The Updating and Individualizing of Sleep Hygiene Rules for Non-clinical Adult Populations

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Abstract: Sleep hygiene is essential for the prevention of somatic and mental disorders, including the prevention of sleep disorders. However, it does not typically address individual differences. The aim of this review is threefold: first, to outline the empirical evidence for particular components of sleep hygiene rules; second, to indicate the importance of individualized sleep hygiene application with regard to the varying degree of validity of sleep hygiene rules in the population; third, to highlight a new field of sleep hygiene, namely light hygiene. PubMed and Google Scholar were used to identify studies that were published between 2007 and 2022. A search was conducted for studies related to sleeping rules topics: sleep regularity, regular exercise, alcohol, caffeine, napping, relaxation and meditation, food intake and light exposure. In applying these sleep hygiene principles, it is essential to pay attention to individual variables such as age, genetic predisposition, health status, and substance (caffeine, alcohol) possible dependence.

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Introduction

Sleep hygiene (SH) is defined as a set of behavioural and environmental recommendations designed to promote healthy restorative sleep. SH usually focuses on the following areas: *daytime/evening routine, sleep environment and consumption of substances that affect sleep*. The first references to this topic date back to the second half of the 19th century (Gigli and Valente, 2013). One of the earliest modern comprehensive concepts of SH rules was defined by Peter J. Hauri in the 1980s (Chung et al., 2018). In 1991, this list of recommendations was updated, and since then, several further modifications have been made. SH rules are not only used to prevent sleep difficulties in the general population but are also used for patients with sleep disorders as part of a treatment approach. Currently, there are several versions of sleep hygiene rules that vary in their directive and detailed nature (Chung et al., 2018).

Sleep hygiene represents an important component of disease prevention and of a healthy lifestyle for the following several reasons: (1) it is easily accessible, (2) it does not require direct long-term involvement of a professional, (3) it is relatively inexpensive, and (4) it can serve as a first-choice intervention for sleep problems or as a prevention of sleep disorders. Following the rules of SH can positively affect not only the quality of sleep itself but also daytime functioning (Brick et al., 2010; Yazdi et al., 2016). On the other hand, awareness of SH does not necessarily mean better sleep (Voinescu and Szentagotai-Tatar, 2015). Moreover, potential users may be discouraged and confused by multiple versions of SH rules and overgeneralization within them (Irish et al., 2015). Therefore, updating the SH rules and maintaining consistency of the SH approach is important for both nonclinical and clinical populations. No less important is a focus on individuality, as SH is usually defined in general terms, without considering the influence of age, chronotype, morbidity or genetic disposition of the individual.

The main aims of this review are to (1) critically review the empirical evidence for the different components of SH and clarify specific guidelines for optimal sleep support; (2) incorporate individual aspects of SH rule application; and (3) highlight the importance of light hygiene as a new field of SH. A summary of the results and recommendations based on recent empirical studies are presented in Table 1.

PubMed and Google Scholar were used to identify studies that were published between 2007 and 2022. A search was conducted for studies related to sleeping rules topic: sleep regularity, regular exercise, alcohol, caffeine, napping, relaxation and meditation, food intake and light exposure. The choice of rules was inspired by the original letter of sleep hygiene by Peter J. Hauri (1991).

Sleep regularity

One of the most important rules of sleep hygiene is a regular sleep schedule, which means going to bed and arising at the same times each day, including weekends. This is based on the effort to maximize synchronization between homeostatic sleep pressure, circadian rhythm, and the sleep period (Zuraikat et al., 2020).

Table 1 – Summary of empirical results and sleep hygiene recommendations for a healthy population

Sleep hygiene recommendations	Summary of recommendations and research results
Regular sleep timing	• Irregular sleep patterns disrupt sleep. A regular sleep schedule throughout the week, including weekends, is important for everyone. • Adolescents and young adults who do not sleep in accordance with their biological needs are the most vulnerable group in terms of physical and mental health effects.
Regular exercise	• Regular as well as irregular exercise improves sleep. The following factors should be considered: age, chronotype, regularity, timing, type of exercise and health status. • Exercise affects the circadian rhythm; late exercise can cause a sleep delay. • Morning exercise is good for synchronizing circadian rhythms; evening exercise does not have as much of a negative impact on "night owls" as it does on "early birds". • Evening low-intensity exercise or yoga is recommended, especially for people suffering from anxiety and depression. However, intensive exercise is not recommended within 2–3 hours before bedtime.
Alcohol avoidance	• Sleep disruption due to alcohol is dependent on the age and sex of the individual and the amount of alcohol consumed. • Acute alcohol use before bedtime reduces sleep latency but increases the number of awakenings in the second part of the night. • Chronic alcohol use is associated with difficulty initiating sleep, poor sleep quality and daytime sleepiness. • One shot of liquor is sufficient to negatively affect sleep in women.
Caffeine avoidance	• All sources of caffeine intake should be considered (tea, coffee, chocolate, medications, etc.). • Caffeine doses of 100–150 mg consumed within 3 hours before bedtime significantly disrupts sleep (objectively and subjectively). • The effects of variable individual metabolisms (polymorphism of cytochrome CYP1A2), which affect the rate of caffeine metabolism and susceptibility to insomnia, should be considered. • Caffeine receptor sensitivity increases with age and caffeine metabolism decreases with age. • Pregnant women should avoid caffeine due to its slow metabolization during pregnancy.
Napping	• The benefits of napping are dependent on the nap timing and duration and the age and health status of the individual. • The ideal length of a nap is approximately 15 minutes; there is no subsequent sleep inertia and this length of nap has a positive impact on nighttime sleep. • No significant negative sleep effects from early napping up to 50 minutes have been shown for adults who are elderly.

Sleep hygiene recommendations	Summary of recommendations and research results
Relaxation and meditation	• These are especially recommended for people with stress, insomnia and anxiety. • The most effective modes are progressive muscle relaxation, mindfulness, yoga nidra, etc.
Food intake	• Food is one of the cues for the circadian rhythm (whether it occurs in the day or night). The timing, amount of food ingested, and the composition of the diet are important: vitamins B1 a B2 synthesis promote sleep, amino acid such as L-theanine is also known to induce sleep. • It is recommended to abstain from eating for 2–3 hours before bedtime. • Time-restricted eating (10 hours of eating and 14 hours of fasting) is beneficial for human circadian rhythms (it serves as a de/synchronizer).
Light exposure	• Light is the strongest synchronizing agent (zeitgeber) for the circadian system. • The timing, intensity and duration of light exposure, the light's wavelength, and contrast of light intensity during the day versus light intensity during the evening influence sleep. • Exposure to blue light between 30–60 minutes before bedtime in a healthy individual leads to a shift in sleep time of up to 30 minutes and a reduction in melatonin secretion. • Natural light exposure during the first hour after waking (to synchronize circadian rhythms) is advisable, along with exposure to light of reduced intensity and wavelength in the evening. • The sensitivity to evening light varies by more than 50-fold among individuals.

Sleep irregularity has a number of health implications. The highest sleep pattern variability is evident in young adults and adolescents, who spend more time in bed on days off compared to school/work days. The magnitude of the difference in sleep timing between work and nonwork days (so-called social jet lag) is related to weight gain and higher insulin resistance (Roenneberg et al., 2012; Bailey et al., 2014; Taylor et al., 2016). Weekend catch-up sleep is also known to be less effective in optimizing neurobehavioral function than the recommended 8–10 hours of sleep at that age (Lo et al., 2017). Irregular sleep rhythms are associated with lower work performance (Phillips et al., 2017), lower ratings of subjective sleep quality, mood declines, and a higher risk of depression (Fang et al., 2021). It is also important to sleep regularly in our biological rhythm. Studies show sleeping in chronotype schedule improves sleep quality, impacts REM (rapid eye movement) sleep and total sleep time (Reiter et al., 2023).

Current clinical sleep therapies also require regularity in wake time but allow or even encourage variability in the time of going to bed at a preferred time when

patients feel sleepy (Johnson et al., 2016; Maurer et al., 2021). Sleep irregularity among shift workers is a major problem that goes beyond the scope of the text.

Recommendation: Go to bed and arise at the same hours throughout the week as much as possible.

Regular exercise

To assess the effect of exercise on sleep quality, several variables should be taken into account. In particular, age, chronotype, exercise consistency, exercise timing, exercise mode and health status were assessed.

Regular exercise in healthy adults has a positive impact on subjective sleep quality, measured by the Pittsburgh Sleep Quality Index (PSQI) as well as objective sleep parameters and sleep duration and can even lead to a reduction in prescribed medications (Kredlow et al., 2015). Regular exercise generally provides higher benefits than occasional exercise, but longitudinal studies on this topic are still lacking (Park et al., 2021).

At the beginning of the 21st century, there was a clear recommendation to avoid exercise in the evening due to increased arousal (Youngstedt et al., 2021), but a number of recent studies underline the importance of evening low-intensity exercise, light stretches or yoga, especially in older adults (Seol et al., 2021) and people suffering from anxiety and depression (Flausino et al., 2012). Late-night low-intensity exercise is contraindicated for individuals who do not engage in physical activity during the day (Youngstedt et al., 2021). It is also important to remember that exercise can influence the circadian system. Engaging in moderate to heavy physical activity in the evening can cause a phase delay, but this does not apply in all cases (Youngstedt et al., 2019). For late chronotypes, both morning and evening exercises induce phase advance. In contrast, in morning chronotypes, phase advance is experienced due to morning exercise, but phase delay is experienced due to evening exercise (Thomas et al., 2020). Morning exercise may reduce circadian desynchronization in the general population and especially in young adults, who are more likely to have the evening chronotype (Lang et al., 2022).

Recommendation: Exercise has a positive effect on sleep, but it is important to consider individual differences in chronotype and adjust the time, intensity and type of exercise accordingly.

Alcohol

Alcohol is known to be a potent somnogen, apparently inducing sleep by increasing adenosine levels and disrupting the sleep architecture. The negative effect of alcohol on sleep is repeatedly mentioned in the literature (Bando and Hotate, 2012; Ebrahim et al., 2013). However, it is one of the most commonly used "over-the-counter" sleep aids (Thakkar et al., 2015; Kurhaluk, 2021). In terms of sleep hygiene, it is necessary to consider the timing, amount of alcohol, type of alcohol intake and sex of the consumer (van Reen et al., 2011). Alcohol absorption runs for a number of

hours and can be inhibited by eating at the same time (Jiang et al., 2020). Research results confirm the negative effect of alcohol, even in small doses (e.g., one shot of liquor 1 hour before sleep) (Bando and Hotate, 2012).

Acute alcohol intake alters the secretion of melatonin and cortisol and alters body temperature in cases of dependency and even in the withdrawal period (Meyrel et al., 2020). The consumption of one shot of liquor 1 hour before bedtime suppresses melatonin secretion by up to 20% (Rupp et al., 2007). Acute alcohol intake in occasional alcohol users disrupts sleep architecture and significantly fragments the second half of the night (Thakkar et al., 2015). Chronic alcohol use is associated with difficulty initiating sleep, poor sleep quality and daytime sleepiness. Particularly problematic is so-called "binge drinking" (occasions of consuming 4 drinks in one day), which is associated with a higher risk of insomnia, especially in people over the age of 50 (Canham et al., 2015). There is a relationship between alcohol consumption and increased inflammatory processes (Wilkinson et al., 2018).

Other individual variables, such as sex, also need to be taken into account (Wall et al., 2016). Alcohol use affects sleep systems differently in men and women. Women show greater sleep disruption than men (Inkelis et al., 2020).

Recommendation: Avoid alcohol consumption in the evening (at least 3 hours before going to bed, 6 hours at best). Although the person may not be aware of it, alcohol has a negative impact on sleep even in small doses, such as one shot of liquor 1 hour before sleep.

Caffeine

Caffeine is the most widely used psychoactive substance. Approximately 80% of the world's population uses coffee daily, and its daily use gradually increases, while the age of consumption begins to decrease (Heckman et al., 2010). Caffeine takes effect in the plasma within 30 minutes on average, and the half-life of consuming one cup of coffee is 3–7 hours. The effect is highly dependent on receptor sensitivity and adaptation, age and other lifestyle factors (Irish et al., 2015).

Generally, 100–150 mg of caffeine (1 espresso contains approximately 90 mg) 3 hours before sleep causes significant sleep disruption in several different ways: increased sleep latency, decreased total amount of sleep, increased amount of superficial sleep stages and a reduction in the duration of the deep and REM sleep stages, as well as multiple sleep stage shifts (Burdan, 2015; Watson et al., 2016). Caffeine consumption also affects melatonin secretion and may delay the onset up to 40 minutes (Burke et al., 2015). There is evidence that regular consumers develop a tolerance to caffeine (Weibel et al., 2020). Morning consumption (approximately 2 cups of coffee) affects the architecture of sleep in low consumers but not in regular consumers (Porkka-Heiskanen, 2011). There are also clear differences in the sensitivity of the caffeine effect on sleep related to the polymorphism of cytochrome CYP1A2. This is characterized by different metabolism speeds (Nehlig, 2016; Tennent et al., 2020) CYP1A2 activity is affected not only by genotype, sex and

Table 2 – Overview of caffeine content in certain beverages and foods

Type of beverage/food	Average concentration	Range of caffeine (mg)*
Filtered coffee	85 mg/125 ml	60–135
Instant coffee	65 mg/125 ml	35–105
Decaffeinated coffee	3 mg/125 ml	1–5
Espresso	60 mg/30 ml	35–100
Tea	32 mg/150 ml	20–45
Iced tea	20 mg/ 330 ml	10–50
Hot chocolate	4 mg/150 ml	2–7
Caffeinated beverages without alcohol	39 mg/330 ml	30–48
Cola	41 mg/330 ml	26–57
Energy drinks	80 mg/330 ml	70–120
Chocolate bar	20 mg/30 g	5–36
Dark chocolate	60 mg/30 g	20–120
Milk chocolate	6 mg/30 g	1–15

*it depends on the brand, but, for coffee and tea, it also depends on the type, length of steeping, filtration, temperature and preparation method; data from: http://www.coffeeandhealth.org

age but also by smoking, which accelerates caffeine metabolism. In contrast, caffeine metabolism is slower in women and pregnant women. By the third trimester, it can take up to 18 hours to metabolize caffeine (Tennent et al., 2020). People who are older are more sensitive to caffeine due to age-related changes in adenosine receptor transmission (Frozi et al., 2018).

Recommendation: Avoid caffeine intake 6–8 hours before sleep. It is important to remember that caffeine is also contained in other products besides tea and coffee. The combination of individual items consumed during the day can easily lead to overconsumption of caffeine and thus overstimulation (Table 2).

Napping

The benefits of napping depend on the length and timing of the nap. Another important nap-related variable is age. In terms of length, research studies suggest that the ideal length of a daytime nap is approximately 15–20 minutes due to minimal sleep inertia, as individuals do not go into deep sleep stages (Hilditch et al., 2017). In terms of time suitable for daytime sleep and age, even 50 minutes of midday sleep does not negatively affect nighttime sleep in individuals who are elderly (Faraut et al., 2017). In the population of older adults, evening napping is, surprisingly, not necessarily associated with negative effects on sleep (Dautovich et al., 2008), but it may cause earlier rising in the morning (Faraut et al., 2017). Early afternoon napping was shown to have shorter sleep latency and increased nocturnal sleep efficiency with higher slow-wave activity compared to late afternoon napping (Faraut et al., 2017).

It is important to distinguish between healthy populations and patients suffering from insomnia. The negative effect on nighttime sleep in insomnia sufferers is due to

reduced sleep pressure, regardless of the timing or length of daytime sleep (Jang et al., 2018).

Recommendation: If necessary, take a 15–20 minutes nap in the early afternoon. For individuals who are elderly, it is possible to extend that time, but the subsequent times of falling asleep and arising should be monitored. Individuals with sleep problems should avoid naps.

Relaxation

Petit et al. (2003) in their sleep education guidelines, recommend setting aside time to "wind down" and use relaxation techniques before bedtime, because those techniques can balance sympathetic overactivity and hyperarousal and reduce stress and tension (Jerath et al., 2019). One of the most commonly used relaxation techniques is Jacobson's progressive muscle relaxation (PSR), and more recently, mindfulness techniques have been widely used. Both of these techniques have shown a positive effect on reducing stress and tension or anxiety while increasing subjective sleep quality regardless of age in students as well as in seniors (Örsal et al., 2014; Black et al., 2015). No negative effect was observed regardless of the participants' ages (Mirzanah et al., 2020). These methods are equally effective in patients with chronic insomnia (Hubbling et al., 2014) or in those with other clinical conditions (Harorani et al., 2020). Self-relaxation training relieves pain, resulting in higher subjective well-being, which is essential for easily falling asleep (Sun et al., 2013). Recently, the effect of yoga nidra has also been investigated. Yoga nidra appears to be a very promising method that generally improves well-being (Gulia and Sreedharan, 2022) and, according to objective sleep measures, increases sleep efficiency and the amount of deep sleep stages while simultaneously reducing cortisol levels (Datta et al., 2021).

Recommendation: Relaxation techniques, such as progressive muscle relaxation, mindfulness or yoga nidra, result in positive effects regardless of sex or age. The most effective relaxation technique seems to be yoga nidra, which even increases the amount of deep sleep. These techniques can be performed before bedtime or during the day.

Food intake

Food intake is another important factor in sleep hygiene. The three most relevant aspects of food intake are timing, duration of food intake during the daytime and composition of the diet.

The timing of food consumption plays a role in the synchronization of peripheral circadian rhythms. Inappropriate timing of food intake can destabilize metabolic processes (Stenvers et al., 2012; Bo et al., 2017) and generally desynchronize circadian clocks (Mukherji et al., 2015). Food consumption later than 2–3 hours before bedtime is known to reduce sleep quality, slow digestion, and increase heartburn and reflux. Nocturnal awakenings and lower sleep duration are also potential consequences (Chung et al., 2020).

The total time spent eating within a 24-hour period is highly relevant. Studies suggest that extended eating over 15 hours may be a factor contributing to metabolic disorders (McHill et al., 2017; Réda et al., 2020). Conversely, time-restricted eating (10 hours of eating and 14 hours of fasting) reduces weight, blood pressure and lipid levels (Wilkinson et al., 2020).

What we consume is also important. Nutrients that affect tryptophan availability, such as protein (Nongonierma and FitzGerald, 2015), or serotonin and melatonin synthesis, vitamins B1 and B2 (Vernia et al., 2021), promote sleep. Amino acids such as L-theanine (which is found in green tea or can be taken as a supplement) are also known to induce sleep (Kim et al., 2019). The amount of fats is associated with both better and worse sleep quality. Type of fat appears to be a significant factor. Unsaturated fats, such as those found in fatty fish, avocado, etc., are associated with better sleep quality (Frank et al., 2017; Wilson et al., 2022). Dietary recommendations for the general population favour vegetable oils, which are low in saturated fat (St-Onge et al., 2016). High-fat meals are not recommended for people with sleep-disordered breathing. Studies involving patients with obstructive sleep apnea have shown that a fatty dinner can increase disease severity (Trakada et al., 2014; Wilson et al., 2022).

Recommendation: Avoid any food consumption 2–3 hours before bedtime. Try to consume foods and nutrients that promote the production of serotonin and melatonin, affect tryptophan availability, and induce sleep (e.g., L-theanine).

Light hygiene

The most up-to-date sleep hygiene recommendations include light hygiene, which is why it is given the most attention in this paper. Light is the strongest synchronizer of our circadian rhythms. Light intensity in nature can reach up to 100,000 lx in direct sunlight and ~25,000 lx out of direct sunlight during the day, decreasing to an intensity of 0.1–0.3 lx during the night, even during a full moon (Rumanova et al., 2020). However, natural conditions are very different from artificial lighting environments. In buildings, light intensity is much lower during the day, with intensity ~500 lx (Blume et al., 2019). Conversely, in the evening and during the night, we are exposed to much more indoor light than outdoors; ~5–15 lx is reached by normal street lamps in cities, ~100–300 lx is the light in normal living rooms, and a PC screen emits ~40 lx, depending on its size (Bedrosian and Nelson, 2017). The contrast of light and dark occurring under natural conditions, i.e., high intensity during the day and darkness in the evening, is important for the proper functioning of the circadian system.

The timing, intensity, duration, and wavelength of light modulate the photic settings of the circadian system (Chang et al., 2011) and affect sleep quality, cognitive performance, alertness (Wahl et al., 2019) and the secretion of hormones that exhibit circadian rhythmicity, such as melatonin or cortisol (Schmid et al., 2021). Exposure to blue light even at low intensities right before bedtime can have serious

consequences for sleep quality, including delay and suppression of REM sleep or sleep timing (Cho et al., 2013; Wahl et al., 2019).

Dimmed artificial light in the evening helps to balance circadian rhythms and positively affects sleep and even short-term memory (Tam et al., 2021). Exposure to orange light in the evening causes less sleep phase shift and more evening sleepiness than exposure to blue light (Münch et al., 2017). Nocturnal sleeping with the light on (~40 lx from a lamp or a TV) has a significant negative effect on sleep architecture and quality compared to sleep in the dark (Cho et al., 2013). The effects of blue light may become less pronounced with increasing age (Daneault et al., 2016), and children and young adults have a more intense response to melatonin suppression by blue light than adults who are elderly (Bedrosian and Nelson, 2017).

In general, there is considerable variability in the sensitivity of the circadian system to light. On average, people are highly sensitive to evening light. Fifty percent suppression of melatonin occurs when illuminance is < 30 lx, but this sensitivity to evening light varies by more than 50-fold among individuals (Phillips et al., 2019). Interindividual differences in light sensitivity may explain differences in vulnerability to disruption of the circadian system and the subsequent impact on human health.

Recommendation: It is advisable to expose oneself to natural bright blue light in the morning and, conversely, to avoid exposure not only to blue light but also to high-intensity light (more than 10 lx) in the evening. Individuals should sleep in a dark room (using blackout curtains) and wear comfortable sleeping masks, if necessary.

Discussion

The presented text summarizes recent research that provides the basis for sleep hygiene rules as they are currently understood. The basic principles and general recommendations for healthy sleep have not changed substantially over the past 40 years. Unfortunately, difficulties in their application are gradually becoming apparent due to the lack of individualized approaches.

Future studies addressing recommendations for healthy sleep should be fully relevant to current life circumstances. They should reflect common behavioural patterns (not sleep alone) while incorporating tolerance to substance (caffeine, alcohol) or habit-related issues associated with those patterns (Weibel et al., 2020). For example, daytime nap is not recommended to people with insomnia, but daytime nap about 15 minutes can be beneficial (positive effect on short-term improvements in physical performance, memory, emotional processing) and without side effects for healthy people (Mantua and Spencer, 2017). It would also be desirable to address the interaction between different habits. For instance, a nap after lunch may reduce the need for caffeine, and the consideration of the sleep-disrupting effects of substance withdrawal could be important in people who are struggling with addiction (Irish et al., 2015). Another example is the interplay between caffeine metabolism and tobacco use. Tobacco use accelerates caffeine metabolism by increasing the activity of the enzyme CYP1A2 in the liver (Tennent et al., 2020). Some rules are

applicable to the whole population with only minimal exceptions, for example the importance of exposure to light in the morning or avoiding light of high intensity in the evening. Light hygiene plays a preventive role not only in sleep disorders but also in mental health. The adoption of habits related to exposing ourselves to natural light and, conversely, avoiding light at times when it is naturally dark, may seem trivial, but it is absolutely essential for the optimal functioning of our bodies, and it has an above-average effect on our sleep (Swanson and Burgess, 2017). On the other hand, inter-individual differences in light sensitivity must also be taken into account in this case (Phillips et al., 2019).

Sleep hygiene is one of the pillars of health and is part of a healthy lifestyle. It is important to explain these rules to individuals and take into account their lifestyle and possible inter-individual differences. In addition, it is advisable to be flexible in demanding strict observance of sleep hygiene rules.

Conclusion

Individual factors have been shown to play an important role in sleep hygiene, including age, chronotype, genetic predisposition or health status. If sleep hygiene rules are offered without an individualized approach, they may not yield the desired results or may not be applicable in a particular case and may therefore be rejected by the recipient because the rules appear generally impractical.

Sleep hygiene remains essential for the prevention of somatic and mental disorders, including the prevention of sleep disorders. Non-compliance with sleep hygiene rules can cause serious sleep problems or lead to progression to clinical conditions.

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