Exercise training improves sleep quality in middle-aged and older adults with sleep problems: a systematic review

Pei-Yu Yang[1], Ka-Hou Ho[1], Hsi-Chung Chen[2] and Meng-Yueh Chien[1]

[1]School and Graduate Institute of Physical Therapy, College of Medicine, National Taiwan University, [2]Department of Psychiatry and Center of Sleep Disorders, National Taiwan University Hospital, National Taiwan University
Taipei, Taiwan

Question: Does an exercise training program improve the quality of sleep in middle-aged and older adults with sleep problems? **Design**: Systematic review with meta-analysis of randomised trials. **Participants**: Adults aged over 40 years with sleep problems. **Intervention**: A formal exercise training program consisting of either aerobic or resistance exercise. **Outcome measures**: Self-reported sleep quality or polysomnography. **Results**: Six trials were eligible for inclusion and provided data on 305 participants (241 female). Each of the studies examined an exercise training program that consisted of either moderate intensity aerobic exercise or high intensity resistance exercise. The duration of most of the training programs was between 10 and 16 weeks. All of the studies used the self-reported Pittsburgh Sleep Quality Index to assess sleep quality. Compared to the control group, the participants who were randomised to an exercise program had a better global Pittsburgh Sleep Quality Index score, with a standardised mean difference (SMD) of 0.47 (95% CI 0.08 to 0.86). The exercise group also had significantly reduced sleep latency (SMD 0.58, 95% CI 0.08 to 1.08), and medication use (SMD 0.44, 95% CI 0.14 to 0.74). However, the groups did not differ significantly in sleep duration, sleep efficiency, sleep disturbance, or daytime functioning. **Conclusion**: Participation in an exercise training program has moderately positive effects on sleep quality in middle-aged and older adults. Physical exercise could be an alternative or complementary approach to existing therapies for sleep problems. **[Yang P-Y, Ho K-H, Chen H-C, Chien M-Y (2012) Exercise training improves sleep quality in middle-aged and older adults with sleep problems: a systematic review. *Journal of Physiotherapy* 58: 157–163]**

Key words: Exercise, Insomnia, Meta-analysis, Sleep problem, Sleep quality

Introduction

The prevalence of insomnia in adults has been reported to range from 10% to 40% in Western countries (Ohayon 1996, Hatoum et al 1998, Leger et al 2000, Pearson et al 2006, Morin et al 2006, Morin et al 2011) and to exceed 25% in Taiwan (Kao et al 2008). Epidemiological surveys have concluded that the prevalence of insomnia, which is characterised by persistent inability to fall asleep or maintain sleep, increases with age (Ohayon 2002). Sleep problems have a significant negative impact on mental and physical health (Kripke et al 2005), impair quality of life, and increase healthcare costs (Simon and von Korff 1997). Lack of sleep can lead to increased fatigue and excessive daytime sleepiness (Bliswise 1996). It can also impair the metabolic, endocrine, and immune systems, among other deleterious effects (Spiegel 2009, Knutson et al 2007, Miller and Cappuccio 2007). However, fewer than 15% of patients with chronic insomnia receive treatment or consult a healthcare provider (Mellinger et al 1995, Morin et al 2011).

To date, the most common treatments for insomnia remain pharmacological agents (Nowell et al 1997, Smith et al 2002, Glass et al 2005). Several systematic reviews have reported that hypnotics improve sleep latency, total sleep time, and total sleep quality, as well as decreasing the number of episodes of awakening during sleep (Nowell et al 1997, Smith et al 2002, Glass et al 2005). However, the size of the effect is unclear, likely reflecting the different populations and follow-up periods reported in these reviews. Moreover, the increased risk of adverse events was found to be statistically significant and poses potential risks for older individuals for falls or cognitive impairment (Glass et al 2005). Although research has found that pharmacological treatment appears an effective treatment for insomnia, evidence of its sustained efficacy is lacking (Morin et al 1999a). In view of the potential risks of tolerance and dependency and the large number of other drugs that older individuals frequently take in conjunction with insomnia medication, an evidence-based non-drug approach is of interest. In the National Health Interview Survey analysis (Pearson 2006), it was reported that over 1.6 million civilian adult US citizens use complementary and alternative medicine to treat insomnia.

Previous reviews have reported that non-pharmacological treatments are as effective as pharmacological therapies for older patients with insomnia (Montgomery and Dennis 2003, Montgomery and Dennis 2004, Morin et al 1999b). The non-pharmacological treatments that have been studied include providing sleep hygiene advice and cognitive

What is already known on this topic: The inability to fall asleep or maintain sleep increases with age, causing fatigue and daytime sleepiness, which impair quality of life. Although effective medications for insomnia exist, they may have side effects, including falls and cognitive impairment in older people.

What this review adds: Regular aerobic or resistance exercise training significantly improves sleep quality in adults over 40 years of age. Those who exercised perceived significantly reduced time taken to fall asleep after going to bed and reduced medication use for insomnia.

behavioural therapy, which advise patients to set a regular bed-time schedule (Espie and Lindsay 1987), limit alcohol and caffeine intake (Morgan 2003), and increase daylight exposure and physical activity (Baillargeon et al 1996, Driver and Taylor 2000, Fetveit 2009). Several studies have concluded that participation in a cognitive behavioural therapy program could reduce sleep latency and time spent awake after sleep onset by approximately 30 minutes, increase total sleep time by approximately 30–45 minutes, and increase sleep efficiency up to approximately 70% to 85% (Morin et al 1999b, Montgomery and Dennis 2003). Furthermore, these studies found that the effects of non-pharmacological treatment are better sustained over time compared to pharmacological interventions. However, the main disadvantage of such approaches is their lack of wide availability, because they must be delivered by highly trained specialists (van Straten and Cuijpers 2009).

Exercise programs are also recommended to help prevent and treat sleep disorders (Youngstedt 2005) as well as the depression associated with these disorders among the elderly (Singh et al 1997, Singh 2001). Having infrequent adverse effects and a low cost, participation in a community-based exercise program may be a favourable and easily accessible means of preventing and treating sleep problems among middle-aged and elderly populations. However, several meta-analyses examining the effect of exercise training on sleep (Kubitz et al 1996, Montgomery and Dennis 2002) yielded equivocal findings due to the small number of trials examined and the limited number of participants in those trials. Since those studies were published, new evidence from additional randomised trials has become available. Therefore, the research question for this systematic review was:

> Does an aerobic or resistance exercise training program improve sleep quality in middle-aged and older adults with sleep problems?

Method

Identification and selection of trials

We searched six electronic databases (PubMed, MEDLINE, CINAHL, EMBASE, the Cochrane Library, and Chinese Electronic Periodical Service) from the earliest available date to April 2012 using keywords for insomnia (*insomnia, sleep problems, sleep disorder, sleep complaints, sleep disturbance, sleep quality*) and for exercise (*exercise, physical activity, physical therapy*). We limited the search results to full-text articles written in English or Chinese. We then checked the reference lists of the original and review articles that the initial search had yielded in order to identify additional full-text articles.

Two reviewers (Yang and Ho) independently reviewed the articles to determine whether they met the predetermined eligibility criteria. Their results were re-checked by another reviewer (Chien) and all three reviewers resolved any disagreement through discussion. The inclusion criteria are presented in Box 1. Trials were excluded if any participants had systemic disorders or if the control group was instructed to engage in stretching or low-intensity exercise. If multiple published reports from the same trial were available, only the report that contained the most detailed and quantified information regarding both intervention and outcomes was analysed.

Box 1. Inclusion criteria.

Design
- Randomised trial

Participants
- Middle-aged and older adults (> 40 yr)
- Sleep complaints (insomnia, depression, or poor sleep quality)

Intervention
- Exercise training program (aerobic or resistance exercise)

Outcome measures
- Self–reported sleep quality (eg, PSQI questionnaire)
- Objective sleep quality (eg, polysomnography)

Control
- No training or health education

Assessment of characteristics of trials

Quality: The methodological quality of the selected trials was independently assessed by two reviewers (Yang and Ho) using the Physiotherapy Evidence Database (PEDro) scale (Maher et al 2003, de Morton 2009). Any disagreement with regard to methodological quality were resolved by discussion.

Participants: Age, gender, and types of sleep problems were recorded to characterise the trials and to determine the similarity of participants between groups and between trials.

Intervention: The target intensity, duration, and frequency of the exercise training program, and the nature of the control intervention were recorded.

Outcome measures: The objectively measured outcomes we considered were sleep onset latency, sleep duration, sleep disturbance, habitual sleep efficiency, daytime dysfunction and use of sleep medication. We also considered subjective measures of sleep quality using standardised instruments or scales, eg, the Pittsburgh Sleep Quality Index (Buysse et al 1989). The Pittsburgh Sleep Quality Index is a widely used, self-rated sleep questionnaire for measuring sleep quality. A total of 19 questions generate seven components, each with a score ranging from 0 (no difficulty) to 3 (severe difficulty). The components are subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleep medications, and daytime dysfunction. The seven component scores are also summed to generate a global Pittsburgh Sleep Quality Index score (ranging from 0 to 21), with a score of more than 5 indicating clinical sleep impairment.

Data analysis

The analyses were performed using RevMan 5 software[a]. The standardised mean difference (SMD) and a 95% confidence interval (CI) of the post-intervention score or change in scores were calculated. An SMD of 0.5 indicates that the mean of the exercise group is half a standard deviation larger than the mean of the control group. An SMD of 0.8 is considered large, an SMD of 0.5 moderate, and an SMD of 0.2 small. A test of heterogeneity was performed for each outcome, and a random-effects model

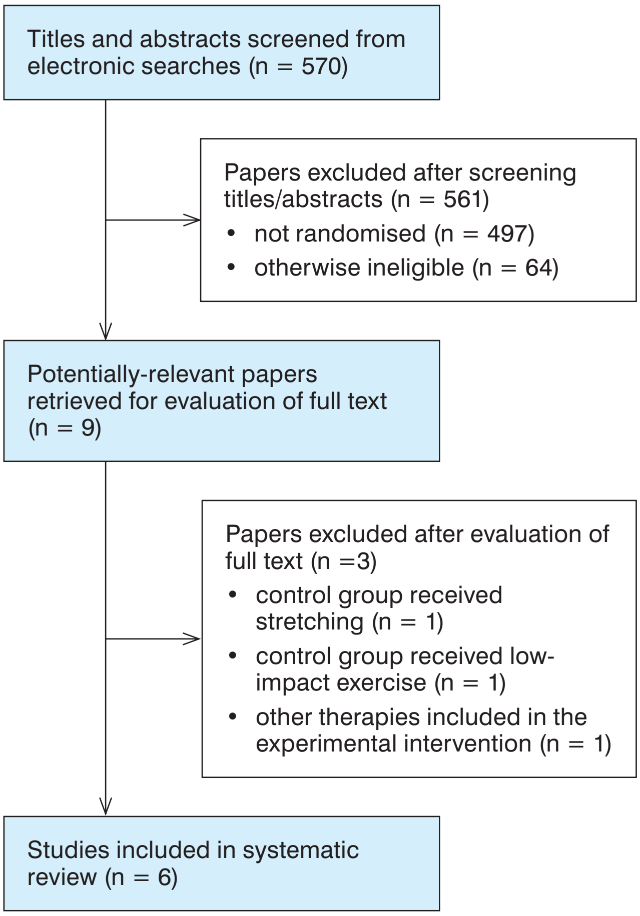

Figure 1. Identification and selection of studies.

was calculated if a significant level of heterogeneity was detected for an outcome. If no significant heterogeneity was detected, a fixed-effect model was used. Statistical significance was set at $p < 0.05$.

Results

Flow of studies through the review

Database searching using the method described led to the retrieval of 570 articles. After the screening of titles and abstracts, nine articles appeared to be eligible (Singh et al 1997, King et al 1997, Tworoger et al 2003, Li et al 2004, Elavsky and McAuley 2007, King et al 2008, Irwin et al 2008, Altena et al 2008, Reid et al 2010). Three articles were subsequently excluded, two because their control groups had engaged in some form of exercise (Tworoger et al 2003, Li et al 2004) and one because the experimental group had engaged in additional therapies that did not meet the inclusion criteria (Altena et al 2008) (Figure 1). No additional articles were identified by the scanning of reference lists. Therefore six trials were included in the analysis.

Characteristics of included trials

The six included trials involved 305 participants. The quality of the included trials is presented in Table 1 and a summary of the trials is presented in Table 2.

Table 1. PEDro scores for included trials (n = 6).

Trial	Random allocation	Concealed allocation	Groups similar at baseline	Participant blinding	Therapist blinding	Assessor blinding	< 15% dropouts	Intention-to-treat analysis	Between-group difference reported	Point estimate and variability reported	Total (0 to 10)
Elavsky & McAuley (2007)	Y	N	Y	N	N	N	Y	Y	Y	Y	6
Irwin et al (2008)	Y	Y	Y	N	N	Y	Y	Y	Y	Y	8
King et al (1997)	Y	N	Y	N	N	N	Y	Y	Y	Y	6
King et al (2008)	Y	N	Y	N	N	Y	Y	Y	Y	Y	7
Singh et al (1997)	Y	N	Y	N	N	N	Y	N	Y	Y	5
Reid et al (2010)	Y	N	Y	N	N	N	Y	N	Y	Y	5

N = no, Y = yes.

Table 2. Summary of included trials (n = 6).

Study	Participants	Intervention	Outcome measures
Elavsky & McAuley (2007)	Decreased sleep quality Exp: n = 60 females, aged 50.5 yrs Con: n = 39 females, aged 48.6 yrs	Ex = Supervised moderate-intensity exercise for 60 min × 3 times/week × 4 months, intensity increased from 50% to 60–75% of HRR. Con = No treatment.	PSQI score
Irwin et al (2008)	Moderate sleep complaints Exp: n = 30 (8 males) aged 69.7 yrs Con: n = 22 (8 males) aged 70.7 yrs	Ex = Tai Chi Chih exercise for 40 min × 3 times/week × 16 weeks. Con = Health education 120 min/week × 16 weeks.	PSQI score
King et al (1997)	Moderate sleep complaints Exp: n = 20 (8 males, aged 62.4 yrs) Con: n = 23 (6 males, aged 60.6 yrs)	Ex = Community-based moderate-intensity exercise for 30–40 min × 4 times/week × 16 weeks, intensity increased to 60–75% HRR based on treadmill-based peak heart rate. Con = No treatment.	PSQI score Sleep diary Functional capacity
King et al (2008)	Mild to moderate sleep complaints Exp: n = 36 (12 males, aged 61.9 yrs) Con: n = 30 (10 males, aged 60.9 yrs)	Ex = Supervised moderate-intensity exercise for 60 min × 5 times/week × 12 months, intensity increased to 60–85% of treadmill-based peak heart rate. Con = Health education for 90 min.	PSQI score Polysomnography Sleep diary
Singh et al (1997)	Major or minor depression or dysthymia Exp: n = 15 (5 males, aged 70.0 yrs) Con: n = 13 (6 males, aged 72.0 yrs)	Ex = High-intensity progressive resistance training for 60 min × 3 times/week × 10 weeks. Con = Health education for 60 min × 2 times/week × 10 weeks.	PSQI score
Reid et al (2010)	Primary insomnia Exp: n = 10 (0 male, aged 62.0 yrs) Con: n = 7 (1 male, aged 63.5 yrs)	Ex = Supervised conditioning and aerobic exercise for 10–15 min/day to 30–40 min × 4 times/week × 16 weeks, intensity increased from 55% to 75% max HR. Con = Recreational or educational activities for 45 min × 3–5 times/week × 16 weeks.	PSQI score SF-36

Exp = experimental group, Con = control group, PSQI = Pittsburgh Sleep Quality Index, HRR = heart rate reserve, SF-36 = short-form 36.

Quality: The quality of the included trials ranged from 5 to 8 on the PEDro scale (Table 1). No trials blinded participants or therapists, while two trials blinded assessors. All trials had retention rates of 85% or greater and all reported between-group differences with point estimates and measures of variability.

Participants: Most of the included trials recruited both men and women participants with sleep problems. The mean age of the participants ranged from 48 to 72 years. However, the 305 participants were predominantly female because one trial recruited only postmenopausal women (Elavsky and McAuley 2007).

Interventions: Five trials examined aerobic exercise (endurance training, walking, or Tai Chi) and one trial examined a resistance exercise program. The duration of most of the trials was between 10 and 16 weeks, with one study continuing for 12 months. The control groups in all the trials received either no treatment or health education for 90–120 minutes per week. All the aerobic exercise programs examined were of moderate intensity, instructing the participants to reach 60–70% of their heart rate reserve or 60–85% of their peak heart rate for 40 to 60 minutes.

Effect of exercise training on sleep quality

Self-reported sleep quality: The effect of exercise training on sleep quality as indicated by the global Pittsburgh Sleep Quality Index score was examined by pooling data from 288 participants across five trials. Participation in exercise training improved sleep quality, with an SMD of 0.47 (95% CI 0.08 to 0.86) (Figure 2, see also Figure 3 on the eAddenda for a detailed forest plot.)

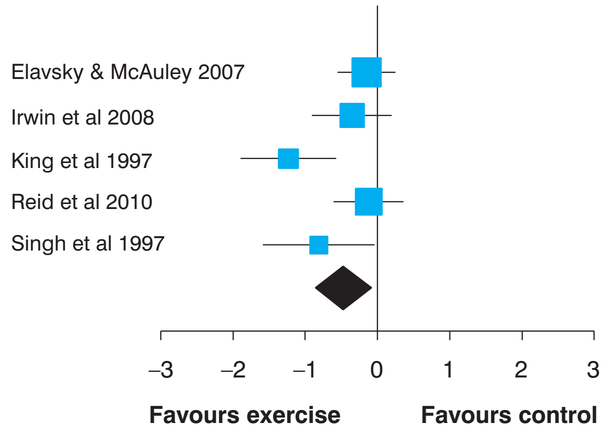

Figure 2. Standardised mean difference (95% CI) of the effect of exercise training on Pittsburgh Sleep Quality Index global score based on data from 5 studies (n = 288).

The effect of exercise training on the 'subjective sleep quality' subscale of the Pittsburgh Sleep Quality Index was examined by pooling data from 239 participants across five trials. Participation in exercise training improved sleep quality, with an SMD of 0.47 (95% CI 0.20 to 0.73) (Figure 4, see also Figure 5 on the eAddenda for a detailed forest plot.)

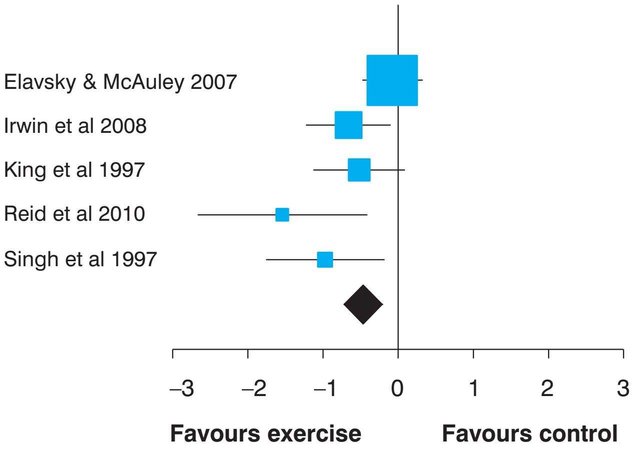

Figure 4. Standardised mean difference (95% CI) of the effect of exercise training on subjective sleep score (0 = good to 3 = poor) based on data from 5 studies (n = 239).

The effect of exercise training on the 'sleep latency' subscale of the Pittsburgh Sleep Quality Index was examined by pooling data from 239 participants across five trials. Participation in exercise training reduced (ie, improved) sleep latency, with an SMD of 0.58 (95% CI 0.08 to 1.08) (Figure 6, see also Figure 7 on the eAddenda for a detailed forest plot.)

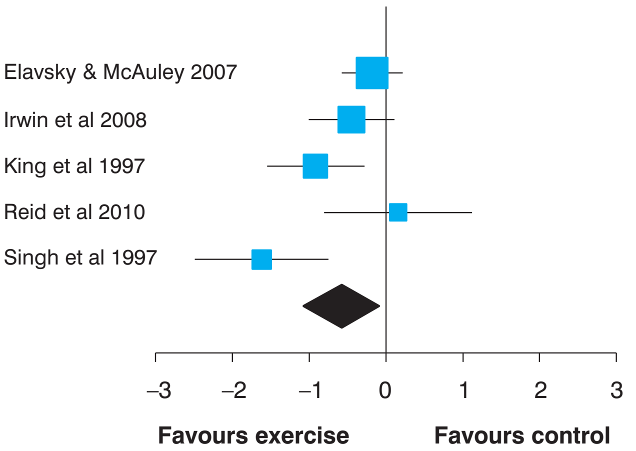

Figure 6. Standardised mean difference (95% CI) of the effect of exercise training on sleep latency score (0 = good to 3 = poor) based on analysis from 5 studies (n = 239).

Exercise training also reduced the use of medication to assist sleeping, with an SMD of 0.44 (95% CI 0.14 to 0.74) on the 'use of sleep medication' subscale of the Pittsburgh Sleep Quality Index. This was based on pooled data from 196 participants across four trials (Figure 8, see also Figure 9 on the eAddenda for a detailed forest plot.)

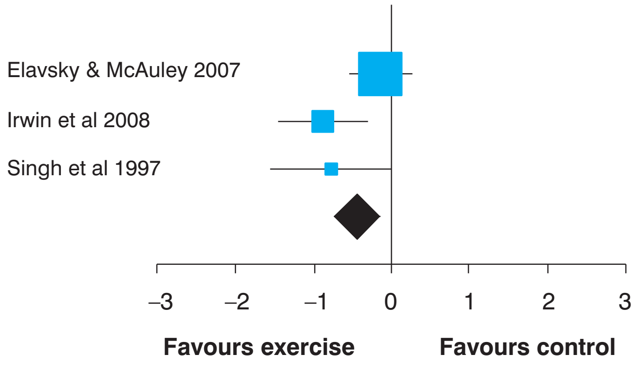

Figure 8. Standardised mean difference (95% CI) of the effect of exercise training on use of medication score (0 = good to 3 = poor), which was measured in 4 studies (n = 196). The data from one study (Reid et al 2010) could not be incorporated into the meta-analysis. See Figure 9 on the eAddenda for more detail.

Exercise training did not cause significant improvement in other domains of the Pittsburgh Sleep Quality Index, including sleep duration, sleep efficiency, sleep disturbance, and daytime functioning (see Figures 10 to 13 on the eAddenda.)

Objective sleep quality: Only one trial measured sleep quality objectively (King et al 2008). Polysomnography indicated that the subjects who had participated in exercise training spent a significantly lower percentage of time in Stage 1 sleep (between-group difference 2.3%, 95% CI 0.7 to 4.0, effect size = 0.66) and a greater percentage in Stage 2 sleep (between-group difference 3.2%, 95% CI 0.6 to 5.7, effect size = 0.41) relative to the control subjects. However, the study identified no other significant group differences regarding other polysomnographic parameters, such as sleep latency and efficiency after participation in the 12-month exercise training program.

Discussion

This meta-analysis provides a comprehensive review of randomised trials examining the effects of an exercise training program on sleep quality in middle-aged and older adults with sleep complaints including insomnia, depression, and poor sleep quality. Pooled analyses of the results indicate that exercise training has a moderate beneficial effect on sleep quality, as indicated by decreases in the global Pittsburgh Sleep Quality Index score, as well as its subdomains of subjective sleep quality, sleep latency, and sleep medication usage. Other sleep time parameters, including sleep duration, efficiency, and disturbance, were not found to improve significantly. These findings demonstrate that the participants did not sleep for a longer duration after participation in exercise training but they nevertheless perceived better sleep quality. Since poor sleep quality and total sleep time each predict adverse health outcomes in the elderly (Pollack et al 1990, Manabe et al 2000), optimal insomnia treatment should not only aim to improve quantity but also self-reported quality of sleep.

Several previous systematic reviews and meta-analyses also attempted to investigate the effect of exercise training on insomnia (Kubitz et al 1996, Montgomery and Dennis

2002, Montgomery and Dennis 2004). However, as most examined only one trial or several small trials, their findings could not provide an indication of the general effect of participation in exercise training on sleep quality (Montgomery and Dennis 2002). Moreover, many previous studies into the relationship between sleep and exercise examined individuals who either had no or relatively few sleep problems or who were relatively young – populations that generally have little scope to improve the quality of their sleep (Montgomery and Dennis 2003). In contrast, this review was able to meta-analyse substantial amounts of data from middle-aged and older adults with sleep problems, with clear effects apparent on several outcomes.

Exercise training improved global self-reported sleep quality with an effect size that was similar to that of sedative hypnotic administration in one systematic review (Nowell et al 1997). However, other meta-analyses of trials of hypnotics studies found much larger (1.20, Smith et al 2002) or smaller (0.14, Glass et al 2005) effect sizes. Therefore it is difficult to speculate about the relative effects of these two interventions.

In addition to medication, several non-pharmacological strategies, such as cognitive behavioural therapy, bright-light therapy, and self-help therapy, have been suggested as alternative treatments to improve sleep quality. One systematic review of non-pharmacological therapies for sleep problems suggested a mild effect of cognitive behavioural therapy on sleep problems in older adults, but evidence of the efficacy of bright light and exercise were limited (Montgomery and Dennis 2004). However, another meta-analysis of self-help therapy for insomnia reported that self-help intervention improves sleep efficiency (effect size = 0.42, $p < 0.05$), sleep latency (effect size = 0.29, $p < 0.05$), and sleep quality moderately (effect size = 0.33, $p < 0.05$) (van Straten and Cuijpers 2009). Our results showed that the effect of exercise training on sleep quality is comparable to those of non-pharmacological strategies.

Consideration of the mechanism underlying the effect of exercise on sleep was beyond the scope of this study, but is believed to consist of a complex set of activities that may be physiologically and psychologically beneficial. It has been proposed that exercise training improves sleep quality through increasing energy consumption, endorphin secretion, or body temperature in a manner that facilitates sleep for recuperation of the body (Horne and Moore 1985, Driver and Taylor 2000, Li et al 2004).

Further research could examine additional aspects of the effect of exercise training in this population. For example, the underlying cause of the sleep problem (eg, depression) and the type of insomnia (sleep initiation versus maintenance) may affect the response to exercise training. A threshold intensity or amount of exercise may be needed to affect sleep quality. The type and location of the exercise may also influence the benefit obtained. These points are important to consider in an elderly population, who may experience limitations in where and how they can exercise.

The meta-analysis examined the combined results of different studies to increase the overall statistical power and the precision of estimates while controlling for bias and limiting random error. Nevertheless, several limitations in generalising the findings must be acknowledged. First, a relatively small number of trials, all of which included a relatively small sample size, were examined. Trials reported in languages other than English and Chinese were excluded, as were trials reported only as abstracts. These exclusions may have led to publication bias. Also, more participants were female, making the observed effects less certain in men.

In summary, the results of this meta-analysis indicate that participation in exercise training has a moderately beneficial effect on sleep quality and decreases both sleep latency and use of sleep medication. These findings suggest that physical exercise therapy could be an alternative or complementary approach to existing therapies for sleep problems, especially since exercise is low cost, widely available and generally safe. ■

eAddenda: Figures 3, 5, 7, 9, 10, 11, 12, and 13 available at jop.physiotherapy.asn.au

Footnotes: [a]Review Manager Version 5; Nordic Cochrane Centre, Copenhagen, Denmark.

Correspondence: Meng-Yueh Chien, School and Graduate Institute of Physical Therapy, College of Medicine, National Taiwan University, Taipei, Taiwan. Email: mychien@ntu.edu.tw

References

Altena E, Van Der Werf YD, Strijers RL, Van Someren EJJ (2008) Sleep loss affects vigilance: effects of chronic insomnia and sleep therapy. *Journal of Sleep Research* 17: 335–343.

Baillargeon L, Demers M, Grégoire JP, Pépin M (1996) Study on insomnia treatment by family physicians. *Canadian Family Physician* 42: 426–432.

Bliswise DL (1996) Historical change in the report of daytime fatigue. *Sleep* 19: 462–464.

Buysse DJ, Reynolds III CF, Monk TH, Berman SR, Kupfer DJ (1989) The Pittsburgh Sleep Quality Index: a new instrument for psychiatric practice and research. *Psychiatry Research* 28: 193–213.

de Morton NA (2009) The PEDro scale is a valid measure of the methodological quality of clinical trials: a demographic study. *Australian Journal of Physiotherapy* 55: 129–133.

Driver HS, Taylor SR (2000) Exercise and sleep. *Sleep Medicine Reviews* 4: 387–402.

Elavsky S, McAuley E (2007) Lack of perceived sleep improvement after 4-month structured exercise programs. *Menopause* 14: 535–540.

Espie CA, Lindsay WR (1987) Cognitive strategies for the management of severe sleep maintenance insomnia: a preliminary investigation. *Behavioural Psychotherapy* 15: 388–395.

Fetveit A (2009) Late-life insomnia: a review. *Geriatrics and Gerontololy International* 9: 220–234.

Glass J, Lanctot KL, Herrmann N, Sproule BA, Busto UE (2005) Sedative hypnotics in older people with insomnia: meta-analysis of risks and benefits. *BMJ* 331: 1169.

Hatoum HT, Kania CM, Kong SX, Wong JM, Mendelson WB (1998) Prevalence of insomnia: a survey of the enrollees at five managed care organizations. *The American Journal of Managed Care* 4: 79–86.

Horne JA, Moore VJ (1985) Sleep EEG effects of exercise with and without additional body cooling. *Electroencephalography and Clinical Neurophysiology* 60: 33–38.

Irwin MR, Olmstead R, Motivala SJ (2008) Improving sleep quality in older adults with moderate sleep complaints: a randomized controlled trial of Tai Chi Chih. *Sleep* 31: 1001–1018.

Kao CC, Huang CJ, Wang MY, Tsai PS (2008) Insomnia: prevalence and its impact on excessive daytime sleepiness and psychological well-being in the adult Taiwanese population. *Quality of Life Research* 17: 1073–1080.

King AC, Oman RF, Brassington GS, Bliwise DL, Haskell WL (1997) Moderate-intensity exercise and self-rated quality of sleep in older adults. *JAMA* 277: 32–37.

King AC, Pruitt LA, Woo S, Castro CM, Ahn DK, Vitiello MV, et al (2008) Effects of moderate-intensity exercise on polysomnographic and subjective sleep quality in older adults with mild to moderate sleep complaints. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences* 63: 997–1004.

Knutson KL, Spiegel K, Penev P, Van Cauter E (2007) The metabolic consequences of sleep deprivation. *Sleep Medicine Reviews* 11: 163–178.

Kripke DF, Garfinkel L, Wingard DL, Klauber MR, Marler MR (2005) Mortality associated with sleep duration and insomnia. *Archives of General Psychiatry* 59: 131–136.

Kubitz KA, Landers DM, Petruzzello SJ, Han M (1996) The effects of acute and chronic exercise on sleep. *Sports Medicine* 21: 277–291.

Leger D, Guilleminault C, Dreyfus JP, Delahaye C, Paillard M (2000) Prevalence of insomnia in a survey of 12,778 adults in France. *Journal of Sleep Research* 9: 35–42.

Li F, Fisher KJ, Harmer P, Irbe D, Tearse RG, Weimer CJ (2004) Tai chi and self-rated quality of sleep and daytime sleepiness in older adults: a randomized controlled trial. *Journal of American Geriatrics Society* 52: 892–900.

Maher CG, Sherrington C, Herbert RD, Moseley AM, Elkins M (2003) Reliablity of the PEDro scale for rating quality of randomized controlled trials. *Physical Therapy* 83: 713–721.

Manabe K, Matsui T, Yamaya M, Sato-Nakagawa T, Okamura N, Arai H, et al (2000) Sleep patterns and mortality among elderly patients in a geriatric hospital. *Gerontology* 46: 318–322.

Mellinger GD, Balter MB, Uhlenhuth EH (1995) Insomnia and its treatment. *Archives of General Psychiatry* 42: 225–232.

Miller MA, Cappuccio FP (2007) Inflammation, sleep obesity and cardiovascular disease. *Current Vascular Pharmacology* 5: 93–102.

Montgomery P, Dennis JA (2002) Physical exercise for sleep problems in adults aged 60+. *Cochrane Database of Systematic Reviews* 4: CD003404

Montgomery P, Dennis J (2003) Cognitive behavioural interventions for sleep problems in adults aged 60+. *Cochrane Database of Systematic Reviews* 1: CD003161.

Montgomery P, Dennis J (2004) A systematic review of non-pharmacological therapies for sleep problems in later life. *Sleep Medicine Reviews* 8: 47–62.

Morgan K (2003) Daytime activity and risk factors for late-life insomnia. *Journal of Sleep Research* 12: 231–238.

Morin CM, Hauri PJ, Espie CA, Spielman AJ, Buysse DJ, Bootzin RR (1999a) Nonpharmacologic treatment of chronic insomnia. An American Academy of Sleep Medicine review. *Sleep* 22: 1134–1156.

Morin CM, Mimeault V, Gagne A (1999b) Nonpharmacological treatment of late-life insomnia. *Journal of Psychomatic Research* 46: 103–116.

Morin CM, LeBlane M, Daley M, Gregoire JP, Mérette C (2006) Epidemiology of insomnia: prevalence, self-help treatments, consultations, and determinants of help-seeking behaviors. *Sleep Medicine* 7: 123–130.

Morin CM, LeBlane M, Bélanger L, Ivers H, Mérette C, Savard J (2011) Prevalence of insomnia and its treatment in Canada. *Canadian Journal of Psychiatry* 56: 540–548.

Nowell PM, Mazumdar S, Buysse DJ, Dew MA, Reynolds CF 3rd, Kupfer DJ (1997) Benzodiazepines and zolpidem for chronic insomnia: a meta-analysis of treatment efficacy. *JAMA* 278: 2170–2177.

Ohayon MM (1996) Epidemiological study on insomnia in the general population. *Sleep* 19: 7–15.

Ohayon MM (2002) Epidemiology of insomnia: what we know and what we still need to learn. *Sleep Medicine Reviews* 6: 97–111.

Pearson NJ, Johnson LL, Nahin RL (2006) Insomnia, trouble sleeping, and complementary and alternative medicine. *Archives of Internal Medicine* 166: 1775–1782.

Pollack CP, Perlick D, Linsner JP, Wenston J, Hsieh F (1990) Sleep problems in the community elderly as predictors of death and nursing home placement. *The Journal of Community Health* 15: 123–135.

Reid KJ, Baron KG, Lu B, Naylor E, Wolfe L, Zee PC (2010) Aerobic exercise improves self-reported sleep and quality of life in older adults with insomnia. *Sleep Medicine* 11: 934–940.

Simon G, von Korff M (1997) Prevalence, burden and treatment of insomnia in primary care. *American Journal of Psychiatry* 154: 1417–1423.

Singh NA, Clements KM, Fiatarone MA (1997) A randomized controlled trial of the effect of exercise on sleep. *Sleep* 20: 95–101.

Singh NA, Clements KM, Singh MA (2001) The efficacy of exercise as a long-term antidepressant in elderly subjects: a randomized, controlled trial. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences* 56: M497–504.

Smith MT, Perlis ML, Park A, Smith MS, Pennington J, Giles DE, et al (2002) Comparative meta-analysis of pharmacotherapy and behavior therapy for persistent insomnia. *American Journal of Psychiatry* 159: 5–11.

Spiegel K, Tasali E, Leproult R, Van Cauter E (2009) Effects of poor and short sleep on glucose metabolism and obesity risk. *Nature Reviews Endocrinology* 5: 253–261.

Tworoger SS, Yasui Y, Vitiello MV, Schwartz RS, Ulrich CM, Aiello EJ, et al (2003) Effects of a yearlong moderate-intensity exercise and a stretching intervention on sleep quality in postmenopausal women. *Sleep* 26: 830–836.

van Straten A, Cuijpers P (2009) Self-help therapy for insomnia: a meta-analysis. *Sleep Medicine Reviews* 13: 61–71.

Youngstedt SD (2005) Effects of exercise on sleep. *Clinical Journal of Sport Medicine* 24: 355–365.