Evidence Portfolio – Brain Health Subcommittee, Question 4

What is the relationship between physical activity and sleep?

a. Is there a dose-response relationship for either acute bouts of physical activity, or regular physical activity? If yes, what is the shape of the relationship?
b. Does the relationship vary by age, sex, race/ethnicity, socio-economic status, or weight status?
c. Does the relationship exist for individuals with impaired sleep behaviors or disorders? If yes, for which sleep disorders?

Sources of Evidence: Existing Systematic Reviews and Meta-Analyses

Conclusion Statements and Grades

Strong evidence demonstrates that both acute bouts of physical activity and regular physical activity improve sleep outcomes in adults. **PAGAC Grade: Strong.**

Moderate evidence indicates that longer duration acute bouts of physical activity and regular physical activity improve sleep outcomes. These positive effects are independent of exercise intensity. **PAGAC Grade: Moderate.**

Moderate evidence indicates that the effects of physical activity on sleep outcomes in adults are preserved across age and sex, with the exception of sleep onset latency, which declines with age. **PAGAC Grade: Moderate.**

Insufficient evidence is available to examine relationships between physical activity and sleep in children and adolescents and whether the relationships vary according to race/ethnicity, socioeconomic status, or weight status. **PAGAC Grade: Not assignable.**

Moderate evidence indicates that greater amounts of moderate-to-vigorous physical activity improves sleep in adults who report sleep problems, primarily symptoms of insomnia, and for obstructive sleep apnea. **PAGAC Grade: Moderate.**

Description of the Evidence

An initial search for systematic reviews, meta-analyses, pooled analyses, and reports identified sufficient literature to answer the research question as determined by the Brain Health Subcommittee. Additional searches for original research were not needed.

Existing Systematic Reviews and Meta-Analyses

Overview

A total of 15 existing reviews were included: 6 systematic reviews[1-6] and 9 meta-analyses.[7-15] The reviews were published between 2011 and 2017.

The systematic reviews included a range of 2 to 34 studies and covered extensive search timeframes: from inception to 2010,[1] inception to 2011,[2] 1983 to 2011,[5] 1985 to 2014,[4] and 2013 to 2017.[3] One systematic review did not report a search timeframe.[6]

The meta-analyses included a range of 5 to 80 studies. Most meta-analyses covered extensive timeframes: from inception to 2012,[14] inception to 2013,[9, 11] inception to 2014,[7, 12] inception to 2015,[10] inception to 2015,[13] 1985 to 2016,[15] and 2003 to 2014.[8]

Exposures

The majority of included reviews examined self-reported physical activity, and few used accelerometers or pedometers to measure physical activity.[2, 12, 15] Several reviews examined physical activity interventions that incorporated aerobic[1, 4, 5, 10, 13, 14] and resistance exercises,[4, 10, 14] while 1 review addressed the effects of a combination of aerobic and resistance training.[10] Four reviews examined walking interventions,[1, 4, 5, 14] and 3 reviews assessed tai chi.[1, 4, 14] Reviews also examined interventions that incorporated yoga,[4, 13] sedentary behavior,[2, 15] stretching,[4] and lifestyle physical activity such as gardening, housework, stair climbing, and dancing.[4] Several reviews examined general physical activity, exercise, or sports participation interventions.[3, 6-8, 11, 12]

Outcomes

Included reviews addressed the sleep outcomes in a variety of ways, including sleep behavior,[5, 8] sleep apnea,[15] obstructive sleep apnea,[7, 9, 10] sleep efficiency[3, 5, 10, 11, 14] and efficacy,[12] sleep quality,[1-6, 11-15] and insomnia.[1, 5, 6, 13, 15] Various tools were used to measure sleep outcomes, including diaries, the Apnea/Hypopnea Index, the Epworth Sleepiness Scale, Pittsburgh Sleep Quality Index, Insomnia Severity Index, polysomnography, and electroencephalogram.

Populations Analyzed

The table below lists the populations analyzed in each article.

Table 1. Populations Analyzed by All Sources of Evidence

	Sex	Age	Chronic Conditions
Aiello, 2016		Age 32–54	Obstructive sleep apnea
Alessi, 2011		Age >=60	Insomnia
Bartel, 2015		Age 10–23	
Costigan, 2013	Female	Age 12–18	
Dolezal, 2017		Adolescents through older adults	
Iftikhar, 2017		Adults	Sleep apnea
Iftikhar, 2014		Adults	Obstructive sleep apnea
Kredlow, 2015		Age 18.3–88.5	
Lambert, 2016		Adults	
Lang, 2016		Age 14–24	
Passos, 2012		Middle age and older adults	Chronic insomnia or sleep complaints
Rubio-Arias, 2017	Female	Mean age 48.6–55.8	
Smagula, 2016		Older adults	
Yang, 2012		Age >40	Sleep complaints (insomnia, depression, or poor sleep quality)
Yang, 2017		Ages 18–100; 18–35; 36–55; >55	

Supporting Evidence

Existing Systematic Reviews and Meta-Analyses

Table 2. Existing Systematic Reviews and Meta-Analyses Individual Evidence Summary Tables

<table>
<tr><td colspan="2">Meta-Analysis
Citation: Aiello KD, Caughey WG, Nelluri B, Sharma A, Mookadam F, Mookadam M. Effect of exercise training on sleep apnea: a systematic review and meta-analysis. Respir Med. 2016;116:85-92. doi:10.1016/j.rmed.2016.05.015.</td></tr>
<tr><td>Purpose: To study the use of exercise (supervised and unsupervised) as management treatment for obstructive sleep apnea (OSA) by analyzing the difference in pre- and post-intervention apnea/hypopnea index in adult patients with OSA, and evaluating the effects of exercise on Epworth sleepiness scale.</td><td rowspan="5">Abstract: INTRODUCTION: Obstructive sleep apnea (OSA) is difficult to manage for those who are intolerant or noncompliant with standard facial mask treatment options. Current treatment options do not address the underlying cause of OSA. Exercise as a treatment option has been found to improve OSA indices. STUDY OBJECTIVES: To assess the efficacy of exercise on apnea/hypopnea index (AHI) in adult patients with OSA via a systematic review and meta-analysis. Additional objectives included evaluation of other indices of OSA and well-being in patients after completing an exercise regimen. MEASUREMENTS AND RESULTS: Web of Science, MEDLINE, CINAHL, and Cochrane Central Register of Controlled Trials were searched based on a priori criteria of all studies evaluating the effect of an exercise program on various sleep apnea indices. Both PRISMA statement and MOOSE consensus statement were adhered to. Eight Articles (182 participants) were included: a meta-analysis using a random effects model showed, a decrease in AHI (unstandardized mean difference [USMD], -0.536, 95% confidence interval [CI], -0.865 to -0.206, I(2), 20%), reduced Epworth sleepiness scale (ESS) (USMD, -1.246, 95% CI, -2.397 to -0.0953, I(2), 0%), and lower body mass index (BMI) (USMD, -0.0473, 95% CI, -0.0375 to 0.280, I(2), 0%), in patients receiving exercise as treatment. Relative risks (RR) and odds ratios (OR) showed decreases in AHI (OR: 72.33, 95% CI, 27.906 to 187.491, RR: 7.294, 95% CI, 4.072 to 13.065) in patients receiving exercise as treatment. CONCLUSION: Among adult patients with OSA, exercise as the sole intervention was associated with improved clinical outcomes.</td></tr>
<tr><td>Timeframe: Inception–2014</td></tr>
<tr><td>Total # of Studies: 8</td></tr>
<tr><td>Exposure Definition: Supervised and unsupervised exercise programs, ranging from 2 months to 6 months, 2–7x/wk for 30–150 minutes/session. Exercise protocols ranged from aerobic exercise (e.g., walking/running on treadmill, stair climbing, Airdyne® machine, stationary bicycle), resistance training, and oropharyngeal exercises.
Measures Steps: No
Measures Bouts: No
Examines HIIT: No</td></tr>
<tr><td>Outcomes Addressed:
Apnea/hypopnea index (AHI) and Epworth sleepiness scale.
Examine Cardiorespiratory Fitness as Outcome: No</td></tr>
<tr><td>Populations Analyzed: Age 32–54, Obstructive sleep apnea</td><td>Author-Stated Funding Source: No funding source used.</td></tr>
</table>

Systematic Review **Citation:** Alessi C, Vitiello MV. Insomnia (primary) in older people. *BMJ Clin Evid.* Oct 2011;pii:2302.	
Purpose: To investigate the effects of drug and non-drug treatments for primary insomnia in older people (aged 60 years and older). **Timeframe:** Inception–December 2010 **Total # of Studies:** 34 (2 adressing exercise) **Exposure Definition:** Exercise programs were moderate intensity exercise (walking, low impact aerobics, and Tai Chi), and lasted for at least three times a week. Programs were at least 16 weeks long and varied in their length of sessions. **Measures Steps:** No **Measures Bouts:** No **Examines HIIT:** No **Outcomes Addressed:** Sleep quality: Pittsburgh Sleep Quality Index scores and change sleep quality score. **Examine Cardiorespiratory Fitness as Outcome:** No	**Abstract:** INTRODUCTION: Up to 40% of older adults have insomnia, with difficulty getting to sleep, early waking, or feeling unrefreshed on waking. The prevalence of insomnia increases with age. Other risk factors include psychological factors, stress, daytime napping, and hyperarousal. METHODS AND OUTCOMES: We conducted a systematic review and aimed to answer the following clinical questions: What are the effects of non-drug treatments for insomnia in older people? What are the effects of drug treatments for insomnia in older people? We searched: Medline, Embase, The Cochrane Library, and other important databases up to December 2010 (Clinical Evidence reviews are updated periodically, please check our website for the most up-to-date version of this review). We included harms alerts from relevant organisations such as the US Food and Drug Administration (FDA) and the UK Medicines and Healthcare products Regulatory Agency (MHRA). RESULTS: We found 34 systematic reviews, RCTs, or observational studies that met our inclusion criteria. We performed a GRADE evaluation of the quality of evidence for interventions. CONCLUSIONS: In this systematic review, we present information relating to the effectiveness and safety of the following interventions: antidepressants, benzodiazepines, cognitive behavioural therapy (CBT), diphenhydramine, exercise programmes, timed exposure to bright light, zaleplon, zolpidem, and zopiclone.
Populations Analyzed: Age ≥60, Insomnia	**Author-Stated Funding Source:** Not reported.

Meta-Analysis **Citation:** Bartel KA, Gradisar M, Williamson P. Protective and risk factors for adolescent sleep: a meta-analytic review. *Sleep Med Rev.* 2015;21:72-85. doi:10.1016/j.smrv.2014.08.002.	
Purpose: To determine the protective and risk factors for adolescent sleep. **Timeframe:** 2003–February 2014 **Total # of Studies:** 41 **Exposure Definition:** General PA, exercise, or sports participation. **Measures Steps:** No **Measures Bouts:** No **Examines HIIT:** No **Outcomes Addressed:** Bedtime. Sleep onset latency. Total sleep time. **Examine Cardiorespiratory Fitness as Outcome:** No	**Abstract:** Teenagers need sufficient sleep to function well daily, yet consolidated evidence advising which factors protect, or harm, adolescents' sleep is lacking. Forty-one studies, published between 2003 and February, 2014, were meta-analysed. Mean weighted r values were calculated to better understand the strength of protective and risk factors for 85,561 adolescents' (age range = 12-18 y) bedtime, sleep onset latency (SOL) and total sleep time (TST). Results showed good sleep hygiene and physical activity were associated with earlier bedtimes. Video gaming, phone, computer and internet use, and evening light related to delayed bedtimes. Good sleep hygiene negatively correlated with sleep latency. Alternatively, sleep latency lengthened as a negative family environment increased. Tobacco, computer use, evening light, a negative family environment and caffeine were associated with decreased total sleep, whereas good sleep hygiene and parent-set bedtimes related to longer sleep length. Good sleep hygiene appears to be protective, whereas a negative home environment and evening light appear to be risk factors. Cautious use of technology (other than television), caffeine, tobacco and alcohol should be considered. These factors, along with pre-sleep worry, are likely to have some negative impact on sleep. Parent-set bedtimes and physical activity may be beneficial. Future research directions are discussed.
Populations Analyzed: Age 10–23	**Author-Stated Funding Source:** Not reported.

<table>
<tr><td colspan="2">Systematic Review
Citation: Costigan SA, Barnett L, Plotnikoff RC, Lubans DR. The health indicators associated with screen-based sedentary behavior among adolescent girls: a systematic review. J Adolesc Health. 2013;52(4):382-392. doi:10.1016/j.jadohealth.2012.07.018.</td></tr>
<tr><td>Purpose: To investigate the association between time spent engaging in recreational screen based sedentary behavior (specifically television viewing, computer/Internet use, and/or electronic gaming) and the physical, behavioral, and psychosocial health indicators in adolescent girls.</td><td rowspan="5">Abstract: PURPOSE: Evidence suggests sitting time is independently associated with a range of health issues in adults, yet the relationship between sedentary behavior and health indicators in young people is less clear. Age-related increases in sedentary behavior are well-documented; the behavioral patterns of adolescent girls are of particular concern. More than one third of adolescent girls' sedentary behavior time is accumulated through use of recreational screen-based behaviors. The objective of this review was to investigate the association between recreational screen-based sedentary behavior and the physical, behavioral, and psychosocial health indicators for adolescent girls. A secondary objective was to identify studies that have adjusted sedentary behavior indicators for physical activity. METHODS: A structured electronic search of all publication years (through December 2011) was conducted to identify studies in: CINAHL, Communications and Mass Media Complete, ERIC, MEDLINE with Full Text, PsycINFO, and SPORTDiscus with Full Text. Included publications were observational and interventional studies involving adolescent girls (12-18 years) that examined associations between screen-based, sedentary behavior and health indicators (physical, psychosocial, and/or behavioral). The search identified 33 studies that evaluated health indicators of screen-based sedentary behaviors among adolescent girls. RESULTS: Strong evidence for a positive association between screen-based sedentary behavior and weight status was found. A positive association was observed between screen-time and sleep problems, musculoskeletal pain and depression. Negative associations were identified between screen time and physical activity/fitness, screen time and psychological well-being, and screen time and social support. The relationship between screen-based sedentary behavior and diet quality was inconclusive. Less than half of the studies adjusted sedentary behavior indicators for physical activity. CONCLUSIONS: Screen-based sedentary behavior is associated with a range of adverse health consequences, but additional longitudinal studies are needed to better understand the health impacts. In addition, screen-time guidelines for youth should be regularly revised and updated to reflect rapid technological changes.</td></tr>
<tr><td>Timeframe: Inception–December 2011</td></tr>
<tr><td>Total # of Studies: 33 total (2 only addressing sleep outcome)</td></tr>
<tr><td>Exposure Definition: Leisure-time screen-based sedentary behavior was observed during television, video, sedentary electronic gaming, and computer and internet usage activities. Data were self-reported using questionnaires/surveys, behavior recall, or accelerometer and observation.
Measures Steps: No
Measures Bouts: No
Examines HIIT: No</td></tr>
<tr><td>Outcomes Addressed: Sleep problems.
Examine Cardiorespiratory Fitness as Outcome: No</td></tr>
<tr><td>Populations Analyzed: Female, Age 12–18</td><td>Author-Stated Funding Source: National Health and Medical Research Council Australia.</td></tr>
</table>

Systematic Review **Citation:** Dolezal BA, Neufeld EV, Boland DM, Martin JL, Cooper CB. Interrelationship between sleep and exercise: a systematic review. *Adv Prev Med.* 2017;2017:1364387. doi:10.1155/2017/1364387.	
Purpose: To summarize the most recent literature exploring how different modalities of exercise influence the subjective and objective qualities of sleep.	**Abstract:** Although a substantial body of literature has explored the relationship between sleep and exercise, comprehensive reviews and definitive conclusions about the impact of exercise interventions on sleep are lacking. Electronic databases were searched for articles published between January 2013 and March 2017. Studies were included if they possessed either objective or subjective measures of sleep and an exercise intervention that followed the guidelines recommended by the American College of Sports Medicine. Thirty-four studies met these inclusion criteria. Twenty-nine studies concluded that exercise improved sleep quality or duration; however, four found no difference and one reported a negative impact of exercise on sleep. Study results varied most significantly due to participants' age, health status, and the mode and intensity of exercise intervention. Mixed findings were reported for children, adolescents, and young adults. Interventions conducted with middle-aged and elderly adults reported more robust results. In these cases, exercise promoted increased sleep efficiency and duration regardless of the mode and intensity of activity, especially in populations suffering from disease. Our review suggests that sleep and exercise exert substantial positive effects on one another; however, to reach a true consensus, the mechanisms behind these observations must first be elucidated.
Timeframe: 2013–March 2017	
Total # of Studies: 34	
Exposure Definition: Exercise intervention that followed the guidelines recommended by the American College of Sports Medicine. **Measures Steps:** No **Measures Bouts:** No **Examines HIIT:** No	
Outcomes Addressed: Sleep: Objective (polysomnography, actigraphy, and accelerometry), or subjective (Pittsburg Sleep Quality Index, another self-report, and proxy-report) measures. **Examine Cardiorespiratory Fitness as Outcome:** No	
Populations Analyzed: Adolescents through older adults	**Author-Stated Funding Source:** Not reported.

<table>
<tr><td colspan="2">Meta-Analysis
Citation: Iftikhar IH, Bittencourt L, Youngstedt SD, et al. Comparative efficacy of CPAP, MADs, exercise-training, and dietary weight loss for sleep apnea: a network meta-analysis. Sleep Med. 2017;30:7-14. doi:10.1016/j.sleep.2016.06.001.</td></tr>
<tr><td>Purpose: To synthesize evidence from available studies to compare the efficacies of supervised aerobic exercise training (studied as a singular intervention), dietary weight loss, mandibular advancement devices, and continuous positive airway pressure in the treatment of sleep apnea.</td><td rowspan="5">Abstract: STUDY OBJECTIVE: To synthesize evidence from available studies on the relative efficacies of continuous positive airway pressure (CPAP), mandibular advancement device (MAD), supervised aerobic exercise training, and dietary weight loss in patients with obstructive sleep apnea (OSA). DESIGN: Network meta-analysis of 80 randomized controlled trials (RCTs) short-listed from PubMed, SCOPUS, Web of science, and Cochrane register (inception - September 8, 2015). PATIENTS: Individuals with OSA. INTERVENTIONS: CPAP, MADs, exercise training, and dietary weight loss. RESULTS: CPAP decreased apnea-hypopnea index (AHI) the most [by 25.27 events/hour (22.03-28.52)] followed by exercise training, MADs, and dietary weight loss. While the difference between exercise training and CPAP was non-significant [-8.04 (-17.00 to 0.92), a significant difference was found between CPAP and MADs on AHI and oxygen desaturation index (ODI) [-10.06 (-14.21 to -5.91) and -7.82 (-13.04 to -2.59), respectively]. Exercise training significantly improved Epworth sleepiness scores (ESS) [by 3.08 (0.68-5.48)], albeit with a non-significant difference compared to MADs and CPAP. CONCLUSIONS: CPAP is the most efficacious in complete resolution of sleep apnea and in improving the indices of saturation during sleep. While MADs offer a reasonable alternative to CPAP, exercise training which significantly improved daytime sleepiness (ESS) could be used as adjunctive to the former two.</td></tr>
<tr><td>Timeframe: Inception–September 2015</td></tr>
<tr><td>Total # of Studies: 80</td></tr>
<tr><td>Exposure Definition: Supervised and aerobic exercise training.
Measures Steps: No
Measures Bouts: No
Examines HIIT: No</td></tr>
<tr><td>Outcomes Addressed: Apnea-hypopnia index, Epworth Sleepiness Scale, Oxygen desaturation index, sleep efficiency, O2 nadir.
Examine Cardiorespiratory Fitness as Outcome: No</td></tr>
<tr><td>Populations Analyzed: Adults, Sleep apnea</td><td>Author-Stated Funding Source: No funding source used.</td></tr>
</table>

<table>
<tr><td colspan="2">Meta-Analysis
Citation: Iftikhar IH, Kline CE, Youngstedt SD. Effects of exercise training on sleep apnea: a meta-analysis. Lung. 2014;192(1):175-184. doi:10.1007/s00408-013-9511-3.</td></tr>
<tr><td>Purpose: To evaluate the efficacy of exercise training on obstructive sleep apnea severity reduction in adults with obstructive sleep apnea.</td><td rowspan="4">Abstract: BACKGROUND: Several studies have shown a favorable effect of supervised exercise training on obstructive sleep apnea (OSA). This meta-analysis was conducted to analyze the data from these studies on the severity of OSA (primary outcome) in adults. Secondary outcomes of interest included body mass index (BMI), sleep efficiency, daytime sleepiness and cardiorespiratory fitness. METHODS: Two independent reviewers searched PubMed and Embase (from inception to March 6, 2013) to identify studies on the effects of supervised exercise training in adults with OSA. Pre- and postexercise training data on our primary and secondary outcomes were extracted. RESULTS: A total of 5 studies with 6 cohorts that enrolled a total of 129 study participants met the inclusion criteria. The pooled estimate of mean pre- to postintervention (exercise) reduction in AHI was -6.27 events/h (95 % confidence interval [CI] -8.54 to -3.99; p < 0.001). The pooled estimates of mean changes in BMI, sleep efficiency, Epworth sleepiness scale and VO2 peak were -1.37 (95 % CI -2.81 to 0.07; p = 0.06), 5.75 % (95 % CI 2.47-9.03; p = 0.001), -3.3 (95 % CI -5.57 to -1.02; p = 0.004), and 3.93 mL/kg/min (95 % CI 2.44-5.42; p < 0.001), respectively. CONCLUSIONS: This meta-analysis shows a statistically significant effect of exercise in reducing the severity of sleep apnea in patients with OSA with minimal changes in body weight. Additionally, the significant effects of exercise on cardiorespiratory fitness, daytime sleepiness, and sleep efficiency indicate the potential value of exercise in the management of OSA.</td></tr>
<tr><td>Timeframe: Inception–March 2013</td></tr>
<tr><td>Total # of Studies: 5</td></tr>
<tr><td>Exposure Definition: Exercise interventions including aerobic, resistance, or a combination of both.
Measures Steps: No
Measures Bouts: No
Examines HIIT: No</td></tr>
<tr><td>Outcomes Addressed: Obstructive sleep apnea severity reduction: Apnea-hyopnea index. Sleep efficiency: Polysomnography. Daytime sleepiness: Epworth Sleepiness Scale.
Examine Cardiorespiratory Fitness as Outcome: Yes</td></tr>
<tr><td>Populations Analyzed: Adults, Obstructive sleep apnea</td><td>Author-Stated Funding Source: National Institutes of Health.</td></tr>
</table>

<table>
<tr><td colspan="2">Meta-Analysis
Citation: 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(3):427-449. doi:10.1007/s10865-015-9617-6.</td></tr>
<tr><td>Purpose: To examine the effects of acute and regular exercise on a range of sleep variables and explore the impact of potential moderators of these outcomes.</td><td rowspan="4">Abstract: A significant body of research has investigated the effects of physical activity on sleep, yet this research has not been systematically aggregated in over a decade. As a result, the magnitude and moderators of these effects are unclear. This meta-analytical review examines the effects of acute and regular exercise on sleep, incorporating a range of outcome and moderator variables. PubMed and PsycINFO were used to identify 66 studies for inclusion in the analysis that were published through May 2013. Analyses reveal that acute exercise has small beneficial effects on total sleep time, sleep onset latency, sleep efficiency, stage 1 sleep, and slow wave sleep, a moderate beneficial effect on wake time after sleep onset, and a small effect on rapid eye movement sleep. Regular exercise has small beneficial effects on total sleep time and sleep efficiency, small-to-medium beneficial effects on sleep onset latency, and moderate beneficial effects on sleep quality. Effects were moderated by sex, age, baseline physical activity level of participants, as well as exercise type, time of day, duration, and adherence. Significant moderation was not found for exercise intensity, aerobic/anaerobic classification, or publication date. Results were discussed with regards to future avenues of research and clinical application to the treatment of insomnia.</td></tr>
<tr><td>Timeframe: Inception–May 2013</td></tr>
<tr><td>Total # of Studies: 63</td></tr>
<tr><td>Exposure Definition: Acute defined as less than one week of exercise, duration was predominantly 1 day. Regular physical activity defined as equal to or greater than one week of exercise, duration ranged from 2 to 52 weeks.
Measures Steps: No
Measures Bouts: No
Examines HIIT: No</td></tr>
<tr><td>Outcomes Addressed: Total sleep time. Sleep onset latency. Sleep efficiency. Wake time after sleep onset: Sleep diaries, self-report questionnaires, electroencephalogram (EEG), and polysomnography (PSG). Examine Cardiorespiratory Fitness as Outcome: No</td></tr>
<tr><td>Populations Analyzed: Age 18.3–88.5</td><td>Author-Stated Funding Source: Not reported.</td></tr>
</table>

<table>
<tr><td colspan="2">Systematic Review
Citation: Lambert SD, Duncan LR, Kapellas S, et al. A descriptive systematic review of physical activity interventions for caregivers: effects on caregivers' and care recipients' psychosocial outcomes, physical activity levels, and physical health. Ann Behav Med. 2016;50(6):907-919.</td></tr>
<tr><td>Purpose: To examine the effects of PA interventions on caregivers' psychosocial outcomes, physical activity levels, and physical health and, if reported, on the care recipients' outcomes as well.</td><td rowspan="5">Abstract: BACKGROUND: Caregiving can adversely impact individuals' psychosocial and physical well-being. An important task in health research is to find effective ways to enhance caregivers' health and functioning. PURPOSE: To provide a systematic review of the efficacy of physical activity (PA) interventions for caregivers on their and the care recipients' psychosocial outcomes, PA levels, and physical health. METHODS: Following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) checklist, a descriptive systematic review of studies examining the effects of PA interventions for caregivers on their outcomes and those of the care recipients was conducted. Studies were primarily identified through searching electronic databases. RESULTS: Fourteen studies were reviewed. PA interventions significantly decreased caregivers' distress and increased their well-being, quality of life, sleep quality, PA levels, self-efficacy for caregiving or exercise, and readiness for exercise. Most PA interventions targeted the caregiver alone. Two studies examined the impact of the intervention on the care recipient and found no significant effect. CONCLUSIONS: PA interventions hold promise in improving caregivers' outcomes. However, more high quality trials are needed before definitive conclusions can be drawn.</td></tr>
<tr><td>Timeframe: 1985–2014</td></tr>
<tr><td>Total # of Studies: 14 total (2 with sleep outcomes)</td></tr>
<tr><td>Exposure Definition: Variety of PA, including walking, yoga, meditation, aerobic exercise, Tai Chi, strength training, stretching, and/or lifestyle PA like gardening, housework, stair climbing, and dancing. Interventions varied in length and frequency with a range of 6 weeks to 12 months with a weekly class to almost daily exercise.
Measures Steps: No
Measures Bouts: No
Examines HIIT: No</td></tr>
<tr><td>Outcomes Addressed: Sleep quality.
Examine Cardiorespiratory Fitness as Outcome: No</td></tr>
<tr><td>Populations Analyzed: Adults</td><td>Author-Stated Funding Source: Prostate Cancer Canada.</td></tr>
</table>

<table>
<tr><td colspan="2">Meta-Analysis
Citation: Lang C, Kalak N, Brand S, Holsboer-Trachsler E, Pühse U, Gerber M. The relationship between physical activity and sleep from mid adolescence to early adulthood. A systematic review of methodological approaches and meta-analysis. Sleep Med Rev. 2016;28:32-45. doi:10.1016/j.smrv.2015.07.004.</td></tr>
<tr><td>Purpose: To examine the variations in measurement methods for PA and sleep from mid adolescence to early adulthood.</td><td rowspan="4">Abstract: Physical activity (PA) is considered an effective, non-pharmacological approach to improve sleep. However, the accurate measurement of PA and sleep among adolescents is fraught with challenges. Additionally, comparing the results of different studies is often difficult due to the diversity of assessment tools, analyses and data reporting procedures used. While previous reviews have considered variables that may confound this relationship, this systematic review examines the variations in measurement methods. Based on this overview, a meta-analysis was performed to assess possible influences of the various approaches on effect sizes. Twenty-one studies were included in the systematic review, of which 12 were appropriate for meta-analysis. For this, four subgroups were formed: subjective PA and subjective sleep, objective PA and subjective sleep, subjective PA and objective sleep, and objective PA and objective sleep. The majority of studies used subjective measures, often with unknown reliability or validity. Few studies employed objective tools to measure sleep. The results suggest that adolescents with higher subjective and objective PA are more likely to experience good sleep subjectively and objectively. More studies employing subjective and objective measures for both PA and sleep are needed. Researchers should take into account several assessment factors unique to the adolescent population.</td></tr>
<tr><td>Timeframe: Inception–June 2014</td></tr>
<tr><td>Total # of Studies: 21 (12 in meta-analysis)</td></tr>
<tr><td>Exposure Definition: Different levels of regular PA. Subgroup analyses conducted by objective (accelerometer and pedometer) versus subjective (self-reported) PA measurement.
Measures Steps: No
Measures Bouts: No
Examines HIIT: No</td></tr>
<tr><td>Outcomes Addressed: Sleep quality score: Survey questionnaire or diary. Sleep efficacy: Electroencephalogram.
Examine Cardiorespiratory Fitness as Outcome: No</td></tr>
<tr><td>Populations Analyzed: Age 14–24</td><td>Author-Stated Funding Source: Not reported.</td></tr>
</table>

<table>
<tr><td colspan="2">Systematic Review
Citation: Passos GS, Poyares DL, Santana MG, Tufik S, Mello MT. Is exercise an alternative treatment for chronic insomnia? Clinics (Sao Paulo). 2012;67(6):653-660.</td></tr>
<tr><td>Purpose: To compare results of exercise to the use of hypnotic medications on insomnia and sleep complaints, and discuss potential mechanisms by which exercise could improve sleep in insomniac patients.</td><td rowspan="4">Abstract: The purposes of this systematic/critical review are: 1) to identify studies on the effects of exercise on chronic insomnia and sleep complaints in middle-aged and older adults and to compare the results of exercise with those obtained with hypnotic medications and 2) to discuss potential mechanisms by which exercise could promote sleep in insomniac patients. We identified studies from 1983 through 2011 using MEDLINE, SCOPUS and Web of Science. For systematic analyses, only studies assessing the chronic effects of exercise on sleep in people with sleep complaints or chronic insomnia were considered. We used the following keywords when searching for articles: insomnia, sleep, sleep complaints, exercise and physical activity. For a critical review, studies were selected on the effects of exercise and possible mechanisms that may explain the effects of exercise on insomnia. We identified five studies that met our inclusion criteria for systematic review. Exercise training is effective at decreasing sleep complaints and insomnia. Aerobic exercise has been more extensively studied, and its effects are similar to those observed after hypnotic medication use. Mechanisms are proposed to explain the effects of exercise on insomnia. There is additional documented evidence on the antidepressant and anti-anxiety effects of exercise. Exercise is effective to decrease sleep complaints and to treat chronic insomnia. Exercise presented similar results when compared with hypnotics; however, prospective studies comparing the effects of exercise with medical and non-medical treatments are warranted before including exercise as a first-line treatment for chronic insomnia are necessary.</td></tr>
<tr><td>Timeframe: 1983–2011</td></tr>
<tr><td>Total # of Studies: 5</td></tr>
<tr><td>Exposure Definition: Exercise programs included moderate aerobic exercise (such as walking) and lasted for at least 4 weeks. Programs varied in length of sessions and frequency.
Measures Steps: No
Measures Bouts: No
Examines HIIT: No</td></tr>
<tr><td>Outcomes Addressed: Total sleep time: Polysomnography. Sleep duration: Pittsburgh sleep quality index. Wake after sleep onset: Polysomnography). Sleep efficiency: Polysomnography): Sleep onset latency: Pittsburgh sleep quality index. Sleep quality and its sub scales: Pittsburgh Sleep Quality Index.
Examine Cardiorespiratory Fitness as Outcome: No</td></tr>
<tr><td>Populations Analyzed: Middle age and older adults, Chronic insomnia or sleep complaints</td><td>Author-Stated Funding Source: Associação Fundo de Incentivo à Pesquisa (AFIP), Centro de Estudos em Psicobiologia e Exercício (CEPE), Fundação de Amparo à Pesquisa do Estado de São Paulo, Centros de Pesquisa, Inovação e Difusão (CEPID/FAPESP).</td></tr>
</table>

<table>
<tr><td colspan="2">Meta-Analysis
Citation: Rubio-Arias JÁ, Marín-Cascales E, Ramos-Campo DJ, Hernandez AV, Pérez-López FR. Effect of exercise on sleep quality and insomnia in middle-aged women: a systematic review and meta-analysis of randomized controlled trials. Maturitas. 2017;100:49-56. doi:10.1016/j.maturitas.2017.04.003.</td></tr>
<tr><td>Purpose: To assess the effect of short-term exercise programs on the quality of sleep and insomnia.</td><td rowspan="5">Abstract: OBJECTIVE: We assessed the effects of programmed exercise (PE) on sleep quality and insomnia in middle-aged women (MAW). METHODS: Searches were conducted in five databases from inception through December 15, 2016 for randomized controlled trials (RCTs) evaluating the effects of PE versus a non-exercising control condition on sleep quality, sleep disturbance and/or insomnia in MAW. Interventions had to last at least 8 weeks. Sleep quality was assessed with the Pittsburgh Sleep Quality Index (PSQI) and insomnia with the Insomnia Severity Index (ISI). Random effects models were used for meta-analyses. The effects on outcomes were expressed as mean differences (MDs) and their 95% confidence intervals (CI). RESULTS: Five publications reported data from four RCTs on PE effects during 12-16 weeks on sleep quality (n=4 studies reporting PSQI results) and/or insomnia (n=3 studies reporting ISI results), including 660 MAW. Low-moderate levels of exercise significantly lowered the PSQI score (MD=-1.34; 95% CI -2.67, 0.00; p=0.05) compared with controls. In a subgroup analysis, moderate PE (aerobic exercise) had a positive effect on sleep quality (PSQI score MD=-1.85; 95% CI -3.62, -0.07; p=0.04), while low levels of physical activity (yoga) did not have a significant effect (MD-0.46, 95% CI -1.79, 0.88, p=0.50). In three studies (two studies of yoga, one study of aerobic exercise), there was a non-significant reduction in the severity of insomnia measured with the ISI score (MD -1.44, 95% CI -3.28, 0. 44, p=0.13) compared with controls. Heterogeneity of effects among studies was moderate to high. CONCLUSION: In middle-aged women, programmed exercise improved sleep quality but had no significant effect on the severity of insomnia.</td></tr>
<tr><td>Timeframe: Inception–December 2016</td></tr>
<tr><td>Total # of Studies: 5</td></tr>
<tr><td>Exposure Definition: Programmed regular PA or exercise lasting at least 8 weeks. Duration ranged from 12 to 16 weeks. Subgroup analysis by aerobic activity and yoga.
Measures Steps: No
Measures Bouts: No
Examines HIIT: No</td></tr>
<tr><td>Outcomes Addressed: Self-reported sleep quality: Pittsburgh Sleep Quality Index (PSQI) and/or insomnia severity using the Insomnia Severity Index.
Examine Cardiorespiratory Fitness as Outcome: No</td></tr>
<tr><td>Populations Analyzed: Female, Mean age 48.6–55.8</td><td>Author-Stated Funding Source: No funding source used.</td></tr>
</table>

<table>
<tr><td colspan="2">Systematic Review
Citation: Smagula SF, Stone KL, Fabio A, Cauley JA. Risk factors for sleep disturbances in older adults: evidence from prospective studies. Sleep Med Rev. 2016;25:21-30. doi:10.1016/j.smrv.2015.01.003.</td></tr>
<tr><td>Purpose: To systematically document the determinants of sleep outcomes in older adults identified through prospective research, focusing on a broad array of sleep disturbances including sleep quality and insomnia.</td><td rowspan="5">Abstract: No systematic review of epidemiological evidence has examined risk factors for sleep disturbances among older adults. We searched the PubMed database combining search terms targeting the following domains 1) prospective, 2) sleep, and 3) aging, and identified 21 relevant population-based studies with prospective sleep outcome data. Only two studies utilized objective measures of sleep disturbance, while six used the Pittsburgh sleep quality index (PSQI) and thirteen used insomnia symptoms or other sleep complaints as the outcome measure. Female gender, depressed mood, and physical illness were most consistently identified as risks for future sleep disturbances. Less robust evidence implicated the following as potentially relevant predictors: lower physical activity levels, African-American race, lower economic status, previous manual occupation, widowhood, marital quality, loneliness and perceived stress, preclinical dementia, long-term benzodiazepine and sedative use, low testosterone levels, and inflammatory markers. Chronological age was not identified as a consistent, independent predictor of future sleep disturbances. In conclusion, prospective studies have identified female gender, depressed mood, and physical illness as general risk factors for future sleep disturbances in later life, although specific physiological pathways have not yet been established. Research is needed to determine the precise mechanisms through which these factors influence sleep over time.</td></tr>
<tr><td>Timeframe: Not reported</td></tr>
<tr><td>Total # of Studies: 21 (4 with PA as predictor)</td></tr>
<tr><td>Exposure Definition: PA.
Measures Steps: No
Measures Bouts: No
Examines HIIT: No</td></tr>
<tr><td>Outcomes Addressed: Self-reported sleep complaints/insomnia symptoms. Global subjective sleep quality. Objectively measured sleep characteristics. Subjective sleep: Pittsburgh sleep quality index (PSQI).
Examine Cardiorespiratory Fitness as Outcome: No</td></tr>
<tr><td>Populations Analyzed: Older adults</td><td>Author-Stated Funding Source: T32 AG000181.</td></tr>
</table>

<table>
<tr><td colspan="2">Meta-Analysis
Citation: Yang PY, Ho KH, Chen HC, Chien MY. Exercise training improves sleep quality in middle-aged and older adults with sleep problems: a systematic review. J Physiother. 2012;58(3):157-163. doi:10.1016/S1836-9553(12)70106-6.</td></tr>
<tr><td>Purpose: To investigate whether aerobic or resistance exercise training programs improve sleep quality in middle-aged and older adults with sleep problems.</td><td rowspan="4">Abstract: 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.</td></tr>
<tr><td>Timeframe: Inception–April 2012</td></tr>
<tr><td>Total # of Studies: 6</td></tr>
<tr><td>Exposure Definition: Exercise programs were aerobic (endurance training, walking, or Tai Chi) or resistance training based. Most trials lasted between 10 and 16 weeks. All aerobic exercise interventions were moderate intensity (60–70% heart rate reserve or 60–85% peak heart rate), and lasted for 40 to 60 minutes.
Measures Steps: No
Measures Bouts: No
Examines HIIT: No</td></tr>
<tr><td>Outcomes Addressed: Sleep quality score, subjective sleep score, and sleep latency: Pittsburgh sleep quality index. Percentage of participants in stage 1 sleep versus stage 2 sleep, sleep latency, or sleep efficiency: Polysomnography.
Examine Cardiorespiratory Fitness as Outcome: No</td></tr>
<tr><td>Populations Analyzed: Age >40, Sleep complaints (insomnia, depression, or poor sleep quality).</td><td>Author-Stated Funding Source: Not reported.</td></tr>
</table>

<table>
<tr><td colspan="2">Meta-Analysis
Citation: Yang Y, Shin JC, Li D, An R. Sedentary behavior and sleep problems: a systematic review and meta-analysis. Int J Behav Med. 2017;24(4):481-492.</td></tr>
<tr><td>Purpose: To conduct a systematic review and meta-analysis on the association between sedentary behavior and sleep problems among adults.</td><td rowspan="4">Abstract: PURPOSE: Sedentary behavior, characterized by a sitting or reclining posture and low-energy expenditure, has been recognized as an independent health risk factor. We conducted a systematic review and meta-analysis to examine the association between sedentary behavior and sleep problems. METHOD: Keyword and reference search were performed in PubMed, Cochrane Library, and Web of Science databases to identify relevant studies. The methodological quality of each study was assessed by standardized tools. The pooled estimates on the relationship between sedentary behavior and sleep problems were calculated in meta-analysis. Subgroup analyses were conducted for studies examining alternative sedentary behavior types, using self-reported or objective measures of sedentary behavior, different age groups, and assessed with different study quality levels. RESULTS: Sixteen eligible studies were identified through a literature search. Meta-analysis found sedentary behavior to be associated with an increased risk of insomnia (pooled odds ratio [POR] = 1.176, 95% confidence interval [CI] = 1.014-1.364) and sleep disturbance (POR = 1.381, 95% CI = 1.282-1.488). No association between sedentary behavior and daytime sleepiness and/or poor sleep quality was observed. Except for study quality levels, no significant differences in sleep disturbance were observed across alternative sedentary behavior types, sedentary behavior measures, and age groups in subgroup analyses. CONCLUSIONS: Prolonged sedentary behavior tends to be associated with an elevated risk of insomnia and sleep disturbance in the existing literature. Future studies with experimental study design and longer follow-up periods are warranted to demonstrate the long-term causal impact of sedentary behavior on sleep problems.</td></tr>
<tr><td>Timeframe: 1985–2016</td></tr>
<tr><td>Total # of Studies: 16</td></tr>
<tr><td>Exposure Definition: Sedentary behavior (e.g., TV watching, computer use, total screen time), self-reported and/or objectively measured (accelerometer).
Measures Steps: No
Measures Bouts: No
Examines HIIT: No</td></tr>
<tr><td>Outcomes Addressed: Sleep disorder, insomnia, poor sleep quality, sleep apnea: Self-reported, measured with various scales.
Examine Cardiorespiratory Fitness as Outcome: No</td></tr>
<tr><td>Populations Analyzed: Ages 18–100; 18–35; 36–55; >55</td><td>Author-Stated Funding Source: No funding source used.</td></tr>
</table>

Table 3. Existing Systematic Reviews and Meta-Analyses Quality Assessment Chart

AMSTARExBP: SR/MA	Aiello, 2016	Alessi, 2011	Bartel, 2015	Costigan, 2013	Dolezal, 2017	Iftikhar, 2017
Review questions and inclusion/exclusion criteria delineated prior to executing search strategy.	Yes	Yes	Yes	Yes	Yes	Yes
Population variables defined and considered in methods.	No	No	No	No	Yes	No
Comprehensive literature search performed.	Yes	Partially Yes	Yes	Yes	Yes	Yes
Duplicate study selection and data extraction performed.	No	No	No	No	No	No
Search strategy clearly described.	Yes	No	Yes	Yes	Yes	Yes
Relevant grey literature included in review.	Yes	No	Yes	No	No	Yes
List of studies (included and excluded) provided.	No	No	No	No	No	No
Characteristics of included studies provided.	No	Yes	Yes	Yes	Yes	Yes
FITT defined and examined in relation to outcome effect sizes.	No	N/A	No	N/A	N/A	No
Scientific quality (risk of bias) of included studies assessed and documented.	Yes	Yes	No	Yes	No	Yes
Results depended on study quality, either overall, or in interaction with moderators.	No	No	N/A	Yes	N/A	No
Scientific quality used appropriately in formulating conclusions.	Yes	No	N/A	Yes	N/A	No
Data appropriately synthesized and if applicable, heterogeneity assessed.	Yes	N/A	No	N/A	N/A	Partially Yes
Effect size index chosen justified, statistically.	Yes	N/A	Yes	N/A	N/A	Yes
Individual-level meta-analysis used.	No	N/A	No	N/A	N/A	No
Practical recommendations clearly addressed.	Yes	No	Yes	Yes	Yes	Yes
Likelihood of publication bias assessed.	Yes	No	No	No	No	Yes
Conflict of interest disclosed.	Yes	No	No	Yes	No	Yes

AMSTARExBP: SR/MA	Iftikhar, 2014	Kredlow, 2015	Lambert, 2016	Lang, 2016	Passos, 2012	Rubio-Arias, 2017
Review questions and inclusion/exclusion criteria delineated prior to executing search strategy.	Yes	Yes	Yes	Yes	No	Yes
Population variables defined and considered in methods.	No	Yes	No	No	No	Yes
Comprehensive literature search performed.	Yes	Yes	Yes	Yes	Yes	Yes
Duplicate study selection and data extraction performed.	No	Yes	Yes	Yes	No	Yes
Search strategy clearly described.	Yes	Yes	Yes	Yes	Yes	Yes
Relevant grey literature included in review.	No	No	No	No	No	No
List of studies (included and excluded) provided.	No	No	No	No	No	No
Characteristics of included studies provided.	Yes	Yes	Yes	Yes	Yes	Yes
FITT defined and examined in relation to outcome effect sizes.	No	Yes	N/A	No	N/A	No
Scientific quality (risk of bias) of included studies assessed and documented.	Yes	Yes	Yes	No	No	Yes
Results depended on study quality, either overall, or in interaction with moderators.	No	Yes	Yes	N/A	N/A	No
Scientific quality used appropriately in formulating conclusions.	Yes	Yes	Yes	N/A	N/A	Yes
Data appropriately synthesized and if applicable, heterogeneity assessed.	Yes	No	N/A	Yes	N/A	Yes
Effect size index chosen justified, statistically.	Yes	Yes	N/A	Yes	N/A	Yes
Individual-level meta-analysis used.	No	No	N/A	No	N/A	No
Practical recommendations clearly addressed.	Yes	Yes	Yes	Yes	No	Yes
Likelihood of publication bias assessed.	Yes	Yes	No	Yes	No	Yes
Conflict of interest disclosed.	Yes	No	Yes	No	No	Yes

AMSTARExBP: SR/MA	Smagula, 2016	Yang, 2012	Yang, 2017
Review questions and inclusion/exclusion criteria delineated prior to executing search strategy.	Yes	Yes	Yes
Population variables defined and considered in methods.	No	No	Yes
Comprehensive literature search performed.	Partially Yes	Yes	Yes
Duplicate study selection and data extraction performed.	No	Yes	No
Search strategy clearly described.	Yes	Yes	Yes
Relevant grey literature included in review.	No	No	No
List of studies (included and excluded) provided.	No	Yes	Yes
Characteristics of included studies provided.	Yes	Yes	Yes
FITT defined and examined in relation to outcome effect sizes.	N/A	No	No
Scientific quality (risk of bias) of included studies assessed and documented.	No	Yes	Yes
Results depended on study quality, either overall, or in interaction with moderators.	N/A	No	Yes
Scientific quality used appropriately in formulating conclusions.	N/A	Yes	Yes
Data appropriately synthesized and if applicable, heterogeneity assessed.	N/A	Yes	Yes
Effect size index chosen justified, statistically.	N/A	Yes	Yes
Individual-level meta-analysis used.	N/A	No	No
Practical recommendations clearly addressed.	Yes	Yes	Yes
Likelihood of publication bias assessed.	No	No	Yes
Conflict of interest disclosed.	Yes	No	Yes

Appendices

Appendix A: Analytical Framework

Topic Area
Brain Health

Systematic Review Questions

What is the relationship between physical activity and sleep?

a. Is there a dose-response relationship for either acute bouts of physical activity, or regular physical activity? If yes, what is the shape of the relationship?
b. Does the relationship vary by age, sex, race/ethnicity, socio-economic status, or weight status?
c. Does the relationship exist for individuals with impaired sleep behaviors or disorders? If yes, for which sleep disorders?

Population

People of all ages, including healthy people and people with sleep disorders, psychiatric disorders, or cognitive impairment

Exposure

All types and intensities of physical activity, including free-living activities, sedentary behavior, play, and single, acute bouts of physical activity

Comparison

People who participate in varying levels of physical activity

Key Definitions

- *Sleep* is defined as a reversible behavioral state of perceptual disengagement from and unresponsiveness to the environment, which consists of two separate states that are as different from one another as they are from wakefulness: Rapid Eye Movement (REM), and Non-REM. PPSM p15

Endpoint Health Outcomes

- Circadian rhythm
- Daytime sleepiness (e.g., Epworth Sleepiness Scale)
- REM sleep onset (latency) and REM sleep
- Sleep (onset) latency
- Sleep duration
- Sleep efficiency (% of time spent in bed that was spent asleep)
- Sleep quality
- Sleep-wake cycle
- Slow wave sleep (stage 4 sleep)
- Total sleep time
- Wake-after sleep onset (WASO)
- Zeitgeber
- Symptoms of sleep disorders as defined by Apnea Hypopnea Index, Insomnia Severity Index, or Respiratory Disturbance Index

Appendix B: Final Search Strategy

Search Strategy: PubMed (Systematic Reviews, Meta-Analyses, Pooled Analyses, and High-Quality Reports)

Database: PubMed; Date of Search: 7-24-17; 285 results

Set	Search Terms
Limit: Language	(English[lang])
Limit: Exclude animal only	NOT ("Animals"[Mesh] NOT ("Animals"[Mesh] AND "Humans"[Mesh]))
Limit: Publication Date (Systematic Reviews/Meta-Analyses)	AND ("2006/01/01"[PDAT] : "3000/12/31"[PDAT])
Limit: Publication Type Include (Systematic Reviews/Meta-Analyses)	AND (systematic[sb] OR meta-analysis[pt] OR “systematic review”[tiab] OR “systematic literature review”[tiab] OR metaanalysis[tiab] OR "meta analysis"[tiab] OR metanalyses[tiab] OR "meta analyses"[tiab] OR "pooled analysis"[tiab] OR “pooled analyses”[tiab] OR "pooled data"[tiab])
Limit: Publication Type Exclude (Systematic Reviews/Meta-Analyses)	NOT (“comment”[Publication Type] OR “editorial”[Publication Type])
Physical Activity	AND (("Exercise"[mh] OR "Exercise"[tiab] OR "Physical activity"[tiab] OR "Sedentary lifestyle"[mh] OR "Lifestyle activities"[tiab] OR "Lifestyle activity"[tiab] OR "Recreational activities"[tiab] OR "Recreational activity"[tiab] OR "Tai ji"[mh] OR "Yoga"[mh] OR "Balance training"[tiab] OR "Qigong"[mh] OR "Functional training"[tiab] OR (“Recess” AND ("Child" OR "Youth")) OR “Physical education and Training”[mh] OR "Free living activities"[tiab] OR "Free living activity"[tiab] OR "motor skills"[mh] OR "motor performance"[tiab] OR "Computer time"[tiab] OR "Computer use"[tiab] OR "Screen time"[tiab] OR "Sitting"[tiab] OR "Television"[tiab] OR "TV viewing"[tiab] OR "TV watching"[tiab] OR "Video game"[tiab] OR "Video gaming"[tiab]) OR (("Aerobic activities"[tiab] OR "Aerobic activity"[tiab] OR "Cardiovascular activities"[tiab] OR "Cardiovascular activity"[tiab] OR "Endurance activities"[tiab] OR "Endurance activity"[tiab] OR "Physical activities"[tiab] OR "Physical conditioning"[tiab] OR "Resistance training"[tiab] OR "strength training"[tiab] OR "Sedentary"[tiab] OR "Tai chi"[tiab] OR "Tai ji"[tiab] OR "Yoga"[tiab] OR "Walk"[tiab] OR "Walking"[tiab] OR "Chi kung"[tiab] OR "Qigong"[tiab] OR "stretching"[tiab] OR “Physical education”[tiab] OR "motor skills"[tiab] OR "motor skill"[tiab] OR "Inactivity"[tiab] OR "Physically inactive"[tiab] OR “Sedentarism”[tiab]) NOT medline[sb]))

Set	Search Terms
Sleep	AND ("Sleep"[mh] OR "Sleep"[tiab] OR "Circadian Clocks"[mh] OR "Circadian Clock"[tiab] OR "Circadian Clocks"[tiab] OR "Circadian Rhythm"[tiab] OR "Circadian Rhythms"[tiab] OR "Sleep-wake"[tiab] OR "Sleep/wake"[tiab] OR "Body clock"[tiab] OR "Body clocks"[tiab] OR "WASO"[tiab] OR "Zeitgeber"[tiab] OR "Sleepiness"[tiab] OR "Apnea"[tiab] OR "Hypopnea"[tiab] OR "Respiratory Disturbance Index"[tiab] OR "Insomnia severity index"[tiab])

Search Strategy: CINAHL (Systematic Reviews, Meta-Analyses, Pooled Analyses, and High-Quality Reports)

Database: CINAHL; Date of Search: 7-24-17; 15 results
Terms searched in title or abstract

Set	Search Terms
Physical Activity	("Aerobic activities" OR "Aerobic activity" OR "Cardiovascular activities" OR "Cardiovascular activity" OR "Endurance activities" OR "Endurance activity" OR "Exercise" OR "Physical activity" OR "Physical activities" OR "Physical conditioning" OR "Resistance training" OR "strength training" OR "Sedentary" OR "Lifestyle activities" OR "Lifestyle activity" OR "Recreational activities" OR "Recreational activity" OR "Tai chi" OR "Tai ji" OR "Yoga" OR "Walk" OR "Walking" OR "Balance training" OR "Chi kung" OR "Qigong" OR "Functional training" OR "stretching" OR (Recess AND (Child OR Youth)) OR "Physical education" OR "Free living activities" OR "Free living activity" OR "motor skills" OR "motor skills" OR "motor skill" OR "motor performance" OR "Inactivity" OR "Physically inactive" OR "Sedentarism" OR "Computer time" OR "Computer use" OR "Screen time" OR "Sitting" OR "Television" OR "TV viewing" OR "TV watching" OR "Video game" OR "Video gaming")
Sleep	("Sleep" OR "Circadian Clocks" OR "Circadian Clock" OR "Circadian Rhythm" OR "Circadian Rhythms" OR "Sleep-wake" OR "Sleep/wake" OR "Body clock" OR "Body clocks" OR "WASO" OR "Zeitgeber" OR "Sleepiness" OR "Apnea" OR "Hypopnea" OR "Respiratory Disturbance Index" OR "Insomnia severity index")
Limit: Publication Type Include (Systematic Reviews/Meta-Analyses)	("systematic review" OR "systematic literature review" OR "metaanalysis" OR "meta analysis" OR metanalyses OR "meta analyses" OR "pooled analysis" OR "pooled analyses" OR "pooled data")
Limits	2006-present English language Peer reviewed Exclude Medline records Human

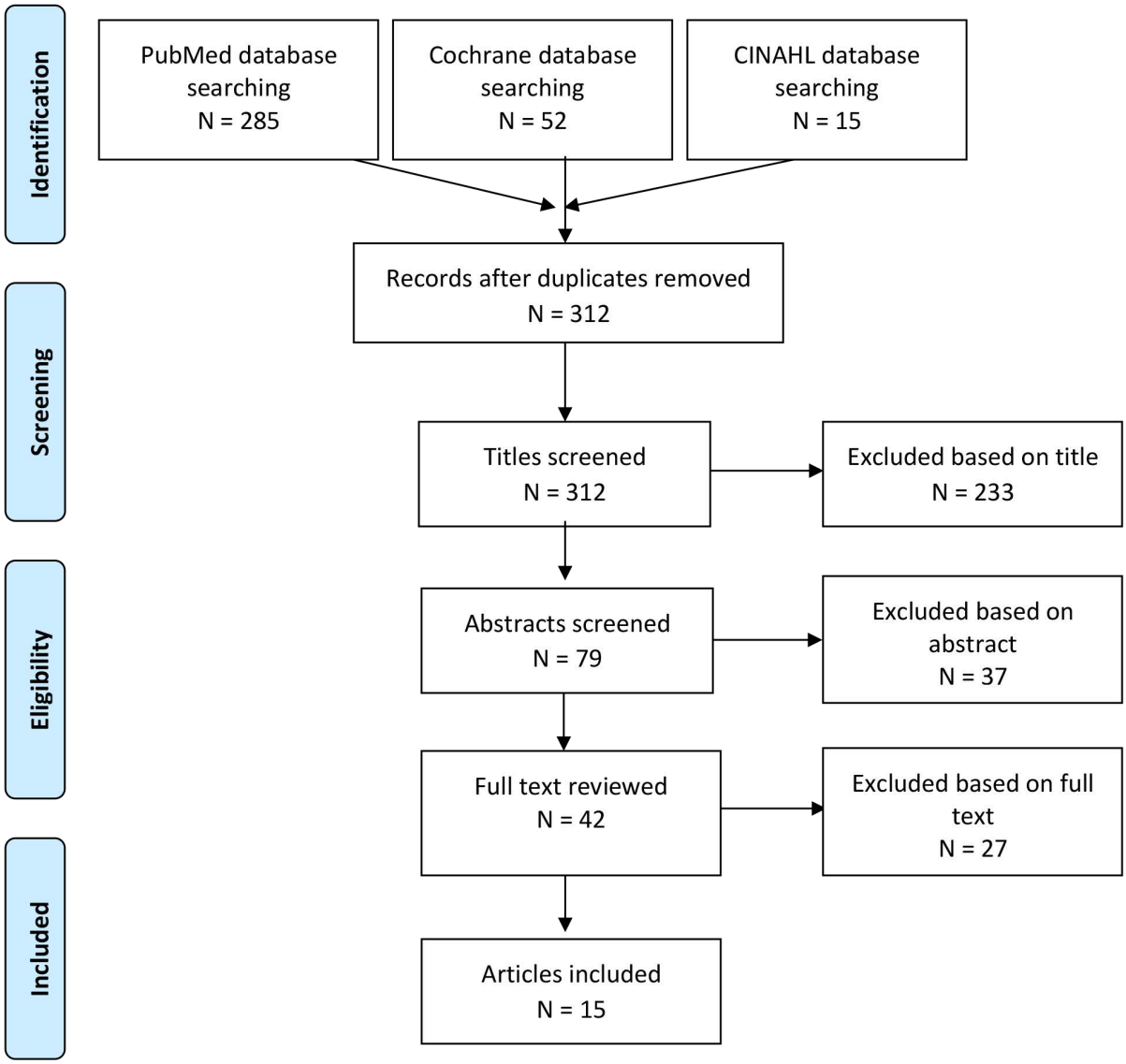
Search Strategy: Cochrane (Systematic Reviews, Meta-Analyses, Pooled Analyses, and High-Quality Reports)

Database: Cochrane; Date of Search: 7-24-17, 52 results
Terms searched in title, abstract, or keywords

Set	Search Terms
Physical Activity	("Aerobic activities" OR "Aerobic activity" OR "Cardiovascular activities" OR "Cardiovascular activity" OR "Endurance activities" OR "Endurance activity" OR "Exercise" OR "Physical activity" OR "Physical activities" OR "Physical conditioning" OR "Resistance training" OR "strength training" OR "Sedentary" OR "Lifestyle activities" OR "Lifestyle activity" OR "Recreational activities" OR "Recreational activity" OR "Tai chi" OR "Tai ji" OR "Yoga" OR "Walk" OR "Walking" OR "Balance training" OR "Chi kung" OR "Qigong" OR "Functional training" OR "stretching" OR (Recess AND (Child OR Youth)) OR "Physical education" OR "Free living activities" OR "Free living activity" OR "motor skills" OR "motor skills" OR "motor skill" OR "motor performance" OR "Inactivity" OR "Physically inactive" OR "Sedentarism" OR "Computer time" OR "Computer use" OR "Screen time" OR "Sitting" OR "Television" OR "TV viewing" OR "TV watching" OR "Video game" OR "Video gaming")
Sleep	AND ("Sleep" OR "Circadian Clocks" OR "Circadian Clock" OR "Circadian Rhythm" OR "Circadian Rhythms" OR "Sleep-wake" OR "Sleep/wake" OR "Body clock" OR "Body clocks" OR "WASO" OR "Zeitgeber" OR "Sleepiness" OR "Apnea" OR "Hypopnea" OR "Respiratory Disturbance Index" OR "Insomnia severity index")
Limits	2006-present Word variations not searched Cochrane Reviews (Reviews) and Other Reviews

Appendix C: Literature Tree

Existing Systematic Reviews, Meta-Analyses, Pooled Analyses, and Reports Literature Tree



Appendix D: Inclusion/Exclusion Criteria

Brain Health Subcommittee
Q4: What is the relationship between physical activity and sleep?

a. Is there a dose-response relationship for either acute bouts of physical activity, or regular physical activity? If yes, what is the shape of the relationship?
b. Does the relationship vary by age, sex, race/ethnicity, socio-economic status, or weight status?
c. Does the relationship exist for individuals with impaired sleep behaviors or disorders? If yes, for which sleep disorders?

Category	Inclusion/Exclusion Criteria	Notes/Rationale
Publication Language	**Include:** • Studies published with full text in English	
Publication Status	**Include:** • Studies published in peer-reviewed journals • Reports determined to have appropriate suitability and quality by PAGAC **Exclude:** • Grey literature, including unpublished data, manuscripts, abstracts, conference proceedings	
Research Type	**Include:** • Original research • Meta-analyses • Systematic reviews • Pooled analysis • Reports determined to have appropriate suitability and quality by PAGAC	
Study Subjects	**Include:** • Human subjects	
Age of Study Subjects	**Include:** • People of all ages	
Health Status of Study Subjects	**Include:** • Healthy people • People with psychiatric disorders or cognitive impairment • People with impaired sleep behaviors or sleep disorders **Exclude:** • People with chronic conditions only (other than psychiatric conditions or cognitive impairment) • People living in long-term care only • Hospitalized patients only • Athletes only	Sample sleep disorders include: restless leg disorder, jet lag, narcolepsy, night terrors, sleep walking, sleep apnea, insomnia, hypersomnia, parasomnia, periodic limb movement disorder, shift work sleep disorder. Sample disorders include: anxiety, mood, depression, schizophrenia, ADHD,

		dementia, mild cognitive impairment, PTSD, stroke, Parkinson's Disease, autism spectrum disorders. Frailty and chronic fatigue syndrome are considered chronic conditions.
Comparison	**Exclude:** • Studies comparing athlete types (e.g., comparing runners to soccer players)	
Date of Publication	**Include:** • Original research published since 2006 • Systematic reviews, meta-analyses, pooled analyses, and reports published since 2006	
Study Design	**Include:** • Randomized controlled trials • Non-randomized controlled trials • Prospective cohort studies • Retrospective cohort studies • Case-control studies • Before-and-after studies • Time series studies • Systematic reviews • Meta-analyses • Pooled analysis • Report **Exclude:** • Cross-sectional studies • Narrative reviews • Commentaries • Editorials	

Intervention/ Exposure	**Include studies in which the exposure or intervention is:**
	• All types and intensities of physical activity, including:
	  ○ free-living activities
	  ○ play
	  ○ sedentary behavior
	• Studies with single, acute bouts of exercise as the exposure
	• Physical activity as treatment for impaired sleep behaviors	

	Exclude: • Studies that do not include physical activity • Studies with physical fitness as the exposure • Studies of a specific therapeutic exercise delivered by a medical professional, aside from treatment for impaired sleep behaviors (e.g., physical therapist) • Studies of multimodal interventions that do not present data on physical activity alone • Studies where physical activity is only used as a confounding variable	
Outcome	**Include studies in which the outcome is:** • Circadian Rhythm • Daytime sleepiness (e.g., Epworth Sleepiness Scale) • REM sleep onset (latency) and REM sleep • Sleep (onset) Latency • Sleep Duration • Sleep efficiency (% of time spent in bed that was spent asleep) • Sleep Quality • Sleep-wake cycle • Slow wave sleep (stage 4 sleep) • Symptoms of sleep disorders as defined by Apnea Hypopnea Index, Insomnia Severity Index, or Respiratory Disturbance Index Total sleep time • Wake-after sleep onset (WASO) • Zeitgeber	Fatigue is not an acceptable outcome.

Appendix E: Rationale for Exclusion at Abstract or Full-Text Triage for Existing Systematic Reviews, Meta-Analyses, Pooled Analyses, and Reports

The table below lists the excluded articles with at least one reason for exclusion, but may not reflect all possible reasons.

Citation	Outcome	Population	Study Design	Exposure	Not ideal fit for replacement of de novo search	Other
Alessi C, Vitiello MV. Insomnia (primary) in older people: non-drug treatments. *BMJ Clin Evid.* 2015;2015:2302.						X
Araghi MH, Chen YF, Jagielski A, et al. Effectiveness of lifestyle interventions on obstructive sleep apnea (OSA): systematic review and meta-analysis. *Sleep.* 2013;36(10):1553-1562, 1562a-1562e. doi:10.5665/sleep.3056.						X
Archer T, Josefsson T, Lindwall M. Effects of physical exercise on depressive symptoms and biomarkers in depression. *CNS Neurol Disord Drug Targets*. 2014;13(10):1640-1653.			X			
Balasubramaniam M, Telles S, Doraiswamy PM. Yoga on our minds: a systematic review of yoga for neuropsychiatric disorders. *Front Psychiatry.* 2012;3:117. doi:10.3389/fpsyt.2012.00117.					X	
Bilgrami Z, McLaughlin L, Milanaik R, Adesman A. Health implications of new-age technologies: a systematic review. *Minerva Pediatr.* 2017;69(4):348-367. doi:10.23736/S0026-4946.17.04937-4.				X		
Bruni O, Novelli L. Sleep disorders in children. *BMJ Clin Evid.* 2010;2010:2304.						X
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