep and awaken progressively later. However, the endogenous circadian system is synchronized to the 24-hour day through environmental time cues (i.e. the 24 hour light-dark cycle) [2]. Melatonin, a hormone secreted by the pineal gland, is responsible for transferring the light-dark information to brain centers that control the sleep wake cycle. Melatonin secretion rises in the evening hours, stays relatively constant during the night, declines in the early morning and is suppressed by light [15, 16]. The first study

supporting the hypothesis that the circadian system changes during adolescence development, and that these changes are related to pubertal changes, demonstrated a significant link between self-assessed pubertal status and self-reported phase tendency (morning/evening preference) in sixth grade girls [13]. Girls with higher puberty scores had a tendency toward evening preference. A similar, though non-significant trend was found in boys. The authors suggested that the gender difference may be related to the fact that some of the girls achieved a higher degree of maturation than the boys [13]. The relation between the circadian phase delay and pubertal development was further confirmed by studies showing a correlation between physical measurements of puberty and the timing of melatonin secretion. More mature adolescents had a later start of melatonin secretion [14]. It has been speculated that a reduction in positive feedback of melatonin secretion to the circadian system during puberty could be responsible for changing the circadian signal to the sleep-wake system, thereby delaying sleep phase [17]. Later studies conducted by different research groups confirmed the findings regarding the changes in intrinsic circadian phase during adolescence [2, 6, 8, 18, 19]. However, it is important to emphasize that most of these studies are cross-sectional and correlation and rely on subjective reports, making it difficult to infer about developmental trends and impossible to draw conclusions about causality. A recent longitudinal study about sleep and puberty shed light on the developmental question regarding the direction of the relation between puberty and sleep[20]. The adolescents in this study were assessed at three different time points on both puberty and sleep measures. The findings demonstrated that changes in objective sleep measures (delayed sleep phase and lower sleep quality) at time 1 predicted an increase in pubertal ratings (more bodily changes) from Time 1 to Time 2. However, the predictive correlations from puberty at Time 1 to sleep at Time 2 were not significant. These findings suggest that the sleep changes during early adolescence were evident before the bodily changes of puberty [20].

In addition to the changes in the circadian system, the possibility exists that the homeostatic system responsible for accumulating sleep need with extended waking may change during adolescence as well. In a recent study by Jenni, Achermann and Carskadon [21], it was found that mature adolescents build up slower homeostatic sleep pressure than early pubertal adolescents. This process may also explain why older adolescents find it easier to stay awake longer than young adolescents [15].

In summary, in addition to psychosocial factors, biological changes in the sleep systems and in particular in the circadian system, are likely to contribute to the significant evening preference and sleep phase delay observed during adolescence. These changes seem to be associated with puberty development. However, more research is needed to explore the mechanisms underlying these relationships. It is important to note that the changes described in adolescents sleep patterns (e.g. delayed bedtime, delayed rising time on weekend, increasing discrepancies between school days and weekends in sleep duration and timing) seem to be widespread. Studies and surveys conducted in different developed countries around the world demonstrate similar trends with regard to these developmental changes[6-8, 19, 22-24].

Whereas most adolescents are likely to experience some phase delay and the associated characteristics of shorter sleep duration and weekday-weekend variations in sleep schedules, in a subgroup of adolescents, these characteristics may lead to the development of a delayed sleep phase disorder and to severe sleepiness and disturbed daytime performance. In the following sections, we will expand on these topics.

DELAYED SLEEP PHASE SYNDROME (DSPS)

Phenomenology and Prevalence

Delayed sleep phase disorder (DSPD) is a circadian rhythm disorder that usually appears during adolescence [25]. It is a disorder of the timing of sleep, characterized by consistent, reported sleep onset times and waking times that are significantly later than those common in our society [26]. The prevalence of the disorder is not well known but is estimated to be between 0.1-3.1% in the general population and between 7%-16% in the adolescents and young adult population [2,27-29]. There is some evidence that adolescent males are more affected than females [30]. Moreover, there seem to be some cultural differences in the prevalence of the disorder. For example, a study conducted on adolescents in Europe showed a low prevalence of the disorder (0.4%) [31]. Although many of the adolescents reported delayed sleep or other indications of the disorder, most of them did not experience negative impact on their functioning. This may result from the fact that school starts somewhat later in Europe in comparison to the U.S, making it easier for the adolescents to cope with delayed sleep.

The International Classification of Sleep Disorders (ICSD) [29], and the DSM-IV-TR [28] include DSPS under the wider category of Circadian Rhythm Sleep Disorders. According to both diagnostic manuals the central diagnostic criteria of the delayed sleep phase type is a persistent delay in sleep onset and wake times (usually for more than 2 hours) relative to the common demands of society. This pattern comes with complaints of inability to fall asleep and awaken at a desired earlier time.

Additional diagnostic criteria are that the sleep disturbance cannot be explained by a different sleep disorder, or other medical and mental disorders, and that the disturbance causes clinically significant distress or impairment in functioning. The ICSD [29] requires in addition that the patients would exhibit normal sleep quality and duration if allowed to choose their preferred delayed schedule, and that sleep assessment for at least seven days demonstrates a stable delay in sleep phase.

Polysomnographic findings demonstrate that when allowed to sleep at their preferred delayed times, people with DSPS show normal REM/NREM sleep patterns. However, when studied at socially expected times they show reduced sleep efficiency (resulting mainly from sleep onset difficulties) and in some individuals, there is an indication for moderately short REM sleep latency. Laboratory measures of other circadian markers also show a delay (e.g. core body temperature, melatonin levels [28].

Typically, adolescents with DSPS complain of difficulties falling asleep before midnight and have excessive difficulty waking up before 10 o'clock in the morning, even for desired activities.[30] As a result of the need to wake up in time for school, many DSPS adolescents will be chronically sleep deprived and may experience "sleep drunkenness" in the morning, characterized by extreme difficulty in awakening and confusion [29]. Performance at school may be negatively hampered by late arrival or by falling asleep during class, difficulties in concentrating and a reduced level of functioning in the morning hours. Even motivated adolescents with DSPS may find themselves struggling in order to wake up and be on time for schools, and will find it impossible to advance their sleep phase without assistance [30, 32]. For example, they may have to set up multiple alarm clocks or ask their family to help

them get out of bed. Motivated students usually succeed to rise up on time, but still find it difficult to fall asleep at a usual hour and therefore they are in risk of accumulating an extreme sleep debt until the weekend, when they usually compensate for the sleep loss, by going to sleep later and waking up later. Less motivated adolescents may sleep in the mornings and miss the first hours of school. This can result in disrupted school performance and subsequently may lead to more school avoidance [30,32]. It is important to distinguish adolescents with DSPS from adolescents with primary school avoidance resulting from "pure" motivational and affective problems. These adolescents may choose to go to sleep late and wake up late in order to avoid school although sleeping late is not matching their internal circadian system. Another important differential diagnosis is between DSPS and primary insomnia. Whereas adolescents with DSPS do not suffer from sleep onset difficulties when going to sleep in accordance with their endogenous circadian clock (on weekends and vacations), individuals with primary insomnia typically demonstrate sleep onset difficulties regardless of the time they go to bed and do not have a consistent sleep onset time. However, in many cases it would be difficult to differentiate between the two because DSPS may lead to the development of insomnia [2,30].

Etiology of Delayed Sleep Phase Disorder (DSPD)

The exact mechanisms explaining DSPS are not well understood [33]. The onset of the disorder may follow medical or socio-psychological stressors and these factors may exacerbate the disorder. A major risk factor for the development of DSPS is having a clear intrinsic underlying circadian evening preference (preference for staying up late at night and waking up late in the morning accompanied by optimal functioning in the evening hours). Children with this natural tendency may develop a marked phase delay during puberty. The combination of this physiological change and environmental factors (early school start time, academic pressure, etc') may contribute to the development of DSPS [30].

Several physiological mechanisms, most of them related to dysregulation of the endogenous circadian time system, may contribute to the etiology of the disorder [2, 16]. One possible factor is the secretion of melatonin, which has been found to be delayed in individuals with DSPS [33, 34]. It has been suggested that individuals with DSPS probably fail to synchronize their internal circadian clock to their environment because of a reduced sensitivity to the light-dark cycles. Exposure to bright light was shown to influence the circadian phase. Bright light in the evening stimulates a phase delay while in the morning it produces a phase advance [17, 33]. To test the hypothesis that DSPS is related to light sensitivity, Aoki and colleagues [33] examined the sensitivity of melatonin suppression in response to light exposure in the evening in patients with DSPS and normal control subjects. They found that in DSPS patient’s suppression of melatonin secretion by light was greater than in controls, suggesting that DSPS patients may be hypersensitive to evening light. Besides differences in light sensitivity, other possible problems related to the circadian rhythm in DSPS patients may include changes in body temperature regulation and a longer endogenous circadian period (i.e. a longer internal day length) [17,35]. Another line of research suggests that DSPS patients show abnormal homeostatic sleep regulatory processes that cause a drive for sleep. For example, Uchiyama and colleagues [36] demonstrated that DSPS patients showed a lower ability to compensate for sleep loss (24 hours sleep

deprivation) during the day and first hours of the night than controls. The authors concluded that the difficulties in compensating for sleep loss predispose DSPS patients to problems with synchronizing their sleep phase. In summary, DSPS may be associated with abnormalities in the circadian rhythm and in its relation to environmental clues (e.g. light-dark cycle) with changes in sleep homeostasis processes or with problems in the interaction between these two sleep systems [2]. In addition, there is evidence for a genetic contribution to DSPS based on genetic polymorphisms studies and on studies showing that family history is present in about 40% of individuals with the disorder [35].

Once delayed sleep phase syndrome has developed, different behavioral factors may contribute to maintaining or exacerbating the problem. For example, increased exposure to evening light and decreased exposure to morning light may enhance DSPS [35]. Different methods adolescents use to cope with the sleepiness caused by the disorder, such as consumption of alcohol, caffeine or other stimulants, may further delay sleep onset and aggravate the condition. Other behaviors that may intensify the problem are lengthy afternoon naps and extended sleep on weekends and vacations [28, 30]. It is also important to note that DSPS has been associated with other mental disturbances such as depression and personality disorders [25, 28].

Treatment of Delayed Sleep Phase Disorder (DSPD)

There are three main techniques to treat DSPS: Chronotherapy, controlled light exposure and melatonin administration. To date, there is little research evidence as to the efficacy of these techniques in adolescents [2, 37]. Chronotherapy is a traditional behavioral technique used to adjust the circadian system to socially accepted hours. The technique is based on gradually delaying or advancing bedtime until the desired bedtime is achieved after which the adolescent is supposed to keep this new schedule during the week, including weekends [34, 38]. Adolescents' cooperation with chronotherapy is not assured, hence it is recommended that the treatment include a behavioral contract specifying the rules and reinforcements for complying with the program [34].

Exposure to bright light at the end of the adolescent's night is another technique used to advance the sleep phase. Bright light during the end of the nighttime or at the beginning of the daytime (after the estimated core body temperature reaches minimum) helps in advancing the sleep phase [2].

The third technique for treating DSPS is direct melatonin administration in the evening (1-5 mg). This treatment was found to be useful in advancing the sleep phase, while also having a mild hypnotic effect [2,16]. For example, Szeinberg and colleagues [16] studied the effects of long-term treatment with melatonin in 33 adolescents with DSPS demonstrating that melatonin was associated with advancing sleep onset time by more than 2 hours on average. It is important to note, however, that the safety of long-term melatonin administration has not yet been established. This is important especially with respect to adolescents, because endogenous melatonin levels change during puberty. Melatonin should therefore be used with caution until its safety is proved in clinical research.[6] In addition, the timing of melatonin administration as well as light exposure is critical in order to avoid the opposite effect (phase delaying effect). Both treatments should be administered in accordance with the individual's initial circadian phase and not at a fixed a priori hour.[35,37]

Treatment success of DSPD in adolescents is not straightforward and may be impeded by factors such as the severity of the disorder, comorbidity with other mental disorders, motivational factors and family support and cooperation. Every treatment plan should take into account the psychosocial factors that may play a role in the development or maintaining of the syndrome. [34, 35].

As mentioned above, DSPS belongs to a group of circadian rhythm sleep disorders. Other disorders in this category include the advanced sleep phase type, irregular sleep-wake type and the free-running type. All circadian rhythm disorders have in common a mismatch between the endogenous circadian rhythm and environmental factors that affect sleep-wake schedules. These disorders may lead to secondary insomnia or excessive daytime sleepiness and are associated with impairment of functioning [28,29]. Because these other circadian rhythm sleep disorders are not prevalent in adolescence, we will not describe them in detail.

INSOMNIA

According to the Diagnostic and Statistical Manual, Fourth Edition, (DSM-IV-TR) [28], an insomnia disorder is characterized by persistent difficulties initiating sleep (e.g. falling asleep) or maintaining sleep (e.g. staying asleep) or by nonrestorative sleep. In addition, the diagnostic criteria require that these symptoms last at least one month and cause clinically significant distress or impairment in daytime functioning**.** The diagnosis does not specify the frequency of insomnia symptoms (e.g., number of times per week, the time it takes the individual to fall asleep). The prevalence of insomnia disorders in the general population is approximately 6%. Primary insomnia, that is, insomnia unrelated to a medical condition, mental disorder, or another sleep disorder, affects about 1.3%-2.4% of the adult population [39, 40]. Only a few studies assessed the prevalence and development of insomnia among adolescents. In one of these studies focusing on European 15-18 years old adolescents, the prevalence of reported insomnia symptoms was 25% while approximately 4% had an insomnia disorder according to DSM-IV criteria. Of those with diagnosed insomnia disorder, approximately half had primary insomnia and 27% had insomnia related to another psychiatric disorder [31]. In a large epidemiological study of 1014 adolescents [41], 13-16 years of age, 10.7% met, during their lifetime, the DSM-IV criteria for insomnia and 9.4% had current insomnia. Of those with a lifetime history of insomnia, 88% also had a present episode. The most common complaint was difficulty in initiating sleep (68.5%), followed by non-restorative sleep (48.1%) and difficulty in maintaining sleep (26.2%). The median age of onset of insomnia was 11 years. Examining the relationships of insomnia to demographic characteristics, it was found that lower parental education was associated with increased prevalence of insomnia and that girls had a tendency toward a higher history of insomnia, although the difference did not reach statistical significance. Approximately half of the adolescents with a lifetime diagnosis of insomnia had one or more co-morbid psychiatric disorders. The authors also examined the links between pubertal development and insomnia, and found that the onset of menstruation was associated with an increased risk of insomnia. However, the pubertal development of boys was not significantly associated with insomnia. Sleep onset insomnia can sometimes be misdiagnosed in teens with DSPS. The authors reported that 1.9% of the sample had DSPS in the last two weeks. About 4% of the

adolescents who had current insomnia and 1.6% of the adolescents without insomnia had current DSPS. Therefore, DSPS did not account for a significant portion of insomnia in this study[41]. A recent study, [42] assessed the prevalence of insomnia in a large sample of 11-17 years-old adolescents, using a one year prospective design. Nearly 27% reported having at least one symptom of insomnia at time 1 and 46% of those adolescents again reported such problems a year later. Approximately 7% had at least one symptom plus daytime fatigue and/or sleepiness. Five percent of the adolescents met these criteria excluding mood, anxiety and substance use disorders. After a year, nearly a fourth of these adolescents still had insomnia.[42] Taken together, the findings of these studies demonstrate that the prevalence of an insomnia disorder during adolescence ranges between 4%-11% which is quite similar to the prevalence reported in the general population [40].

Etiology of Insomnia

Insomnia is most likely caused by a combination of physiological/genetic factors and psychosocial factors (e.g. exposure to acute stress, poor sleep habits problematic cognitions about sleep). [30] A possible contributing factor during adolescence is the change in circadian rhythm, causing a delay in sleep onset. This may increase the risk for insomnia in those adolescents who try to fall asleep before their endogenous time (e.g. before they feel tired, just because it is getting late). Lying awake in bed for long hours may give rise to concerns and anxieties that could further aggravate difficulties in falling asleep. In addition, sexual arousal and the socio-emotional changes and stressors occurring during adolescence (e.g., academic pressures, conflicts, and autonomy issues) may also add to the development of insomnia during this sensitive period [10, 41].

Treatment of Insomnia

The recommended treatment for insomnia in adolescents (as well as in adults) includes different psycho-behavioral interventions, usually referred to as cognitive-behavioral therapy for insomnia (CBT-I).[43] CBT-I includes techniques such as; relaxation strategies (e.g., breathing, positive imagery), keeping good sleep habits (e.g., establishing a bedtime routine, regular sleep schedule), stimulus control (e.g., use bed only for sleep), sleep restriction (e.g., stay in bed no longer than the usual amount of sleep each night) and cognitive techniques aimed at changing distorted thoughts about sleep (e.g., "I will never succeed to fall asleep") [30, 44]. The implementation of these techniques should be accompanied by a careful evaluation for possible individual factors (including psychodynamic issues) and age-specific stressors that may contribute to the development of the problem [10].

SLEEPINESS

As described in the previous sections, many adolescents get insufficient sleep because of the tendency to delay sleep and sufficient sleep is excessive daytime sleepiness (e.g. an

increased tendency to fall asleep during wakefulness). Different studies have demonstrated that adolescents are sleepier than younger prepubertal children, and that sleepiness is a very common complaint during adolescence.[45] For example, in a recent large cross sectional survey of 3235 high-school students in Canada, approximately 40% of the students reported excessive daytime sleepiness. Morning sleepiness was especially common, with more than fifty percent feeling "really sleepy" between 8 and 10 A.M.[46].

Maybe the first study about the development of sleepiness during adolescence was conducted by Carskadon and her colleagues in 1980 [5]. In that study, sleepiness was assessed by the Multiple Sleep Latency Test (MSLT), as developed by Carskadon and Dement [47] approximately 30 years ago. This test evaluates sleepiness by measuring latency of falling asleep during the day. During an MSLT, subjects are allowed to fall asleep while lying comfortably in bed in a dark and quiet room. The procedure is repeated at least 4 times a day, each time for 20-minutes with interval of 2 hours between the naps. A higher level of sleepiness is indicated by a faster speed of falling asleep, and by an increased number of sleep onsets during multiple tests [6, 47]. In the original adolescents study conducted by Carskadon and colleagues [5], sleepiness of 19 adolescents was assessed with the MSLT during 3 successive summers. Pubertal status was assessed using the five stages of sexual maturity according to the Tanner physical examination of secondary sexual characteristics. On all of the assessed nights, the adolescents were allowed to sleep from 10:00 pm to 8:00 am. It was found that, although the more mature adolescents slept not less than the less mature adolescents, the former demonstrated a higher level of sleepiness on the MSLT than the less mature adolescents did. Specifically, prepubertal and early pubertal adolescents rarely fell asleep on the MSLT and never fell asleep in less than nine minutes. However, pubertal adolescents fell asleep more frequently and faster, especially during the midafternoon tests. The authors concluded that during adolescence sleepiness increases regardless of the length of nocturnal sleep duration, indicating the involvement of physiological changes. The typical tendency to shorten total sleep time during adolescence may augment daytime sleepiness even more. These findings suggest that pubertal adolescents need more sleep in order to maintain a level of alertness similar to that of younger children [5, 45].

In a different study, Carskadon and colleagues [15] assessed the effects of early school start time on sleep patterns and daily sleepiness of 9^{th} and 10^{th} graders.

School start time in 10^{th} grade was 65 minutes earlier than in 9^{th} grade. Nocturnal sleep was assessed by actigraphy (body motility monitor) and demonstrated that 10^{th} graders were sleeping less than 9^{th} graders because of earlier rise time. Using the MSLT to assess daytime sleepiness, the researchers found that sleep latency on the MSLT was shorter in 10th graders (mean = 8.5 minutes) than in 9th graders (mean = 11. 4 minutes). The authors noted that the 10^{th} graders sleep latency time was bordering on pathological sleepiness levels. The most significant difference was on the first test of the morning at 08:30 (which is already school time), when it took the older adolescents only 5.1 minutes to fall asleep vs. 10.9 minutes in the younger group.

In another study conducted in Israel, 10-12 years old "early risers" (started school at 7:10 twice weekly) were compared to "regular risers" (starting at 8:00), on measures of self-reported daytime fatigue and sleepiness. It was found that early risers complained significantly more about daytime fatigue and sleepiness as well as attention and concentration difficulties in school than regular risers.[48] Noland and colleagues [49] assessed sleep behaviors and perceptions of sleep of 384 9^{th} to 12^{th} graders via a self-administered

questionnaire. Almost all of the students (93.7%) complained that not getting enough sleep made them feel more tired during the day. Similarly, Wolfson and Carskadon [3] found that students who had "less than adequate sleep habits" (i.e. shorter sleep times, large weekend delays) reported more tiredness and greater daytime sleepiness than the "adequate sleep habit" group.

Only a few studies explored the effect of controlled sleep restriction on daytime sleepiness of adolescents. In one of these studies [50], 16 children between the ages of 10 to 14 were randomized to either a sleep restriction group (5 hours in bed) or a control group (11 hours) for one night. Sleepiness, assessed by MSLT was significantly higher in the sleep restriction group [50]. Fallone and colleagues [51] examined the effects of acute sleep restriction (4 hours for one night) on the daytime behavior of 8-15 years-old children. The sleep-restricted group showed shorter daytime sleep latency and increased subjective sleepiness than the control group.

Overall, the findings from these studies demonstrate that excessive sleepiness is a significant problem in adolescents. In most cases, daytime sleepiness results from insufficient sleep. However, it is important to note that additional factors may be involved in causing sleepiness. Other sleep disorders, such as obstructive sleep apnea, insomnia, narcolepsy as well as certain medications and psychopathology (e.g. depression), may cause sleepiness and should therefore be considered when an adolescent complains about excessive sleepiness [6, 45].

DISTURBED DAYTIME PERFORMANCE

As described in this chapter, chronic partial sleep deprivation and excessive sleepiness are serious problems during adolescence. A very important issue rising in this context concerns the long-term behavioral consequences of these developmental changes in adolescents' sleep patterns. Overall, the research in this area has demonstrated the negative effects of adolescents' typical sleep habits and sleepiness on their academic performance, cognitive and neurobehavioral functioning, emotional regulation and risk taking behavior [52]. In the following sections, we will describe these findings in more detail.

Adolescents' Sleep and Sschool Performance

In a comprehensive review about the effect of adolescents' sleep on school performance, Wolfson and Carskadon [53] concluded that there is a significant relationship between adolescents' poor sleep patterns and poor, negative academic performance. In particular, decreased nocturnal sleep, irregular sleep-wake schedule, late bedtime and rise time, poor perceived sleep quality, evening preference, early school start time and increased daytime sleepiness were found to be associated with poor school performance in adolescence. For example, in a large survey completed by 3120 high school students, Wolfson and Carskadon [3] found that students who received low grades (C and lower) reported less total sleep time and later bedtimes on school nights than students with higher grades (A, B). In addition, students with worse grades reported later bedtime and rise time on weekends and a bigger

difference in bedtime between school days and weekends than students with higher grades [53].

Recent studies provide further support for the finding regarding the negative influence of disturbed adolescent sleep on school performance. For example, Giannotti and Cortesi [54] studied sleep patterns in Italian adolescents and found that sleep problems, phase delay preference and increased complaints of daytime sleepiness were associated with poor self-reported school achievement. In another study, adolescents who reported longer weekend delay showed lower academic performance. However, school performance was not related to other sleep measures such as sleep duration during the weekdays or weekend oversleep.[55] Lastly, in a cross sectional study evaluating the impact of adolescents' sleepiness and sleep disordered breathing it was found that reported snoring or apneas and sleepiness were significant independent predictors of poor academic performance in mathematics and language after adjusting for age, sex, body mass index, specific school attended, and sleep habits [56]. A possible explanation for the results linking adolescence sleep patterns and school performance is that students who go to sleep earlier and sleep more perform better at school because they are more alert and attentive [57]. However, because most studies in this field are correlational, it would be wrong to establish a cause and effect link. In addition, one should notice that most of the studies in this field (a) rely heavily on student self-reported measures of sleep; (b) provide little information on how school performance was assessed and about possible intervening variables (i.e. anxiety, motivation, SES, school type, parental involvement) [53]. Therefore, the findings regarding the links between adolescents' sleep problems and school performance should be interpreted with caution.

Adolescents Sleep and Cognitive Performance

Growing research suggests that decreased sleep quality and shorter sleep duration and accompanying sleepiness are significantly associated with impaired neurobehavioral functioning in school-aged children [58-60]. However, not many studies have specifically focused on adolescents sleep problems and their relations to neurobehavioral performance. The few controlled studies that did examine this question yielded inconsistent results. Fallone and colleagues [45] concluded in their review paper about sleepiness and its behavioral consequences, that verbal fluency and creativity may be impaired because of sleepiness, but that the findings regarding other cognitive functions such as attention, memory or problem solving are less consistent. For example, in a study comparing a group of 8-15 years old children, that were assigned to a restricted sleep group (4 hours for one night), to a control group, it was found that sleep restriction was associated with inattentive behaviors but not with impaired performance on tests of response inhibition and sustained attention [51]. Randazzo and colleagues [50] found that even one night of restricted sleep (5 hours) in 10-14 years old, resulted in impaired cognitive functioning on a verbal creativity and concept formation (Wisconsin card sorting test) tests. However, measures of less complex cognitive functions such as memory and figural creativity were not affected. The authors concluded that executive functions skills may be especially sensitive to sleep loss, whereas motivation may overcome the possible effect of sleep loss on less complex cognitive tasks. Sadeh and colleagues [60] assessed the effect of sleep restriction and extension on neurobehavioral

functioning of 4th and 6th graders. The children were asked to extend or restrict their sleep by an hour for 3 nights. It was found that children who extended their sleep improved their performance on a digit memory test and on the reaction time of the Continuous Performance Test (CPT) in comparison to their performance at baseline. Children who restricted their sleep reported lower alertness and they performed worse on a test of simple reaction time.

A recent study [61] assessed how neurobehavioral functioning is related to sleep deprivation and sleepiness in a cross-sectional sample of 236 adolescents. Sleep was assessed by actigraphy and overnight polysomnography and sleepiness by a questionnaire. Executive functioning was assessed by two different measures (one based on parental reports and one performance based). The results showed that sleepy adolescents received lower scores on both measurement of executive functioning, after controlling for socio-economic status. However, caregiver education modified the association between sleepiness and the parent-reported executive functioning. Among sleepy adolescents, those with less-educated caregivers had lower scores. Contrary to the hypothesis, actigraphic sleep duration was not associated with the executive functioning measures [61]. In another study, the links between sleep duration and working memory performance were assessed online in 143 adolescents aged 13-18. Adolescents reporting shorter sleep (less than 8 hours) performed worse on the working memory tasks compared with borderline sleepers [8-9], but not compared with long sleepers (more than 9 hours) [62]

It is important to note that the findings linking impairment in executive functions to sleep loss or sleep problems are not specific to adolescents. Similar findings were demonstrated in younger children and adults [59, 63, 64].

Adolescents Sleep and Affective Functioning

Several studies evaluated the links between adolescents sleep patterns and emotional difficulties. Most of these studies demonstrated that adolescents with problematic sleep patterns have more depressive symptoms. Wolfson and Carskadon [3] found in their cross-sectional study that students with shorter nocturnal sleep on school nights reported increased levels of depressed mood. In another study of 15-year-old youngsters, it was found that adolescents with sleep problems were more likely to to suffer from anxiety, depression, conduct disorder and lower social competence than those without sleep problems. In addition, adolescents with multiple sleep problems scored significantly higher on depression and anxiety than those who reported neither needing more sleep nor insomnia [65]. In a recent cross-sectional study [66] on the relationships between sleepiness, sleep time and adolescents' psychological functioning, sleepiness was found to be associated with higher anxiety and depression scores and with perceived negative health. However, sleep duration and variability in sleep duration were not significantly associated with any of the psychological measures.

To summarize, decreased sleep duration and sleepiness may increase depressive and anxiety symptoms in adolescents [3]. Dahl [11] suggested that inadequate or insufficient sleep may especially hinder affect regulation that requires the integration of cognitive and emotional processing. The opposite direction also receives support in the literature, implicating that depressed adolescents are more likely to suffer from sleep disorders [67]. A partial explanation for the link between problematic sleep and depressed mood may be the interference of stress and emotional arousal in the sleep of adolescents suffering from

emotional problems. Regardless of the chicken and egg question, the co-occurrence of both problems may lead to a negative spiral of fatigue and sleepiness, poor emotional regulation, decreased motivation and poor academic functioning, which may further interfere with sleep and mood [6].

Sleep and Risk Taking Behavior

Risk taking behavior increases during the adolescence years. Many factors may account for this behavior and only recently, some studies tried to explore whether poor sleep may also be a contributing factor to risk taking behavior. O'Brien and Mindell [55] studied this question via self-reported questionnaires in a sample of 388 adolescents. Their results demonstrated that adolescents who reported longer weekend delay and higher levels of sleep problems also reported significantly higher levels of risk-taking behaviors. In particular, students with a weekend delay of 2 hours or more reported lower safety behaviors, more smoking, more alcohol and marijuana use and increased sexual activity, compared to students with a weekend delay of 1 hour or less. In addition, students with shorter sleep duration on school nights reported more alcohol use than students who slept longer. The authors hypothesized that reduced cognitive performance related to poor sleep makes it difficult for adolescents to consider the consequences of risky behaviors, or that a third variable, such as lower parental control, could be responsible for both poorer sleep habits and higher risk taking behavior. Giannotti and Cortesi [54] reported that 88% of the adolescents in their sample had experienced accidents (at home, school or driving) and that the increased vulnerability to accidents was associated with sleep problems, daytime sleepiness and increased use of stimulants and tobacco.

Another major risk taking behavior in adolescence is careless driving. Car accidents are a leading cause of death in adolescents, and adolescents' lack of sleep and sleepiness may be a risk factor for falling asleep at the wheel [6]. A recent study conducted by Danner and Phillips [68] assessed the effects of delayed high-school start times on sleep and motor vehicle crashes. Self reported sleep patterns and car accidents were assessed before and after a 1-hour delay in school start times. It was found that two years after the change in school start time, the average rate of accidents dropped by 16.5% compared to two years prior to this change. The average accident rate in other places, where no change in school time was introduced, increased during the same period by 7.8%. In addition, after the delay in school start time, the sleep patterns of adolescents changed; they slept longer during the night and reduced sleep during the weekends. Carskadon [69] found that among students who drive, 67% reported having driven while impaired by sleepiness. However, they did not perceive driving while sleepy as a high-risk behavior. In general, students rated driving under the influence of alcohol as more dangerous than impairment caused by sleepiness. Interestingly, students who reported they had driven while feeling sleepy or under the influence of alcohol rated this behavior as less dangerous than students who did not have such experiences. Although there is growing awareness that sleepiness can lead to car accidents, adolescents and young adults should be more thoroughly educated about the risks of sleepy driving [69].

FUTURE DIRECTIONS

A growing body of literature based mainly on surveys and cross-sectional studies, (and, to a lower extent, on laboratory studies) demonstrates that there are serious negative consequences to insufficient sleep during adolescence. Nevertheless, the research in this area still faces some methodological limitations, which make it hard to draw clear conclusions about cause and effect links between adolescents' sleep patterns and daily performance [45, 53]. Many of the concerns about the negative implications of decreased nocturnal sleep and sleepiness on daytime behavior are based on research lacking objective assessment of either sleep or daytime functioning. Basing the assessment of sleep, sleepiness and outcome measures such as school performance and mood on reports from the same subjective source (the students), increases the chance that the reported associations would be elevated and biased. Future studies should therefore use, in addition to the frequently used self-reports, also objective measures of sleep (i.e. actigraphy) and sleepiness (e.g. MSLT)[34, 45]. In addition, the assessment of daily performance should be based on multiple measures or sources (grades, teachers reports, parental report, student reports, computerized tests) .[53]. Moreover, most of the studies conducted in the field established the short time consequences of inadequate sleep, but there is a considerable lack of knowledge regarding the long term effects of poor sleep and sleep disorders, such as delayed sleep phase syndrome and insomnia during adolescence. Longitudinal studies are needed in order to fully understand the predictive relations between adolescents' physiological changes, sleep development and daytime functioning [34, 53]. Likewise, researchers are still far from defining the specific neurobehavioral systems affected by poor sleep. There is a need for more well-controlled studies that will take into account possible mediators and moderators (e.g. SES, motivation, psychopathology) in order to delineate clear links between sleep, sleepiness and different domains of adolescents functioning [45]. Another important question to be evaluated is whether there are certain times of the day that adolescents perform better. Considering the delayed phase tendency, adolescents may be more alert and may function better in late morning and afternoon classes [57].

The growing body of research on the negative consequences of adolescent chronic insufficient sleep is not yet translated into practice. It is necessary to raise the awareness of parents, teachers and school administrators to assure that adolescents get more sleep. Studies that compared early school start time to later start time clearly demonstrated that many adolescents pay a significant price because of early school start time. Although sleep researchers have recommended that public schools delay high school start time, most school systems did not accept their suggestions [57]. It seems especially important that scientists and the school systems would collaborate in order to evaluate the advantages of later school start time for adolescents functioning and in order to develop prevention and intervention programs that will help adolescents acquire and maintain healthy sleep habits [53, 57].

CONCLUSIONS AND GUIDELINES FOR HEALTHY SLEEP IN ADOLESCENTS

Adolescents around the world are experiencing a decreased amount of sleep time, which is in clear contrast to their sleep needs. Different psychosocial (i.e. academic pressure, work, social activities) and physiological (i.e. pubertal phase delay) described in this chapter account for the unique sleep patterns of adolescents. Among the many implications of chronic insufficient sleep during adolescence are: daytime sleepiness, poor academic functioning, decreased neurobehavioral performance, mood problems and increased risk-taking behaviors.

Although it is impossible to change the natural biological tendency towards a shift delay, certain behavioral steps can be taken to help adolescents minimize the gap between their sleep needs and their typical sleep patterns. For those adolescents who have an intrinsic phase delay, this may be especially important to prevent the development of a sleep disorder. Even though many adolescents are aware of the potential negative effects of sleep deprivation, lack of knowledge on how to cope with the problem is widespread.

Therefore, adolescents should be aware of their growing sleep needs and of the developmental shift in the circadian clock leading to decreased sleep time. In order to maximize their sleep, adolescents should be encouraged to: (1) Keep consistent regular bedtimes and rise times, ensuring spending adequate time in bed. Preferably, this regular schedule should be implemented also on weekends. (2) Avoid sleeping late into the noon hours on weekends because this may hinder the adolescent to fall asleep at night and may impair the synchronization of the sleep-wake cycle leading to a further phase delay. For the same reason, napping in the early afternoon hours should be avoided or limited to 30 minutes (3) Use the bed only for sleeping. Any other activity (i.e. television, reading for a long time) may associate the bed with alertness and may cause sleep problems. (4) Create a routine before bedtime that will include calming and relaxing activities to break the connection between the stimulating activities of the day and sleep. (5) Reduce or avoid exposure to bright light in the evening to prevent a further phase delay and increased exposure to light in the morning. (6) Avoid using any drugs, alcohol, caffeine, or stimulating substances because in addition to their well-known risks, they have documented negative effects on sleep. (7) Maintain regular eating. Eating a heavy meal just before bedtime can interfere with sleep but going to sleep on an empty stomach is not recommended either. (8) Keep regular exercise in the beginning of the day and avoid exercise in late evening hours. This can help to advance the circadian clock. (9) Avoid using sleeping pills unless there is an indication for a severe sleeping disorder, requiring professional intervention. A doctor should obviously monitor any use of medication [30, 57].

Besides the steps adolescents can take by themselves, parents, teachers and health care practitioners should be aware of the high prevalence of problematic sleep patterns and sleep difficulties in adolescents. Chronically sleepy adolescents, who are late for school and perform poorly at school without any clear reason, should be carefully examined for sleep disorders. If the adolescent shows excessive sleepiness even though he/she gets sufficient time to sleep, the presence of possible underlying physiological sleep disorders with potentially obstructive effects on daytime functioning, such as breathing related sleep disorders, should be examined [30] These recommendations may help to improve sleep

quantity and quality and lead to a better quality of life and daytime functioning in adolescence.

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