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Sleep Quality Improvement and Exercise: A Review

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Abstract- Changing times and advancements in technology have taken a toll on human health. Poor sleep quality is rampant in every age group thus an apharmacological cure is slowly becoming a necessity of the times. Exercises/physical activities are a strong contender in the race. But still a lot work has to be done to finally conclude about its efficacy as the treatment. This article aims at reviewing the relation between sleep quality and exercise. This article reviews the experimental and epidemiological work done on the topic along with the reviews published on the same. The emphasis here is on the studies done and the possible mechanisms underlying the relationship. The article also talks about the lacunae in research and future directions for research.

Index Terms- Acute exercises, chronic exercise, exercise, physical activity, sleep, sleep quality

I. INTRODUCTION

Sleep is a functional state that comprises a complex combination of physiological and behavioural processes which includes a natural lie down for humans.[1,2]. It is an instinctive state of rest characterised by a reduction in voluntary body movement and decreased awareness of the surrounding [3]. It has some characteristic manifestations, such as a cyclic pattern, relative immobility and an increase in the response threshold to external stimuli.

Since the discovery of REM sleep a number of articles/ reviews have been published regarding the various mechanisms, functions etc of sleep. But still we are very far away from complete understanding of sleep which makes it an enigma even now. In coming times because of the change in lifestyle and work patterns the urgency of understanding it is even more. The functions of sleep can be summarized as (1) boosts immune function (2)has a role in brain maturation(4)development of the body(5)increase in brain mass(6) memory consolidation(7)increase in performance(8)modulates metabolic processes at molecular level(10)maintains catecholamines in the brain[2-15]. Sleep is multifaceted and hence difficult to review from all aspects.

Exercise is physical activity that is planned, structured, and repetitive for the purpose of conditioning any part of the body[16]. For the purpose of this review the articles with physical activity also have been considered and the term exercise will be used for both. Exercise is used to improve health, maintain fitness and it is a very important treatment method for physical therapist. Exercise give various health benefits the details of which are out of the domain of this article but the effects on quality of sleep will be discussed in detail. There are various types of exercises and with all of them having different effects.

The purpose of this article is to write a comprehensive review on the effects of exercise on sleep. The article is planned as following:

1. Sleep-a basic understanding
2. Exercise- relevance and type
3. Sleep and exercise
4. Acute exercise studies
5. Chronic exercise studies
6. Possible mechanisms for the effects of exercise on sleep quality
7. Summary and conclusion
8. Future research
9. References

II. SLEEP – A BASIC UNDERSTANDING

Sleep had always been an enigma because of its multifaceted and multidimensional features. Even today it is difficult to understand it completely without the holistic view. It has been a topic of discussion right from biblical times. The Bible and the Talmud have numerous references from varieties of sleep ("he provides as much for his loved ones while they sleep" psalms127:2), to stages of sleep)"a sleep which is not sleep, a wakefulness which is not wakefulness" Talmud Pesahim 120b), functions of sleep, effects of deprivation etc.[17]. In some references it has also been compared to death-"The deepest sleep resembles death"(Bible, I Samuel 26:12)or it was also called the brother of death(Homer's Iliad, circa 700 BC).

Sleep was explained by people all over history in different manners. Lucretius called it absence of wakefullness[18]. Santos called it a functional state that comprises a complex combination of physiological and behavioural processes[2]. But sleep can also be defined by the physiological and physical changes which occur during sleep[18]. This includes position and movement of the body as a whole or its parts like eyes etc and physiological changes like thermal changes, decreased brain activity etc. The characteristics of sleep may be summarised as:

1. Decreased voluntary movement and appreciation of the surroundings[3,19]
2. State of generally decreased activity.[19]
3. Human sleep involves lying down posture[1,19]
4. Even though it a state of decreased consciousness, arousal is possible because of internal or external stimuli [19]
5. Brain activity has certain characteristic features [3,19]

Depending upon the physical as well as the physiological parameters sleep may be of two stages-Rapid eye movement

(REM) sleep and Non rapid eye movement (NREM) sleep[1,3,19]. According to American association of sleep medicine (AASM) scoring manual NREM is further divided into N_1, N_2 ,N_3 on the basis of EEG waves. REM sleep has two phases –Tonic and Phasic ; REM and NREM move in a cyclic manner with an average of 90-110mins.

The sleep patterns are also related and do get altered because of a number of factors like age, sex stress, psychological state, disease conditions, occupation[1-20]

Keeping in mind that almost all living beings have a phase of sleep, the functions of sleep must be numerous and it must be one of the most important things for survival. The postulated functions of sleep have been discussed earlier. Most of these functions have been deduced from sleep deprivation studies which have also tried to establish that wakefulness is associated positively with sleep propensity [21]. Sleep propensity can be explained as the likelihood of sleep at any level of organisation (global or local) [21].

Sleep regulation will always have to be studied in relation to wakefulness and they both are said to be regulated by basically two factors –circadian rhythm and homeostasis[2, 3, 19, 22-25]. The need to sleep can be understood as physiological (highly vulnerable periods of sleep) or subjective (individual's perception)[24]

III. Exercise – relevance and type

According to "The origin of species- Charles Darwin" environment brings about a change in the genes, that indicates that our day to day existence decides our fate[26,27]. Human beings have always been a hunter-gatherer which most of the times along with other factors like brain development made us superior to other animals hence ensured better evolution[26-28]. Development and technological advancements brought with them the sedentary lifestyle which lead to an endemic of lifestyle disorders [26-29]. These effects of sedentary lifestyle can be tackled by regular physical activity and/ or exercises thus decreasing morbidity and mortality[26,27].

Human body responds to progressively increasing repetitive physical activity by introducing physiological, biochemical, and anatomical changes in the major systems of the body even in older adults[29-32]. These changes depend on a number of factors like intensity, duration, frequency of exercises, age, sex and physical condition of the person exercising [30,34]. Body's response to exercise involves simultaneous coordination of multiple systems of the human body [32].

In sleep literature exercise have been studied as acute or chronic and as aerobic or anaerobic. They have been defined as following for the purpose of this review:

Acute exercises: They are the set of exercises which are executed as a single bout followed by the examination of the effects on primary outcomes.

Chronic exercise: They are the set of exercises invoving multiple sessions, longer in duration followed by analysis of its various effects and benefits in a broad perspective.

Aerobic exercise: These are physical exercises of a relatively low intensity and long duration. It depends primarily on aerobic energy system. These can also be called endurance training or conditioning exercises[35].

Anaerobic exercise: These are physical exercises of a relatively high intensity and short duration. It depends primarily on anaerobic energy system[36]

IV. Sleep and Exercise

According to the American sleep disorder association (ASDA) exercise is one of the apharmacological intervention used to promote sleep[29, 37]. The principle that exercise promotes to sleep, remains a constant thus breaking all the barriers of civilizations, races, religions even though empirical research does not support it much[38]. It is one of the most widely studied daytime behaviour associated with sleep. This was further reinforced by a landmark survey conducted in Finland published in the year 1988. Individuals were randomly selected (n=1190) and open ended question about the factor which is the best for promotion of their sleep was inquired. Results declared found exercise as the most important factor [39, 40]. Despite of all these numerous studies conducted the results are still inconclusive. This difference in belief and science can be attributed to following factors as reported in various studies[38-46].

1. Most of the studies were conducted on normals. This can be explained on the basis of ceiling and floor effects as described by Youngstedt[43]. According to this the efficacy of sleep promoting stimuli should be proportional to the degree of pre-stimulus sleep impairment. Because of these it is difficult to achieve a statistically significant improvement.
2. The sample sizes were generally small in interventional studies
3. Exercises prescribed are difficult to follow and implementation of daily routine for sedentary workers makes it a difficult permanent apharmacological management especially for patients who are already tight pressed for their time.
4. Most of the work done is on slow wave sleep.
5. Most of the studies are short term studies. There are no studies to the best of my knowledge which have worked on long term effects and followup.
6. Sleep itself is very subjective and difficult to study. There is a vast amount of interplay between numerous factors affecting it.
7. Smaller factors like age and sex of the participant, time, duration and type of exercise have not been studied very well.

The studies done with exercise as an intervention can be broadly be classified as:

1. Acute exercise studies
2. Chronic exercise studies

These studies have been done on normal individuals, certain population eg geriatric[46,44], medical students[20]etc, certain conditions like insomnia[44] etc.

V. Acute exercise studies

This area of study is majorly unexplored. This may be due to inconclusive evidence regarding the usage and implementation of these exercises as a treatment strategy. It is speculated that acute

exercise during the day time leads to an increase in sleep. This was reported in an epidemiological study done in Finland which also reported that it was the single most important factor in the positive result [41, 45, 46]. However some positive results have been reported in a few studies following acute exercises. The effects reported are on slow wave sleep (SWS), REM, repeated eye movement –latency (REM-L) and total sleep time (TST) [45] but no effect has been reported on sleep latency (SL) and wakefulness after sleep onset (WASO) [39]. The improvement in SWS is especially important as some studies have reported an increase in SWS being associated with a decrease in REM sleep[39,47, 48].

But in spite of all these effects being quoted the major lacunae is the focus on good sleepers who are unlikely to have any major improvement due to floor- ceiling effect. So, further research is indicated to validate the results on patients with sleep deprivation, so that the results may be used as a standard adjunct treatment protocol.

VI. CHRONIC EXERCISE STUDIES

The studies included have used resistance exercise, moderate intensity exercises, high intensity exercises, endurance exercises, physical activity or regular exercises as an intervention[38-54]

A study on sedentary workers with 50% of 1RM concluded no significant effect on the quality of sleep. This could be contributed to various factors like type of exercise, sample type or dose of exercise. The floor and ceiling effect was not ruled out either[51]. In another study where older adults were prescribed moderate intensity exercises positive effects was found on SWS. On PSQI significant improvement was found on sleep duration, sleep disturbance and daytime dysfunction. On PSG the numbers of awakenings were lesser and stage 2 and SWS had increase. It was concluded that there is a positive impact of regular moderate intensity on sleep parameters [49].

A Cochrane review published on physical exercise on sleep problems in adults aged 60+ have reported improvement in Sleep Onset Latency (SOL), total sleep duration & global sleep quality. But the review concluded that there was a lack of well-designed trials to come to a conclusion but the intervention is worth investigating [44].

The effects of chronic exercises include significant differences on increased total sleep time, increased SWS and reduction in sleep latency and reduction in REM[38,39,41,42,46,50,53,54,55].

Some evidence also suggests that chronic endurance exercises may be more helpful in enhancing SWS as compared to other modes [38].

To summarize, it may be suggested that chronic exercise and its effects may be used as behavioral modification tool to bring about an improvement in quality of sleep but substantial data is still required to calculate the exact dosimetry of the intervention along with the time of intervention.

VII. POSSIBLE MECHANISMS OF EFFECTS OF EXERCISE ON SLEEP

1. Effect On Mental Health

According to a number of studies done till date, the effect of exercise on mental health is closely related to depression and anxiety[56-57]. According to Daniel M Landers[57], the benefits of exercise on anxiety and depression are similar to as reported by other treatment.

Table 1 Effects of exercise on mental health [39,42,46,49,56-57]

Decreased Anxiety	Decreased Depression
• Aerobic exercises give best result • Patient who have a high level of anxiety to start with respond earlier • Patients who have low fitness levels to start with give better results • Regular exercise gives better result if performed for longer duration	• Regular exercises gives better results if done regularly • Exercises done several times a week gives better results • Vigorous exercises give better results • Patients with an increased level of depression to start with gives better results

Number of awakenings in the night is one of the important indicators of anxiety which is effectively decreased by exercises. Various studies have been published about a positive role played by acute exercises in decreasing trait anxiety [39,56,57]. Petruzello et al examined the results of 27 narrative reviews and concluded that approximately 81% authors, physical activity and or fitness led to a decrease in anxiety. 19% of the studies concluded that most of the findings support reduction of anxiety with exercise. But even though the results varied, none of the studies had concluded that there was no relationship [57].

The work on exercises and depression can be traced long back in history. Across the meta analysis published ,it was said that acute and chronic exercises are related to a reduction in depression. The effects were found to begin very early and they continued even after the cessation of the exercises. These results were found to be consistent across age, gender, exercises group size, type of depression inventory [39,42,46,49,56-57].

2. Effects on thermoregulatory mechanism

Temperature regulation is an important aspect of homeostasis. It is the maintenance of the core body temperature within a narrow range by controlling the dissipation and absorption of heat to and from the body.[58]

Modulation in core body temperature affect the sleep parameters[59-65] .This change in core body temperature can be brought about actively (by exercises etc.) or passively (by warm bath, thermo suit, electrical blankets, warm footbath etc.)[61-64]

These methods of increasing the temperature can be implemented at various times (before sleep[61-62,64-65] or during sleep[63]). The time of application also seems to play a role as reported in various studies[61-65]. In a review article, Liao et al reported that slow wave sleep can be increased and the sleep fragmentation can be decreased with passive body heating that changes the core temperature in the evening. Similar results were reported by different researchers using different methods to decrease the

temperature before sleep.[38,39,46] Fletcher et al used electrical blanket to bring about an increase in core body temperature during sleep and they report decreased efficiency and more number of arousals.[63] further proves that there is a relationship between core body temperature and sleep.

Neuroanatomical studies also concluded that preoptic area or anterior hypothalamus plays a key role in thermoregulation. Initiation of sleep can be brought about by increased firing rate of the neurons of the preoptic area which in turn may be brought about by warming them. These neurons can be warmed by changes in core body temperature. Hence the hypothesis that sleep might serve as a down regulation function can be supported[39,52].

Horne et al has conducted studies on relationship between exercise and sleep. They reported a positive relationship between SWS and exercise [58,59].

3. Effects on circadian Rhythm

Circadian rhythm is the 24 hour interval clock which responds to endogenous factors like core body temperature etc. and to exogenous factors like light etc. A disturbance in either of these factors leads to a disturbance in the rhythm which in turn affects sleep. It is suggested by various studies that one of the most important factor here is light.[46]Various studies have been done to implicate exercise and sleep. Some important studies here were the impact of time of exercise on sleep[39,66] and the correlation between effects of exercise on circadian rhythm parse.[38,46]

Aerobic exercises performed late in the evening has reported to be associated with poor sleep quality as compared to exercises in the afternoon.[56]

It is postulated by Driver and Taylor that exercise done in a well lighted area may improve the sleep for individuals with altered circadian rhythm. They also suggested further research to find out the relation between light, exercise and sleep[38].

There seems to be an agreement in the reviews regarding shift work and its ill effects on health. Physical activity has been suggested to decrease fatigue levels, improving the tolerance of shifts but at the same time there is a problem of poor adherence to exercises too[52, 67]. It has also been reported that exercise acts as a zeitgeber and it brings about a shift in the phase response curve[68]. There are various other additional factors which are responsible for the effects.

4. Effects on restoration of the body

Aristotle had proposed the humoral mechanisms of sleep control [69]. Although the mechanism of their control is not the same as suggested by him but there is an existence of sleep regulatory mechanism which has been proved [68]. Some of these factors are Growth Regulating Hormone(GHR), cytokines, interleukin-1, prostaglandin D_2, adenosine, tumour necrosis factor(TNF), prolactin 100, corticotropin like intermediate lobe peptide vasoactive intestinal peptide[3,28,35,69,70,71,72]. Acute exercises have been shown to bring about an increase in cytokines which in turn can be related to regulation of sleep. This may be one of the restorative mechanisms though others like muscle repair[46,73] have also been discussed along with compensation of high energy expenditure [46,73]. All these factors work towards the restoration effects.

In conclusion , it may be said that a number of hypothesis' exist regarding the mechanism underlying the effects of exercise on sleep primarily due to complex nature and ambiguity in mechanisms controlling it.

VIII. SUMMARY AND CONCLUSION

Sleep is an enigma even now primarily because of the huge amount of interaction which takes place between external and internal factors to bring about sleep. The problems with sleep research have been discussed earlier. The general recommendations after most of the reviews are still inconclusive. But a few points may still be commented upon which are as follows:

1. Exercise is a positive behavioral modification tool for all age groups to bring about an improvement in sleep quality.
2. Exercise can be very effective in older populations for not only for improvement in sleep but also for other ailments.
3. Acute exercises don't seem to be very effective in bringing about an improvement in quality of sleep but the number of studies done is still lesser so it is not very conclusive either.
4. Effects of aerobic and resistance training done for long duration may bring about improvement in sleep quality.
5. Exercises done just before bedtime seem to have negative effect on sleep quality.

IX. FUTURE RESEARCH

Future research may be directed towards analysis of:

1. Effect of acute exercises on poor sleepers but not insomniacs
2. Effect of resistance exercises on poor sleepers but not insomniacs
3. Effects of exercises on patients with different training levels egsedentary, moderately trained and trained.
4. Effects of temperature variations on sleep quality.
5. Effect of time of intervention on sleep quality.
6. Exercise as apharmacological management of sleep.

S.no	Investigator	Size	Sample characteristics	Type of study	Intervention	Outcome measure	Key results
1.	Ferris LT et al [28]	8	Sedentary older adults	Pilot	• Resistance training to improve upper& lower body strength	• PSQI • Strength	• Mean body strength- significant improvement • Global PSQI- significant improvement
2.	Youngstedt SD et al [45]	401	-	Meta-analysis	• Acute exercise	• SOL • stage 2 sleep • SWS • REM sleep • REM-L • TST • WASO	• SOL-not significant • Stage2-significant increase • SWS-significant • REM-significant reduction • REM-L-Significant delay • TST-significant increase • WASO-unchanged
3.	King CA et al[49]	43	50-76 yrs, sedentary lifestyle, moderate sleep complaint at baseline	RCT	• Aerobic exercise gradually increasing(4days/wk for 16 wks)	• PSQI	• Global score-significant improvement • SOL- significant decrease • TST- significant improvement
4.	Faria AP et al[51]	27	Sedentary men aged 20-40 yrs, good sleep quality	Pre-post experimental	• Resistance exercises with 50% of 1 RM(acute exercise)	• PSG	• No significant change
5.	Singh NA et al[54]	32 (28 for outcoes)	• Depressed patients(fulfilled DSMIV criteria) • Age>60	RCT	• Progressive resisted exercise (3days/wk for 10 wks)	• Sleep(PSQI &likert scale) • Activity level • Depression • Quality of life	• Improvement in both parameters of sleep as compared to control(significant) • Significant change in total physical activity level and strength • Significant improvement in depression • Trend towards improvement

6.	Passos GS et al[55]	48	Insomnia patients		• Moderate intensity aerobic exercise • High intensity aerobic exercise • Moderate intensity resistance exercise	• PSG • Anxiety scale	• SOL< • TWT< • TST> • SE> • Reduction in anxiety scale • All the above in Moderate intensity aerobic exercise
7	King CA et al[74]		50-76 yrs, sedentary lifestyle, moderate sleep complaint at baseline	RCT	• Moderate intensity aerobic exercise(5days/ wk for 52 wks)	• PSG • Sleep log	• Self rated-<disturbance, SOL, >rested • PSG-<awakenings &stage-1 • PSG- >stage -2
8.	Sherrill DL et al [75]	722	Randomly selected adults	Correlational	• Some form of physical activity done regularly	• Self reported question naire	• Regular exercise is associated with lesser incidence of disturbed sleep
9.	Yoshida H et al[76]	5	Healthy university male students	Experimental	• Interventions at diff times of day • aerobic	• PSG • OSA • KSS	• Good sleep effects with late evening exercises
10.	Singh NA et al [77]	60	Depressed sedentary older adults	RCT	• Progressive resisted exercise at 80% &20% RM (3 days/wk for 8 wks)	• PSQI	• PSQI global score- significant improvement

Table 2: Studies done to find out the effect of exercise on sleep

PSQI-Pittsburg sleep quality index, PSG-Polysomnography, RCT- randomised control trial, SOL-sleep onset latency, SWS-Slow wave sleep, REM- repeated eye movement, REM-L- repeated eye movement latency, TST- total sleep time, WASO- wakefulness after sleep onset, TWT- total wake time,OSA-Oguri-Shirakawa-azumi sleep inventory, KSS-Kanseigakuin sleepiness scale.

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