Original Article

An Investigation on the Effect of Exercise on Insomnia Symptoms

Haleh Dadgostar, Afsaneh Basharkhah, Mir Farhad Ghalehbandi[1], Fatemeh Kashaninasab[1]

Department of Sports Medicine, Hazrat Rasool-e-Akram Hospital, Iran University of Medical Sciences, Tehran, [1]Mental Health Research Center, Tehran Institute of Psychiatry, Iran University of Medical Sciences, Tehran, Iran

Abstract

Background: Insomnia affects the daily activities of the sufferers and reduces attention and memory. Cognitive behavioral therapy is an expensive treatment and is not applicable to all patients, and long-term treatment with sleep medication can have side effects such as drug dependency. As an alternative form of non-pharmacological treatments, the effect of exercise therapy on improving the symptoms of insomnia is addressed in the current study. **Methods:** A total of 32 patients diagnosed with insomnia participated in the study, from which 16 received combined resistance-aerobic exercise therapy. The rest of the patients comprised the control group. The intervention group went through a 12-week intervention in the form of aerobic exercise for 3 days a week and resistance training for another 3 days a week. Patients' sleep quality was assessed by the Pittsburgh test before and after the intervention. **Results:** The results showed that combined aerobic-resistance exercise can improve sleep quality in patients with insomnia as well as increase subjective sleep quality and actual sleep duration, and decrease daytime dysfunction due to sleeping problems. **Conclusions:** This study shows that, along with other insomnia treatments, exercise can improve the sleep quality of patients.

Keywords: *Aerobic exercise, insomnia, resistance exercise, sleep, sleep quality*

Introduction

Insomnia is a very common disorder worldwide and its prevalence is estimated at about 30% the population.[1] The prevalence of insomnia increases with age, with a prevalence of up to 60% reported in the elderly.[1,2] Insomnia can reduce the quality of life, cause dysfunction in daytime activities, and diminish memory and focus. Furthermore, it can cause depression, anxiety, and metabolic syndromes.[2,3] According to the ICSD3, insomnia is diagnosed whenever the subject or his/her parents or caregiver, report at least one of the following symptoms for at least 3 nights per week for 3 months[3]: (a) difficulty in sleep initiation, (b) difficulty of sleep in the absence of the parent or caregiver, (c) early wakening in the morning, (d) resistance against in-time sleeping, and (e) difficulty in sleep persistence.

Cognitive behavioral therapy (CBT) is the first line in the treatment of insomnia. Medication is only prescribed where CBT is not successful or not applicable.[3] Both CBT and medication have some disadvantages. CBT is an expensive treatment and is not applicable to all patients. Long-term treatment with sleep medication for insomnia can have side effects such as chronic fatigue, vertigo (and its consequences such as fracture), cognitive distortion in old-aged cases,[4] drug dependency, daytime drowsiness, etc.[1] Therefore, miscellaneous non-pharmacological treatments have been suggested for insomnia. Exercise therapy can be a promising alternative treatment due to its low costs, availability, and self-reliance.[4]

A number of previous studies have examined the impact of exercise therapy on insomnia. Mourady *et al*. (2017)[3] performed research on 141 pregnant women using Insomnia Severity Index (ISI) and Pittsburgh sleep quality index (PSQI) questionnaires to evaluate the correlation between exercise and insomnia, depression and anxiety. The results showed that physical activities have positive effects on the health-related quality of life.[3] In a study conducted by Karimi *et al*.[5] (2016), the interventions were aerobic exercise (walking) for half an hour, three days a week, and the study was conducted on 46 elderly people (including 23 in the case group and 23 in the control group). It was shown that the sleep quality

How to cite this article: Dadgostar H, Basharkhah A, Ghalehbandi MF, Kashaninasab F. An investigation on the effect of exercise on insomnia symptoms. Int J Prev Med 2023;14:16.

Address for correspondence:
Dr. Afsaneh Basharkhah, Department of Sports Medicine, Hazrat Rasool-e-Akram Hospital, Iran University of Medical Sciences, Tehran, Iran. E-mail: afsane.basharkhah@gmail.com

Access this article online

Website: www.ijpvmjournal.net/www.ijpm.ir

DOI: 10.4103/ijpvm.ijpvm_204_21

Quick Response Code:

of individuals measured by the Pittsburgh questionnaire in the case group significantly improved compared to the control group.

However, as noted in various references, there is still insufficient evidence to prove the positive effects of exercise therapy on insomnia, and therefore this issue needs further investigation (based on the 2017 European Guideline and the 2017 ACSM Guideline.[4,6] Moreover, there has been very limited experimental investigation on the effects of "resistance exercise" training on sleep in patients with insomnia. To the author's knowledge, the effect of simultaneous aerobic and resistance exercises on insomnia has not been studied before. The purpose of this study is to address these gaps by evaluating the effects of a 12-week combined aerobic-resistance exercise program on insomnia symptoms, as measured by the PSQI. The research procedure and results are outlined in the following sections.

Participants and Methods

The present research is an interventional randomized clinical trial (RCT), which was carried out on visitors to the sleep clinic of Hazrat Rasool-e-Akram Hospital (in Tehran, Iran) between 2018 and 2019. The inclusion criteria were: (a) confirmed diagnosis of insomnia by psychiatrist in accordance with ICSD3, (b) systolic blood pressure less than 180 and diastolic blood pressure less than 100 (the same criteria is used for individuals who take blood pressure drugs), (c) habitual daily exercise of less than 30 min. a day, prior to the intervention, and (d) interest in participation in this study. Exclusion criteria were: (a) previous cardiopulmonary history, (b) uncontrolled respiratory disease, (c) uncontrolled diabetes, (d) inability to participate in regular exercise (for any reason), and (e) prevalence of other sleep disorders affiliated with psychiatric disorders (e.g., Schizophrenia, bipolar disorder, etc.) or medical disease.[2] The information about the diseases for exclusion criteria is derived from the questions in the demographic section at the beginning of our questionnaire.

The sample size is chosen to be 16 for each of the intervention and control groups. The choice of the sample size is based on the formulation presented in Röhrig *et al*.,[7] with a confidence coefficient of 0.95, a power of 0.8 and using mean and standard deviations employed in similar studies (e.g.,[7,8]). Participants include 12 men and 20 women, with an average age of 43.7 years.

Ethical considerations included the following: (a) interventions were performed after obtaining the consent of patients, (b) patients were assured that their information would not be disclosed, (c) the objectives and procedure of the interventions were elaborated for the patients, and (d) the ethics committee code IRCT20100623004251N12 was acquired from the Iranian registry of clinical trials.

Study procedure

The research procedure is outlined in Figure 1. Both the intervention and control groups were first asked to complete PSQI and demographic questionnaires. The content of the demographic questionnaire was the patient' age, sex, and somatic disease. Then the 10-RM was determined for the intervention group, and the group received adequate training on the aerobic and resistance exercises. Patients were followed up 4 and 8 weeks after the start of the study and 10-rm was measured again. At the end of the 12-week intervention period, both control and intervention groups filled the PSQI questionnaire again. The PSQI forms were filled in presence of a doctor to ensure that the evaluation results are not affected by ambiguity in the questionnaire.

The PSQI questionnaire employed in this study for the evaluation of sleep quality, is a self-report questionnaire that assesses sleep quality over a 1-month time interval. The measure consists of 19 individual items, creating 7 components that produce one global score, and takes 5–10 min. to complete.PSQI has internal consistency and a reliability coefficient (Cronbach's alpha) of 0.83 for its seven components. The PSQI components are: (a) "Subjective sleep quality," (b) "Sleep latency," (c) "Sleep duration," (d) "Sleep efficiency," (e) "Sleep disturbance," (f) "Use of sleeping medication," and (g) "Daytime dysfunction."

Each item is weighted on a 0–3 interval scale. The global PSQI score is then calculated by totaling the seven component scores, providing an overall score ranging from 0 to 21, where lower scores denote a healthier sleep quality. The cutoff score for PSQI defining cases of poor sleep quality is 6 or more.[9]

Interventions

Resistance exercises were scheduled for three sessions a week (even or odd days) in a duration of 12 weeks, resulting in a total of 36 sessions. The focus of the resistance exercise was on the major muscle groups. Each session included three movements for the upper limbs and three movements for the lower limbs. According to the 10-RM of each individual, either dumbbell or pulley exercises were assigned. Patients with lower strength, exercised with the dumbbells that had the weight variability up to 4 kg. Patients with higher strength, on the other hand, performed the pulley exercises in sport clubs.

The intensity of the exercises was 50% 10-RM in the first 4 weeks, 60% 10-RM in the second 4 weeks, and 70% 10-RM in the third 4 week.[10] Patients performed three sets of exercises in the first two weeks of each 4 week period, 10 times each; while in the second two weeks of each 4 week period, they performed three sets of exercises, 12 times each. The patients had 30 second rests in-between sets, and 1 min. rests in-between different

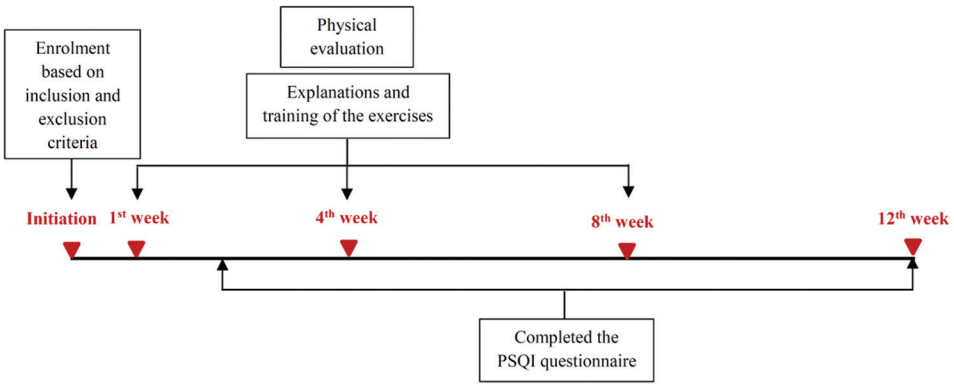

Figure 1: The study procedure flowchart

exercises. Patients were instructed to perform warming up and cooling down stretching exercises for 10 min. before and after the exercises, respectively. The aerobic exercises were designed in the form of medium intensity walking (60% heart rate reserve or positive talk test) for three days a week in-between the resistance exercises days. The walking duration was set at 30 min. in the first 4 weeks, 45 min. in the second 4 weeks and 60 min. in the third 4 weeks.[6-14] After each exercise session, patients record the time and intensity of their exercise in a logbook designed for this purpose. The patients were contacted on a weekly basis in order to make sure they abide by the exercise plan.

Statistical analyses

The data was then analyzed using appropriate statistical tests, as described in the following. Normality of the data distribution were initially checked using Kolmogorov--Smirnov test. Since not all the data distributions were normal, non-parametric equal tests were used (i.e., Wilcoxon and Mann–Whitney statistical test). The significance level was determined at $P < 0.05$. The mean and standard deviation value of the PSQI sub and total scores were employed as the descriptive statistics. The data analysis was performed by SPSS statistic software (version 21 IBM Corp., Armonk, NY, USA).

Results

The PSQI test results are presented in Table 1. As demonstrated, the pretest sub and total scores of PSQI are not statistically different between the intervention and control groups, as *P* pretest is consistently above 0.05. In the intervention group, "subjective sleep quality," "sleep duration," "sleep efficiency," and "daytime dysfunction" sub-scores, and the "total PSQI score" were significantly improved during the intervention. Changes in these scores were not statistically significant in the control group. The "sleep latency," "sleep disturbance," and "use of sleep medication" sub-scores did not change significantly in the before and after PSQI measurements in both the intervention and control groups.

Discussion

The main objective of this research was to analyze the effect of simultaneous resistance and aerobic exercises on sleep quality in patients with insomnia. The results showed that there was a significant difference between the two groups at posttest stage regarding the elements of subjective sleep quality, sleep duration, sleep disturbance, use of sleep medication, daytime dysfunction, and general quality of sleep, while none of the PSQI parameters is significantly changed in the control group. This shows the effectiveness of exercise on improving symptoms of insomnia. The results also showed that "sleep latency" and "use of the sleep medication" are not significantly altered by exercise therapy.

Our results are consistent with Ferris *et al*.,[15] King *et al*.,[16] and Li *et al*.[17] that supported the effectiveness of physical activity on quality of sleep. In addition, Mercier *et al*.[18] reported that 6 weeks aerobic exercise was effective in improving the quality of sleep of the adult. Comparing the results of the present studies with previous studies [see Table 2], it should be noted that the results of previous studies on the effect of exercise on sleep quality variables are very different and sometimes contradictory to each other. These differences make it difficult to provide a single picture on the effect of exercise on patients' sleep quality using a review of previous studies. However, paying attention to the details of previous studies can provide the basis for achieving some key results.

Several reasons can be given to justify the difference between the results of the present studies and some previous studies. First, some researchers have studied the effects of "short-term" exercise on insomnia, while others have addressed the impacts of "long-term" exercise. The present study can be categorized under the second group, as the interventions lasted for a period of 12 weeks. This can cause some disagreements between the results of the present research and those concerned with short-term exercise interventions. As indicated by the meta-analysis of Kredlow *et al*.,[19] short-term exercise has little effect on

Table 1: Mean score of the elements of PSQI before and after intervention

Parameter	Intervention group			Control group			Mann-Whitney
	Mean (SD) pretest	Mean (SD) posttest	*P*	Mean (SD) pretest	Mean (SD) posttest	*P*	
Subjective sleep quality	2.13 (0.62)	1.63 (0.50)	0.024	2.38 (0.72)	2.25 (0.68)	0.576	*P* pretest=0.253
							P posttest=0.009
							P delta=0.0307
Sleep latency	1.8 (0.81)	1.13 (1.2)	0.074	2.00 (1.03)	1.88 (1.2)	0.889	*P* pretest=0.538
							P posttest=0.0805
							P delta=0.0077
Sleep duration	2.38 (0.72)	1.50 (0.89)	0.007	2.25 (1.00)	2.13 (0.96)	0.577	*P* pretest=0.950
							P posttest=0.040
							P delta=0.0031
Sleep efficiency	1.63 (1.02)	0.63 (0.89)	0.008	1.38 (1.02)	1.25 (1.13)	0.767	*P* pretest=0.544
							P posttest=0.105
							P delta=3.633×10^{-5}
Sleep disturbance	1.38 (0.50)	1.38 (0.50)	1	1.00 (0.00)	1.00 (0.00)	-	*P* pretest=0.008
							P posttest=0.008
							-
Use of sleep medication	2.50 (1.03)	2.38 (1.02)	0.533	2.88 (0.34)	3.00 (0.00)	0.164	*P* pretest=0.332
							P posttest=0.008
							P delta=0.0529
Daytime dysfunction	2.06 (1.12)	1.31 (0.87)	0.018	2.69 (0.48)	2.38 (1.02)	0.572	*P* pretest=0.096
							P posttest=0.001
							P delta=0.0170
Summation of scores	13.94 (3.70)	9.94 (3.99)	0.009	14.56 (3.31)	13.88 (3.28)	0.553	*P* pretest=0.414
							P posttest=0.007
							P delta=2.050×10^{-4}

Statistically Significant. Statistically Significant

Table 2: Comparison of the results of this study with those of previous on the effect of 'long-term' exercise intervention on symptoms of insomnia

PSQI parameters	King *et al*. (2008)*[16]	Reid *et al*. (2010)[24]	Passos *et al*. (2011)[22]	Mercier *et al*., (2018)**[18]	D'Aurea *et al*. (2019)[8]		Current study
Intervention							
Type of exercise	Aerobic	Aerobic	Aerobic	Aerobic	Resistance	Stretching	Combined aerobic-resistance
Duration	12 months	16 weeks	6 months	6 weeks	4 months	4 months	3 months
Sleep duration (hours)	1.25	NS	NR	0.69	1.2	1.6	0.8
Sleep latency (minutes)	-5.2	-12.4	-8.4	-15.3	-47.5	-37.9	-26.4
Sleep efficiency (%)	NR	NR	7.4	9.6	19.5	13.3	12.2
PSQI scores							
Subjective sleep quality	NR	-1.82	NR	NR	NR	NR	-0.5
Sleep latency	NR	-0.6	NR	NR	NR	NR	-0.8
Sleep duration	-0.28	-0.9	NR	NR	NR	NR	-0.9
Sleep efficiency	NR	-0.5	NR	NR	NR	NR	-1.0
Sleep disturbance	-0.16	-0.5	NR	NR	NR	NR	NS
Use of sleep medication	NR	-0.4	NR	NR	NR	NR	NS
Daytime dysfunction	0.13	-0.8	NR	NR	NR	NR	-0.8
Total	-5.62	-2.11	NR	-2	-5.3	-3.9	-4

NS: Change statistically not-significant. NR: Not reported. *The study was conducted on individuals older than 55 years. **The study was conducted on cancer patients

parameters such "sleep duration," "sleep latency" (Kredlow *et al*.[19] In contrast, long-term exercise has a moderate to high effect on the total PSQI score and a moderate to very high effect on all PSQI subgroups. The results of the current study are in general agreement with this conclusion, except for the "sleep latency," "sleep disturbance," and "use of sleep medication" sub-scores, for which we have found no significant change with exercise intervention.

Second, in the present study, moderate-intensity exercise was prescribed to patients with insomnia. "Exercise intensity" is a factor influencing outcomes. A study by Williams *et al*. (2014)[20] suggests that if children's daily physical activity intensity increases from moderate to severe, sleep duration decreases, but sleep quality and sleep efficiency improves.

Another important factor is the "time" of daily exercise. Some studies, such as Yamanaka *et al*. (2015)[21] have concluded that daily exercise time has a significant effect on the nature of its effect on sleep. The study shows that exercise in the early morning hours improves the quality of sleep at night, because the time interval between exercise and sleep provides the opportunity to reduce the effect of stimulation of the sympathetic nervous system by exercise. Some studies, such as Passos *et al*.,[22] have rejected this and found no difference between the effects of daily exercise time on sleep quality. In the present study, daily exercise time was optional and no specific time for exercise was specified.

The nature of the target group also affects the results. For example, in adults, the effects of exercise on sleep quality are often more pronounced than in younger age groups (such as children and adolescents) (Dolezal *et al*., 2017[23]). Some previous studies have focused on specific groups such as the elderly over 55 (King *et al*., 2008)[16] and cancer patients (Reid *et al*., 2010),[24] which differ from the present study.

In the present study, both the case and control groups used sleep-related medications prescribed by the psychiatrist during the study, and in addition to medications, the case group performed strength and aerobic exercise for 3 months, and whether exercise has affected the parameter of drug use in the PSQI questionnaire or not has not been evaluated.

The unique aspects of the present work are threefold. First, in the present study, a combination of aerobic and strength exercises were performed as interventions and it was shown that compared to the control group, it significantly improves the sleep quality of insomnia patients. The exercise program was also defined as progressive with the development of skeletal muscles. The combination of aerobic and strength exercises in the present studies is considered as an innovation and in previous studies, intervention are either only as aerobic exercise (such as King *et al*., 2008,[16] Reid *et al*., 2010,[24] and Passos *et al*., 2011[22]) or just strength training (such as D'Aurea *et al*., 2019).[8]

Second, in the present study, in addition to the beginning of the interventions, at the end of the first month and the end of the second month, physical evaluation was performed and the individuals' strength and musculoskeletal development were assessed. This was done to evaluate the effect of exercise on muscles and their respiratory system and the necessary preparation for more intense exercise in the next month, and in this respect was superior to previous similar studies.

Third, in this study, weekly contact with individuals in both case and control groups ensured the correct progress of the exercises. Also, PSQI questionnaires were completed in the presence of a physician so that the evaluation results were not affected by the ambiguities of the examiner. These measures are rarely observed in similar studies.

There are numerous studies in which the mechanism of the effect of exercise on sleeping quality is addressed, researchers have not yet converged to a single mechanism. There are several hypotheses about the mechanism, including increase in the adenosine as a result of appropriate variations in the circadian rhythm,[25] and excretion of the growth hormone that eventually leads to the improvement of sleep quality and prevents daytime dysfunction.[26] There is some evidence suggesting that reduction in body temperature in the evening is an initiation for the night sleep.[27,28] Exercising activates the hypothalamus heat regulation and reduces the body temperature. The thermogenic effects of the exercises might be an acceptable justification for improvement of sleep latency.[29] Furthermore, the effect of exercise on reduction of anxiety is reported in the literature,[30] and anxiety is one of the causes of insomnia. Hence, some studies have reported that exercising can improve sleep quality through reduction of anxiety.[31] Exercising can also increase the metabolism of brain serotonin by increasing the release of tryptophan.[32] This is important as one of the causes of insomnia is decreased serotonin activity.[33]

Limitations of the Present Study and Suggestions for Future Studies

This study was faced with limitations such as lack of follow-up after the 12 weeks of interventions due to concerns about the number of people under study, lack of segregation of patients with various mental disorders such as depression, anxiety and so on. One of the problems of the present study was to attract patients and to motivate them to participate and stay in the study, because due to insufficient sleep, patients had daily dysfunction and lack of appetite for daily work and encouraging them to do 12 weeks of exercise was difficult. Inactivity was another important problem that was associated with most of the participants in this study, and teaching them sports movements was a very basic concept. Despite providing these trainings, the lack of a history of sports activities also led to errors in sports movements and the resulting injuries, which made it difficult to continue studying some of the participants.

In future research, it is suggested that the effectiveness of aerobic and resistance exercise on sleep quality in patients

with insomnia with a larger sample size, and also, patients with various mood disorders be examined separately by type of disease and in addition to increasing the duration of intervention, Follow-up of quarterly, 6-month and even more effects of interventions. On the other hand, according to the results of this study, which showed the subjective effects of aerobic and strength training on sleep quality in patients with insomnia by the Pittsburgh questionnaire, it is suggested that the sleep status of these patients be examined more broadly by objective tests such as polysomnography and Actigraphy

Conclusions

Insomnia is the second most common complaint after pain in the primary care setting. Insomnia causes high costs for the individual and the community due to the decline in daily functioning. Drug therapy as the first line of treatment has many side effects and CBT as the second line of treatment is costly and time consuming. According to this study, the quality of sleep can be improved by performing organized physical activities that consist of a combination of aerobic and resistance exercises. The results supported the effectiveness of the physical activities on the quality of sleep.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

Received: 17 May 21 **Accepted:** 28 Sep 21
Published: 18 Feb 23

References

1. Huang CY, Chang ET, Lai HL. Comparing the effects of music and exercise with music for older adults with insomnia. Appl Nurs Res 2016;32:104-10.
2. Zheng B, Yu C, Lin L, Du H, Lv J, Guo Y, *et al*. Associations of domain-specific physical activities with insomnia symptoms among 0.5 million Chinese adults. J Sleep Res 2017;26:330-7.
3. Mourady D, Richa S, Karam R, Papazian T, Moussa FH, El Osta N, *et al*. Associations between quality of life, physical activity, worry, depression and insomnia: A cross-sectional designed study in healthy pregnant women. PLoS One 2017;12:e0178181.
4. Riemann D, Baglioni C, Bassetti C, Bjorvatn B, Dolenc Groselj L, Ellis JG, *et al*. European guideline for the diagnosis and treatment of insomnia. J Sleep Res 2017;26:675-700.
5. Karimi S, Soroush A, Towhidi F, Makhsosi BR, Karimi M, Jamehshorani S., *et al*. Surveying the effects of an exercise program on the sleep quality of elderly males. Clin Interv Aging 2016;11:997-1002.
6. American College of Sports Medicine. ACSM's Guidelines for Exercise Testing and Prescription. 10th ed. Lippincott Williams & Wilkins; 2018.
7. Röhrig B, du Prel JB, Wachtlin D, Kwiecien R, Blettner M. Sample size calculation in clinical trials: Part 13 of a series on evaluation of scientific publications. Dtsch Ärztebl Int 2010;107:552-6.
8. D'Aurea CV, Poyares D, Passos GS, Santana MG, Youngstedt SD, Souza AA, *et al*. Effects of resistance exercise training and stretching on chronic insomnia. Braz J Psychiatry 2019;41:51-7.
9. Buysse DJ, Reynolds CF II, Monk TH, Berman SR, Kupfer DJ. The Pittsburgh sleep quality index: A new instrument for psychiatric practice and research. J Psychiatr Res 1989;28:193-213.
10. Prentice WE. Rehabilitation Techniques for Sports Medicine and Athletic Training. Medicine & In Sports & Exercise. 5th ed., McGraw-Hill; 2011;197-213.
11. Fletcher GF, Ades PA, Kligfield P, Arena R, Balady GJ, Bittner VA, *et al*. Exercise standards for testing and training: A scientific statement from the American Heart Association. Circulation 2013;128:873-934.
12. Haskell WL, Lee IM, Pate RR, Powell KE, Blair SN, Franklin BA, *et al*. Physical activity and public health: Updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. Circulation 2007;116:1081-93.
13. U.S. Department of Health and Human Services. 2008 Physical Activity Guidelines for Americans [Internet]. Washington (DC): U.S. Department of Health and Human Services. Availablefrom: http://www.health.gov/paguidelines/pdf/paguide.pdf". [Last accessed on 2016 Mar 28].
14. U.S. Department of Health and Human Services. Exercise and Physical Activity [Internet]. Bethesda (MD): National Institute on Aging, National Institutes of Health. Available from: http://www.nia.nih.gov/HealthInformation/Publications/ExerciseGuide". [Last accessed on 2016 Mar 28].
15. Ferris LT, Williams JS, Shen CL, O'Keefe KA, and Hale KB. Resistance training improves sleep quality in older adults a pilot study. J Sports Sci Med 2005;4:354.
16. King AC, Pruitt LA, Woo S, Castro CM, Ahn DK, Vitiello MV, *et al*. Effects of moderate-intensity exercise on polysomnographic and subjective sleep quality in older adults with mild to moderate sleep complaints. J Gerontol A Biol Sci Med Sci 2008;63:997-1004
17. Li F, Fisher KJ, Harmer P, Irbe D, Tearse RG, Weimer C. Tai Chi and self-rated quality of sleep and daytime sleepiness in older adults: A randomized controlled trial. J Am Geriatr Soc 2004;52:892-900.
18. Mercier J, Ivers H, Savard J. A non-inferiority randomized controlled trial comparing a home-based aerobic exercise program to a self-administered cognitive-behavioral therapy for insomnia in cancer patients. Sleep 2018;41:zsy149.
19. Kredlow MA, Capozzoli MC, Hearon BA, Calkins AW, Otto MW. The effects of physical activity on sleep: A meta-analytic review. J Behav Med 2015;38:427-49.
20. Williams SM, Farmer VL, Taylor BJ, Taylor RW. Do more active children sleep more? A repeated cross-sectional analysis using accelerometry. PLoS One 9:e93117.

21. Yamanaka Y, Hashimoto S, Takasu NN, Tanahashi Y, Nishide SY, Honma S, *et al*. Morning and evening physical exercise differentially regulate the autonomic nervous system during nocturnal sleep in humans. Am J Physiol Regul Integr Comp Physiol 2015;309:R1112-21.
22. Passos GS, Poyares D, Santana MG, D'Aurea CV, Youngstedt SD, Tufik S. Effects of moderate aerobic exercise training on chronic primary insomnia. Sleep Med 2011;12:1018-27.
23. Dolezal BA, Neufeld EV, Boland DM, Martin JL, Cooper CB. Interrelationship between sleep and exercise: A systematic review. Adv Prev Med 2017;2017. doi: 10.1155/2017/1364387.
24. Reid KJ, Baron KG, Lu B, Naylor E, Wolfe L, Zee PC. Aerobic exercise improves self-reported sleep and quality of life in older adults with insomnia. Sleep Med 2010;11:934-40.
25. Montgomery P, Dennis JA. Physical exercise for sleep problems in adults aged 60+. Cochrane Database Syst Rev 2002;2002. doi: 10.1002/14651858.CD003404.
26. Weltman A, Wideman L, Weltman JY, Veldhuis JD. Neuroendocrine control of GH release during acute aerobic exercise. J Endocrinol Invest 2003;26:843-50.
27. Murphy PJ, Campbell SS. Nighttime drop in body temperature: A physiological trigger for sleep onset? Sleep 1997;20:505-11.
28. Kräuchi K, Cajochen C, Werth E, Wirz-Justice A. Warm feet promote the rapid onset of sleep. Nature 1999;401:36-7.
29. Kryger M, Roth T, Dement WC. Principles and practice of sleep medicine. 6th ed. Philadelphia: Elsevier; 2017.
30. Youngstedt SD Effects of exercise on sleep. Clin Sports Med 2015;24:355-65.
31. Herring MP, O'Connor PJ, Dishman RK. The effect of exercise training on anxiety symptoms among patients: A systematic review. Arch Internal Med 2010;170:321-31.
32. Sudo A, Arito H, Fukuda K. Effects of swimming exercise on circadian sleep-waking rhythms and brain serotonin metabolism in rats. Industrial Health 1984;22:153-61.
33. Petitjean F, Buda C, Janin M, Sallanon M, Jouvet M. Insomnia caused by administration of para-chlorophenylalanine: Reversibility by peripheral or central injection of 5-hydroxytryptophan and serotonin. Sleep 1985;8:56-67.