THE CARB-APPROPRIATE REVIEW

THE SLEEP ISSUE

A MONTHLY RESEARCH REVIEW BY

CLIFF HARVEY PHD

In association with The Holistic Performance Institute

HLP™

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ABOUT CLIFF

Dr Cliff Harvey is an author, clinician, and researcher. He was one of the first clinical nutritionists to begin working with ketogenic and low-carb diets, way back in the 1990s and is also considered a pioneer in the area of mind-body integrative healthcare.

Cliff's early post-graduate work was in mind-body healthcare, while his master's research focussed on the use of medium-chain triglycerides to mitigate 'keto-flu' and encourage faster induction of nutritional ketosis.

His doctoral thesis continued to investigate keto-flu and ketogenesis, and the effects of different types of low-carbohydrate diets along with the individualisation of dietary prescription and how 'carbohydrate tolerance' varies from person-to-person.

He is a former world champion strength athlete, submission grappler, and author of several best-selling books, including *The Carbohydrate Appropriate Diet*, *Carb-Appropriate 101*, *Time Rich Cash Optional* and *The Credo.*

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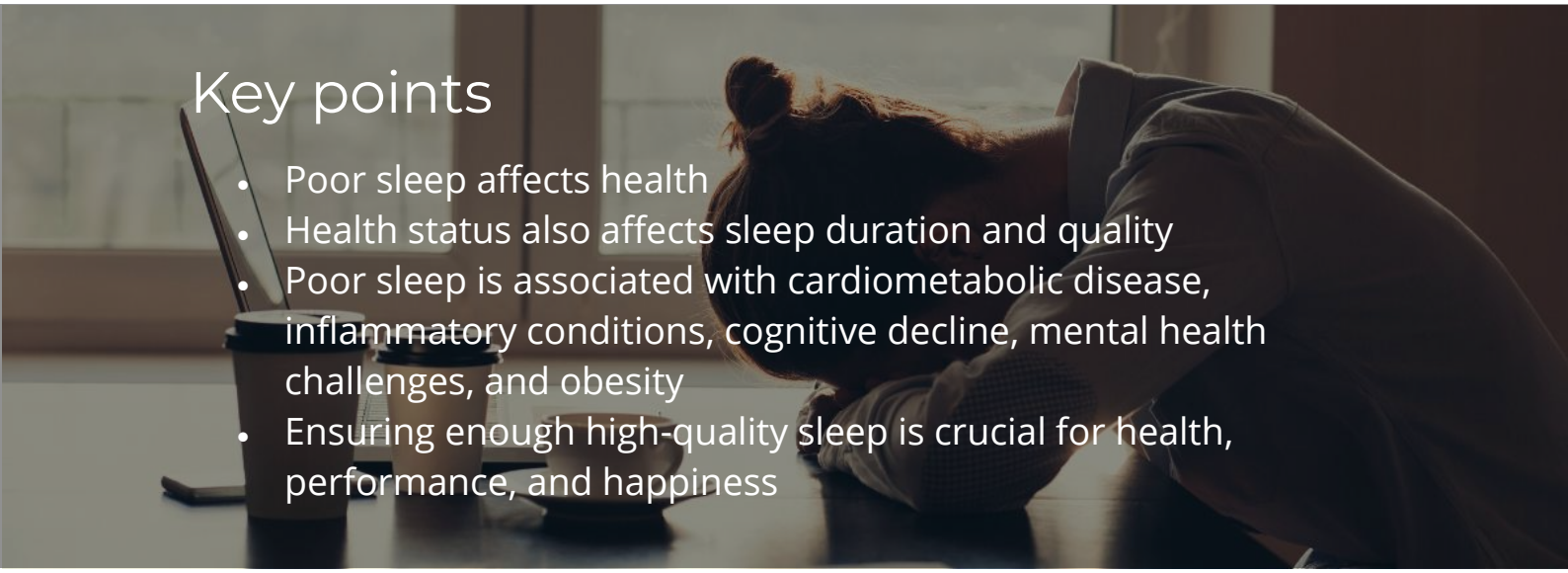
THIS MONTH

HOW SLEEP AFFECTS HEALTH



Key points

- Poor sleep affects health
- Health status also affects sleep duration and quality
- Poor sleep is associated with cardiometabolic disease, inflammatory conditions, cognitive decline, mental health challenges, and obesity
- Ensuring enough high-quality sleep is crucial for health, performance, and happiness

Until recently, sleep was perhaps the under-recognised piece of the health puzzle. It's not that it was *completely* ignored, but the conversation generally revolved mostly around diet and exercise. Now, we are beginning to see, more and more, the enormous role that healthy sleeping patterns play in our overall health and our performance. Consequently, there is a large and growing body of research that investigates the roles that sleep plays as both a contributor to health and disease and the ways that it helps to improve our health and performance.

What happens when we sleep?

When we sleep, our body reduces our sensory and muscle activity and our consciousness goes into an altered state. During sleep, we go through several phases of sleep. These are broadly categorised as rapid eye movement (REM) and non-REM sleep.

During sleep, due to the reduced overall activity, the body can accelerate its recovery by building tissue and restoring immune and hormone functions. It has also recently been discovered that sleep is critical to remove toxins created by normal day-to-day functioning from the brain. These metabolites are not removed during the day but when we sleep are rhythmically 'washed' from the brain and central nervous system by the *glymphatic* (glial + lymphatic) system. Much of the body's rebuilding, repair, and waste removal is carried out during REM sleep.

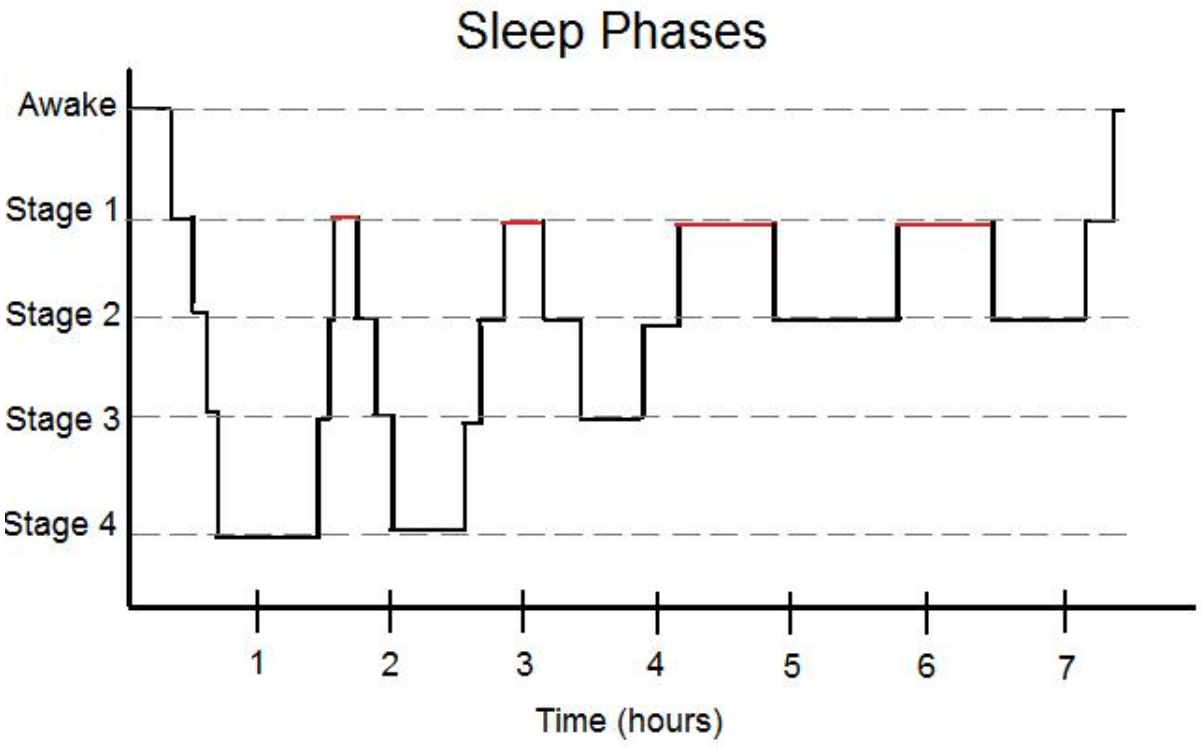
Rebuilding, repair, and waste removal is carried out during sleep

The cycles of sleep

Within minutes we enter stage one sleep, characterised by alpha and theta brain waves. After several minutes of light, stage one sleep, we enter stage two. This stage is characterised by 'sleep spindles', bursts of neural activity.

Deep sleep (also called *slow-wave sleep*) involves stage three and four. In these stages, muscle activity is inhibited, and it is harder to awaken. The brain produces more delta waves. In this stage is when much of the repair of the body takes place and so, getting enough deep sleep is critical to health.

About 90 minutes after falling asleep we enter REM sleep characterised by rapid, jerking movements of the eyes. In this phase, the brain reactivates (most dreaming occurs during REM sleep). REM sleep plays an important role in learning and memory function, as it allows the brain to process and organise learning and memory.



Note: REM sleep is indicated by red lines.

Kernsters [CC BY-SA (https://creativecommons.org/licenses/by-sa/3.0)]
https://commons.wikimedia.org/wiki/File:Simplified_Sleep_Phases.jpg

How much sleep should we get?

According to the National Sleep Foundation of the US, which convened an expert panel to evaluate optimal sleep times, the recommended amounts of sleep for various ages are[1]:

0-3 months: 14-17 hours per night

4-11 months: 12-15 hours

1-2 years: 11-14 hours

3-5 years: 10-13 hours

6-13 years: 9-11 hours

14-17 years: 8-10 hours

18-64 years: 7-9 hours

65+ years: 7-8 hours

However, the *quality* of sleep is also extremely important, with adequate periods of deep sleep and REM sleep. While there is no consensus on exactly how much REM and deep sleep we require to function optimally, deep sleep should account for at least 13% of total sleep duration, while REM sleep typically accounts for at least 20% of sleep in healthy people.[2]

There can also be significant variations between people, and while most of us probably do best around the norms suggested above, it is known that variability between people exists and some thrive on greater or lesser sleep times and different sleep patterns.

> Some people thrive on greater or lesser sleep times and different sleeping patterns

Is sleeping in our genes?

Twin studies have shown that a substantial proportion of the variance for sleep variables is due to genetic factors with around 30-40% of the variability in sleep quality and duration attributed to 'nature' vs nurture.[3] So, that means that although many of our sleep traits are influenced by our genes, far more is influenced by our behaviours and lifestyle.

> Sleep is influenced by our genes, but far more is influenced by our behaviours and lifestyle

THE EFFECTS OF SLEEP DEPRIVATION ON HEALTH

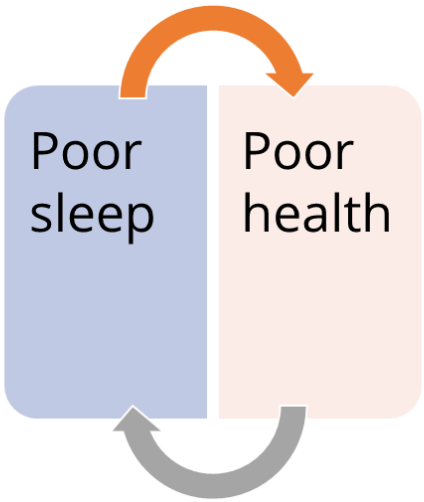
Both short and long sleep durations are associated with increased mortality risk in adults and the elderly.[4-6]

Short sleep is associated with increased mortality risk.[1] It is also associated with an increased risk of [4]:

- Diabetes mellitus (RR, 1.37; CI 1.22–1.53)
- Hypertension (1.17; 1.09–1.26)
- Cardiovascular diseases (1.16; 1.10–1.23)
- Coronary heart diseases (1.26; 1.15–1.38)
- and obesity (1.38; 1.25–1.53)

Long sleep durations are also associated with mortality,[2] diabetes, cardiovascular disease, stroke, coronary heart disease, and obesity.[6]

It is important to note that *correlation does not equal causation.* Illnesses and health conditions can alter sleep patterns (through physical pain and discomfort or mental and emotional anguish) but conversely, poor sleeping patterns can also alter physiological processes that precipitate poor health. There is likely *bidirectionality* in which sleep can worsen health, and health conditions can also worsen sleep, leading to a vicious cycle of both poorer health and poorer sleep.



[1] Overall risk ratio (RR) 1.12; 95% confidence interval (CI) 1.08–1.16

[2] RR 1.39; 95% CI 1.31–1.47

Arthritis and back pain

Sleep interventions that improve sleep, including cognitive behavioural therapy (and medication), reduced insomnia and pain in people with low-back pain.[7]

Attention-deficit/hyperactivity disorder

While findings are mixed, sleep disturbances are associated with worsened clinical and cognitive outcomes in adolescents with ADHD.[8]

Cardiovascular disease

Systematic reviews have identified the lowest risk level for cardiovascular disease of ~7 hours of sleep per night. Sleep durations less than 7 hours are associated with a 6% increase in risk per hour of sleep lost. Sleep durations over 7 hours per night are associated with a greater risk of approximately 13% per 1-hour increase.[9] Other reviews have found similar results with both long and short durations of sleep associated with significantly increased risk of stroke.[10]

Cognition and brain health

Lack of sleep is known to worsen cognitive abilities and particularly, sleep improves the ability to store memories for later retrieval.[11]

Lack of sleep is known to worsen cognitive abilities

In children

A significant effect has been found between sleep duration and cognition. Long durations of sleep in children are associated with better cognitive functioning. It has been shown that IQ is significantly associated with sleep loss, but memory, processing speed and attention are not. Worryingly, in this review of the evidence, it was shown that in most children studied, sleep durations were not within the range of recommended sleep. As such, the effects of loss of sleep on cognition may be underestimated, as most children were already sleep-restricted.[12]

Inadequate sleep results in changes to the structure and function of the brains of children and adolescents

In adolescents

Adolescents are considered to be at risk for deteriorated cognitive functioning due to insufficient sleep. It is known that inadequate sleep results in changes to the structure and function of the brains of children and adolescents.[13] Additionally, both objective and subjective reductions in

sleep quality increase stress and cortisol levels which impact sleep duration and quality.[14] In a review of the effects of experimental sleep manipulation on adolescents, partial sleep restriction was shown to have little to no effect on adolescent cognitive functioning but total sleep deprivation was found to reduce alertness and task completion, while both sleep extension and sleep improvement improved working memory. It has also been shown that sleeping directly after learning improves the ability to retain that learning.[15]

In older adults

- In meta-analyses of sleep duration in older adults:
- Self-reported short and long sleep was associated with poorer cognition
- This was shown in both cross-sectional and prospective studies
- Associations of short and long sleep were found across multiple measures of cognition

Both short and long sleep duration are associated with a greater than 40% increase in poorer cognition scores. [iii] In cross-sectional studies of sleep duration and cognition, extremes of sleep duration were significantly associated with poorer performance over multiple domains (such as performance, executive function, verbal memory, and working memory).[16] Those with sleep-disordered breathing were 26% more likely to develop cognitive impairment.[17]

Dementia

People with dementia tend to have disturbed sleep and while this could be related to dementia causing the sleep disturbance, it is likely to be bidirectional and studies suggest that sleep disturbances can increase the risk of dementia. Compared with people without sleep disturbances, those with disturbed sleep have a higher risk of dementia and Alzheimer's disease. For example, people with sleep problems have been demonstrated to have a 68% greater likelihood of cognitive impairment or Alzheimer's disease [iv] and approximately 15% of Alzheimer's disease in the population may be attributed to sleep problems.[18]

People with sleep problems have a 68% greater likelihood of cognitive impairment or Alzheimer's disease

[iii] OR 1.40; 95% CI 1.27–1.56

[iv] RR 1.68; 95% CI 1.51–1.87

- Subgroup analysis has also shown that insomnia increases the risk of Alzheimer's disease but not vascular or all-cause dementia
- Sleep-disordered breathing was associated with a higher incidence of all-cause dementia, AD, and vascular dementia[19]

In a meta-analysis of studies including over 69000 participants, individuals with sleep problems had around 55% to 400% greater risk of a range of cognitive challenges including Alzheimer's disease, cognitive impairment, and preclinical Alzheimer's disease than people without sleep problems.[18]

Individuals with sleep problems had up to 400% greater risk of cognitive challenges

Diabetes

Sleep disturbances including short (less than 6 hours) and long (greater than 8 hours) sleeping time, insomnia (initiating or maintaining sleep), sleep apnoea, and abnormal sleep timing have been associated with increased diabetes risk,[20] and both long and short sleep are associated with increased HbA1c (a measure of average blood sugar levels).[21] Risk of diabetes is associated with increases of 48% for people sleeping less than 5 hours a night and 36% for those sleeping more than 9 hours. Sleep apnoea has shown the strongest association with diabetes, more than doubling risk, while poor sleep quality and shift work both increase risk by ~40%.[20]

Inflammation

Over 70 studies featuring more than 50000 participants have evaluated the effects of sleep deprivation on inflammation. Sleep disturbance was associated with higher levels of c-reactive protein, and the inflammatory marker interleukin 6 (IL-6). Shorter sleep duration was associated with higher levels of c-reactive protein, but not IL-6. Long sleep durations (>9 hours) were also associated with increased inflammation marked by higher c-reactive protein, and IL-6. Interestingly, neither long nor short sleep or sleep disturbance were associated with increased levels of tumour necrosis factor-α, one of the key markers of autoimmune inflammatory conditions like Crohn's disease.[22]

Note: The addition of a multi-nutrient in a higher-protein diet (1.5 g/kg/bw per day) and containing arginine, glutamine, zinc sulphate, vitamin C, vitamin D3, and omega-3 fatty acids compared with lower protein intake (0.8 g/kg/bw)) did not significantly mitigate the reduced wound-healing resulting from shortened sleep but did improve immune/inflammatory responses after skin injury (as shown by higher post-injury IL-6 and IL-8 concentrations).[23]

Mental Health

Sleep quality, duration of sleep, and sleep latency (the time take to get to sleep) are known to affect daytime mood.[24] Sleep disturbances also result in significant increases in anxiety.[25]

- Sleep deprivation results in significantly increased anxiety levels, but sleep restriction does not
- Conversely, while not significant, there is also a trend towards greater anxiety with extremes of long sleep[26]

Preliminary evidence also suggests a link between sleep disturbances and psychosis. This association may be partly causative and resultant (from neurocognitive anomalies and symptom severity).[27]

> Sleep deprivation results in significantly increased anxiety

Among older adults, there is a high prevalence of sleep disturbance and depression. Evidence suggests a bidirectional relationship between these, with poor sleep contributing to depression and depression encouraging poorer sleep.[28]

Bipolar disorder is also associated with sleep disturbances.[29] Individuals at high risk of bipolar disorder report greater incidences of the irregularity of sleep/wake times, poor sleep, and circadian rhythm disruption. It has been suggested that poor sleep quality, night-time awakenings, and inadequate sleep are possible predictive factors for bipolar disorder. [30]

Risk-taking and suicide

Sleep disturbances, insomnia, and nightmares are associated with suicide risk.[31-33] This might be affected by an elevation in impulsivity which could increase the tendency to act on suicidal ideation.[33]

> Sleep disturbances, insomnia, and nightmares are associated with suicide risk

A systematic review (26 studies, 579,380 participants) indicated that insufficient sleep was associated with 43% greater odds of risk-taking across diverse categories of risk, including alcohol and drug use, smoking, violent or delinquent behaviour, transport risk-taking/road safety, and sexual risk-taking.[34] Sleep duration may also affect the risk of suicide. The lowest association with suicidality is seen between 8 and 9 hours of sleep per night, with every 1-hour increase in sleep associated with an 11% decrease in suicidal ideation.[32]

Multiple sclerosis

It is an almost universal finding that sleep disturbances have significant associations with cognitive dysfunction in multiple sclerosis. In studies, self-reported sleep disturbance generally predicted self-

reported (but not objective) measures of cognitive dysfunction. Conversely, objective sleep measures (e.g., polysomnography, actigraphy) generally predicted objective impairments in processing speed and attention; however, objective sleep disturbance was more variable in predicting performance in other cognitive domains (e.g., memory, executive function).[35]

Sleep disturbances have significant associations with cognitive dysfunction in MS

Obesity

Sleep duration is likely to influence weight gain and overweight/obesity and resulting health effects.[36] Meta-analyses have revealed that reduced sleep duration is associated with between 30-71% greater risk of obesity in children. [36-38]

Sub-group analysis shows that short sleep duration is associated with a greater risk of developing overweight or obesity in:

- infancy (seven studies, 14738 participants, risk ratio [RR] 1.40; 95% CI 1.19 to 1.65; $p < .001$)
- early childhood (eight studies, 31104 participants, RR 1.57; 1.40 to 1.76; $p < .001$)
- middle childhood (three studies, 3005 participants, RR 2.23; 2.18 to 2.27; $p < .001$)
- and adolescence (three studies, 26652 participants, RR 1.30; 1.11 to 1.53; $p < .002$).[36]

While the reasons for this association are not entirely clear, in children a link has been found between short sleep duration and the development of insulin resistance, sedentary behaviours and unhealthy eating patterns.[39] It has also been shown that partial sleep deprivation results in increased energy intake (i.e. you eat more) and that people overeating as a result of sleep deprivation tend to eat more fat and less protein,[40] and have a poorer diet overall,[41] characterised by more snacking and soda use.[42] This relationship is also bidirectional, with a poorer diet likely to lead to poorer sleep.[41] Conversely, getting adequate sleep is associated with a higher intake of fruits and vegetables.[42]

Sleep duration and quality are associated with increased risk of obesity

Neurodegeneration

An extremely strong connection between sleep disorders and neurodegenerative diseases has been drawn. For example, in those with a REM sleep disorder (disabling the ability to achieve proper REM sleep), the risk of developing a neurodegenerative disease was 33.5% at five years follow-up, 82.4% at 10.5 years and 96.6% at 14 years,

with nearly half of these developing Parkinson's disease.[43]

Conclusion

Sleep has a 'bi-directional' relationship with health. That is to say, sleep affects health, poor health affects sleep, and sleep affects and is affected by the foundations of health. For example, when we eat poorly, don't move, are stressed, or less mindful, our sleep suffers, conversely, when we sleep poorly, we don't eat or move as well, and we are less mindful and more prone to stress.

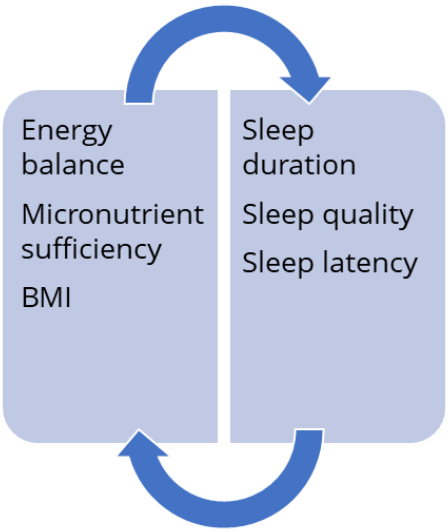
On balance, ensuring that we get enough high-quality sleep is critical to health, performance, and happiness.

DIET, SUPPLEMENTS, & SLEEP

Key points

- Getting enough total energy from your diet is likely to improve sleep duration and quality
- Sufficient protein is also likely to improve sleep
- Specific diets have variable effects on sleep architecture, but a broad reading of the research suggests that diets based on mostly unrefined foods improve sleep
- While diets that include excessive snacks, and especially snacks high in sugar, or diets high in ultra-refined foods worsen sleep
- Being replete in specific nutrients like vitamins C and D and the minerals zinc and magnesium is also beneficial to sleep

The effects of poor-quality or lack of sleep on health are well documented (see "The Effects of Sleep on Health"). Nutrition and diet influence the quality and duration of our sleep and this effect is 'bi-directional',[44] meaning that diet and nutrients influence sleep *and* that sleep affects how we eat. So, this can create a positive or negative cycle of improved or diminished sleep over time, further improving or reducing health.



What overall effects do diet and nutrients have on sleep duration and quality?

The assumption is that diet and sleep are closely related. It has been suggested that diets high in ultra-refined foods, sugar and fats, and low in vegetables are associated with reduced sleep driven by increased cortisol (and that this could play a role in the causation of Alzheimer's disease).[45]

However, the overall effects of diet and nutrients in observational studies are relatively small. For example, in a study of over 2000 healthy Japanese adults, only small associations were observed for the effect of nutrients vitamins D and B12, and food groups bread, pulses, fish and shellfish[v] on sleep duration in men. While no significant correlations between dietary intakes and sleep duration were observed in women.[46]

In a study of nurses involved in shift-work, there was no significant association between diet and sleep quality, but there was a significant association [vi] between body mass and sleep quality.[47] This suggests that the effects of diet and nutrients on sleep is most likely to result from the overall effects of diet on cardiometabolic health (i.e. diabetes, prediabetes, and obesity). Other observational research has shown that poor sleepers have significantly higher body mass and fat mass percentage than good sleepers. It has also been shown that 'good' sleepers (6–8 hours per day), showed greater reductions in fat mass, an effect especially true in women compared to men (−3.6 vs. −2 kg, $p = 0.05$). Women who reported sleeping more than 6 hours per night also had an increased probability of losing fat mass than women who reported sleeping less than 6 hours.[vii] [48]

'Good' sleepers achieve better fat-loss

In a study of people following the Mediterranean Diet, sleep duration was associated with greater intake of fruits and vegetables, while reduced sleep was associated with unhealthy eating behaviours, including greater intakes of sweets and snacks. Short sleep duration and poor sleep were also associated with an increase in body mass and fat mass.[49] A Mediterranean diet itself is associated with better sleep durations (i.e. not too long and not too short) and with better sleep quality.[50-52]

Data from the National Health and Nutrition Examination Survey Data (2005-16) also suggests that those not meeting their sleep needs are significantly more likely to skip

[v] 'Small' correlations: $r < 0.3$

[vi] $p = 0.0032$

[vii] OR = 4.47, 95% CI: 1.42–14.04, $p = .010$ and OR = 5.10, 95% CI: 1.15–22.70; $p = .032$, respectively

breakfast and/or lunch, while also being more prone to snacking and late-night eating, resulting in higher intakes of energy, carbohydrate, fat, added sugar, and caffeine (mostly from snacks). So, lack of sleep in itself is likely to cause poorer eating habits and increase the known obesogenic (fat-gain) elements of the diet.[53]

> Lack of sleep likely to cause poorer eating habits and increase the risk of obesity and metabolic disorder

Effects of macronutrient distribution

Diets containing different macronutrient amounts are suspected to play a role in sleep. Overall, though, changes in carbohydrate and fat content (i.e. comparing low-fat to low-carb diets) has resulted in only minor differences in some components of sleep. There is evidence of a trend towards reduced time-to-sleep and short-wave sleep, and increased REM sleep in higher carbohydrate interventions, and greater sleep arousal in low-carb diets.[54] However, the results of studies on low-carb or ketogenic diets and sleep have been very variable and show marked differences in effects depending on the degree of calorie restriction, and the time-frame of the study in which sleep quality and length is measured. In a study looking at the *low-carb diet score* (i.e. those who habitually eat most vs least carbohydrate) lower-carbohydrate diets were associated with better sleep (and reduced depression),[55] however, these studies need to be interpreted with caution because they rely on macro content of habitual diets, not low-carb diets per se, and without attention to 'quality' of diet.

There can also be transient effects of a low-carbohydrate diet on sleep during the adaptation to reduced glucose availability and increased fat and keto-adaptation. This typically resolves in several days. There are sympathetic nervous system effects ('stress' responses) during the early adaptation to a ketogenic diet that can affect sleep but qualitative research suggests that the overall effect on sleep, from a ketogenic diet, is a positive one.[56]

> Changes in carbohydrate and fat content have resulted in only minor differences in some components of sleep

Higher protein diets have shown some positive effects on night-time arousal and wakening.[54] It is plausible that this is related to our desire to seek enough protein (protein leverage theory) and this is why protein reduces cravings for all foods. Clinically we commonly observe that where

people are not taking in enough energy or protein, sleep duration is shortened in response, a likely consequence of the need to have more daylight hours available to 'hunt and gather'. Studies have shown no clear differences between higher and lower protein diets of greater or lesser than 2.2 g per kg,[57] and this suggests that higher-protein diets (over what we require to thrive) offer no further benefits to sleep. In short, getting optimal protein to thrive is likely to improve sleep, but additional protein is unlikely to further enhance sleep quality or duration.

Consuming optimal protein is likely to improve sleep

Food types and sleep

There is some evidence that milk, fatty fish, fruit, and increased vegetable intakes promote better sleep.[54, 58] Conversely, lower intakes of fruit and vegetables are associated with short and long sleep durations (which are both associated with poorer health), as are markers of fruit and vegetable consumption like carotenoids and vitamin C.[59]

Other foods containing either high antioxidant levels (kiwi), melatonin (tart cherry) and zinc-containing foods like oysters might help to improve sleep.[58] Lower intakes of whole grains and higher intakes of red meat and lower diet quality overall are associated with a greater incidence of obstruction sleep apnoea.[60]

Eating behaviours and sleep

In a study of over 2000 children, no significant effects of specific nutrients or foods were shown on sleep, however, 'unhealthy eating habits and environments' such as eating alone or in front of the television, was independently associated with sleep as were between meals and after dinner snacking.[61]

'unhealthy eating habits and environments' worsen sleep quality

Specific nutrients and sleep

In infants

Both nutrients and timing of nutrients have been reported to influence sleep. In infants, various nutrients have been shown to naturally fluctuate in breast milk with circadian rhythm, and these nutrients such as tryptophan, nucleotides, essential fatty acids and omega-3 fatty acids might impact infant sleep.[62]

Melatonin

Children with dermatitis often have poor sleep due to the itching and discomfort of the condition. In a study of 48 children with

atopic dermatitis, sleep latency (the time taken to get to sleep) was reduced by 21 minutes in those taking 3 mg of melatonin compared to a placebo.[63]

Vitamin C

Studies have shown an association between vitamin C and improved sleep durations.[59] This association has been assumed to be because of overall nutrient sufficiency in a healthy diet containing greater intakes of natural, unrefined foods, especially fruits, berries and vegetables. However, in a study on the application of intravenous vitamin C in dialysis patients (500 mg/5 cc, 3 x per week over 8 weeks) there was a notable difference in night-time itching and restless leg syndrome in the intervention group. There was also an improvement in subjective sleep quality, sleep latency and daily function between the two groups and sleep disorders were significantly lower[viii] in the intervention group.[64] This *might* suggest an independent effect of vitamin C on sleep.

Vitamin D

Vitamin D receptors have been found in the brain regions involved in sleep regulation and this vitamin is known to be involved in regulating the sleep-wake cycle. Low levels of vitamin D are correlated with poor quality sleep and short sleep duration.[65, 66]

Insufficiency of the vitamin is also suggestive of a lack of daytime circadian patterning,[66] in other words, lesser exposure to sunlight (and hence lower vitamin D levels) impairs our normal day-night patterns and thereby reduces sleep. However, supplementation has proven beneficial, and so sufficiency of this vitamin, and not just circadian rhythms, might have a distinct effect on sleep. In a study of vitamin D supplementation (50,000 iu every fortnight) overall sleep scores were improved, as were the subgroups of sleep duration, sleep latency, and sleep quality.[67] Additionally, vitamin D deficiency has been associated with poor sleep quality [ix] in heart failure patients.[68]

Vitamin D levels have also been associated with obstructive sleep apnoea (and with neck circumference, a factor in OSA),[69] resulting in poorer sleep in some studies,[70] but not others.[71] A systematic review of available studies in 2017 concluded that There was a relative insufficiency in serum vitamin D levels among OSA patients. It was unclear whether low vitamin D was a risk factor for OSA or if OSA was a risk factor for low vitamin D and it was also possible that the association between vitamin D and OSA was due to overweight/obesity.[72]

A 2018 systematic review and meta-analysis has investigated the role of vitamin D and sleep. Lower vitamin D levels were associated with poor sleep quality, short sleep duration, and sleepiness. Subgroup analyses further indicated that serum

[viii] p =0.0001

[ix] (odds ratio, 2.22; P = .033).

vitamin D[x] of less than 20 ng/mL could significantly increase the risk of unhealthy sleep.[73]

> Lower vitamin D levels were associated with poor sleep quality, short sleep duration, and sleepiness

Magnesium

Magnesium is required for enzymes used in the production of neurotransmitters. It is an agonist of GABA, one of our primary 'relaxing' neurotransmitters, and blocks the N-methyl-d-aspartate (NMDA) receptor and so, it's considered a generally 'relaxing' mineral,[74] which can improve sleep, especially slow-wave sleep.[75] Surveys suggest that a relative magnesium 'deficiency' (enough to affect sleep quality) might be common, especially in those with obesity, alcoholism, or advancing age.[76] In new-borns serum magnesium levels were correlated with 'quiet' sleep,[77] while in adults, chronic sleep deprivation results in reduced intracellular magnesium levels which might further affect both sleep and cardiovascular events.[78] (Note: Magnesium is intricately involved with preserving cardiovascular tone and heart rhythm).

In a sleep deprivation study of athletes, supplementation of 100 mg of magnesium per day for one month mitigated the reduction in anaerobic threshold and peak oxygen uptake seen in unsupplemented athletes. The authors conclude that *"these results indicate that decreased exercise tolerance observed in the sleep-deprived state could be improved by oral Mg administration".*[79]

> Chronic sleep deprivation results in reduced intracellular magnesium levels

In an observational study of 1487 Chinese adults, dietary magnesium was compared to sleep. The average intake of magnesium was 332.5 mg per day. Those in the highest quartile of magnesium intake had ~12% lesser likelihood of falling asleep during the day.[80]

In a study of 100 adults with poor sleep quality scores,[xi] one group was given a 320 mg magnesium/day supplement as magnesium citrate and the other group a sodium citrate placebo for seven weeks. At baseline, 58% of the participants were consuming less than the U.S. Estimated Average Requirement (EAR) for magnesium. Consuming less than the EAR was associated with significantly higher BMI and

[x] 25(OH)D

[xi] Pittsburgh Sleep Quality Index (PSQI) score higher than five

plasma C-reactive protein (CRP) concentration (only 40 participants had plasma CRP concentrations higher than 3.0 mg/L (an indication of chronic inflammatory stress)). Overall sleep disturbance scores[xii] in the magnesium group improved from 10.4 to 6.6.[81]

Zinc

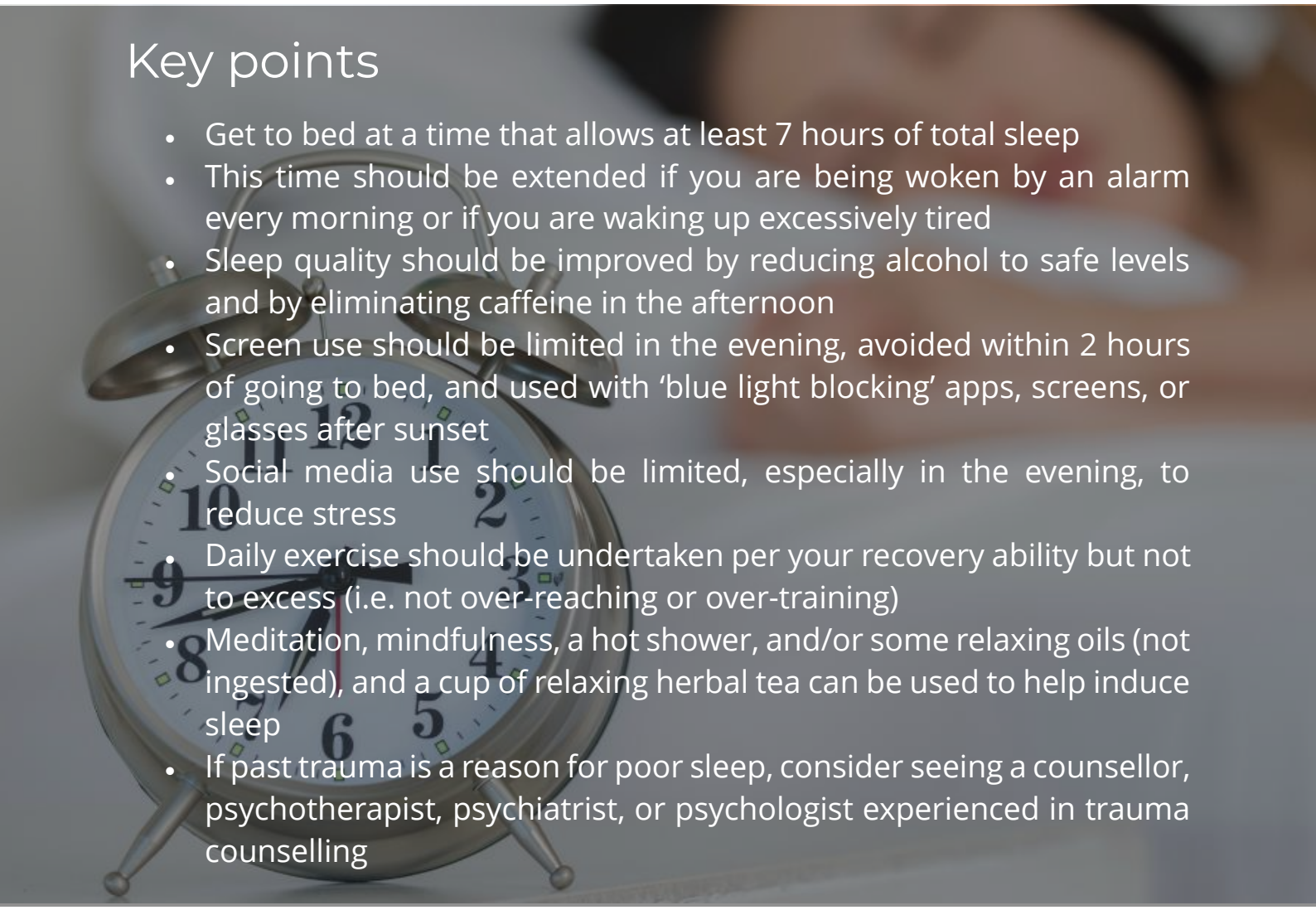
Recent research has concluded that zinc serum concentration varies with the amount of sleep, while orally administered zinc increases the amount and the quality of sleep in both mice and humans.[82]

> Orally administered zinc increases the amount and the quality of sleep

In a double-blind, placebo-controlled study over 12-weeks both zinc-rich foods and zinc supplemented foods improved the time take to fall asleep and improved sleep quality.[83] In a study of intensive care nurses, The total sleep quality, and sleep latency scores for those supplementing with zinc were significantly improved vs a control group. Supplements resulted in significantly higher serum zinc levels than the control group.[84]

[xii] PSQI

HOW TO IMPROVE YOUR SLEEP



Key points

- Get to bed at a time that allows at least 7 hours of total sleep
- This time should be extended if you are being woken by an alarm every morning or if you are waking up excessively tired
- Sleep quality should be improved by reducing alcohol to safe levels and by eliminating caffeine in the afternoon
- Screen use should be limited in the evening, avoided within 2 hours of going to bed, and used with 'blue light blocking' apps, screens, or glasses after sunset
- Social media use should be limited, especially in the evening, to reduce stress
- Daily exercise should be undertaken per your recovery ability but not to excess (i.e. not over-reaching or over-training)
- Meditation, mindfulness, a hot shower, and/or some relaxing oils (not ingested), and a cup of relaxing herbal tea can be used to help induce sleep
- If past trauma is a reason for poor sleep, consider seeing a counsellor, psychotherapist, psychiatrist, or psychologist experienced in trauma counselling

The effects of sleep on health and the effects of aspects of health (like nutrition, mindfulness, and exercise) on sleep are clear. A large body of research shows that this relationship is bi-directional and also that there are many things we can do to improve our sleep and by extension our health.

The reality is that most of these interventions are also what we do simply to improve our health and performance.

As I often say, *if you take care of the big things in health…and the little things tend to fall into line!*

There are some specific things we can do for our 'sleep hygiene' which can also provide the 'icing on the cake' that tips our balance from poorer, to better sleep.

Eat mostly unrefined foods

Diets that focus on a mostly unrefined selection of foods like the Mediterranean Diet, tend to promote longer and better-quality sleep,[50-52] and this is especially true when they include more fruits and vegetables. Conversely, diets higher in sugar, sweets, and snacks are associated with reduced sleep quality.[49] Ultra-refined foods are also associated with obesity and this is known to also affect sleep.[48, 49] Eating more unrefined foods, and especially foods like veggies, berries, and fruit (if you tolerate carbohydrates well) also help to supply vitamin C and flavonoids associated with better sleep.[59]

> Diets that focus on unrefined foods tend to promote longer and better-quality sleep

Eat 2-4 meals per day. Don't snack!

Missing main meals and snacking is associated with worsened diet quality *and* poorer sleep.[49, 53] So, instead, we should focus on eating good, healthy meals, until we are full, and then eat again (a healthy, well-balanced meal) when we are hungry, rather than snacking.

> Missing main meals and snacking is associated with poorer sleep

Eat plenty of protein and veggies

Vegetables are associated with improved sleep,[54, 58, 59] as are adequate protein intakes.[54] You don't need to go overboard with this as very high protein intakes don't necessarily improve sleep further.[57]

> Eat 2-3+ fist-sized serves of vegetables at each meal and 1-2 palm-sized serves of a protein food

Get out in the sun for at least 10 min per day (but don't burn!)

Vitamin D helps to regulate the sleep-wake cycle,[65, 66] and sun exposure also helps to regulate our natural circadian (day-night) patterns.[66] So, getting out into the sun helps provide a one-two punch for improving sleep.

If we can't get out in the sun all the time, or during winter when vitamin D production from sun exposure is lower, taking a vitamin D supplement can also help to preserve vitamin D level and improve sleep duration and quality.[67, 73]

Get out in the sun with face, arms, and legs (or more!) exposed for 10 min per day, and/or take a vitamin D supplement (600 – 4000 iu [max] per day)

Consider zinc and magnesium before bed

Magnesium helps reduce excessive nerve firing and is considered our primary 'relaxing' mineral[74] which can improve sleep.[75] Magnesium is likely to both improve sleep and reduce drowsiness, while poor levels of magnesium worse sleep.[76-78, 80] It can also reduce some of the negative effects on performance from not getting enough sleep.[79]Magnesium supplementation has been shown to benefit sleep.[81]

Similarly, zinc is involved in many hundreds of enzymatic reactions in the body, some of which are critical to sleep-cycles. Zinc supplementation and higher intakes of zinc-rich foods improve the amount and quality of sleep,[82-84]

Consider a zinc/magnesium supplement containing ~400 mg magnesium and 15 mg zinc.

Note: A great way to get sufficient zinc and magnesium is within a quality multi-vitamin that also includes ~900 mcg of copper (which is important to have 'in balance' with zinc)

Meditate before bed

Mindfulness and meditation target key risk factors of poor sleep, such as awareness, control, and most importantly acceptance (especially of the things you can't control!)[85]

Meditative practices such as 'mindfulness-based stress reduction' (a meditation practice based originally drawn from Eastern traditions like Buddhism and now used as a medical intervention) is likely to improve sleep quality as much or more as other active interventions, and more than passive 'control' actions.[86-88] Similarly, mindful movement practices like meditation, yoga, chi gong, and Pilates have been shown to have beneficial effects on sleep quality, along with improvements in quality of life, physical performance, and depression,[89, 90] and might help to reduce chronic pain and improve sleep quality in people with chronic illness.[91]

Use mindfulness of breath meditation before bed

Get more (and earlier) sleep

There is a clear link between reduced sleep duration and poorer health. For example, in a study comparing sleep extension with napping, improved *sleep hygiene,* and post-exercise recovery strategies in athletes (18-24 yrs.) it was found that longer sleep had the greatest effect on subsequent performance. [92]

Interestingly, while we often hear advice that 'banking' sleep is ineffective (getting more sleep before or after a period of reduced sleep), a systematic review of sleep patterns of shift-workers has suggested that banking sleep before shift-work can help to improve safety, performance, and reduce fatigue.[93]

Try going to bed ½ an hour or more earlier than usual

Consider cognitive behavioural practices

Pre-sleep practices drawn from cognitive behavioural therapy result in increased sleep times, reduced time-to-sleep, and improved sleep quality, resulting in additional improvements to daytime sleepiness, depression, and anxiety.[90, 94, 95]

Have a warm bath or shower before bed

Taking a warm bath or shower increases body temperature and this results in greater peripheral blood flow and vasodilation to reduce body temperature to normal. This heating-and-cooling is thought to help elicit sleep and increase the release of sleep-inducing hormones like melatonin as it mimics one of the 'sleep signals' of our circadian rhythm – the inevitable cooling of the environment as the sun sets. A bath or shower of ~40-42.5 degrees Celsius has been shown to improve sleep quality and time-to-sleep when taken around 1-2 hours before bed.[96]

Try having a warm bath or shower before bed

Exercise

Exercise improves sleep quality, duration and time-to-sleep.[97-100] In particular, exercise is effective for helping to combat insomnia.[100, 101] Exercising in the evening also helps rather than hinders sleep duration and quality overall, however, vigorous exercise less than an hour before bed can reduce sleep duration, increase the time it takes to get to sleep and reduce sleep quality.[102] In a more recent review (from 2017) of intervention studies, 29 of 34 studies concluded that exercise improved

either sleep duration of quality,[103] and in a meta-analysis of the same year a significant improvement in sleep was seen with exercise.[97] In those with sleep disturbance, there is an association with obesity (which is improved by exercise) and improvements to the severity of sleep disturbances and quality of life resulting from exercise.[104]

Resistance exercise

Most of the recent reviews have focussed on aerobic or mindful exercise regimens. In a recent review of the effects of resistance (weight) training, chronic resistance exercise was found to improve all aspects of sleep, with the greatest benefit for sleep quality and the suggestion that resistance exercise also improves anxiety and depression.[105]

Get into a habit of regular exercise but be aware of exercising intensely too close to bed-time

Reduce use of screen devices and exposure to media...

There is a strong and consistent association between bedtime use of screen devices like phones and tablets with inadequate sleep, poor sleep quality and excessive daytime sleepiness. [106] There is a greater than two-fold increased risk of having sleep problems if you compulsively use the internet ('internet addiction').[107]

Reduce the use of screen devices wherever possible after dark, and use blue-light blocking glasses or apps

Light therapy

Human circadian rhythms are influenced heavily by light and dark cycles. When it is lighter, we wake up and when it is darker, we tend towards sleep. Thus, bright light therapy has been considered a way to help influence circadian rhythms and encourage better sleep. Meta-analysis has shown that bright light exposure (only earlier in the day!) can improve sleep duration, sleeping problems in general, reduce insomnia and reduce Alzheimer's related sleep-problems.[108]

Get out in natural sunlight in the morning and mid-day

Reduce caffeine

Caffeinated beverages have health benefits and can help to improve cognition and reduce the risk of neurodegenerative disorders,[109-111] but excessive use or use late in the day can reduce sleep quality and

duration. Caffeine can reduce the time it takes to get to sleep and sleep quality. Additionally, slow-wave sleep crucial to the recovery and repair of the body is reduced, while sleep arousal is increased. Several factors influence the effect of caffeine on sleep; timing of intake and dosage is most important, while older adults may be more sensitive to these effects than younger people. There is also significant genetic variation in tolerance to caffeine.[112]

Restrict caffeine to the morning and if you're having trouble sleeping, reduce your intake of coffee, tea, and/or cocoa

Limit alcohol

Higher intakes of alcohol consumption increase the risk of sleep apnoea and reduce the quality of sleep.[113]

Drink less than 5 drinks per week and avoid drinking more than 3 drinks on any given day

Reduce noise

Noise (such as road or aircraft noise) can affect sleep quality.[114]

Aromatherapy

Use of relaxing aromatherapy oils might help to improve sleep quality.[115]

Look into deeper reasons for sleep disturbances

Inflicted trauma, including sexual violence and abuse, physical violence, or psychological aggression is known to increase sleep disturbance.[14] Interventions (some of which have been above) such as improved 'sleep hygiene', cognitive behavioural therapy, mindfulness and relaxation practices, and psychotherapy and hypnotherapy can help us to deal with trauma and improve sleep.[116] Cognitive behavioural therapy shows particularly strong effects for improving sleep,[116] although these effects seem to be mostly related to subjective (self-reported) rather than laboratory measures of sleep.[117]

Socioeconomics and sleep

Socioeconomic status is also known to affect sleep quality and in turn, lower sleep quality can reduce cognition and mental and physical performance and thus, reduce socioeconomic status (this is another good example of bidirectionality). A 2018 systematic review in the journal *Psychiatry and Mental Health Studies* of the impact of socioeconomic status on sleep suggested the following points[118]:

- Socioeconomic status affects the development of sleep disorders in low-income populations,

independently of gender, age, education, and country
- Sleep disorders may be indicators of high levels of stress
- Circadian rhythms and circadian cycle are affected by socioeconomic status
- Socioeconomic status and circadian disruption are associated with metabolic diseases such as diabetes and cancer
- The most widely correlated measures of socioeconomic status related to sleep disorders are social class, discrimination, ethnicity, low-income, occupation, education, obesity, neurodevelopmental and motor disabilities
- The most well-studied sleep disorders in association with socioeconomic status are insomnia, sleepiness, circadian rhythms sleep disorders, obstructive sleep apnoea and sleep disorders induced by substances like caffeine, opioids, nicotine, and alcohol

Consider seeing a licensed professional to help you deal with psychological trauma

Conclusion

Sleep has a large and bi-direction effect on health, meaning that the worse you sleep, the worse your health *and vice versa!* To improve our health and performance, improving sleep should be a priority, and to improve sleep we need to create 'sleep rituals'. These sleep rituals are often called 'sleep hygiene practices' have been shown to improve sleep quality and duration.[116]

Summary

- Get to bed at a time that allows at least 7 hours of total sleep before waking
- This time should be extended if you are being woken by an alarm every morning or if you are waking excessively tired
- Sleep quality should be improved by reducing alcohol to safe levels (i.e. <5 drinks per week) and by eliminating caffeine in the afternoon and them moderating intake to your tolerance level
- Screen use should be limited in the evening, if possible, avoided within 2 hours of going to bed, and used with 'blue light blocking' apps, screens, or glasses after sunset
- Social media use should be limited, especially in the evening, to reduce stress
- Daily exercise should be undertaken per your recovery ability. Build your volume and intensity incrementally so that it does not become an excessive stressor that inhibits sleep
- Meditation, mindfulness, a hot shower, and/or some relaxing oils (not ingested), and a cup of relaxing herbal tea can be used to help induce sleep
- If past trauma is a reason for poor sleep, consider seeing a counsellor, psychotherapist, psychiatrist, or psychologist experienced in trauma counselling

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