INTRODUCTION

Sleep is an important physiological process for physical, cognitive, emotional, and mental functions of children and adolescents [1,2]. Healthy sleep includes the absence of sleep disturbances or sleep disorders, appropriate and regular sleep onset and wake-up times, good sleep quality, and sufficient sleep duration [3,4]. The American Academy of Sleep Medicine recommends that children ages 6–12 sleep for 9–12 hours per night and adolescents ages 13–18 sleep for 8–10 hours per night [3]. Unfortunately, the sleep duration of modern children and adolescents continues to decrease due to late bedtimes, excessive use of electronic devices, and academic pressure [5-8]. Approximately 40% of American adolescents report sleeping for less than 7 hours per night [9,10]. Quantitative and qualitative sleep problems have a negative impact on the physical and mental health of children and adolescents, including the risk of obesity.

Obesity is a common condition among children and adolescents. According to the Korea National Health and Nutrition Examination Survey data from 2019 to 2022, the prevalence of overweight and obesity was 23.5% and 14.2%, respectively [11]. Obesity in children and adolescents is not well-controlled, is highly likely to progress to adult obesity, and is a risk factor for high blood pressure, heart disease, stroke, kidney disease, and type 2 diabetes in adults [12]. Poor sleep affects eating patterns, bio-behavioral factors, activity patterns, and economic and environmental factors, which negatively affect brain function, endocrine function, and mood regulation, increasing the risk of overweight/obesity and metabolic dysfunction.

This study reviewed the effects of lack of sleep, sleep irregularity, and sleep problems on overweight/obesity in children and adolescents.

SLEEP DURATION AND OVERWEIGHT/OBESITY

Lack of sleep is a risk factor for overweight and obesity in children and adolescents. Short sleep duration and disrupted sleep increase the risk of obesity among adolescents [13,14]. A meta-analysis of the relationship between sleep duration and over-
weight/obesity reported that children and adolescents with shorter sleep durations had a two-fold higher risk of overweight and obesity [15]. In a study of 2,200 children aged 9–16 years, later bedtime and wake-up time were associated with poorer diet quality and higher body mass index (BMI) z-score [16]. The same results were reported in studies of various races and ethnicities, including Hispanics, Caucasians, Saudi Arabian boys, and Korean children and adolescents [17–19]. In a study of Korean adolescents, longer sleep durations on weekdays and weekends were reported to be associated with a lower BMI [20].

Although short sleep duration has been linked to weight gain, research results on sleep duration and BMI vary. Some studies have shown negative associations between sleep duration and BMI [21], but there are also studies showing a U-shape relationship [22]. Later sleep onset time, longer sleep latency, and propensity for eveningness have also been associated with a higher BMI [23,24].

SLEEP REGULARITY AND OVERWEIGHT/OBESITY

Not only sleep duration and sleep onset, but also sleep regularity, and a variety of weekday-weekend sleep patterns are important factors affecting calorie consumption, overweight status, and obesity. It has been reported that adolescents who do not have problems with sleep duration but have greater sleep variability increase their total calorie and snack intake, leading to overweight and obesity [25].

Research results on the weight of adolescents who sleep more on weekends than on weekdays vary. Higher social jetlag and greater weekday–weekend sleep time differences have been reported to be associated with metabolic dysfunction, higher waist-to-height ratio, and obesity [26–28]. A study of 240 Canadian adolescents aged 8–17 years also found that excessive sleep on weekends was associated with higher BMI, which was more pronounced in girls [29]. On the contrary, a study on 2,156 subjects aged 19–82 years reported that sleeping more on weekends was effective in preventing obesity [30].

Fluctuations in sleep duration cause changes in appetite-regulating hormones, such as insulin, ghrelin, and leptin, leading to increased food intake [31]. In a cohort study of 324 adolescents, high habitual sleep variability (HSV) was associated with high fat and carbohydrate energy intake, and one hour of HSV was reported to increase total daily energy intake by 170 kcal [25].

In addition to the regularity of sleep time, circadian rhythms also affect eating behaviors. In adolescents with an early phase preference, increased sleep duration was effective in preventing weight gain, but this effect was not found in adolescents with a late phase preference [32]. Additionally, adolescents with a late phase preference often obtain more calories than they need through snacking [16].

THE MECHANISM OF OVERWEIGHT/OBESITY CAUSED BY SLEEP PROBLEMS

Sleep problems and overweight/obesity are linked through biological, cognitive, emotional, and behavioral mechanisms, including increased food rewards, decreased inhibitory control, metabolic disturbances, and emotional reactivity [33]. Conditional or cumulative models have been proposed for sleep problems and overweight/obesity. The conditional model is the single, most appropriate model that increases the risk of obesity, while the cumulative model combines each risk factor to cause overweight/obesity.

Short sleep, shift work, and sleep disorders such as obstructive sleep apnea have negative effects on various endocrine and molecular systems, including the hypothalamic-pituitary-adrenal axis, circadian pacemakers in peripheral tissues, adipose tissue metabolism, sympathetic nervous system activation, oxidative stress, and whole-body inflammation [34].

Sleep problems cause obesity by promoting emotional and behavioral changes, such as increased food rewards, increased emotional reactivity, decreased inhibitory control, metabolic disturbances (e.g., insulin sensitivity), and poorer dietary quality and meal timing. Sleep problems also cause an increase in energy consumption without an increase in energy expenditure, resulting in increased fat mass and BMI [35]. Let us consider some of the mechanisms that have been studied in relation to sleep problems and overweight/obesity.

Sleep problems and insulin sensitivity

Insufficient sleep duration can have a negative impact on insulin sensitivity, and sleep restriction can increase fasting blood sugar and insulin resistance [36]. Adolescents who sleep less than 8 hours a day have higher insulin resistance than those who sleep more, which is related to obesity, central distribution of fat, and increased dietary intake of food [37–40]. In contrast, good sleep quality, early weekly sleep onset, and low circadian misalignment reduce insulin resistance [37].

Sleep problems and food intake

Adolescents with sleep problems may also experience food intake issues [41]. Problems with food reward processes, decreased insulin sensitivity, and disruption of meal timing are the mechanisms most strongly associated with food intake problems due to sleep disturbance. Adolescents with poor sleep and sleep schedule variability show changes in reward-related neural activation [42]. In a study in which 32 normal-weight adolescents and 32 obese adolescents (ages 12–18) were instructed to have normal sleep (9 h/night) and short sleep (5 h/night) for three weeks, respectively, the normal-weight adolescents increased their food reward after sleep restriction, while the obese adolescents showed consistently high food reward regardless of sleep duration [43].

Short sleep duration or poor sleep timing may cause adolescents to eat in an irregular and unhealthy manner. Adolescents
with shorter sleep duration and later chronotypes are more likely to skip breakfast, eat lunch and dinner irregularly, not eat three meals a day regularly, and consume unhealthy foods, such as high-calorie foods [33,43]. Conversely, adolescents with disordered eating attitudes and food preoccupation are more likely to have sleep variability, sleep disturbances, and daytime sleepiness [44]. In a study of 62 thin and 64 obese girls aged 14–18 years, those who slept less than 5 hours a night had higher carbohydrate intake and higher levels of ghrelin than those who slept more than 7 hours [45]. This result was not observed in boys.

Unfavorable home and neighborhood environments negatively impact both sleep and food intake. Unstable families and noisy and unsafe neighborhood environments negatively impact adolescents’ overall sleep. Communities with lower household incomes consume more energy-dense, pre-packaged foods, which can affect adolescents’ sleep and food intake [46].

Sleep problems and mood regulation
Mood is closely related to eating behavior. The act of food consumption plays a positive role in stabilizing emotions and mood. Depressive and emotional symptoms are known to increase preference for unhealthy foods [47]. Sugary and energy-dense foods affect the brain’s reward center and cause overweight/obesity [48]. Sleep is also related to emotion regulation and sleep deprivation can strengthen negative emotional responses. Adolescents with high emotional instability had worse sleep quality, higher rates of sleep disturbance, and worse sleep-related daytime dysfunction compared to emotionally stable adolescents [49]. In a neuroimaging study on changes in brain function after sleep deprivation, the amygdala and limbic activity increased in response to negative stimuli [50]. Poor or short sleep has a negative impact on adolescents’ affective functioning, and food intake is increased to compensate for the impact of negative emotions [51,52].

Sleep problems, physical activity, and screen time
In addition to energy intake, energy consuming activities, such as physical and personal activities, are important mechanisms for weight control. Decreased physical activity and increased sedentary activity are associated with decreased energy expenditure and obesity.

Adolescents who sleep less than 8 hours a day tend to engage in fewer sports, muscle-strengthening, aerobic, or moderate-to-moderate physical activity [53,54]. Poor sleep reduces physical activity and increases sedentary activity, thereby reducing energy consumption. Physical activity may be more closely related to sleep quality than sleep duration. Poor sleep quality, but not sleep duration, was associated with fewer healthy diets, greater unhealthy dietary habits, less physical activity, and overweight [55]. In a study that included 186 adolescents aged 12–17 years, later weekend bedtime and greater bedtime shift were more strongly associated with overweight severity than sleep duration [55]. Increased screen time is a risk factor for overweight/obesity [56]. In a cross-sectional study including 432 adolescents aged 14–19 years, it was reported that short sleep duration and high screen time (>3 h/day) were associated with abdominal obesity in adult phase [57]. In the National Longitudinal Study of Adolescent to Adult Health, which included 12,692 adolescents aged 11–19 years, screen time was found to mediate obesity [58]. A meta-analysis of 20 studies reported that inadequate sleep quantity and quality were associated with excessive bedtime media use [59].

Improvement of sleep problems and weight control
The overall dietary quality of adolescents is related to sleep duration, quality, and regularity. In adolescents, when sleep onset time advanced and sleep duration increased, the consumption of fruits and vegetables increased, and the consumption of salty foods and high glycemic index (GI) foods decreased [60,61]. When teenagers who habitually go to bed late adjust their sleep habits to a healthy level, their desire for high-GI foods decreases [60]. Shortened sleep duration has been reported to nearly double the consumption of sweet/dessert foods [61].

CONCLUSION
Sufficient sleep time and regular sleep are important in preventing obesity/overweight in children and adolescents, but children and adolescents around the world, including Korea, have insufficient sleep time. Increased academic pressure, excessive use of electronic devices, and increased sedentary activity increase the likelihood that children and adolescents will have poor sleep and unhealthy food intake [11].

Short sleep increases the risk of overweight and obesity in adolescents, and later bedtime and wake-up time are associated with both obesity and poor sleep quality. Greater sleep variability causes changes in appetite-regulating hormones such as insulin, ghrelin, and leptin, which increase fat and carbohydrate intake and total daily energy intake, thereby increasing the risk of overweight and metabolic dysfunction [31]. Adolescents who sleep less have high insulin resistance, which increases the risk of obesity and diabetes, and may show high food intake due to changes in reward-related neural activation [42]. Sleep deprivation can increase mood dysregulation and food intake due to increased amygdala and limbic activity [52]. On the contrary, if adolescents maintain a consistent sleep schedule and sleep for sufficient hours, it is advantageous to lose weight and prevent metabolic dysfunction [55].

Sleep deprivation and overweight/obesity in adolescents are both important public health problems. Encouraging children and adolescents to get sufficient and regular sleep, develop healthy eating habits, and encourage sufficient physical activity is important to prevent sleep problems and overweight/obesity. In order for adolescents to maintain healthy sleep and eating habits, systematic policy support from schools and the creation of a home atmosphere are important. In the future, I hope that detailed mechanisms will be confirmed and specific measures will be established through additional research on quantitative and qualitative issues of sleep and overweight/obesity.
Conflicts of Interest
Wan Seok Seo, a contributing editor of Chronobiology in Medicine, was not involved in the editorial evaluation or decision to publish this article.

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