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Review Article

Biological clock vs Social clock conflict in Adolescents

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Abstract
Alteration of day and night is one of the essential circadian rhythms that build the phenomenon of sleep/wake in humans and other animals. Daily rhythms impact different individuals differently. Light exposure and an individual's circadian response are two aspects that create diversity in phenotype. These diverse phenotypes are called chronotypes. Chronotype varies over the life history stages. Chronotype is seen as morning type in children, evening type in adolescents, and again reverts back to the morning type in adults and old-aged individuals. It is observed that adolescents being evening types have bedtime later in comparison to children and adults. Adolescent physiology/ body clock does not allow them to sleep early and school routine/social clock does not let them sleep till late. Thus, their night phase is shrunk and sleep hours are reduced, which hinders their daytime functioning, including mental tasks such as cognition, learning and memory-based exercises, and physical tasks such as physical presence during field and athletic events. These days sleep debt is a critical health concern in the adolescent population. The current review focuses on the adolescent sleep-needs and various factors affecting their healthy sleep. This also encompasses the understanding of biological clocks, their misalignment, disrupters, causes and impact. The present study would be helpful in finding out the difference between the biological clock and social clock of the adolescent population, elaborates the need for sleep education and suggests a solution to this alarming problem of sleep debt in teens.

Keywords: Adolescent physiology, Biological clock, Circadian rhythms, Clock disruption, Sleep-wake cycle, Social clock

CLOCKS IN HUMAN: AN INTRODUCTION

All living systems have endogenous, self-sustained biological clocks. Thus biological clocks are ubiquitous. These are inherent timing mechanisms that time the periodicity of various underlying physiological, behavioural and biochemical processes. These endogenous clocks synchronize themselves with external cues such as light, food, society, etc (Van Drunen and Eckel-Mahan, 2021). The ebb and flow of daily life impact individuals differently. This shows that light exposure and an individual's circadian response are two aspects that create diversity in phenotype. These different phenotypes are called chronotypes (Roenneberg, 2015; Kalmbach *et al.,* 2017). This temporal difference of day and night between the two chronotypes could be as large as ten hours (Roenneberg *et al.,* 2007). Studies indicate that chronotype changes significantly throughout the life span (Randler *et al*., 2017). Various cross-sectional studies demonstrate that pre-adolescents are morning type, but when they reach their adolescence, they show maximum shifts towards evening types and exhibit the same till 20 years of age; thereafter, they re-shift towards early-type (Roenneberg *et al*., 2004; Tonetti *et al.,* 2008; Randler et al., 2016). Besides age, there are reports indicating gender-based differences in chronotype (Duffy *et al*., 2011; Tonetti *et al*., 2008). Chronotypes are linked to individual's sleep-wake variability, cognition, learning behaviour, and other endogenous clock properties, thereby creating individual temporal niches (Kerkhof, 1985; Karan *et al.,* 2021). As we live in a 24X7 world, keeping aside the body's physiological demands, lead to increased risk

for health and safety. Maximum work profiles in our social and professional world, irrespective of an individual's chronotype, prefer morning schedules over any other time of the day. In this course, young adults, especially adolescents, are the most vulnerable age group, as most dramatic changes in human life take place in this phase (Susman *et al*., 2003).

The focus of this review is to bring out the cause and consequence of sleep disturbance in adolescent students. Previous studies have shown that sleep behaviour changes during the adolescent years because of the physiological demand of the body. Teenagers prefer being awake late at night but out of the compulsion of school regime they have to get up early as most of the schools in our country have an early start time (Knutson and Lauderdale, 2009). This latency in going to bed and rising early creates chronic sleep debt in adolescents' life (Hansen *et al*., 2005). For adolescents, the school timings not only hold the key position in the plan of the daily schedule but are also responsible for their overall health and well-being. By addressing the problem of "early school start time," we can deal with most adolescent health problems. Other societal factors like late-night- screen time, mobile use, internet addiction, workouts, study schedules, exam stress, use of caffeinated drinks at night and many such individual issues also contribute to this problem (McKay *et al.,* 2021). As we are aware, the penalty of the sleep debt is severe; and the payoff is the students' physical and mental health, which compromises their potential for day-time functioning. We have tried to explain the importance of the biological clock and its synchronization with the social clock.

We witness a periodic recurrence in the forms of rhythms in almost every phenomenon formulated by nature. We witness these rhythms in every natural phenomenon. Whether it is the alteration of day and night or seasons and tides, everything runs in harmony in nature. Every individual on this planet, from algae to human-being have their internal rhythm. These internal rhythms of an individual are synchronized with the cyclic movements of the environment. Circadian (Circa = about; Diem = a day) rhythms in living beings are regulated by a biological timepiece positioned in the Suprachiasmatic Nuclei (SCN) which lies in the hypothalamus. This clock tunes them with the outer world by accepting various environmental cues (Lockley and Foster, 2012). The body clock sets up the chronotype of a person according to the time preferred by the body's internal demands, which leads to determining major behavioural patterns like- sleep-wake cyclicity, emotional balance, introvert-extrovertness, mental-physical performance. The body clock also maintains other crucial biological processes like metabolic activity and physiological demands that include, meal time preference, regulation of blood glucose, the release of the required hormone and many such responses (Kozlowska *et al.,* 2020). Suprachiasmatic nucleus is a tiny region of the brain in the hypothalamus responsible for running the circadian body clock and other rhythms associated with the body's peripheral organs (Hilton *et al.,* 2001; Hastings *et al*., 2003). Circadian rhythmicity is associated with the changes with day-light and day-length. When changes in the light wavelength and light intensity are conspicuous; they are critical for the entrainment of the endogenous circadian timekeeping system in nature. Such non-parametric entrainment underlies a phase-dependent (discrete or phasic) sensitivity of the circadian rhythms to daily light-dark cycles. The dark phase is equally important for existence as the light phase of the 24-hour cycle of the day. Dark hours are generally associated with the rest of the sleep.

Sleep, which seems to be very simple, is a very complicated process. It involves several regions of the brain. In addition to it, neurotransmitters and hormonal pathways also play a crucial role. None of these factors can build sleep alone on their own. This complex interplay of different factors makes the process of sleep unique and valuable; therefore, sleep cannot be taken for granted.

In the case of adolescents, it is observed that they are going to bed later in comparison to children and adults. Thus, their night/rest phase is shrunk in comparison to other age groups. Studies have suggested that the duration of sleep keeps on reducing till the age of adolescence but the required duration does not change during teenage years (Crowley *et al*., 2018). When we step ahead to understand the adolescent circadian clock and sleep behaviour, in light of their physiological demand and the consequences of daily sleep deprivation for attending school in early hours, gives a new angle to address adolescent behaviour (Jain and Khare, 2020). Alongside, Sleep disruption is also one of the root cause of up- and down-regulation of various cognitive and emotional behaviours in individuals (Fig.1). A questionnaire-based study was done on *approx.*1,50,000 adolescents in which the subjects have shown a diversion towards being evening-type. This change occurred earlier in girls, which matches with the early onset of puberty in them (Tonetti *et al.,* 2008; Randler, 2011). This change again reverts when an individual enters adulthood, which leads to a shift in their chronotype again towards being early-type (Roenneberg *et al*., 2004). Many studies have shown that the sleep hours during the free days or in the summer break are more in comparison to the work or the school days (Hansen *et al*., 2005; Jenni *et al*., 2005). Other studies have also shown that their biological rhythm is not lethargy, which makes them bound to the bed in the morning hours and keeps them wake-up till late in the night.

One more study based on actigraphic data of sleep showed a trend of development where reduced sleep and delayed onset from child to adolescent are seen (Galland *et al*., 2018). Another study was conducted to find out sleep debt between biological time and educational time, which has shown the severity of sleep deficit in varied age groups (Foster *et al*., 2013). Also, survey-based studies from China and Canada indicates that adolescents are prone to chronic sleep debt (Chen *et al*., 2014; Patte *et al.,* 2017). In today's era, sleep deprivation has reached dangerous levels. This situation is alarming, but fortunately, it is still a controllable affair, which can be solved by keeping the school timings according to the biological clock of adolescents.

Alterations on a chronic basis in sleep pattern during the adolescent period may lead to severe sleep-related disorders in their later ages, which may harm their health. It is recommended that approx. 9 hours of sleep is required for healthy functioning of the body *(*Short *et al.,* 2018*;* Fuligni *et al*., 2019). Less than 8 hours of sleep on daily basis creates constant sleep debt which has a direct impact on cognitive power, emotional balance and physical health of an individual (Lockley *et al*., 2004). Studies have also shown that weak immune system, low metabolism, high blood sugar levels, cardiovascular disorders, hypertension, anxiety, stress, obesity and cancerous growth in adolescent are related to the restricted sleep schedule (Foster *et al*., 2013; De Souza and Hidalgo, 2014; Luyster *et al*., 2012; Kling and Landgraf, 2021). A study was done to find out the harmful effects of the short duration (5.7 hours per night for one week) of sleep on a healthy body in comparison to those people who were kept under control condition (8.5 hours per night for one week); this also revealed that the activity of total 711 different types of genes (responsible for circadian expression) are either up-regulated or down-regulated, because of insufficient sleep (Möller-Levet *et al*., 2013). Based on self-reports of sleep duration made in questionnaire across 40 countries of the world, a systematic review reported that the short duration of sleep adversely affects the mental and physical health of individuals (Chaput *et al*., 2016). Those adolescents who received recommended amount of sleep were at their best mental health status (Fuligni *et al*., 2019) whereas, those who slept less than the recommended sleep duration have shown psychological complaints (NorellClarke and Hagquist, 2018). Disturbances in sleep lead to the formation of diseases in the body.

Several findings suggest a relation between sleep debt and obesity (Cappuccio *et al*., 2008; Chen *et al.,* 2008; Miller *et al*., 2018), also the evidence-based research from experiments and epidemiology from the past 30 years has connected sleep debt with obesity (Sluggett *et al*., 2019). Both chronic sleep debt and obesity are issues concerning public health and in light of the researches mentioned earlier, it becomes more noteworthy (Agha and Agha, 2017). Therefore, sleep correction becomes significant in the treatment of obesity (Chaput and Dutil, 2016).

Clock disruption and its effect on adolescents

Borbély was the first to propose the two-process model of sleep (Borbély, 1982), which explains the role of the circadian system (Process C) and homeostatic system (Process S) in maintaining sleep-wake behaviour. The circadian system is responsible for sleep timings irrespective of previous sleep/wake cycles, whereas the homeostatic system is responsible for increasing sleep drive for the amount of wakeful

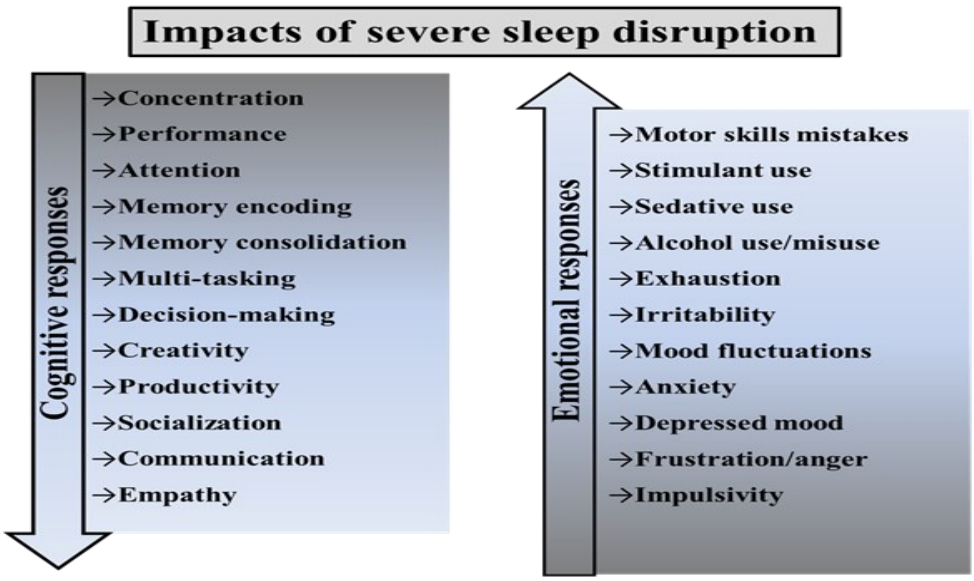

Fig. 1. *Impacts of severe sleep disruption on cognitive and emotional responses (redrawn from Wulff et al., 2010).*

period of that individual. If the circadian system or central clock of a living organism is disrupted, it will lead to the misalignment of the entire network of peripheral clocks (Jain and Khare, 2020), which are working in synchrony with each other (Foster *et al*., 2013). Adolescence is especially an age where delaying in the sleep-wake cycle is notable, and that can be easily understood with the help of the above-mentioned two-process model of sleep. Here, with the progress in pubertal age (Carskadon *et al*., 2004), circadian system shifts to later timings of the day that results in phase-delay in circadian timekeeping system (Hagenauer *et al*., 2009; Hummer and Lee, 2016). This shift can be seen in their chronotypes (about their sleep-wake times; Roenneberg *et al*., 2004). Changes in bio-regulation of sleep-wake cyclicity are responsible for sleep burden in adolescents but these alterations in adolescent physiology are not taking place in seclusion (Kozlowska *et al.,* 2020). It is a well-known fact that our body functions efficiently when both biological and social clocks are simulated with each other. In ancient period, both the social and biological time-scales were almost in synchrony because of the less intervention of artificial light at night, technology-based 24x7 lifestyle and unruly academic burden on young people. (Foster and Keitzman, 2014) Difference between social and biological clock creates a misalignment of various rhythms governing smooth body functioning. This desynchrony becomes a potential threat especially to adolescents as they are already undergoing a physiologically turbulent phase (Fig. 2). Therefore, changes in adolescents are an outcome of the mixed effect of the environment in which they live, their daily routine/lifestyle and many other psycho-social factors. There are many factors such as school and exam stress, internet and social media addiction, use of substance and high caffeine drinks which create clock disruption in adolescents.

Clock disrupters

a) School regime

Keeping track of time is the basic block on which the theory of the school system, as well as the biological processes, are laid upon, but still, both these sectors have their understanding of time (Peterson, 1996). The meaning of development in the perspective of the school system is evaluated in terms of the number of academic years crossed (based on annual curriculum and daily time-table (Ward, 2021). This trend is more or less the same on the global platform. On the other hand, the biological evaluation of time measurement is done by calculating the development levels. Developments can also be evaluated on a short term basis by considering the response of our body clock in the

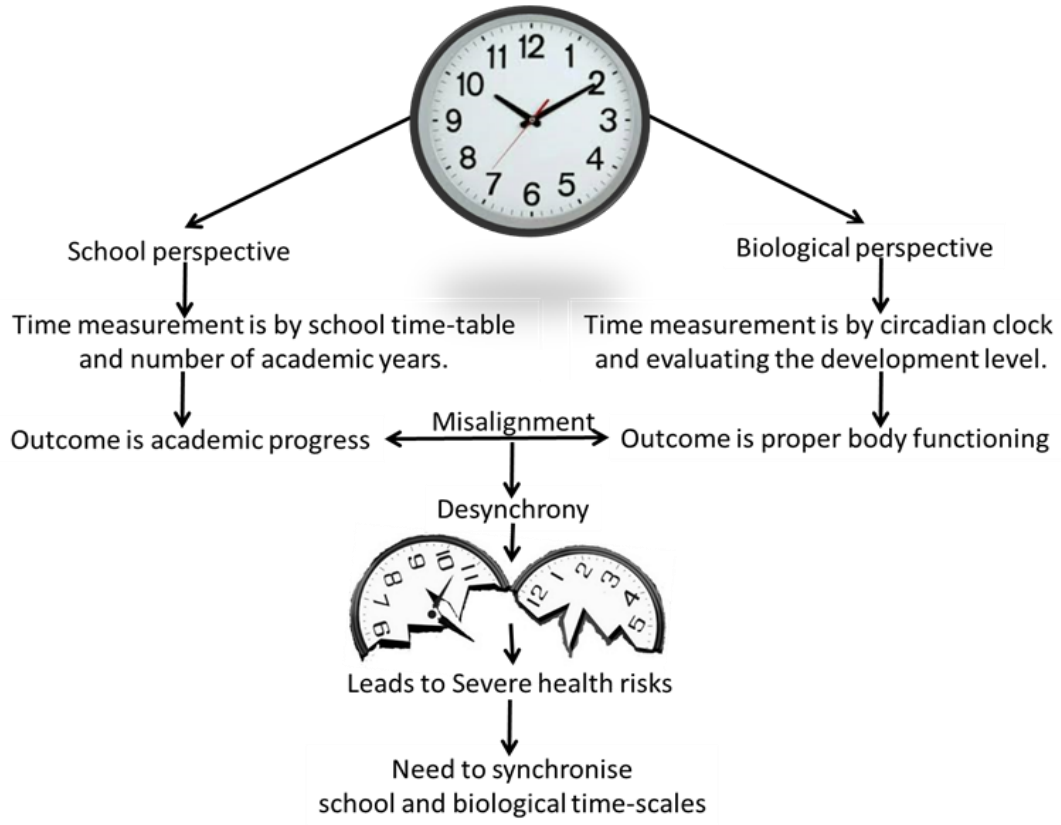

Fig. 2. *Importance of time in school and biological perspective and how their misalignment creates a desynchrony which leads to health risks.*

circadian frame. School curriculum and cut-throat competitive exams have compelled students to give extra time to studies from their bed hours(Shochat *et al.,* 2014) and there is no way to compensate night-time sleep-loss during morning hours as early school start time does not allows them to sleep till late (Chaput *et al.,* 2016). Amid all this school going adolescent's physiological demands are compromised. In addition to it, the majority of schools have morning schedules that force evening type adolescents to wake-up early irrespective of their internal clock. This schedule, on a chronic basis, leads to the circadian misalignment and reduced Sleep (Liu *et al.,* 2021). On a chronic scale, this condition serves as the major cause of "Social jet lag" in adolescents (Wittmann *et al*., 2006).

School hours

The school schedule is the main cue around which the routine of adolescents is weaved. There is a need for simulation of the educational system according to adolescent biology. Sleep deprivation among students is not the sole cause behind rescheduling school hours; it is also interlinked with other factors. A few of them are memory-based learning and sleep; circadian variation, chronotype and individual differences sleep hygiene. Good Sleep plays a very important role in building long-term memories (Diekelmann and Born, 2010) and disturbances in it can damage the foundation of the same (Stickgold *et al*., 2000). Sleep consolidates memory, which is important for mental health and overall well being (Wilhelm *et al*., 2011). During the adolescent years, it is the student's natural tendency to attain alertness in the later period of the day and remain awake until late at night, making them more likely an evening type individual. Evening type is associated with better attention (Bai *et al.,* 2021). The performance of the adolescents also improves later in the day (Hansen *et al*., 2005; Hahn *et al*., 2007; West *et al*., 2011). A study conducted by Matchock and Mordkoff (2009), showed that at 0800 hours the attention level of individuals belonging to all the chronotypes is significantly low and at 1200, 1600 and 2000 hours their scores almost double up. Another study conducted on the school going students of age group 13-14 years by giving them word-pair test at 1000 & 1400 hours and then evaluating their performance. It was found that they performed better in the later test (Kelley and Lockley, 2013). There are other related studies also, which provide evidence for similar time-in-day effects (Schmidt *et al*., 2009; Haraszti *et al*., 2014). According to a study done on students of Spain (12-16 years), late-type students performed significantly poor (Escribano *et al*., 2012).

Exam stress

Examination time is considered to be one of the major stress giving times in an individual's life span. An adolescent who is already undergoing so many ups and downs physiologically and socially feel under immense tension when the pressure of achieving good academic grades exceeds. This leads the student to the condition of stress and altered psycho-physical behaviour (Rani, 2017). Exam stress is not just a single term but is associated with sleeplessness, anxiety, time pressure, appetite loss (Putwain, 2008). Exam time stress leads to physical problems (Zunhammer *et al*., 2013) as well as sleep-related problems. Curtailing on the sleep adversely affects the cognition strength of students and results in poor performance in academics (Curcio *et al*., 2006; Carskadon, 2011). Certain reports also suggested a difference in examination pressure found in the students studying through science stream and humanities stream. This difference is may be due to Practical classes during school and coaching classes after school (Rani, 2017). Boys are less stressed than girls in their routine (Dewald-Kaufmann *et al*.2014; Steven, 2016). A study conducted on college-going students shown that the examination stress also results in the suppression of their cardio-respiratory rest function while sleeping at night (Sakakibara *et al*., 2008). Exam stress is found to be the highest in the examination week, lower than that is seen in the week just before the examination and at least two weeks before the examination started. This kind of pattern is indicative of the role of psychological intervention in the perception of stress (Dewald-Kaufmann *et al*., 2014).

b) Screen time

Today our society has turned global, and thus as consequences, there are 24-hour work profiles (Coveney, 2014). In the past ten years, electronic devices have found their space in almost every home on a global level or it can be said that almost every adolescent has access to the technological screen in one form or the other. They have been brought into play in such a way that they entered our bedrooms from the living room. Reports suggest that more than 90% of adolescent remain with some of the other multimedia devices in their bedrooms when they go to sleep, which hinders the normal sleep timings by delaying it (NSF, 2006). Exposure to light in the evenings will interrupt circadian rhythms by suppressing the release of melatonin. The rhythm of the melatonin hormone is closely linked to sleep and sleep timing (Arendt, 2019). In the evening, exposure to artificial light will alter patterns of sleep and thus changes the sleep duration (Touitou and Point, 2020). Besides, electronic devices emit light with a short wavelength (i.e. blue light). In this

range, the circadian system is alarmingly sensitive to light (Cajochen *et al.,* 2011; Bertani *et al*., 2021). Excessive use of these gadgets at bedtime has significant detrimental effects on sleep duration and quality (Hysing *et al*., 2015). 24/7 access to the technology, especially mobile and laptop screens (which emits blue wavelength) have played a significant role in increasing alertness and delayed sleep onset (Rüger *et al*., 2012). The weekday-weekend gap in getting-up time is larger in adolescents but in adult evening types, which shows circadian misalignment (Adan, 1994; Broms *et al*., 2011).

A widely acclaimed review of 36 studies published in 2010 showed that excessive media use in children and adolescents is associated with delayed bedtime and shorter sleep periods (Cain and Gradiser, 2010; Kokka *et al*., 2021). A broad US-based survey examined whether the sleep pattern persisted between 2009 and 2015 and the factors that could contribute to its decrease. By 2015, more than 40% of teenagers regularly slept less than 7 hours a night, 16-17% more often than in 2009. During the analysis period, time for usage of digital media screens increased (including mobile devices, social media and reading of online news) and also the chances for a shorter period of sleep increased. Notably, during these years, there has been no rise in other behaviours which could be suggested to interfere with sleep (TV, pay job, homework; Twenge *et al*., 2017).

The cross-sectional data from the Millennium Cohort Study in the UK were used in another large-scale research (Scott *et al.,* 2019). The authors analyzed social media usage by 11,872 adolescents aged between 13 to 15 years and sleep results associations using 2014 data. The use of social media was measured using one item: the time spent on social media on a typical weekday. Larger use of social media has been related to weaker sleep after covariate control. Specifically, highly addictive social media users who used social networks more than 5 hours a day (20.8%) were more likely to record a late sleep onset during the school week, compared to users who used social media 1 to 3 hours a day (31.6%). Handys (mobiles) are omnipresent and a part of daily life. In fact, they are seen as an important tool for social interaction by young people. A longitudinal study evaluated the impact of mobile phone use in Western Australia for over four years from 2010 to 2013. Individuals were asked what time text messages or telephone calls were typically sent or received and whether they continued after the lights are off. Over these years, the use of cell phones at night has increased, equally leading to corresponding increases in bad sleep practices (Vernon *et al*., 2018).

Studies have mostly used the survey-based data and correlation statistics, although a recent experimental study requested teenagers to avoid using their mobiles one hour before their normal bedtime and also to complete a sleep diary along with. Results revealed that during the intervention week, teenagers avoided using their mobile 80 minutes before, put their lights off 17 minutes before, and sleep lasted 21 minutes longer than school-night (Bartel *et al*., 2019). Along with circadian misalignment, such individuals also tend towards psychological dysregulation, addiction to alcohol abuse and involvement in substance use (Gau *et al*., 2007, Pieters *et al*., 2010; Saxvig *et al*., 2012, Stolarski *et al*., 2021). Survey also shows that the students have given data for a relation between sleep-related issues and alcohol consumption along with substance use (Lund *et al*., 2010; Pieters *et al*., 2010).

c) Caffeine

Caffeine is the commonest consumed psychoactive substance. It blocks adenosine receptors (Roehrs and Roth, 2008). Caffeine is seen as a problem for sleep because adenosine is a neurochemical substance whose level increases wakefulness in the brain (FavrodCoune and Broers, 2021); adenosine is suggested to stimulate sleep and play a role in homeostasis in sleep (Basheer *et al*., 2004). Afternoon or evening caffeine consumption can be an issue of concern as the half-life of single-dose takes between 3-7 hours and may hinder the process of falling asleep (Roehrs and Roth, 2008). In recent years, energy drinks have received publicity; in particular, the youth consumption trend has increased. Caffeine is a major component of energy drinks It gives 113-200 mg energy shot with 70-200 mg presence in a 16-ounce drink (NCCIH, 2018). More than two-thirds of the adolescents were registered to use energy beverages in the UK (DHSC, 2018), and one-third in the USA (NCCIH, 2018). Energy drinks have been noted to gain popularity among adolescents in recent years, as it increases the alertness and helps battle the sleepiness (Bryant and Wolfson, 2010, Yasuma *et al*., 2021).

Factors other than the above-listed causes are also responsible for creating motivation for the later sleep timings in adolescents.

Impacts of clock disrupters

a) Metabolic Imbalances

Many past studies revealed how human physiology and a few disorders are directly linked with circadian rhythms (Schernhammer *et al*., 2003, Gale *et al*., 2011, Martino *et al.,* 2008, Wulff *et al.,* 2012). Metabolic homeostasis, specifically in adipose tissue is an important element that is responsible for energy metabolism. Adipose tissue is the reservoir that fulfils the major energy demands of the body whereas, brown

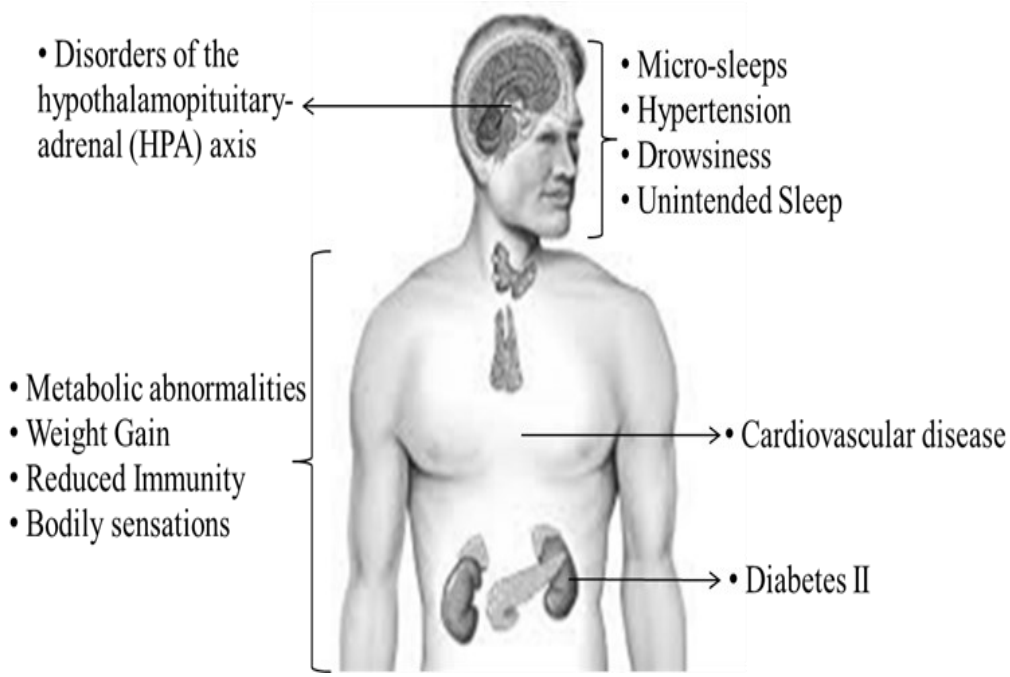

Fig. 3. *Effects of sleep disruption on physiological responses (redrawn from Foster and Wulff, 2005).*

adipose tissue accumulates lipids for adaptive thermogenesis caused by cold weather. Adipose tissues secrete multiple hormones, cytokines and metabolites that control the signal for appetite in CNS and metabolism in peripheral tissues (Choe *et al*., 2016), e.g. leptin has unique hypothalamic receptors and is released from the principal adipocytes. Leptin increases thyroid hormone levels and stimulates the sympathetic central nervous system, which leads to increased formation of the uncoupling protein which leads to greater use of energy (Con *et al*., 2017). Leptin hormone release follows circadian rhythmicity, where the night is the time when a maximum of serum leptin level is recorded (Tsujino and Sakurai, 2012). Now,

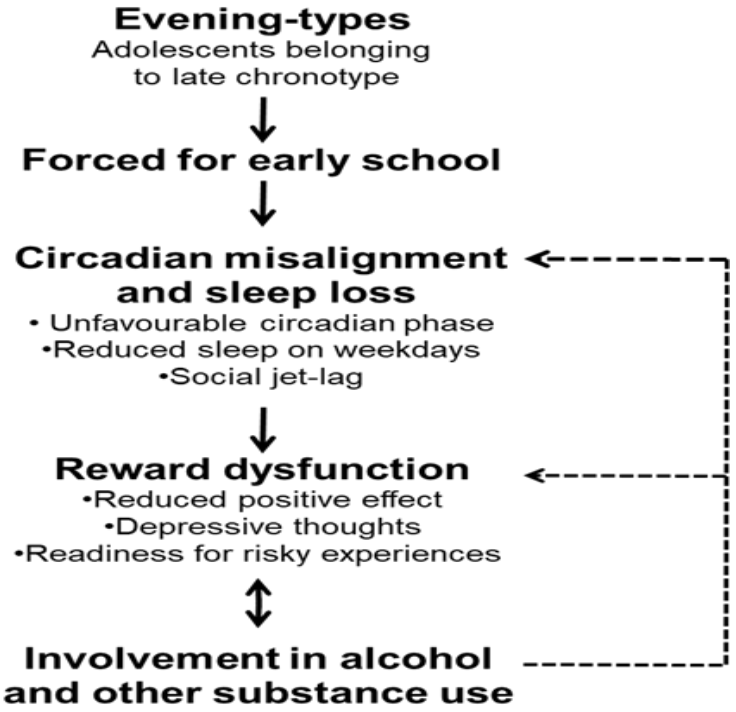

Fig. 4. *A conceptual map showing circadian misalignment leading to the alcohol abuse and substance use in adolescents (based on Hasler and Clark, 2013; Hasler et al., 2015).*

disturbance in the night time sleep may lead to circadian misalignment that can indirectly affect the whole chain of the secretion of leptin, process of thermogenesis and homeostasis of energy. On the opposite, certain hypothalamic hormones display more night activity, e.g., growth hormone peaks between 2:00 to 4:00 a.m in the night. Imagine if the adolescent has a disturbance in nighttime sleep, then it will adversely impact the growth of that individual. Therefore, particular attention must be given to children's sleep patterns also (Sato and Ida, 2017).

Chrono-disruption is the misalignment of peripheral clocks with the central clock (Garaulet *et al.,* 2010), which leads to some serious diseases (Ahmad, 2020). Majority of diseases are lifestyle disorders such as cardiovascular diseases, depression, obesity and metabolism (Garaulet *et al.,* 2014) (Fig. 3). The circadian clock plays a significant role in the homeostasis of energy and metabolism. Circadian therapies thus, focused on rhythm, diet and exercise that have been introduced in recent times to maintain metabolism, which is referred to as 'chrono-pharmacology,' 'chrono -nutrition' and 'chrono-exercise,' respectively (Azmi *et al*., 2020). Factors such as shift work, disturbed sleep, insomnia, that are capable of triggering circadian rhythm disruption need assessment particularly in people with metabolic disorders, such as obesity (Garcez *et al*., 2021). Plans to schedule workout and meals according to their normal biological rhythms can boost treatment efficiency in these patients.

b) Psychological disorders

There is ample literature available that demonstrates the between mood, light, and circadian rhythms (Bedrosian and Nelson, 2017; Arns *et al*., 2021). Light at night can be considered as one of the most prominent biological and behavioural clock disrupters that leads to psychological imbalances. Many mood disorders are either characterized by sleep and circadian rhythm disturbance or by an abnormal light-dark cycle. Seasonal affective disorder (SAD) is a recurring depressive disorder in which a patient's mood swings between dysthymia (in winters) and euthymia (in summers). Other disorders such as Shift Work Disorder, Severe Depression, Bipolar Disorder, PTS, Common Anxiety are directly linked with irregular sleep pattern (APA, 2013). However, the essence of the relationship between circadian rhythm dysfunction and psychopathology is poorly known (Jones and Benca, 2015). However, rodent studies have shown that even experimentally induced circadian rhythm disorders can induce changes in healthy animals. If resynchronization of circadian rhythm in patients is targeted, then symptoms of mood disorders can be improved. Although circadian disturbances may not be the only cause of mood diseases, they may cause or intensify symptoms in people with a tendency of mood-related disorders.

c) Alcohol, substance abuse and reward dysfunction

According to the reports, approximately 31% of college-going students live their life in circumstances favourable for an individual to get into alcohol abuse, which is likely to be increased by 6% (Chawla *et al*., 2007). The tendency for consuming alcohol and nicotine is more in evening-type individuals when compared with morning types.

Eveningness shows its relation with the reward-related brain dysfunction, which comprises depression, reduction in reward response and increased need for sensation seeking (Hasler *et al*., 2010; Tonetti *et al*., 2010) (Fig. 4). Brain areas involved in the reward processing also show a changed activity, especially in evening types (Hasler *et al*., 2012). Adolescents who are comparatively insensitive towards the reward may develop a tendency to seek reward through alcohol abuse (Spear, 2000). Two studies conducted on adolescents report that the larger the difference between the sleep of weekdays and weekend, which points towards circadian misalignment, leads to the increase in risk-taking behaviour (O'Brien and Mindell, 2005; Pasch *et al*., 2010). Circadian misalignment generally goes hand in hand with sleep loss and sleep disturbance, which greatly impacts the increased homeostatic drive which in turn is responsible for the involvement in reward dysfunction, risk-taking, alcohol abuse and substance use (Tamura *et al*., 2021).

d) Road accidents

Road accidents nowadays have increased in multiple folds in comparison to the later in a decade. A noticeable fact is that adolescent drivers have also increased in number. It is seen that the adolescent drivers are more prone to the morning accident in comparison to the older ones (Danner and Phillips, 2008; Czeisler, 2009; Vorona *et al*., 2011). It is a fact that sleepiness and tiredness due to incomplete sleep have a direct link with motor accidents (Garbarino, 2001; Connor *et al.,* 2001, Connor, 2002; Philip *et al*., 2002). These accidents are the clear case of functional inactivity due to the wake-up schedule which is out of the circadian phase. Pack *et al.* (1995) is accredited for making this on the record and universally accepted that individuals with sleepiness but without any known sleep-related disorder could be the reason for road accidents. Pack's team analyzed the reports of the crashes in North Carolina in the year 1990 and 1992. The reports revealed the review of those crashes in which the driver was thought to have slept while driving the vehicle. Out of these 55% of crashes

happed with individuals who were at the age of 25 or below (Lowden *et al*., 2009; Akerstedt and Kecklund, 2001). Among teenagers the problem of being drowsy while driving is a major issue of concern (Pizza *et al*., 2010; Taylor and Bramoweth, 2010). According to some studies done on high school grade students (having a driving license), where 11% of the total went into crash while driving automobiles due to sleepiness as its main cause. Also, 40 % have registered that they feel sleepy while driving, while two-third of them were the sufferer of day-time sleepiness and one-fifth had poor sleep quality (Sagaspe *et al*., 2007).

These studies are suggestive of the need for the counter strategy to deal with the problem of road accidents due to sleep deficit in adolescents (Oyegbile, 2020). Setting up school timings according to the biological clock of adolescents will address the majority of this problem and rest can be solved by advising the youth not to drive when drowsy and saying a 'No' to drink and drive. Planned napping could be another alternative solution for the same (Smith-Coggins *et al*., 2006).

Sleep education is a must

Sleep education is an instrument to deal with the psychosocial and lifestyle factors that can improve the lives of individuals. Adolescents may take part in behaviour that does not encourage them to sleep, although the use of good practices in 'sleep hygiene,' such as regular sleep and a sleep-friendly routine, may help (Sari and Annisa, 2021). Schools should provide an atmosphere where teens can get information about sleep, just like other valuable information about health and hygiene in their classroom. Sleep education programme focuses on increasing teenagers' consciousness about the significance of sleep and enhancing sleep health. Reviews of these programs' effectiveness indicate that awareness of sleep hygiene has significantly improved while sleep behaviour improvement is still limited (Froy, 2012; Tahara and Shibata, 2013; Oike, 2017).

A suggestive solution

Studies in the field of circadian biology and sleep medicine influence the education system directly (Azmi, 2020). There is a need for proper sleep hygiene (Sari and Annisa, 2021). The USA addressed this problem by shifting the schools toward later timings, where middle and high schools were recommended to begin not before 8.30 a.m. (Brown *et al.,* 2002). This delaying aimed to minimize insufficient sleep and social jetlag, thus reducing the mismatch in adolescents' social and biological clocks. Authorities and policymakers must be aware of the risks of sleep debt and they should consider the late school hours over the early hours to make adolescents, healthy learners (Kelley and Lee, 2014; Sari and Annisa, 2021). Along with the general approach towards delaying school hours, there should be an understanding of the effect of chronotype on an individual's behaviour (Karan *et al*., 2021). This not only will save the health of students but also will benefit the young teachers.

Our government is making efforts to create a healthy environment for school going students (Stolarski *et al*., 2021). Later start of school may solve the purpose to a great extent (Jacob and Rockoff, 2012; Kirby *et al*., 2011). Our knowledge of the need for sleep is enhancing on a daily basis. Still, there is a need for spreading awareness regarding the importance of sleep among common people (Chauvette *et al*., 2012; Grosmark *et al*., 2012). In other countries, change has already started to appear; even the awareness regarding this is being spread by some agencies like the National Sleep Foundation and Start School Later campaign. Shifting school timings to later hours is a practical approach because misalignment of the sleep schedule with the school timing, if carried over for a prolonged period, will result in regularly persistent and irrefutable sleep-debt. Adolescents already undergo tremendous developmental changes on the level of their brain and body, and in addition to it, if they will not get proper sleep to rejuvenate, then this chronic sleep debt may hamper their emotional, mental, physiological and metabolic well-being on a serious note (Hansen *et al*., 2005; Giedd, 2009; Giedd *et al*., 2012; Sawyer *et al*., 2012; Sørensen *et al*., 2012; Foster *et al*., 2013; Ahmad, 2020). Alignment of the biological and school clock will help adolescents in improving their health, along with the better academic performance that too in a relatively less stressed atmosphere (Ward, 2021). Also, this initiative will not require any new methodology for teaching-learning or any kind of expenditure. This will reduce health risk without using any medication or treatment (Liu *et al*., 2021). There is considerable data in support of adolescent population being under the disadvantages of unsuitable school hours. Keeping the timing of the schools in sync with the adolescent biological clock is the call of the hour, which is both practical and essential. It also reflects that a better environment can be created for the adolescents, in the light of good transdisciplinary research data available on sleep science, neurobiology and educational research (Gabrieli, 2009; Meltzoff *et al*., 2009).

Conclusion

Today's teens face obstacles such as completion of home-work in late-night study schedules, social media activity, and their own physiology itself pose a limit to their daily amount of sleep. The impact of social influ-

ences is doubtless profound, with an important role in the proliferation and habitual use of electronic media. Further study is required to determine the mechanistic course of effect of the electronic media on sleep. Chronic sleep debt is a critical health concern because of the important role of sleep in different aspects of our lives. However, it must be remembered that other sleep and circadian variables are often explored as potentially influential factors such as sleep quality, sleep duration, regularity and sleep onset. Encouragingly, movements to recognize and incorporate strategies for improvement of sleep for adolescents' well-being have gained traction. The knowledge about sleep education needs to be spread to educate the adolescent and youths and empower them to change jeopardizing behaviour related to sleep needs.

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Conflict of interest

The authors declare that they have no conflict of interest.

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