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The Relationship of Sleep Deprivation with the Poor Academic Performance and Adolescents' Mental Health

A Review of Neuroscience Perspective

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ABSTRACT
Adolescent mental health problems have a proportion of up to 16% of the total burden of disease for people aged 10-19 years in the world. Various studies suggest that lack of sleep in adolescents can affect poor academic performance and the emergence of mental health problems such as depression. This article is intended to review the relationship between lack of sleep in adolescents with poor academic performance and the emergence of mental issues from a neuroscience perspective. We conducted a literature review regarding sleep deprivation and physiological phenomena that occur in the adolescent brain, which is then associated with mental health problems and decreased academic performance. At the end, we propose several solutions that can be used as policy guidelines to improve adolescent academic performance and maintain adolescent mental health.

Keywords: *mental health, sleep deprivation, adolescents, academic performance*

1. INTRODUCTION

WHO shows data that 1 in 6 people in the world, aged 10-19 years. And it turns out that adolescent mental problems have a proportion of up to 16% of the total burden of disease in the world. Half of the mental issues start at age 14, but most go undetected and untreated. Globally, depression is a major problem among adolescents. Even suicide is the number 4 cause of death between the ages of 15-19 years. Adolescent mental problems that do not get attention to interfere with their physical and mental health, resulting in disruptions in fulfilling their developmental tasks later into adulthood [1].

Data from various studies in Indonesia also shows the occurrence of depression among adolescents. A study conducted a depression screening on 230 new students at a university in Surabaya was found that 17 people had depression, and 65 people had the potential for depression. The majority of symptoms of depression experienced include feeling bad about themself, difficulty concentrating, loss of interest in activities, drastic weight changes, and difficulty sleeping through the night [2].

One of the factors that can trigger depression in adolescents is lack of sleep [3]. Data in the United States shows that 87% of high school teens sleep less than 8 hours per night and 57.8% of junior high school teens sleep less than 9 hours per night [4]. On the other hand, teenagers in South Korea average only 4.9 hours of sleep per night. South Korea's adolescent suicide rate stands at 10.7 per 100,000 per year until some researchers speculate that chronic sleep deprivation is one of the contributors to this phenomenon [5].

According to the CDC, 93% of high school and 83% of middle school students in the United States start school before 8:30 am. Adolescents who do not get enough sleep tend to be overweight [6], reduced physical activity, tend to experience unhealthy behaviors such as drinking alcohol [7], smoking, illegal drugs, to experience low academic performance [8]. Sleep deprivation has become a common problem in American adolescents, with only less than a third of high school students in the United States getting at least 8 hours of sleep a day [9].

School hours in Indonesia also experience the same thing. The 2013 Indonesian national curriculum

currently used makes Indonesian pupils on average starting at 06.30 to 07.00 and finishing at 15.00 [10]. The education curriculum in Indonesia has changed at least ten times since it was started in 1947. And among all the curricula that have ever been implemented, none has a school entry rule after 08.30 am [11,12].

This review will describe the relationship between lack of sleep in adolescents with decreased academic performance, impaired emotional control, and depression from a neuroscience perspective from different research results and sources. With a scientific explanation related to this phenomenon, it is hoped to provide a new perspective on changing Indonesia's education policy.

2. METHOD

This article was written using the literature review method, covering the introduction, research methods, discussions, and conclusions [13]. The literature review aims to add an in-depth understanding of studies relevant to the topic or problem discussed [14]. To explain the relationship between sleep deprivation, decreased academic performance, emotional disturbances, and depression in adolescents, this study was conducted by searching using the keywords "emotional," "adolescent," "lack of sleep," and "poor academic performance." The search was carried out through Google Scholar, PubMed, and Frontier media. In addition to searching from international sources, this review was also carried out by searching for national publications through the keywords "emosional", "remaja," "waktu tidur kurang," and "performa akademik buruk" through Google Scholar media. The limitation of the journal publication year taken in this study is the last ten years. However, if research sources beyond the previous ten years are considered important to be included, they are still taken and discussed in this study.

In the first part, we will explain the definitions of sleep deprivation, poor academic performance, and adolescent mental health based on our review of journals and various sources. Then in the next section, we explain the relationship between them from a neuroscience perspective based on our literature review.

3. DISCUSSION AND FINDINGS

3.1. Sleep Deprivation Definition

A study in Bandung showed that 26% of vocational high school students were depressed with the number of social media addictions which was statistically significantly related to the level of depression [15]. In a large-scale study with a population of 9.846 adolescents, a negative correlation has been found between gadget use and sleep duration [16].

Sleep deprivation itself has a term that is almost the same as sleep deficiency. These two words have different meanings. Sleep deprivation is a condition that occurs when the body does not get enough sleep. While sleep deficiency has a broader meaning, it includes the presence of one or more of the following: sleep deprivation, sleeping at the wrong time (outside of regular body hours), not sleeping well, having a sleep disorder that results in insufficient or low sleep quality [17].

3.2. Hormonal Time Shift, Brain Maturation, and Neuroendocrine Aspects of Adolescents

Teenagers experience changes in circadian rhythms, resulting in peak melatonin production (a hormone that induces sleep), which was secreted later at around 11 pm to 8 am [18]. In Indonesia itself, according to the regulation of the Minister of Education number 23 of 2017, the duration of school learning hours is 8 hours a day and 40 hours a week. This was done five days a week. So, the average school in Indonesia starts at 07.00 in the morning and ends at 15.00. Of these 8 hours, there is only a 30-minute break a day [19].

Various studies show strong evidence regarding circadian and homeostatic regulation, which was sensitive to gonadal hormones. Activation (direct and transient) of the effects of gonadal hormones on the circadian system and sleep homeostasis has been observed during gonadal hormone fluctuations in women. This is similar to the process of gonadectomy and the administration of estrogen, testosterone, progesterone, or neuroactive steroid metabolites in mice that produced indirect effects on sleep and circadian patterns in both males and females [20].

During adolescence, there are also quite drastic hormonal changes that make growth spurts and secondary sex characteristics appear. Increased growth hormone causes a growth spurt. Meanwhile,

the increased testosterone levels in men and estrogen begin to grow secondary sex characteristics [21].

Adolescents are also prone to stress. During stress, physiologically, the body performs a neuroendocrine response by releasing corticotropin-releasing hormone and arginine vasopressin from the hypothalamus to the anterior pituitary [22]. The anterior pituitary then secretes adrenocorticotropic hormone (ACTH). ACTH then goes to the adrenal cortex and adrenal medulla to make them secrete glucocorticoids and adrenaline, and noradrenaline [23]. That is why the term adrenaline rush appears because this is the phenomenon of releasing adrenaline when a person's condition is under pressure or stress. At each age range, the endocrine response to stress can be different. Especially in the adolescent stage, the response to glucocorticoid release is much greater than in other age ranges [24]. This difference in response can also be triggered by differences in the number of glucocorticoid receptors in the adolescent brain. It is evident that increased Glucocorticoid Receptor (GR) mRNA in the prefrontal cortex during adolescence. Thus, there is a correlation between stress response and the tendency for stress-related psychiatric problems to increase in adolescence [25].

In adolescence, the brain is also experiencing maturation. Factors that affect brain maturation in adolescents include heredity and environment, sex hormones (estrogen, progesterone, testosterone), physical, mental, economic, psychological status, surgical intervention, nutritional status, pharmacotherapy, drug abuse (nicotine, caffeine, alcohol), and sleep [26]. It should be noted, sleep is one of the factors in adolescent brain maturation. Thus, sleep is an integral part of brain development in the adolescent phase. The following section will discuss the relationship between sleep deprivation and various disorders in adolescents.

Brain volume increases in adolescents, consisting of white matter and gray matter. White matter volume increases linearly with age. From the age of 4-22 years increased by about 12.4%. Meanwhile, the gray matter volume increases nonlinearly and in a specific region. The frontal lobe, the maximum size is formed at the age of 12.1 years (male) and 11 years (Female). The parietal lobe, the maximum size is formed at the age of 11.8 years (male) and 10.2 years (Female). The temporal lobe, the maximum size is formed at the age of 16.5 years (male) and 16.7 years (Female). And uniquely, men's gray matter volume is 10% larger than women's [27]. This difference in gray matter volume is related to differences in physical activity patterns between men and women because physical activity is

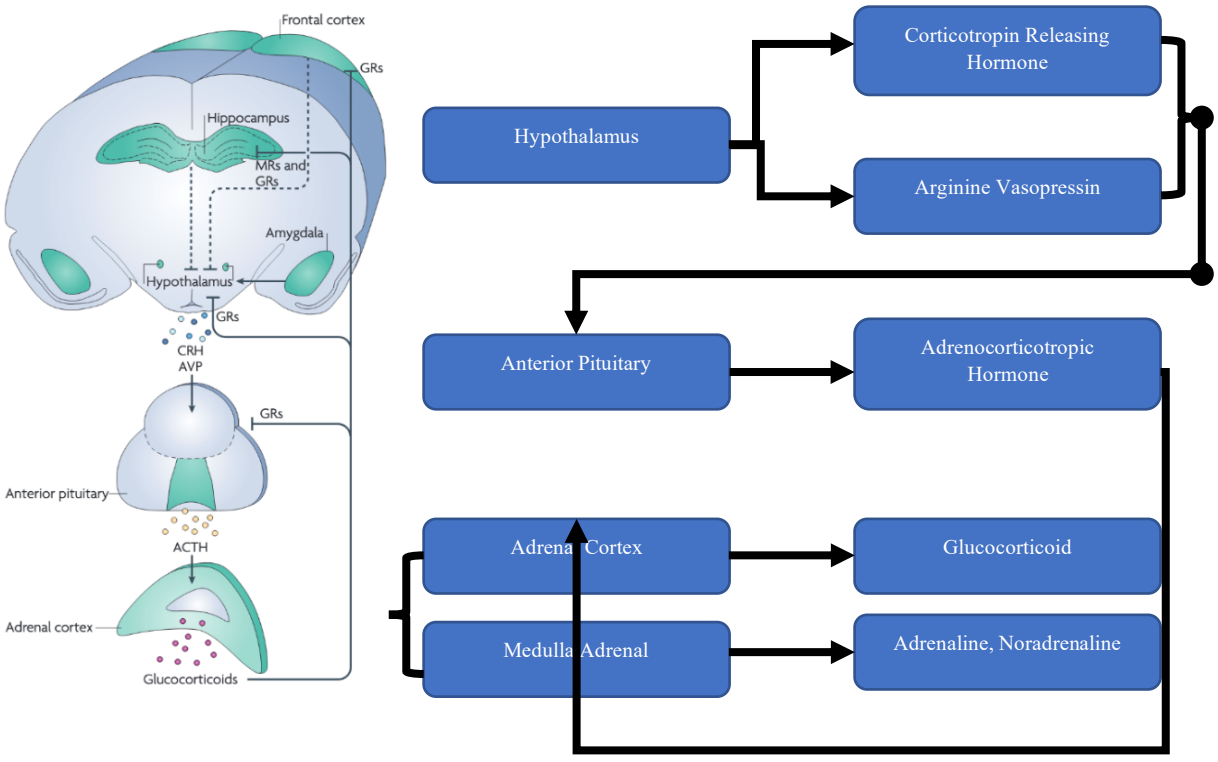

Figure 1. Neuroendocrine response pathway to stress in adolescents (24)

directly proportional to the increase in the volume of gray matter and hippocampus [28].

3.3. Depression Level of Indonesian Adolescents

According to 2018 Basic Health Research data, it is known that the prevalence of symptoms of depression and anxiety in adolescents aged 15 years and over is 6.1% of the total population of Indonesia, or around 11 million people [29]. When correlated with specific studies in several schools and regions, these national data show different results. A study about the level of adolescent depression in a high school in Jakarta found that 60.9% of adolescents in that school were depressed [30]. And the results of the analysis of the study showed that there was a statistically significant relationship between depression levels and suicidal ideation. Another study in Denpasar showed that the depression rate of students at SMA Negeri 4 Denpasar was 30% and found a relationship between depression and negative academic achievement [31]. Meanwhile, a similar thing happened in Salatiga. According to research within subjects from 175 students of SMAN 1 Salatiga, 24% of male students and 40% of female students experienced symptoms of depression [32].

In addition, a study was conducted using a quantitative descriptive purposive sampling method on new students at a university in Surabaya. Of the 230 students who became the subject of his research, 17 were depressed, and 65 were potentially depressed. Of all the students with the potential for depression, it was found that the majority of symptoms experienced included bad self-esteem, difficulty concentrating, loss of interest in activities, drastic changes in body weight, and difficulty sleeping throughout the night [2].

3.4. Correlation between Sleep Deprivation and Emotional Control Disturbances

Many factors influence the emotional development of adolescents, including changes in interactions with schools, physical changes, changes in interaction patterns with parents, changes in interactions with peers, and changes in external views [33]. One of the changes in the interaction with the school is that the school hours are so busy, and the assignments given are so many that it takes up a child's sleep time every day. A study found that lack of sleep will affect adolescent emotional control [34]. Only a few days after sleep deprivation, adolescents will experience a bad mood disorder and reduce their ability to regulate negative emotions. On the other hand, anxiety rates also increase in sleep-deprived adolescents [35]. Adolescent girls tend to be more susceptible to mood disturbances due to lack of sleep, but teenage boys also experience the same thing [36]. Emotional disturbance control in sleep-deprived adolescents tends to be negligent, unable to solve problems, and easily depressed and daydreaming [37]. Lack of sleep in adolescents can even cause more severe psychological effects such as stress, depression, to suicidal ideation [38].

Lack of sleep will negatively affect neurobiological changes due to sleep duration disturbances in brain areas associated with motivation and reward [39]. This manifests as a disturbance of the pleasurable effect that should arise in pleasant conditions. Lack of sleep impacts increasing anxiety and will also increase sympathetic responses, blood pressure, proinflammatory cytokines, and blood cortisol levels at night [40].

Amygdala is the part of the brain most often associated with its primary function in the center of emotional regulation. The amygdala also has a role in the mechanism of sleep. When an individual experiences sleep deprivation, functional deficits occur between the amygdala and the ventral anterior cingulate cortex (vACC), which will result in a decrease in mood and cause the amygdala to increase its response to negative stimuli [41]. Lack of sleep will cause sleep debt, which will reduce the ability of the medial prefrontal cortex (MPFC) to suppress amygdala activity. This will cause emotional instability [42]. Suppose this sleep deprivation occurs prolonged in the REM (rapid eye movement) phase. In that case, it will be associated with changes in function in various brain regions and result in changes in receptor activity, which results in mood changes such as anger [43].

Motomura, in his study, hypothesizes that eliminating potential sleep debt (PSD) through lengthening sleep will have an impact on mood by changing the functional relationship between the prefrontal cortex and the amygdala [42]. Fifteen male subjects were selected for a 9-day sleep prolongation followed by one whole night without sleep in that study. After ten days of this intervention, then by MRI, a regional evaluation of cerebral blood flow (rCBF) was performed along with a questionnaire to assess negative mood as an outcome of their study. Their results found that negative mood and amygdala rCBF

were markedly decreased after prolonged sleep. So they stated, "The amygdala has a significant negative functional relationship with the medial prefrontal cortex (FCamg-MPFC), and this negative relationship is greater after sleep lengthening than baseline."

3.5. Correlation between Sleep Deprivation with Cognitive Function and Academic Performance

The existence of sleep deprivation has been shown to reduce concentration and interfere with one's multitasking ability, so it can be dangerous for people whose work requires high concentration and good multitasking skills [44]. Sleep deprivation also consistently lowers a person's performance on tasks that require long-term attention, resulting in longer and slower response times [45]. It is also correlated with loss of work motivation that can occur in people with sleep deprivation [46].

After 24 hours of sleep deprivation, a person can significantly lose tonic alertness, selective and sustained attention, working memory, and executive function [47]. In people with sleep deprivation, the extension of sleep duration for six consecutive days has improved sustained attention and concentration [48]). This proves how vital sleep duration is to the ability to concentrate.

Good sleep quality, longer duration, and consistency are strongly associated with better academic performance [49]. Studies in Indonesia also show that adolescents who are sleep deprived experience low concentration in receiving learning in class. And it turns out that the reason for their lack of sleep is because their time is running out to study and do assignments [50].

The other study found a unique fact. That research divided the three groups of individuals into the third group with normal sleep duration, a third with only half a night's sleep, and another third with no sleep at all. Then the next day, all the subjects underwent an MRI examination. It turned out that in the group that slept only half a night, most of their brain activity was in the region associated with feelings of fear, and the least activity was in the area related to emotional control. While the group that did not sleep at all, brain activity in the area associated with feelings of fear tended to be low, but 12 hours later, the brain activity looked the same as the group who slept normally. This illustrates that limited sleep time at night is much worse than people who don't sleep at all. The

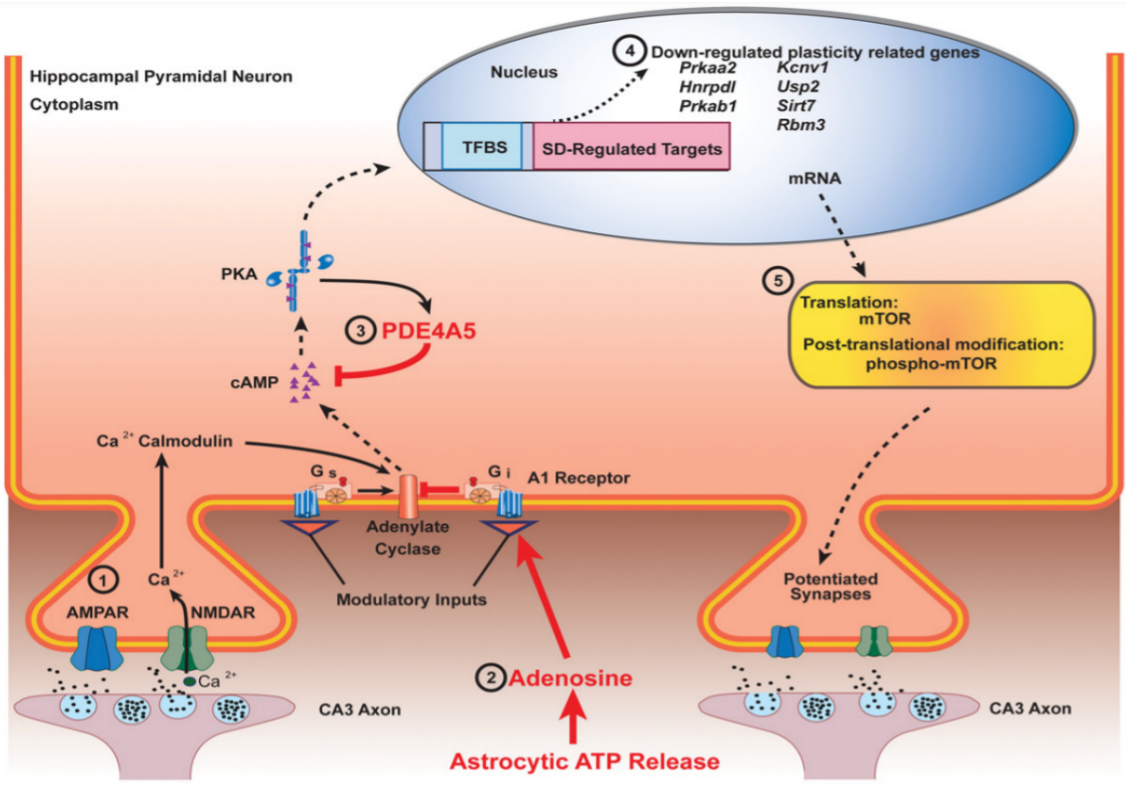

Figure 2. Schematic overview of hippocampal signalling pathways in sleep deprivation conditions. The red letters in the image indicate increased activity. The dotted black arrow indicates the weakening of the signal path (54).

researchers hypothesized that this was related to the loss of REM (rapid eye movement) phase in the group who slept only half the night, whereas the REM phase is important for memory consolidation and tends to occur in the later period of normal sleep duration [51].

Another study showed that a group of people who experienced partial sleep deprivation had impaired attention skills related to the prefrontal cortex region of the brain. However, in executive functions, the ability to learn and remember statistically was not significantly different unless the sleep deprivation was already at a severe stage [52].

Sleep deprivation conditions can interfere with memory consolidation through various mechanisms, including [53,54]:

- Sleep deprivation modulates glutamatergic signals through changes in the composition of NMDA and AMPA subunits. The impaired function of these receptors triggers a molecular signaling cascade by reducing calcium influx.
- Sleep deprivation will increase extracellular adenosine, an endogenous factor for sleep, and astrocytes, which are a source of adenosine. Adenosine acts through the Adenosine A1 receptor to reduce plasticity by increasing inhibition in the hippocampus.
- Increased phosphodiesterase 4A due to sleep deprivation interferes with intracellular cAMP signaling.
- Sleep deprivation lowers gene-associated transcriptional plasticity
- Sleep deprivation downregulates mammalian targets of rapamycin signaling (mTOR), a key regulator of protein synthesis required for memory consolidation [55].

Sleep deprivation in adolescents will cause unavoidable negative consequences for the learning process, including sleepiness and fatigue in class. This is caused by physical activity and sleep duration, which have a significant relationship to the incidence of sleepiness in class, with the dominant effect being on sleep duration [56].

4. CONCLUSION

From the discussion that has been done, we already know that teenagers are a group of individuals who are so complex. Adolescents must be managed holistically to improve their quality of life. Poor academic performance, tend to be emotional, and prone to depression in adolescents can be influenced by several things:

• Internal factors: physical changes, hormonal changes, and changes in brain structure

• External factors: physical activity, environmental treatment, starting school hours too early, and many school assignments

According to these factors, it is necessary to think about policy changes in the world of education, including the duration of study in school and the number of assignments at school to improve students' academic performance as well as the need for support from parents and peers in increasing physical activity and the ability of adolescents to release stress experienced in every day of their lives.

AUTHORS' CONTRIBUTIONS

Ahmad Fachrurrozi is the sole author and the originator of the ideas presented. The author is also responsible for finding all the literature that supports the data in this review article. Finally, the author presents it in the form of a complete manuscript in English.

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