Mini-Review on Clinical Update Sleep 2023

Sleep disorders and exercise: a mini-review

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Abstract: Sleep disturbance in a growing problem in the general population. As the prevalence of sleep disturbance rises, interest in treatment modalities including non-pharmaceutical interventions also grows. One of these potential modalities is exercise therapy. In individuals without sleep disorders, exercise appears to be beneficial in improving sleep architecture without any impact of the timing of exercise in relation to onset of sleep. The mechanisms for this are largely unknown but may be due to a combination of the effects of exercise on body temperature, autonomic control, endocrine and metabolic function. In obstructive sleep apnoea (OSA), supervised exercise therapy appears to have positive impact on daytime sleepiness with an unknown impact on sleep quality. The effect of exercise on central sleep apnoea (CSA) will be difficult to ascertain due to the low prevalence of this condition. In primary sleep disorders such as insomnia, narcolepsy and restless syndrome exercise may be useful in improving sleep architecture but the quality of the evidence supporting this remains low. In addition, the timing of exercise in relation to sleep onset remains under investigated. In individuals with circadian rhythm disorders, evening exercise appears to delay sleep onset. In shift-pattern workers, individuals with increased cardiorespiratory fitness report better sleep quality, suggesting exercise may be protective in this important population. To allow high quality evidence-based recommendations to be made about the value of exercise in individuals with sleep disorders, there is a significant need for large prospective studies with objective and subjective sleep quality as a primary outcome.

Keywords: Exercise; sleep; sleep apnoea; insomnia; restless leg syndrome

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Introduction

Sleep disturbance is a common and growing clinical problem with a reported prevalence of between 4% and 40% in the general population (1). It can be characterised by common conditions such as insomnia and obstructive sleep apnoea (OSA), as well as less common conditions such as narcolepsy, central apnoea and circadian rhythm sleep disorders. It is associated with significant comorbidity and impact on wider public health (2), and as a result, there is considerable interest in identifying measures to

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Table 1 Summary of the effects of exercise on sleep disorders and the limitations of the studies included

Sleep disorder	Effects of exercise on sleep disorder	Limitations of studies
Obstructive sleep apnoea	Improves sleep time, sleep efficiency, arousal index, apnoea-hypopnoea index and subjective sleep quality (3,4)	(I) Limited data; (II) some studies report significant positive outcomes whereas other studies report less consistent results
Central sleep apnoea	Reduces apnoea-hypopnoea index (5)	Limited data
Insomnia	Improves sleep latency, total sleep time, sleep efficiency, sleep onset latency and Pittsburgh Sleep Quality Index (6,7)	Optimal timing of exercise in insomnia remains unknown
Narcolepsy	(I) Children: increases sleep time and sleep efficiency, reduces daytime sleep episodes (8); (II) adults: reduces daytime sleepiness and frequency of cataplexy (9)	Limited data on exercise as a therapeutic intervention for narcolepsy despite being included in international guidelines
Restless legs syndrome	Improves subjective measures of sleep and of restless legs syndrome symptoms (10,11)	Limited data
Circadian rhythm disorders	Improves sleep quality in shift work sleep disorder (12)	Limited data

improve sleep health. Exercise as a means to improve sleep quality has long been investigated, but its impact remains unclear. This review will describe the effect of exercise on individuals without sleep disorders and then discuss sleep-disordered breathing and primary sleep disorders in turn. This review will demonstrate that despite a dearth of high-quality evidence, the literature is suggestive of the value of exercise therapy for sleep disorders, and that definitive studies to determine benefit are warranted (*Table 1*). Although sleep and exercise are synergistic, this review will focus on individuals with sleep disorders. It will not discuss the impact of sleep quality on exercise performance.

Methods

Literature for this review was identified using the following terms in Medline and Embase: exercise, exercise therapy, exercise training, lung rehabilitation, pulmonary rehabilitation, sleep, sleep pathophysiology, sleep disorders, sleep disordered breathing, polysomnography, sleep apnoea, OSA, hypoventilation, obesity hypoventilation, snoring, central sleep apnoea (CSA), insomnia, narcolepsy, sleep wake disorders, restless leg syndrome, circadian rhythm disorders, shift worker sleep disturbance. No restrictions on dates or study design. English language articles were included. The databases were searched from inception to November 2022.

The effect of exercise on normal sleep

Before exploring the effects of exercise on individuals with sleep disorders, it is important to discuss the effects of exercise on individuals with normal sleep and potential mechanisms to explain these effects. Meta-analysis has convincingly demonstrated that individuals who undertake exercise experience improved sleep architecture compared with those who do not (13). Although older data has suggested that exercise soon before bedtime can be deleterious on sleep quality, more recent studies have demonstrated that exercise soon before bedtime does not impair and may in fact improve sleep architecture (14-16). In addition, in a cross-sectional survey of healthy adults, individuals reported better subjective sleep quality on days when they performed exercise, compared with days they did not. However, comparatively, morning exercisers were more likely to report good sleep quality compared with evening exercisers (17). Recent meta-analyses have demonstrated that a short period of exercise in the evening has no deleterious effect on sleep parameters; however, high intensity exercise in the hour before bedtime may impair sleep architecture (18,19). These summarised data provide a reasonably clear view on the impact of exercise on sleep in individuals without sleep disorders; exercise improves sleep architecture, most likely without any preference for timing of the exercise, despite long-standing recommendations that exercise should be avoided in the hours before bedtime. An interesting comparison is the impact of exercise on sleep in professional athletes. Despite the above effects on individuals without sleep disorders, professional athletes, who presumably do not tend to suffer from sleep-disordered breathing or organic sleep disorders, report reduced quality and/or quantity of sleep (20,21). This is believed to be

Table 2 Summary of literature reporting the effect of exercise on physiological functions during sleep

Function	Effect of exercise
Body temperature	Exercise increases body temperature but this does not appear to have an impact on sleep quality
Autonomic	Parasympathetic drive is reduced during and in the immediate aftermath of exercise, but this does not appear to have impact on sleep quality
Endocrinology	Largely equivocal. Growth hormone may or may not be increased during sleep in individuals who perform regular exercise
Metabolic	No data on the effect of exercise on metabolic function during sleep

secondary to training practices resulting in unusual working hours and sleep habits, travel associated with competing (22) and psychological stress (23). Athletes tend to demonstrate poorer objective markers of sleep quality (24) and report excessive daytime sleepiness (EDS) (25). Therefore, even in individuals without diagnosed sleep disorders, exercise can have varying impact on sleep quality depending upon environmental factors.

There are multiple plausible mechanisms (*Table 2*) to explain why exercise may improve or worsen sleep quality and this is likely an explanation for the lack of clear outcomes from these studies. Sleep is improved by a decrease in body temperature, while an increase in body temperature prolongs sleep onset (26). Exercise results in an increase in body temperature, and so if performed immediately prior to bedtime, may result in a prolongation of sleep onset. This may explain why high intensity exercise in the hour prior to bedtime may have a negative impact on sleep quality. Sleep is associated with a reduction in sympathetic drive and increased vagal activity. Parasympathetic drive can take up to 48 hours to recover after high intensity exercise (27), and so it would be unsurprising if exercise was associated with poor sleep. The data presented here, however, are not entirely consistent with this, suggesting other mechanisms may also be contributing. During sleep, growth hormone, prolactin and melatonin are increased, while cortisol levels are reduced (28). The data on the effect of exercise on endocrine function during sleep is dated and contradictory. A study comparing the effect of exercise with no exercise in healthy participants demonstrated that growth hormone levels were considerably increased in exercising individuals (29). On the other hand, growth hormone was not increased in a cohort of ten healthy participants who had taken part in a graded daytime exercise regime (30). An explanation for this difference may have been the intensity of the exercise. Another small study of healthy participants demonstrated that in individuals conducting moderate level of exercise, growth hormone levels fell for the first half of the night and then rose for the second half (31). The exact effect of exercise prior to sleep on endocrine physiology remains elusive. Although sleep and metabolic function have an intimate relationship, no data have been identified reporting on the effects of exercise on metabolism and sleep. Further work is needed to determine the contribution of each of these potential mechanisms to the interaction between exercise and sleep before definitive conclusions can be made. This review will now explore different sleep conditions, and the data available that discusses the potential of exercise as a therapeutic agent to treat them.

OSA

OSA is the most common condition causing sleep-disordered breathing. As a condition frequently associated with overweight individuals, exercise training as a means to weight reduction has attracted considerable interest. In addition to its obvious potential impact on weight, exercise therapy has the potential to improve sleep-related symptoms too. In a large study of OSA patients, lack of regular exercise was an independent predictor of EDS. As EDS is related to poor sleep quality, one may assume that regular exercise may improve sleep quality. Fortunately, a lot of studies investigating exercise in OSA report on sleep parameters as secondary outcomes. A pre-post study of eleven individuals with OSA demonstrated a significant improvement in total sleep time, sleep efficiency, arousal index and apnoea-hypopnoea index (AHI) after a 6-month exercise programme of moderate aerobic intensity (3). These changes in sleep parameters were accompanied by an improvement in body mass index (BMI). A pre-post study combining a supervised exercise programme and a calorie-restriction diet also reported improvements in

polysomnographic markers and AHI, with an increase in mean nocturnal oxygen saturation (32). A case-control study reported that a 12-week exercise (breathing and aerobic) programme resulted in an improvement in AHI and subjective sleep quality, when compared with control, and that this improvement was not associated with a change in anthropometrics (4). A number of randomised studies have reported less consistent results. A supervised cycle ergometry programme in exercise-naïve OSA patients resulted in an improvement in AHI, arousal index and overnight desaturation index when compared to controls (33). A study comparing a 12-week supervised aerobic exercise class with stretching-control treatment demonstrated improved AHI and overnight desaturation index in the exercise group, but non-significant improvements in total sleep time, wake after sleep onset and sleep efficiency (34). Similarly, a randomised study comparing the impact of a community walking group in patients with OSA reported an improvement in AHI in under 60-year-old, without improvement in other markers of sleep quality (35). Studies that compared exercise therapy to continuous positive airway pressure (CPAP) therapy failed to demonstrate positive impact of exercise. A randomised trial comparing CPAP therapy with CPAP therapy and exercise together reported no difference in sleep parameters over and above the impact of CPAP therapy (36). A randomised study comparing CPAP therapy, exercise therapy and oral devices reported that while CPAP therapy improved AHI, exercise therapy did not (37). It is important to note that none of these studies were powered to assess sleep quality as a primary outcome. In addition, it is difficult to delineate whether the potential benefits of exercise therapy are simply due to its impact on reducing BMI, or whether it provides additional benefit on sleep quality. Systematic reviews and meta-analyses have assimilated many of these studies and concluded that while the quality of the evidence is not high, and the number of studies is limited, in OSA, supervised exercise therapy does appear to have beneficial effect on severity of disease (AHI) and daytime sleepiness, over and above its impact on BMI, with an unknown impact on sleep quality (38-40). Crucially, further definitive studies powered to investigate sleep outcomes are required for this relatively cheap intervention.

CSA

The effect of exercise on CSA has been minimally investigated. A small study in patients with CSA and heart failure compared individuals who took part in a 6-month cardiac rehabilitation programme (n=10) and those that did not (n=8). In the exercise group, the AHI and number of CSAs were reduced after 6 months, whereas in the control group they were not. Of note is that the number of obstructive apnoeas did not decrease (5). In contrast, a pre-post study comparing individuals with heart failure and CSA, OSA and no sleep apnoea demonstrated that a 4-month exercise programme had no impact on severity or sleep quality in the CSA group (41). The prevalence of CSA is low (less than 1% of the general population); it is especially low when compared with the prevalence of OSA. As a result, definitive studies will remain difficult to perform and the impact of exercise on CSA is likely to remain undetermined for the foreseeable future.

Insomnia

Insomnia is a common sleep disorder, associated with considerable impairment in daytime functioning (42), and a high economic and workplace-efficacy burden (43). Although the mainstay of treatment is cognitive behavioural therapy and pharmacological therapy (44), owing to cost and availability of cognitive behavioural therapy and the potential toxicity of pharmacological agents, alternatives are sought. Exercise has been extensively investigated for its potential value in improving sleep quality in patients with insomnia. In small randomised studies (6,7) moderate aerobic exercise has been demonstrated to improve objective (reduced sleep onset latency, increases total sleep time, increased sleep efficiency and reduced wake after sleep onset) and subjective (Pittsburgh Sleep Quality Index) markers of sleep quality. Resistance training and stretching exercises have also been shown to improve polysomnographic markers compared to controls, with no difference between the impact of either resistance training or stretching (45). In older adults, the positive impact of aerobic and resistance exercise was matched by the impact of a Tai Chi programme (46), suggesting that undertaking physical activity of any form is important, regardless of its modality. Importantly, the optimal timing of exercise in insomnia remains unknown. In individuals with normal sleep, timing of exercise does not appear to have any significant impact on the benefits that exercise provides and it would be useful to understand this effect in patients with insomnia too.

Meta-analysis has demonstrated that although there are some data suggestive of the value of exercise in insomnia (*Figure 1*), the quantity and quality of this evidence is low,

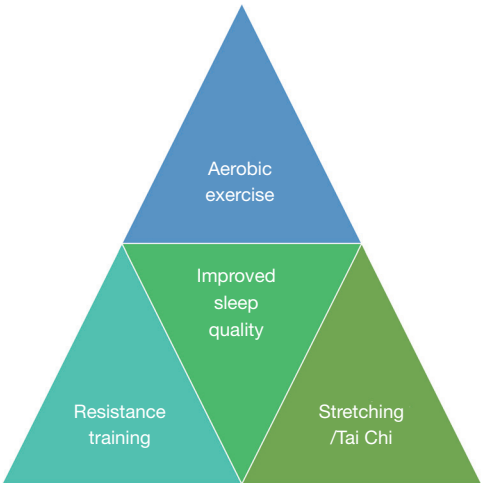

Figure 1 Modalities of exercise that have been demonstrated to improve sleep quality in patients with insomnia.

and larger prospective studies are needed to determine its value definitively (47).

Narcolepsy

Narcolepsy is a relatively rare, but significantly debilitating, condition characterised by EDS, hypnogogic hallucinations, sleep paralysis and cataplexy. Although international guidelines include exercise as a therapeutic option (48), there are little data to support this recommendation. A deficiency in the neuropeptide hypocretin (orexin) is believed to be causative for the majority of narcolepsy cases (49). In healthy individuals, exercise resulted in an increase in plasma hypocretin levels (50), and this has led to a suggestion that exercise may be beneficial in increasing hypocretin levels in patients with narcolepsy and consequently improve symptoms. In a survey, the majority of children with narcolepsy, their parents and physicians reported that they had used exercise to manage their condition and found it useful (51). Furthermore, children with narcolepsy who frequently engaged in physical activity demonstrated longer total sleep time, higher sleep efficiency and less daytime sleep episodes compared with those who did not partake in physical activity (8). In adults with narcolepsy, cardiopulmonary fitness was inversely related to daytime sleepiness and frequency of cataplexy (52). The extrapolation of this data suggests that individuals who engage in exercise are more likely to demonstrate increased cardiopulmonary fitness, and therefore that exercise is associated with reduced daytime sleepiness and frequency of cataplexy. In contrast to this, wheel running in hypocretin-knockout mice (and therefore, a model for narcolepsy) has been shown to result in an increase in frequency of cataplexy episodes. In addition, wheel running improved wakefulness to the same degree in knockout and wild-type mice (9). These data suggest that hypocretin deficiency does not benefit from exercise and may result in an increase in cataplexy episodes. While the most recent international guidelines recommend the use of exercise in patients with narcolepsy, they note that they are based on little evidence (48). There is a need to conduct prospective studies to determine the value and/or risk of exercise in patients with narcolepsy, particularly in the adult population.

Restless legs syndrome (RLS)

RLS is a condition characterised by an uncontrollable urge to move one's legs, particularly at evening and night. This has a deleterious impact on sleep quality, and as a result causes EDS and reduced quality of life (53). The rationale for using exercise as a potential therapy for RLS comes from observations that individuals who report lower levels of physical activity are more likely to suffer from RLS and insomnia (54). Exercise has been investigated in a number of small studies for its impact on RLS symptoms. Although not obtained from directly investigating sleep quality, most RLS symptom scores include a subjective assessment of sleep. Prolonged cardiovascular exercise programmes seem to improve symptoms of RLS when compared with controls. Groups conducting lower body resistance exercises (55), aerobic exercise (10) or a combination of both (11) demonstrated improved RLS symptom scores compared with controls. Yoga has also been demonstrated to improve symptoms of RLS and sleep quality (56). These data are useful in demonstrating that the type of exercise performed is not necessarily crucial, but that the performance of physical activity in itself may be beneficial (*Figure 2*). Although these studies suggest that exercise is useful in controlling symptoms of RLS, it is important to note that they tend to be small, underpowered or pilot studies. This is reflected in a systematic review that concluded that the evidence supporting the use of exercise in RLS is limited and not of high quality (57).

Circadian rhythm sleep disorders

Circadian rhythm sleep disorders are a group of conditions

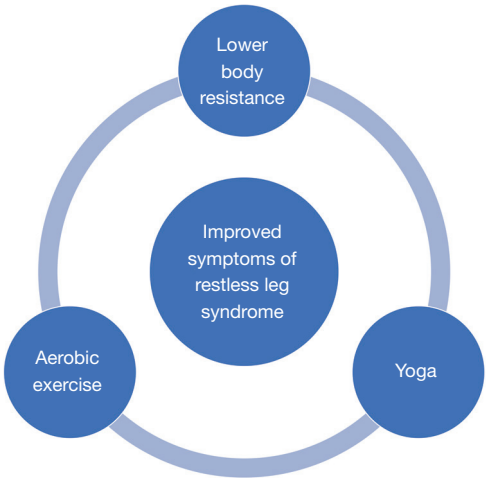

Figure 2 Modalities of exercise that have been demonstrated to improve symptoms of restless leg syndrome.

which cause a disturbance in the sleep/wake cycle resulting in those affected falling asleep and waking at unconventional times of the day. Although four different intrinsic types of disorders are recognised (delayed sleep phase disorder, advanced sleep phase disorder, non-24-hour sleep-wake disorder and irregular sleep-wake rhythm disorder), the outcome of each is disturbed rest, poor sleep quality and impact on activity during wakefulness. Exercise has long been considered a potential therapy for adjusting circadian rhythms in patients with these disorders, but little research has been performed in this field. Most of the literature reports on studies performed with healthy individuals and extrapolates the results to individuals with circadian rhythm disorders. In healthy individuals, morning exercise appears to 'advance' the circadian rhythm (i.e., resulting in earlier wakening), whereas evening exercise delays the circadian rhythm (i.e., delays the onset of sleep) (58,59). Those with an earlier chronotype exhibited this diurnal pattern of morning and evening exercise, whereas those with a later chronotype experienced an advance in circadian rhythm regardless of exercise timing. While there is much left to understand in this field before firm recommendations about the value of exercise can be made, an immediate implication of these findings concerns the impact of evening exercise on sleep quality. The data appear to suggest that evening exercise can make the onset of sleep later, which may in turn have an impact on the quality and length of sleep, in the conventional 24-hour sleep/wake cycle (60). An important extrinsic-type condition is shift-work sleep disorder, which is garnering increased attention for its long-term impact on shift pattern workers (61). Although limited in number, the majority of studies investigating the value of exercise demonstrate its benefit in shift-pattern workers, in terms of improved subjective and objective sleep quality (12,62). Improvement in sleep quality after an exercise programme has been observed equally in shift-pattern and non-shift-pattern workers (63), suggesting that exercise may not be an intervention for improving sleep solely in shift-pattern workers. Finally, a systematic review reported that individuals with higher cardiorespiratory fitness reported better sleep quality, suggesting that exercise is a protective factor against the effects of shift-pattern work (64). In summary, exercise may be a useful adjunct for improving sleep quality in circadian rhythm sleep disorders and specific timing of exercise appears to be an important factor when considering exercise as a potential therapeutic tool. However, there are limited data to provide conclusive recommendations.

Summary

Despite long-standing interest in the effect of exercise on improving sleep, this review has demonstrated that the quality of the evidence to support this remains low, with many outstanding questions (*Table 3*). The literature is suggestive that exercise is likely to improve sleep quality in individuals with OSA, insomnia, narcolepsy, RLS and circadian rhythm disorders. Although older data suggested that the timing of exercise was important in determining its value in improving sleep, more recent data appears to refute this. To fully understand the interaction between exercise as a therapeutic modality in patients with sleep

Table 3 Key areas that require further research in this field

Condition	Research area
Normal sleep	Determine whether timing of exercise impacts on sleep quality
Obstructive sleep apnoea	Determine whether sleep quality as a primary outcome is influenced by exercise, whilst accounting for change in body mass index
Insomnia	Determine the impact of exercise on sleep quality in prospective randomised studies
Narcolepsy	Investigate the impact of exercise on hypocretin levels, comparing with healthy controls
Shift-pattern workers	Randomised study to determine whether exercise improves sleep quality

disorders, prospective studies where objective and subjective sleep quality are the primary outcome are needed. Notwithstanding this limitation, as exercise is unlikely to be harmful in these individuals, and the existing data is suggestive of its value, it could be considered as a method to improve sleep quality.

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