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Original Research Article

Morning exercise improves sleep quality in university students

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ABSTRACT

Background: Although sleep is influenced by exercise, a proper management of physical activity's time promotes the quality of sleep. The objective of this study was to evaluate, in university students, the effect of morning or evening physical exercise on sleep pattern, along with the dynamics of hormones controlling sleep quality.
Methods: We recruited 92 healthy sedentary adolescents, 18-20 year-old, poor sleepers, with normal anthropometric characteristics and no musculoskeletal or neurological problems. They were randomly distributed into 3 groups: 34 subjects practicing morning physical activity, 28 subjects practicing evening physical activity, and 30 subjects remained sedentary. The quality of their sleep was assessed using the Spiegel validated questionnaire. Body temperature was recorded in the morning and evening, and saliva samples were collected. Saliva cortisol and melatonin levels were evaluated by ELISA.
Results: The group practicing exercise in the morning experienced a better quality of sleep (71.4%) versus the one exercising in the evening (44.1%, $p<0.05$). In parallel, the levels of melatonin and cortisol significantly increased, at night and morning simultaneously, in participants exercising in the morning. Moreover, body temperature significantly decreased in participants that exercised in the morning compared to those who practiced evening exercise, or maintained a sedentary lifestyle ($p<0.05$).
Conclusions: Our data indicate that morning physical activity exerts a positive impact on the sleep quality, probably by decreasing cortisol and increasing melatonin levels in the evening. We presume that morning activity may efficiently reduce the burden of sleep disorders, particularly those caused by COVID-19 lockdown.

Keywords: Adolescents, Cortisol, Melatonin, Physical activity, Sleep quality

INTRODUCTION

One third of human's life is consumed by sleeping due to its importance in maintaining the body's homeostasis particularly the regenerative aspect. This is also essential for mind reset in order to drive better performance during the diurnal activities.[1] Nowadays, the importance of sleep has been ignored and replaced by nightlife styles, thus accumulating a debt of sleep which translates into elaborate stress and unhealthy life. During the course of 50 years, a total of 1.5 hours of sleep time is being lost on average.[2] For instance, 45% of individuals aged 25-45 years lack the adequate time for sleep; a serious misfortune exposing them to various health issues.[3] Moreover, it is becoming more evident that sleep disorders are increasingly afflicting humans due to the current COVID-19 lockdowns and its imposed mobility restrictions.[4-6]

Typically, a night's sleep has four stages: falling asleep, light sleep, deep sleep and rapid eye movement (REM) sleep, which is being the most important step for memorization. It is therefore necessary to go through all these stages to benefit from the restorative and energizing effect of sleep. Thus, the longer is the time for deep sleep, the shorter it is for light sleep, and the lower is the number of awakenings, irrespective of the total duration of sleep.[1] In order to maintain a daily performance amalgamated with an excellent mood, both the amount and the quality of sleep must be respected. Sleeping less than 6 to 7 hours (every 24 hours) can cause multiple comorbidities such as hypertension, diabetes, and yields a 12% higher risk of death.[7] Adolescence is marked with high proportion of night owls thus driving bedtimes one to three hours later than during pre-adolescence, with difficulty getting up early in the morning.[8] There are both biological and psychosocial reasons for this "phase delay". The circadian biological rhythm is imbalanced by adopting a late phase; the window favoring the appearance of sleep often appears very late in the evening and sometimes even at the start of the night.[9] From the hormonal point of view, the secretion of melatonin is delayed in the morning, while it is increased in the evening. The length of the circadian period of melatonin and that of the central body temperature would be higher in adolescents than that observed in adults, which would facilitate the presence of phase delays in the former.[10]

Numeric psychosocial factors also influence the delay in sleep. In fact, adolescents have irregular hours of sleep blamed on busy schedules at schools/universities, familial commitments, extracurricular and social activities, not to mention the addiction to the social media and the digital world revolution.[11] From a physiological point of view, there is a balance between two major circuits of neurons in the brainstem and the hypothalamus: one stimulates wakefulness, the other sleep, which are regulated by a panoply of neurotransmitters and hormones, the most important of which are cortisol (released by the adrenal cortex to endure daily stress from morning awakening) and melatonin (released by the pineal gland which signals for us to sleep).[11]

Therapeutic strategies for sleep disorders by physical exercises have been successful in improving sleep quality, thus avoiding pharmacological treatments. According to Uchida et al people who engage in regular physical activity have the duration and quality of their sleep improved during the following nights, because the energy spent during the day must be compensated by deep sleep.[12]

The work of Reid et al also demonstrated that aerobic practice helps increasing deep sleep and decreasing light stages of sleep, this could therefore help reducing cardiovascular disease risk factors by lowering blood pressure at rest.[13] In addition, hypertensive people can reach lower blood pressure post-exercise.[14] Nonetheless, the hypothesis that physical activity promotes sleep is also related to energy conservation, body tissue restoration, and theories of sleep thermoregulation.[15] However, it is difficult to know the magnitude of these benefits, and to what extent variables such as age, type and duration of exercise modulate these benefits.

Although several studies showed a beneficial effect of exercise on sleep quality, there are no systemic studies targeting adolescents and their sleep hormones level. Thus, the aim of our study was to evaluate if the morning and/or the evening physical exercise affect(s) sleep quality, along with its impact on cortisol and melatonin levels.

METHODS

This research was approved by the ethical committee of the Lebanese University. All volunteers signed an informed consent of agreement to participate in the study. We recruited 105 volunteers (male) with history of sedentary life complaining of poor sleeping during the night, all being first year students living in the university dorms and drawn from different colleges of the Lebanese University. The study was carried out at the Lebanese University over the period of 14 months (September 2019 to October 2020).

As shown in Figure 1, during September 2019 three groups were randomly formed; morning exercise (ME): 35 participants attended the gymnasium for a regular and moderate exercise of stretching and aerobics from Monday to Thursday for 1 hour between 8:00 and 9:00 a.m. for one month, Evening exercise (EE): 35 participants underwent the same exercise as ME but between 8:00 and 9:00 p.m. under the supervision of a monitor. No exercise (NE): 35 students did not perform any physical exercise and were considered as control. All subjects presenting neurological, musculoskeletal or endocrine problems, and/or taking medication, dietary supplement or energy drinks were excluded from the study. Instructions were given to participants to refrain from consuming caffeine, alcohol, and foods interfering with the analyzed hormones 24 hours prior to the analysis. Moreover, participants were instructed to avoid daily naps during the experimental period. At the beginning and the end of the training period, participants were asked to answer a Spiegel validated questionnaire composed of 6 items related to sleep (sleep onset delay, sleep quality, sleep duration, night waking episodes, dreams and their status/feeling in the morning).[16,17] On the last day of the training period, 3 assistants asked the participants, after brushing their teeth, to salivate 2 ml in a jar in the early morning (5: 00 a.m.) and another one at night (11:00 p.m.), and they monitored their sublingual body temperature with a high precision digital thermometer MT 850. Saliva samples were centrifuged and the supernatant was collected and stored at -80ºC until assayed. The levels of cortisol and melatonin in saliva were evaluated by ELISA using a kit from Immuno-Biological Laboratories, Inc (IBL-America, Minneapolis, USA), according to the manufacturer's protocol, and as previously described by Ackermann et al in 2010.[18]

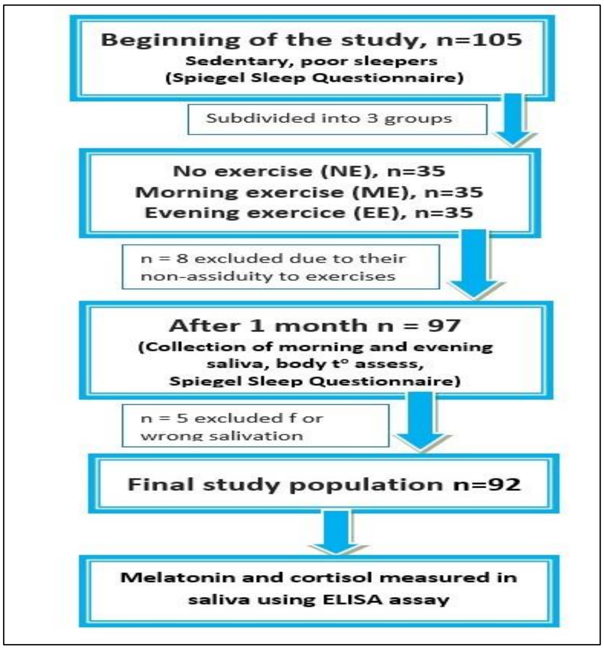

Figure 1: Experimental protocol.

Statistical analysis was performed using Student's t-test or Fisher's test (as indicated) and the GraphPad prism 9.0 software. The means and standard error of the mean (SEM) were compared as indicated in the results section, and $p<0.05$ was considered statistically significant.

RESULTS

Effect of exercise timing on sleep pattern in adolescents

In this section we evaluated, through the Spiegel questionnaire, the effect of morning and evening exercise on the quality of sleep in our cohort. It is worth noting that all participants had a mean±SEM age of 19.3±1.2 year, and had almost the same anthropometric characteristics (presented as mean±SEM); weight 63.7±5.8 kg, BMI 21±2.4 kg/m^2, and height 168.9±4.3 cm. A description of the socio- demographic characteristics of this sample appear in Table 1. They were all poor sleepers, as they reported 30 minutes and more of unwanted awake time (sleep latency and awakenings during sleep) on a rate of at least three nights a week (verified by the questionnaire).

Table 1: Socio-demographic details of the participants.

Demographic variables	M±SEM	Number of participants (n)	Percentage
Sex			
Male		92	100
Female		-	
Age (year)	19.3 ± 1.2	92	100
Height (cm)	168.9±4.3	92	100
Body weight (Kg)	63.7±5.8	92	100
BMI (kg/m^2)	21.0±2.4	92	100
Level of education			
First year university		92	100
Faculties			
Medicine, pharmacy, health		20	21.74
Science		32	34.78
Humanities		20	21.74
Law		20	21.74
Marital status			
Single		92	100
Married		-	

(M ± SEM: mean and standard error; BMI: body mass index)

The scale of the Spiegel questionnaire was from 1 to 30 thus, subjects scoring below 17 are considered to have a sleep disorder. At the beginning of the study all participants scored between 11.3 and 16.9, which uniformly confirmed the presence of sleep disorder at baseline.

After one month (end of the study), using the same questionnaire, the Spiegel score significantly increased in the ME and EE groups (Figure 2). Despite this increase in the Spiegel score absolute values, we evaluated the number of participants who scored above 17, thus indicating improved quality of sleep. The NE group practically maintained the same score category <17 ($p>0.05$). Interestingly, both the ME and EE groups significantly shifted the number of participants to score value >17, thus indicating absence of sleep disorder as assayed by Fisher's exact test ($p<0.05$) for both groups. This improvement in sleep pattern was 71.4 and 44.1% for the ME and EE groups, respectively (Table 2).

Timing of exercise improves the dynamics of cortisol and melatonin secretion in adolescents

Since practicing exercise in general, but particularly in the morning, yielded an improvement (%) in the quality of sleep, we sought to evaluate the levels of cortisol and melatonin in our cohort. Saliva samples in provenance of all participants (as indicated in the methods section) were assessed for the levels of cortisol and melatonin. As shown in Figure 3, the levels of evening cortisol (Panel A) significantly decreased in both the ME and EE groups, but not in the sedentary group (NE), compared to the morning levels. In parallel, the levels of melatonin (Panel B) showed a trend of increase at night in all three groups, however this increase was statistically significant only in the ME group (p<0.05). This is in line with our observation that the increase in the Spiegel score was significant in the ME group when compared to EE and NE participants.

In parallel, the body temperature recorded at the end of the study was slightly, but significantly, lower in ME and EE groups at night (compared to morning recording), but not in the NE participants (Figure 4).

Table 2: Spiegel questionnaire score before and after physical activity.

	Spiegel score start of study		Spiegel score end of study		
Groups	**N Score <17**	**N Score>17**	**N Score <17**	**N Score>17**	**Improvement (%)**
NE	30	0	25	5	16.6
ME	28	0	8	20	71.4
EE	34	0	19	15	44.1

(Scale M±SEM from 1 to 30; <17 indicating sleep problems). N = number of subjects per group. The percent improvement indicated the number of participants that move from <17 to >17 score.

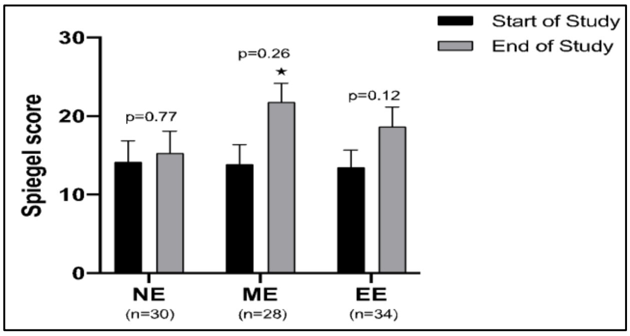

Figure 2: Spiegel score in all three groups (NE, ME, and EE) at the start and end of the study.

*Indicates p<0.05 using Students t-test to compare the values at the start and end of the study for each group.

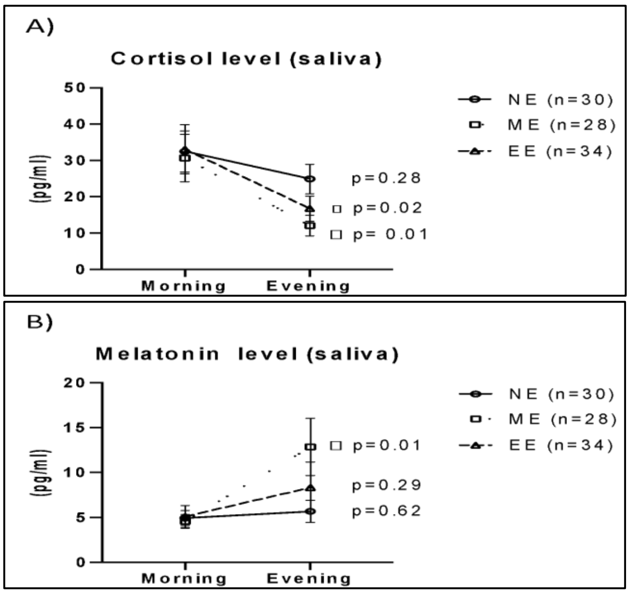

Figure 3: Amounts of saliva (A) cortisol and (B) melatonin in pg/ml (mean±SEM) measured in the morning and the evening of all three groups (NE, ME, and EE) at the end of the study.

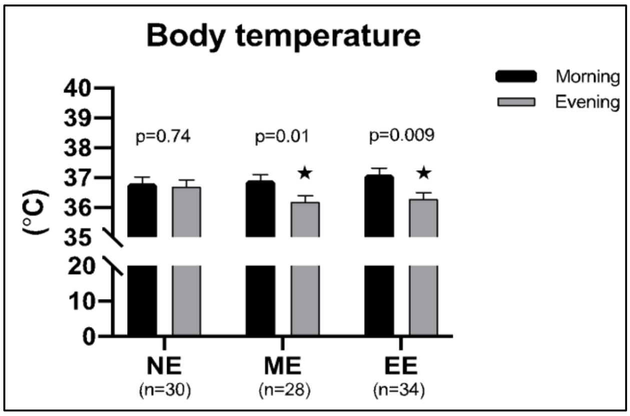

Figure 4: Morning and evening body temperature in all three groups (NE, ME, and EE).

*p<0.05 when comparing morning and evening body temperature in each group.

DISCUSSION

It is commonly accepted that physical exercise is one of the most important factors promoting normal sleep cycle. This is supported by several studies that investigated the links between physical activity and sleep in adults however, in our study, we examined the effect of the time of physical exercise on the quality of sleep in university students, along with the evaluation of cortisol and melatonin levels.[19]

We found that exercise in general, particularly in the morning, significantly improved the quality of sleep in our cohort through the improvement of Spiegel score; in fact this test has been used by different researchers to assess sleep disturbances and subsequently sleep recovery, or amelioration after drug treatment or different interventions.[20] This was associated with a significant decline of cortisol in the evening and a significant increase in the evening melatonin levels. These changes were not noticed in the sedentary group.

The choice of university students for our study was built around the irregular sleep-wake cycle they experience due to delayed bedtime, most often blamed on social and/or academic requirements.[11] We focused on subjects living in the university dorms (they return home on weekends), to minimize the variations in sleep disorders related to the environmental factors. Our data revealed for the first time, that university students who exercised in the morning acquired the best sleep profile when compared to those who exercised in the evening and/or did not exercise. This was associated with increased melatonin in the evening and decreased cortisol levels; a perfect physiological pattern for these two hormones. In fact, an important marker of the hypothalamic-pituitary-adrenocortical function are cortisol levels as they follow a curve with peaks in the morning and deep declines in the evening.[21] Strassman et al suggested that basic cortisol levels may be increased after long-term training or after overtraining, however a more recent study by Hackney and Viu showed that a significant decrease in the level of nocturnal cortisol is linked to two intensive training sessions in one day.[22,23] Although exercise causes various stress reactions in the neuroendocrine system, a recent study reported that physical activities correlated with improved mood and reduced cortisol circulation rates.[24]

The importance of melatonin, which is secreted by the pineal gland, has been emphasized in sleep disorders from the biochemical point of view of the endocrine system. This hormone is linked to falling asleep; it is secreted strongly during the night and rarely during the day and is closely related to the onset of sleep, deep sleep and the maintenance of good quality of sleep.[25] Atkinson et al reported that physical exercise affects endogenous melatonin concentrations, although there are conflicting results regarding this effect.[26] In line with these reports, our study confirmed that physical activity improved the quality of sleep by increasing the level of melatonin at night, especially in participants who exercised in the morning. Physical exercise may act as a time cure for the human circadian pacemaker, similar to a bright light pulse.

It has been reported that aerobic exercise in the morning or the afternoon stimulates earlier melatonin release and shifts the circadian rhythm forward.[27] For people who exercise outdoors, morning exercise may have the added benefit of exposure to sunlight. This helps entrain circadian rhythms and makes it easier to fall asleep early.[28] Research has found that evening exercise may negatively affect sleep quality for early birds, but not for night owls.[29] This may be one reason why certain people have no trouble exercising at night, whereas others struggle to sleep afterward. In one of the few studies that allowed participants to keep their regular exercise routine during the study instead of assigning a new one, there was no significant effect found on sleep quality for people who exercised in the morning versus the evening. It may be that we are naturally inclined to exercise at a time of day that fits well with our personal chronotype.[30]

It is worth noting that the use of saliva for the dosage of cortisol and melatonin may appear unusual due to the commonly used blood samples in medical analysis. However, saliva is a much more precise medium than plasma for the hormonal assay given that, in plasma, cortisol and melatonin are linked to plasma proteins and the free fraction which is active is very low. In addition, there are many cross-reactions in the plasma assay that are not appreciated in the biochemical analysis. The presence of these free hormones in saliva makes their dosage in this environment easier and more reliable.[31,32] In addition, the non-invasive collection of saliva along with the volume of sample collected make it a convenient and easy medium to handle, store, and process as previously reported.[33,34]

Overall, these results support the idea that “being physically active can confer resistance to stress”. This stress is becoming increasingly detrimental with the current COVID-19 pandemic that is imposing sleep disorders through mobility restrictions and consequently reduced physical activity.[6,35,36] Effects of physical exercise on the following nocturnal sleep were controversial in the literature. Most of the studies dealing with sleep and physical exercise report a positive impact of moderate sports in the evening on sleep quality.[37-39] Our present study also showed that physical activity in the evening improved sleep quality, however the morning activity ameliorated, to a greater extend, the sleep quality in our cohort. This is supported by the higher increase of melatonin levels in the evening due to morning exercise, and to the higher improvement of sleep quality in our participants. I

n parallel, cortisol levels were decreased in the evening in both groups, but to a greater extend in participants who exercised in the morning. Moreover, an earlier study by Yamanaka et al that reportedly supports our findings, blamed the benefit of the morning exercise on enhanced parasympathetic activity, in contrast with evening exercise that predominantly increased the sympathetic activity. The sympathetic activity is sustainably higher for a few hours after stimulation, while the parasympathetic activity becomes predominant by the following nocturnal sleep.[39] The change in autonomic balance toward parasympathetic dominance is known to promote the transition from wakefulness to sleep.[28] Note that the parasympathetic predominance during sleep occurs earlier in younger adults than in older individuals due to the delayed onset of slow-wave sleep. This is why the mild impact of morning exercise was observed only on the second half of the nocturnal sleep episode in older individuals. Unfortunately, our questionnaire did not contain information concerning the first or the second half of the night which constitutes one of the limitations of this study. In the same direction results from the study of Fairbrother et al indicated that early morning may be the most beneficial time to engage in aerobic exercise to enhance nocturnal blood pressure changes and quality of sleep.[40]

It is worth noting that the imposition of a morning or evening daily training from 8:00 to 9:00, to minimize variations between our cohorts, might have resulted in a new sleep-wake schedule for the participants. Consequently, this could synchronize the circadian rhythm. In fact, morning exercise may increase sleep pressure, which in turn leads to maintenance of stable sleep throughout the night, thus triggering an improvement in the overall architecture of sleep pattern.[41] It is therefore probable that morning exercise advanced the phase of the internal circadian rhythm, while evening exercise did not. Young adults have the greatest potential of all ages to experience circadian disruption caused by misalignment of their (later) internal circadian rhythms with early-morning obligations.[42] Therefore, morning exercise has the greatest potential to alleviate circadian misalignment in young adults.

CONCLUSION

Under our experimental conditions, our data indicate that moderate exercise practiced early in the morning could lead to an improvement in the overall architecture of sleep pattern in university students. We demonstrated that this improvement of sleep quality was associated with increased melatonin level and reduced cortisol level in the evening. Thus, the use of aerobic exercise in the morning reveals as a non-pharmacological mean to improve the quality of sleep. Future research should focus on the different endocrinological mechanisms involved in our model.

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