Sleep Quantity and Sleep Quality

Subjects: Health Care Sciences & Services
Contributor: ジュン コウヤマ

Sleep is one of the basic physiological processes for human survival. Both sleep quantity and sleep quality are fundamental components of sleep. We should pay more attention to obtaining sleep of good quality (restfulness, no sleepiness, no need for more sleep, sufficient objective sleep depth, etc.), although there have not been enough studies on the associations between sleep quality and health or disorders in children and adolescents.

Keywords: restfulness ; sleepiness ; sleep duration ; insufficient sleep syndrome ; Pittsburgh Sleep Quality Index (PAQI) ; Epworth Sleepiness Scale (ESS)

1. Introduction

There is no doubt that sleep is one of the basic physiological processes for human survival [1]. However, with increasing economic and social demands, chronic sleep loss has been appreciated [2]. Under such circumstances, for most people in Japan, striving to achieve their best seems to become an important principle, even if this comes at the expense of sleep [3]. At least people in the modern society of Japan seem to be trying to reduce the duration of their sleep on the basis of the superficial idea that they can live effective lives without sleep, although much information on the importance of sleep has accumulated [1]. They want to spend the minimum effective time asleep, because recently people have thought of sleeping time as useless time. In fact, in Japan, sleep duration has decreased by 59 min during the last 50 years [4]. In the USA, the mean sleep duration decreased from 7.40 h in 1985 to 7.18 h in 2004. The percentage of adults in the USA sleeping for 6 h or less increased between 1985 (22.3%) and 2004 (28.6%) [5].

During 1905–2008, the sleep duration of children around the world aged 5–18 years decreased by approximately 0.75 min per night per year [4]. These declines were obvious in Asia (the mean change of minutes per year; −0.50), Canada (−0.73), parts of Europe (−0.92), and the USA (−0.53), while sleep duration increased in Australia (+1.27), Scandinavia (+0.00) and the UK (+0.57) [6]. The sleep durations of preschoolers in Japan, especially nocturnal ones, reduced markedly over a period of nearly 70 years (between 1935–1936 and 2003) [7]. In both studies conducted in 1935–1936 and 2003, bedtime, waking time, and nap duration were asked through a direct interview to each mother. In 1935–1936, the average sleep duration of infants aged 6–11 months was 13.0 h, with a nocturnal sleep duration of 11.3 h, while in 2003 the average was 11.7 h with a nocturnal sleep duration of 10.1 h. For 3-year-old children, the average in 1935–1936 was 11.3 h with a nocturnal sleep duration of 11.0 h, and in 2003 the figures were 11.1 h and 9.7 h. The average sleep duration of 6-year-old children in 1935–1936 was 10.8 h, with the same nocturnal sleep duration, while in 2003 the figure was 10.2 h with a nocturnal sleep duration of 9.8 h. According to the Japan Society of School Health [8], the sleep duration of school pupils in Japan has recently been decreasing. From 1981 to 2016, sleep durations of grades 5 and 6 elementary school (ES) pupils decreased by 17 min in males and 24 min in females. Similarly, those of junior high school (JHS) pupils decreased 40 (male) and 38 (female) minutes. In comparison with 1992, male and female senior high school (SHS) pupils slept 12 (male) and 6 (female) minutes less in 2016. It would not be a mistake to say that the sleep duration of children has recently decreased. Sharma and Kavuru [9] described modern society as a sleep-deprived society, stating that the average sleep duration in modern times is 6.8 h, as opposed to 9 h a century ago, although they gave no citation for this. In modern society, sleep is often not made a priority due to competing interests such as sports, media usage, and so on. Some people believe they can reduce their sleep duration if they can have high quality sleep.

Regarding recent trends in US adult sleep duration, the mean sleep duration showed little change from 2004 to 2012, and the percentage of adults sleeping for 6 h or less (29.2%) also showed little change from 2004 to 2012 [5]. A systematic review [10] on adult sleep duration in 15 countries revealed that sleep duration from the 1960s until the 2000s increased in seven of the countries (Britain, Bulgaria, Canada, France, Korea, the Netherlands, and Poland (range: 0.1–1.7 min per night per year)), decreased in six of the countries (Austria, Belgium, Finland, Germany, Japan, and Russia (range: 0.1–0.6 min per night per year)), and showed inconsistent results for Sweden and the USA. In spite of the aforementioned description of a sleep-deprived society [9], we are unable to confirm decreases in adult sleep duration since there is no

data available from the early 1900s. However, it should also be noted that Matricciani et al. described that not adults' sleep duration but adults' sleep quality is declining recently [11].

The importance of sleep quality has gained recognition as an important sleep characteristic much later than studies conducted solely on sleep quantity. In 1964, Hammond reported that those who had a sleep duration of 7 h showed the lowest mortality during a 2-year follow up, with increasing death rates on both the shorter and the longer sides of this nadir [12]. Hammond also reported an association between insomnia and mortality in men [12]. Although no detail on the definition of insomnia was given in the report, non-restorative sleep or "not feeling refreshed after sleeping" was described as a symptom of insomnia in the 4th [13] and the 5th [14] editions of the Diagnostic and Statistical Manual of Mental Disorders, respectively. Thus, it may not be wrong to say that Hammond's insomnia could express a kind of sleep quality. After this study, however, many studies were conducted with a focus on the relationship between sleep duration and both mental and physical disorders, and Ford and Kamerow revealed in 1989 that insomnia increased the risk of psychiatric disorders [15]. At present, there is no definitive definition that can be used to assess sleep quality. In fact, a scale that is commonly used worldwide for assessing sleep quality (the Pittsburgh Sleep Quality Index (PSQI)) is known, but the questions in the PSQI are about "usual" sleep habits during the last month. According to Pilz et al. [16], the PSQI reveals sleep quality on workdays. The PSQI is presumed not to be a perfect scale for measuring sleep quality.

2. Sleep Quantity

Sleep quantity decreases from about 18 to 16 h per day in the newborn infant to 7 to 6 h in older individuals. These age-related changes are well-known [17][18]. Although no one knows why these alterations occur and what factors determine them, several figures for the optimal sleep quantity at different ages have been recommended [19][20][21]. Age is not the only determinant of sleep quantity. Sleep quantity is also markedly different among countries. In 17 predominantly Asian and predominantly Caucasian countries/regions [22], sleep quantity was investigated through an Internet survey among children aged from birth to 36 months. This study revealed that total sleep quantity ranged from 11.6 h (Japan) to 13.3 h (New Zealand). The differences seen in sleep quantity may be contributed to cultural differences.

Screen time [23] and extracurricular after-school activities [24] have been identified as factors that contribute to the decrease in sleep quantity. Delayed bedtime was found to decrease the sleep quantity of 3-year-old children [25], and a long waiting time for a late meal may lead to decreased night-time sleep duration in preschoolers [26]. Quante et al. [24] divided the factors that reduce sleep quantity into intrinsic factors and extrinsic ones. In addition to the aforementioned factors, the intrinsic ones include the reduction of the accumulation of sleep pressure building up during the day; early school schedules were one of the latter class of factors. Family lifestyle [27] must also be included among the extrinsic factors. Fukuda et al. [27] reported that children's bedtime is also determined by delayed waking and meal times. According to a survey conducted during 2016–2018 in 28 public schools (15 ESs, 8 JHSs, and 5 SHSs) [28], the factors significantly associated with a reduction in sleep quantity were longer after-school activity and more sleepiness (in all types of schools), higher grades and longer weekday screen times (in both ES and JHS), irregular dinners, skipping breakfast, longer weekend screen time and better self-reported academic performance (in ES), and higher standardized body mass index (BMI) (in SHS). These associations of short sleep duration with grade-related decline [17][18], screen time [23], after-school activity [24], breakfast skipping [29] and BMI [30] were consistent with previous studies. There are so many issues in modern society that are associated with a decrease in sleep quantity.

3. Sleep Quality

Sleep quality is difficult to define objectively. Even if the polysomnographic recording for a person shows a typical sleep progress chart of a night with a higher rate of deep sleep in the first third of the night, increasing REM sleep and N2 sleep stage duration in the last third of a night, and a low incidence of intermittent waking, the quality of the sleep of the night is defined as poor if the individual was unsatisfied with the night's sleep [31]. For this reason, we have to define the quality of sleep subjectively.

The Ministry of Health, Labour and Welfare in Japan organized a nationwide research team on the quality of sleep (19FA0901). The author was one of the review board members of the team. The team discussed sleepiness during the day, restlessness, and restfulness as candidates for assessing sleep quality. In 2021, the team reached five conclusions: 1. Sleep quality is a superior sleep index to sleep quantity for assessing sleep; 2. Restfulness obtained through sleep is a useful index for assessing sleep quality; 3. Although PSQI and restfulness are correlated, these two indices are not identical; 4. PSQI includes sleep quantity and insomnia, while restfulness is complementary to either sleep duration, time in bed, or both; and 5. To obtain adequate sleep, people aged 64 or less need a longer sleep duration, whereas those aged 65 or more need a shorter time in bed.

By means of a choice-based conjoint analysis, Ramlee et al. concluded that the top three parameters that determine sleep quality among 17 parameters were total sleep quantity, refreshed feeling upon waking, and the daytime mind state after sleep [32].

Although the study was carried out among older men, Faerman et al. [33] assessed the correlations between subjective sleep quality, determined by 5-point scales for sleep depth and restfulness in the morning, and actigraphic data, as well as heart rate, heart rate variability, and demographic and psychological variables. They found no correlation between the subjective and the objective measures. This result is consistent with a previous study by Kaplan and colleagues [34]. In 3173 men and women aged between 39 and 90, Kaplan et al. assessed the relationship between a morning rating of the prior night's sleep (sleep depth and restfulness) and polysomnographic and quantitative electroencephalographic descriptors of that single night of sleep. They concluded that objective data contribute little to explaining subjective sleep quality. They also assessed a single night of at-home polysomnographic recording of sleep followed by a set of morning questions concerning the prior night's sleep quality in older men (n = 1024) and women (n = 459) [35]. They found that the commonly obtained polysomnographic measures contributed little to the subjective ratings of the prior night's sleep quality.

Clark et al. [36] reported that the onset of sleep disturbance predicts a subsequent risk of hypertension and dyslipidemia. The onset of impaired sleep in this study included subjective issues such as difficulty in falling asleep, difficulty in maintaining sleep, early morning awakening, and non-restorative sleep. Bin [37] wrote a commentary on this article and summarized the main findings of this report into two statements: 1. Sleep disturbance predicts the occurrence of hypertension and dyslipidemia, and 2. Sleep quality appears a more important risk factor than sleep duration for these disorders.

Falbe et al. assessed restfulness by asking the question "On how many days in the past week have you felt like you needed more sleep?" of 2048 children in grades 4 and 7 [38]. They defined restfulness as having the feeling that more sleep was needed on three days or fewer, based on the notion that perceived restfulness may reflect good sleep quality. Sleeping near a small screen, but not a TV, was associated with a significantly higher prevalence of perceived insufficient restfulness, after adjustment for sleep quantity. This did not vary significantly by grade, gender, physical activity, or race. As regards the reason why TV presence was not related to less restfulness, they speculated that TV sets do not interrupt sleep when turned off. They also demonstrated the association between a longer screen time and less restfulness.

Using "feeling fresh" after waking-up as a representative issue to assess sleep quality of children, the following factors were shown to affect child sleep quality: gene, parent/caregiver, sleep disorders/medical problem, sleep habits/environment/medications, and screen exposure [39].

So far, as mentioned above, sleep depth, restfulness, non-restorative sleep on the prior night, sleepiness, and having the feeling that one needed more sleep on three or fewer days in the past week have been used as subjective measures of sleep quality. Among these, information on restfulness from sleep is routinely obtained using the standard questionnaire in Specific Health Checkups, which is the annual health screening and promotion service organized by the Japanese Ministry of Health, Labour and Welfare [40]. Kaneko et al. [41] investigated the association between restfulness from sleep and subsequent risk of cardiovascular disease using the medical records (obtained from the Japan Medical Data Center) of 1,980,476 individuals (mean age of 45 ± 11 years, male vs. female ratio of 1.49, and mean follow-up period of 1122 ± 827 days) without either prior cardiovascular disease or prior sleep disorders. Among the general population without a prior history of relevant cardiovascular disease, it was found that the incidence of myocardial infarction, angina pectoris, stroke, heart failure, and atrial fibrillation was significantly lower in those with good restfulness from sleep. However, this study did not assess the association of cardiovascular disease with sleep quantity.

4. Quantity Versus Quality

Seow et al. [42] studied the association of both sleep quantity and sleep quality with physical and mental disorders in Singaporean adults. Although this study used PSQI as an index to assess sleep quality, it showed that both short sleep duration and poor sleep quality were associated with chronic pain, obsessive compulsive disorders, and mental disorders. In addition, poor sleep quality was found to be associated with major depressive disorder, bipolar disorder, generalized anxiety disorder, and physical disorder. After these analyses, the authors concluded that sleep quality is a more important indicator for psychological and overall health than sleep quantity.

Lao et al. [43] examined associations between sleep measures and the development of coronary heart disease among 2740 adults aged 40 years or above who participated in a Taiwanese cohort. These authors assessed both sleep quantity

and sleep quality. Sleep quality was assessed using a 5-point scale. The question was “How do you evaluate your sleep situation last month?”, and the five possible selections were as follows: use of sleeping pills or drugs, difficult to fall asleep, dreamy sleep, can fall asleep but easily awaken, and sleep well. Since the number of participants who selected the first option was small, this option was combined with the second one. Thus, sleep quality was assessed on a 4-point scale. For sleep quantity, the participants were asked “How many hours do you usually sleep a day?” with the following four options: less than 4 h, 4–6 h, 6–8 h, and 8 h or more. The study also assessed the sleep score, reflecting both sleep quantity and sleep quality, against the development of coronary heart disease. Short sleep duration and poor sleep quality were found to be associated with an increased risk of coronary heart disease. Participants who had lower sleep scores also showed a higher risk of the disease. The authors concluded that both sleep quantity and sleep quality should be considered for developing strategies for improving sleep, with the aim of preventing coronary heart disease.

Moore et al. found that the effects on health of sleep quality, assessed by 5-point scale (1 = poor and 5 = excellent; mean value of 3.1 with a standard deviation of 1.2), were greater than the effects of sleep quantity, even after adjusting for other individual characteristics [44]. They also showed that the impact of sleep quality on physical health increased as the subjects slept for shorter durations.

Yang et al. [45] investigated the association between sleep measures (quantity and quality) and BMI among 10,007 adults living in the Philadelphia area. Sleep quality was assessed by asking about the participants’ sleep quality on a 5-point scale, with 1 being restless and 5 being restful. The question on sleep duration was “How many hours of sleep do you get at night?”. The overall sleep quality score was 3.61, with a standard deviation of 1.29. On average, men reported better sleep quality than women. Fifty-five per cent of the women and 53% of the men slept for at least 7 h every night; 27% slept for between 6 and 7 h, and 20% slept for less than 5 h. The study found that better sleep quality was related to lower BMI in women, while men who slept for less than 5 h had a higher BMI than those who slept for 7 h or more. In order to reduce BMI, it may be useful to help men to increase their sleep duration and women to improve their sleep quality. These authors also examined the effect of both sleep quantity and sleep quality in mediating the relationship between perceived discrimination and health, and found that sleep quality rather than sleep duration mediates the unfavorable effect [46].

A meta-analytic study demonstrated that both short and long sleep duration, and difficulty in maintaining sleep, were associated with a greater risk of type 2 diabetes [47]. From these results, Cappuccio et al. concluded that quantity and quality of sleep consistently and significantly predicted the risk of the development of type 2 diabetes. The risk varies between 28% in people who report habitual sleep of 5–6 h per night and 84% in those with difficulties in maintaining their sleep.

In patients with chronic kidney disease, Ricardo et al. reported that ESS, but not PSQI, was associated with an increased risk of all-cause mortality [48]. In addition, they found significant associations between greater sleep fragmentation and an increased risk of end-stage renal disease, and between both greater sleep fragmentation and shorter sleep duration and both a greater decline in estimated glomerular filtration rate and increased protein excretion. From these results, they concluded that short sleep, as well as poor sleep quality, are risk factors for the progression of chronic kidney disease.

Taking these reports into consideration, we should emphasize that more attention should be paid to obtaining good quality sleep (restfulness, no sleepiness, no need for more sleep, sufficient objective sleep depth, etc.) in terms of avoiding sleep-related health problems.

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