Author Manuscript

Author Manuscript

Author Manuscript

Author Manuscript

HHS Public Access

Author manuscript

Sleep Med Rev. Author manuscript; available in PMC 2017 August 01.

Published in final edited form as:

Sleep Med Rev. 2016 August ; 28: 69–85. doi:10.1016/j.smrv.2015.08.004.

Has Adult Sleep Duration Declined Over the Last 50+ Years?

Shawn D. Youngstedt[1,*], **Eric E. Goff**[2], **Alex M. Reynolds**[3], **Daniel F. Kripke**[4], **Michael R. Irwin**[5], **Richard R. Bootzin**[6], **Nidha Khan**[1], and **Girardin Jean-Louis**[7]

[1]College of Nursing and Health Innovation, College of Health Solutions, Arizona State University, Phoenix, AZ

[2]Biomedical Sciences Program, School of Medicine, University of South Carolina

[3]Department of Psychology, University of South Carolina

[4]Scripps Clinic Viterbi Family Sleep Center, La Jolla, CA

[5]Cousins Center for Psychoneuorimmunology, Semel Institute for Neuroscience, University of California, Los Angeles

[6]Department of Psychology, University of Arizona, Tucson, AZ

[7]Center for Population Health, School of Medicine, NYU Langone Medical Center, NY

Summary

The common assumption that population sleep duration has declined in the past few decades has not been supported by recent reviews, which have been limited to self-reported data. The aim of this review was to assess whether there has been a reduction in objectively recorded sleep duration over the last 50+ years.

The literature was searched for studies published from 1960–2013, which assessed objective sleep duration (TST) in healthy normal-sleeping adults. The search found 168 studies that met inclusion criteria, with 257 data points representing 6,052 individuals ages 18–88 years. Data were assessed by comparing the regression lines of age vs. TST in studies conducted between 1960–1989 vs. 1990–2013. Weighted regression analyses assessed the association of year of study with age-adjusted TST across all data points. Regression analyses also assessed the association of year of study with TST separately for 10-year age categories (e.g., ages 18–27 years), and separately for polysomnographic and actigraphic data, and for studies involving a fixed sleep schedule and participants' customary sleep schedules.

Analyses revealed no significant association of sleep duration with study year. The results are consistent with recent reviews of subjective data, which have challenged the notion of a modern epidemic of insufficient sleep.

[*]Corresponding author: Shawn D. Youngstedt, College of Nursing and Health Innovation, Arizona State University, 550 N. 3rd Street, Phoenix, AZ, 85004, USA; Tel: +1-602-496-0242; Fax: +1-602-496-0886; Shawn.Youngstedt@asu.edu.

Publisher's Disclaimer: This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final citable form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

Keywords

Normal sleeper; polysomnography; actigraphy

Introduction

It has been widely stated that modern industrialized societies have become sleep-deprived. Some studies have suggested that average sleep duration has declined over the last few decades [1–4]. Such findings, combined with extensive epidemiologic evidence associating short sleep with health risks [5–7] and experimental evidence of adverse effects of sleep deprivation [8–10], have provoked widespread concern that chronic insufficient sleep has become a public health crisis.

However, recent reviews of self-reported data have cast doubt on whether nighttime sleep or 24-h sleep has decreased in recent decades, and whether there has been an increased prevalence of short sleep (<6 h), for which risks have been most clearly established. For example, a review of eight studies by Knutson et al. found no significant 31-year trend (1975–2006) towards a higher prevalence of self-reported nighttime sleep of ≤ 6 h [11]. Bin et al. reviewed 12 studies from 15 countries assessed from the 1960s–2000s, and found that sleep duration had increased in 7 countries, decreased in 6 countries, and had not clearly changed in 2 countries [12]. In a subsequent meta-analysis of 38 studies conducted in 10 countries in the 1970s–2000s, Bin et al. [13] found that average 24-h sleep duration had increased in most countries (including the US), and that the prevalence of sleeping ≤ 6 h had decreased in most countries (including the US). Rowshan Ravan et al. studied 36-year trends (1968–2004) in sleep duration among Swedish women, and found no change in 50-year old women, and a decline of only 15 minutes in 38-year old women [14]. Moreover, Bonke reviewed five representative time-use studies spanning 1964–2009, and concluded that “the same number of hours is slept today as in the mid-1960s, with nearly the same prevalence of short and long sleepers” [15].

Discrepancies between studies of population temporal trends in sleep duration can be attributed to multiple factors, including characteristics and representativeness of the respondents, wording of the questions, and instructions given to respondents [16, 17]. Perhaps the biggest limitation of this literature is that it has been limited to self-reports of sleep duration (some of which were retrospective), which can be inaccurate [18, 19] due in part to response biases. The aim of this review was to examine whether there has been a decline over the past 5 decades in sleep duration, as indexed by objective data.

Methods

The search of the literature was modeled after a previous meta-analysis by Ohayon et al., which assessed objective sleep patterns across age [20]. PubMed, PsychLit, selected journals, and reference lists of located manuscripts were searched for studies published between 1960–2013 which met the following criteria: 1) inclusion of presumably healthy adults (as described by the authors), participant ages ≥18 y without sleep problems; 2) report of all-night average total sleep time (TST) measured by polysomnography (PSG) or

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

actigraphy; 3) assessment of sleep under minimally-disturbed conditions, including baseline or placebo conditions, and not involving particularly invasive procedures (e.g., catheterization). Many of the studies included a control group of presumably normal sleepers who had been compared with participants with sleep disorders. Studies involving individuals with extremely high levels of physical fitness were excluded under the assumption that sleep of such individuals might not be representative of the population. Key search words were sleep with normal, normative, healthy, controls, and adults.

The literature searches were performed by two of the authors: either EEG or NK. Questions regarding whether a study met inclusion criteria were resolved in discussions between EEG and SDY or AMR and SDY. Data from the studies were extracted by EEG and AMR.

The search identified >3,500 studies, of which 168 met the inclusion criteria, generating 257 data points across 6,052 individuals. Studies were separated into PSG (Table 1) and actigraphic studies (Table 2). Citations for all included studies are listed in the reference list (#55–222). Coding for each study included the mean sample age (or mid-point of the age range if the mean age was not available), number of men and women subjects, mean sample total sleep time (min), and estimated year of study. Studies with multiple age groups generated multiple data points for the analyses. When available, separate data points for men and women were used. Since most of the studies recorded sleep in the laboratory, only the laboratory data were used for studies that included both home and laboratory data, except for separate analysis of the actigraphy data.

Since the year of publication of a study often differed from the year in which a study was conducted, the following rules were used to estimate the year that a study had been conducted. 1) Year of study was estimated by subtracting 10 months from the posted date of journal receipt of the manuscript for studies with <50 subjects, 14 months for studies with 50–99 subjects, 18 months for studies with 100–149 subjects, and 22 months for studies with ≥150 subjects. 2) If information was available regarding the date a paper was accepted, but not the date that it was received, the median across-the-literature duration in months between date received and date accepted (4 months) was subtracted from the date of publication, and Rule 1 was followed. 3) If neither date accepted nor date received information was available, the median number of months between date received and date published (11 months) was subtracted from the date of publication, and Rule 1 was followed.

The TST data were first assessed by comparing the intercepts of the regression lines of age vs. TST for studies conducted between 1960–1989 vs. 1990–2013. We chose this split to obtain a more balanced number of data points across the years split. Another reason for the1989/1990 split was that it has been posited that the obesity epidemic, which started shortly after this time, can be partly attributed to declines in sleep. Examining the intercepts allowed an assessment of temporal differences in TST across all data points (without adjustment for age). A temporal decline in TST would be revealed by a smaller intercept for the 1990–2013 studies compared with the 1960–1989 studies. Another rationale for the1989/1990 split was that it has been posited that the obesity epidemic, which started shortly after this time, can be partly attributed to declines in sleep [21].

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

To further assess a temporal trend of TST across all data points, a linear regression analysis of year of study (weighted for sample size) and participants' age vs. TST was calculated. To plot these data, age-adjusted TST was determined based on the slope of the linear regression between TST and age across all data points. An *a priori* decision was made to remove outlying samples, for which mean age-adjusted TST was ≥ 2 standard deviations from the mean value across the literature. Two data points were removed based on this criterion. Weighted linear regression analyses were also conducted for year of study vs. TST across 10-year age categories (e.g, ages 18–27 years, 28–37 years, etc.).

Separate weighted linear regression analyses were conducted for data from studies in which participants followed their usual sleep schedules and for studies involving a fixed sleep period; for polysomnographic and actigraphic data; and for data involving men only and women only. Plots of year of study vs. age-adjusted TST were performed for each of these analyses.

Results

The intercepts and slopes of the regression lines of age vs. TST did not differ for studies conducted between 1960–1989 and 1990–2013 (Figure 1). In the regression analysis across all data points (n=257), there was no significant association of year of study with TST (b=. 03, p=0.56) (Figure 2), nor was there a significant association of study year with TST for any of the 10-year age categories (Figure 3) (p=0.40–0.92). Likewise, there was no significant association of year of study in analyses restricted to PSG (n=225) (b=0.03, p=0.63) or to actigraphic data (n=32) (b=−0.17, p=0.38) (Figure 4); or in analyses involving only men (n=71) or only women (n=17) (Figure 5). Finally, there was no significant association in analyses derived from studies in which subjects followed their usual sleep periods (n=154) (b=0.13, p=0.10) or a fixed sleep period (n=68) (b=−0.14, p=0.24) (Figure 6).

Discussion

The results indicate relative stability of objectively-recorded sleep durations in healthy sleepers assessed over the last half-century. Similar results were found across all age groups; in both men and women; for both PSG and actigraphic data; and under conditions of fixed sleep periods and participants' usual sleep schedules. These data are consistent with recent comprehensive reviews that found no consistent or compelling evidence of significant decrements in self-reported sleep duration and/or prevalence of short sleep over a similar range of years [11–15]. Together, these data cast doubt on the notion of a modern epidemic of insufficient sleep.

There were several limitations of the literature, which might have confounded demonstration of temporal changes in sleep duration. First, although virtually all of the studies failed to describe the racial/ethnic composition of the samples, it is a reasonable assumption that participants in most of these studies were not representative of the population. Recent research has suggested that the prevalence of short sleep is relatively high among Blacks, and that this prevalence might be increasing more among Blacks than among Whites [22].

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

Furthermore, most of the studies either excluded women or failed to report separate data for women and men. Thus, there was an insufficient number of data points (n=17) to adequately assess whether there was a temporal decline in women's sleep duration, which might have occurred as more women have entered the workforce over the past 50 years [11, 15]. Study samples have also likely been unrepresentative of the population in other factors which have been associated with sleep duration, including employment status, education, occupation, and socioeconomic status.

A second limitation is that most of the studies assessed sleep with PSG in the laboratory, a process that can result in curtailed sleep duration. The confound was reduced in most of the PSG studies by disregarding data obtained during the first night of laboratory recording (eliminating "first night effects") [23]. Interestingly, in a post-hoc assessment of studies that measured sleep objectively both at home and in the laboratory, the median difference between home and laboratory TST was only 3.2 min (Table 3). However, the use of PSG recording could have inhibited sleep, and sleep might have been more disrupted in earlier PSG studies due to greater novelty associated with PSG, as well as less technologically advanced methods, such as the use of collodion for securing electrodes.

Constraints of PSG recording might not capture a decline in nighttime sleep that has occurred at home when people are more able to follow their customary habits, which might involve staying up later. Roenneberg et al.'s surveys of thousands of adults assessed from 2002–2010 have found a decline of approximately 30 min in reported sleep duration on weekdays [24]. However, the present review did not find a similar change in home actigraphic sleep duration over the past 10–20 years. Likewise, a recent study by Gubelmann et al. found no decline in reported time in bed from 2005–2011 among a large Swiss sample (n=3,853) [25].

A third limitation is that studies with fixed sleep periods (usually 8 h) could have resulted in sleep restriction for some individuals, particularly if the timing of the sleep periods was not consistent with the participants' usual sleep schedule. This restriction could have been generally greater in earlier studies if sleep duration truly had declined. However, a similar age-adjusted mean TST was observed for studies involving fixed (443.3±31.7 min) and habitual sleep schedules (435.1±37.4 min), and there was a similar absence of a significant secular trend in TST for fixed and habitual sleep schedules (Figure 6). Figure 6A might reflect a societally-imposed or custom-imposed 8-hr ceiling in how long people usually spend sleeping. It is also possible that PSG technicians have been reluctant to extend the night shift beyond 8 h.

A fourth limitation is that compared with more recent studies, it is possible that earlier studies did not screen as well for absence of sleep apnea and other sleep disorders; this difference in screening methods might have resulted in lower estimates of sleep duration. However among adults above middle age, a small amount of sleep apnea or periodic limb movements is so common that it might be considered normal. Relatively more drug studies in recent years could have contributed to more extensive participant screening of normal sleepers, resulting in samples that sleep longer than population norms. However, a similar absence of a decline in sleep duration was found in the 18–27 year old adults, for whom the

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

prevalence of sleep apnea and other health problems is relatively low. Also contrary to the hypothesis that more recent studies have had more homogenous samples of good sleepers, a post-hoc analysis showed no significant correlation between year of study and sample standard deviation of TST ($r=-0.01$).

A fifth limitation is that mean nighttime sleep duration data for a sample might not reflect temporal changes in the prevalence of short or long sleep, nor changes in 24-hr sleep duration which might have occurred. Interestingly, Figures 1–3 suggest a higher prevalence of sleep of ≤6 h over the last 20 years, particularly among 18–27 year old participants.

In recent decades, the siesta tradition has waned considerably in some countries [26]. Without corresponding increases in nighttime sleep, this could have resulted in a temporal decline in 24-h sleep in these countries. Partial support for this hypothesis was provided by Bin et al., who found in a meta-analysis that 24-h sleep duration decreased by 22 min from 1989–2002 in Italy [13], whereas there was not a decline in 24-h sleep in 8 of the other 9 countries assessed, none of which has had a notable siesta tradition (Australia, Canada, Finland, Germany, Netherlands, Norway, Sweden, United Kingdom, United States).

However, there has been limited empirical investigation of temporal trends in napping. Wolf-Meyer traces a historical decline in napping to the industrial revolution, increased structure of the work day, and the origins of sleep medicine which has promoted a theoretical need for 8 hours of sleep at night [27, 28]. Thus, through much of the 20th century, napping in many industrialized countries was regarded as a sign of laziness [28]. However, attitudes and practices of napping have apparently changed over the past 10–20 years, as evidenced by formal sanctioning of work-day napping and commercial napping services in some cities.

Napping is relatively more common among older adults who have less nighttime sleep and less consolidation of the sleep-wake cycle than young adults. Compared with previous older cohorts, some factors could have resulted in less napping in contemporary seniors, such as later retirement age, more physically and socially active lifestyles, and greater rates of residence in senior living facilities.

Nonetheless, the present review is the first to explore historical patterns of objective sleep duration, which has long been regarded as the gold standard for defining sleep duration [18]. Further, the findings have several implications. Although historically 8 h of sleep was thought to be optimal for health and well-being, an extensive epidemiologic literature has indicated that 7 h of self-reported sleep is associated with the lowest health risks [29], with progressively higher risks associated with shorter as well as longer reported sleep. However, since objectively-recorded sleep duration is generally 30–60 min less than self-reported sleep, optimal objective sleep duration for longevity and health might be only 6–6.5 h. For example, Kripke et al. recently found 5–6.5 h of actigraphic sleep was associated with lower mortality than <5 h and > 6.5 h [30]. The present review adds to recent reviews of self-reported data, which have also indicated no decline in sleep duration over the last 50 years. If the optimal duration of objective sleep is indeed between 6–6.5 hours, the review also suggests that more participants in these studies might be at risk due to long sleep than to short sleep.

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

Had sleep duration truly declined by 1–2 hours over the last 50 years, as many sleep researchers have claimed, the signal to detect this would be at least as great as that associated with age, which shows only a decline of about 1 h from young adulthood to the elderly (Figure 1). The results also contradict the hypothesis that such a decline in sleep is a probable culprit in modern epidemics of obesity and diabetes [21].

Notwithstanding these findings, assumptions about a steady decline in sleep duration over the past few decades persist, and could be explained by many factors. First, increased public awareness about sleep and the dangers of inadequate sleep, coinciding with an exponential increase in sleep disorders diagnoses with the emergence of sleep medicine [31], could have partly shaped these perceptions. Greater knowledge about sleep, perhaps especially a greater ability to distinguish between sleep and time spent in bed, could lead to perceptions of less sleep.

Second, sleep is commonly considered in the context of leisure time and being a respite from daily stressors [32]. In what seems to many to be an increasingly fast-paced and stressful world, there is a perception of having less free time for “rest.” Third, evidence indicates that the prevalence of depression has increased over time [33], and depression is associated with reports of poor or inadequate sleep [34].

Fourth, self-reported behavior is influenced by perceived social norms [26, 35], and the perception that we have become a sleep-deprived society has likely been shaped partly by promotion of this message in the popular media and by sleep scientists. However, much of the narrative regarding an epidemic of declining sleep has been based on arguments which have not been well-supported by empirical data. We address some of these arguments in the following section, although much of this discussion is also not well-supported by empirical observations.

Decline of Sleep in Children?

A particularly poignant argument for an epidemic of insufficient sleep is that sleep among children and adolescents has declined, due to many factors, including greater use of electronic media at night and reduced parental enforcement of bedtimes. The fear that children are sleeping less has apparently existed for over a century [36], and in recent years this fear may have contributed to the increased rates of hypnotic prescriptions for children [37].

A recent empirical review by Matricciani et al. found that reported sleep duration of children and adolescents has declined by an average of 70 min per night since 1895 [38]. However, these data should be considered within the context of the tremendous difference in physical activity levels of modern children compared with children of over a century ago who were required to work on family farms, and for 60 h per week in mines, sweatshops, factories, etc. [39]. The Matricciani et al. review found that reported sleep duration of children and adolescents has declined by only about 15 min per night since 1970 [38], and this difference could also be partly explained by dramatic declines in children’s physical activity levels during this period of time, as walking/cycling to school and playing outdoors have been largely replaced by car rides and sedentary indoor activities [40]. Changes in reported sleep

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

duration of children should be verified with a review of objective sleep data analogous to the present review.

Twenty-four hour society?

The cliché of an ever-expanding 24/7 society [41] is not well-supported by empirical evidence, at least not over the past 50 years. For example, evidence suggests that the prevalence of shift-work has remained stable at about 15–20% over this interval of years [42, 43]. Such data might seem counterintuitive in light of the increased number of 24-h services and businesses. However, while many of these businesses (e.g, restaurants and convenience stores) can operate all-night with just a few employees, over the past half-century there has been a dramatic disappearance of factories which once employed thousands of shift-workers. Moreover, over the past 10–20 years, protective regulations and practices which limit shift-work and sleep deprivation and/or better accommodate individual's preferences (e.g,. flex time and telecommuting), have been implemented for various occupations, including medical residents, truck drivers, and transportation workers [44, 45].

A Decline in Sleep Over the Centuries?

It is a widely repeated hyperbole that never before in human history have we faced such challenges to our sleep [46]. It has been hypothesized that industrialization, urbanization, and technological advances have caused us to ignore or override our natural tendency to sleep more, and we do so at great costs to our health and quality of life. Wolf-Meyer has noted that this "fall from grace" sentiment can be traced back at least as far as the pioneering work of Nathaniel Kleitman [27, 28]. However, historical accounts belie the myth that people slept longer or better centuries ago, when sleep was compromised by pestilence, fear of night marauders, poorer ability to control ambient temperature or treat illnesses, etc. [28, 47]. By Ekirch's estimation, sleep centuries ago typically occurred in two nighttime in-bed periods, with each period lasting approximately 3–4 h, suggesting that average sleep duration probably did not exceed 7 h (personal communication) [48].

The light bulb has been blamed for sleep loss [49]. However, recent anthropologic studies of people in societies with little or no electricity have failed to indicate that these people sleep more than people in industrialized societies [50, 51].

In summary, it is beyond dispute that disrupted and inadequate sleep are highly prevalent and associated with significant risks, and that experimental sleep deprivation has myriad negative effects [52, 53]. Thus, the notion of a recent epidemic of insufficient sleep, and speculation that this is a primary contributor to modern epidemics of obesity, diabetes, metabolic syndrome, etc., rests largely on the question of whether sleep duration has declined in the last few decades. Consistent with recent reviews of subjective data [11–15, 54], this review does not support this notion, at least not in healthy sleepers

Acknowledgments

This manuscript is dedicated to Dr. Richard R. Bootzin, our dear friend and colleague who passed away on December 4, 2014. Dr. Bootzin contributed to earlier drafts of this manuscript. Research supported by RO1-HL095799; R01-MD007716; R01-AG034588; R01-AG026364; R01-CA160245; R01-DA032922 the Cousins Center for Psychoneuroimmunology. Susan Noh assisted with this study.

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

List of Abbreviations

PSG	polysomnography
TIB	time in bed
TST	total sleep time

References

1. National center for health statistics. Quick-Stats: percentage of adults who reported an average of ≤ 6 hours of sleep per 24-hour period, by sex and age group—United States, 1985 and 2004. MMWR Morb Mortal Wkly Rep. 2005; 54:933.
2. Kronholm E, Partonen T, Laatikainen T, Peltonen M, Härmä M, Hublin C, et al. Trends in self-reported sleep duration and insomnia-related symptoms in Finland from 1972 to 2005: a comparative review and re-analysis of Finnish population samples. J Sleep Res. 2008; 17:54–62. [PubMed: 18275555]
3. Jean-Louis G, Williams NJ, Sarpong D, Pandey A, Youngstedt S, Zizi F, et al. Associations between inadequate sleep and obesity in the US population: Analysis of national health interview survey (1977–2009). BMC Public Health. 2014; 14:290. [PubMed: 24678583]
4. Ford ES, Cunningham TJ, Croft JB. Trends in self-reported sleep duration among US adults from 1985 to 2012. SLEEP. 2015; 38(5):829–832. [PubMed: 25669182]

*5. Cappuccio FP, D'Elia L, Strazzullo P, Miller MA. Sleep duration and all-cause mortality: A systematic review and meta-analysis of prospective studies. Sleep. 2010; 33(5):585–92. [PubMed: 20469800]

6. Hall MH, Smagula SF, Boudreau RM, Ayonayon HN, Goldman SE, Harris TB, et al. Association between sleep duration and mortality is mediated by markers of inflammation and health in older adults: The health, aging and body composition study. Sleep. 2015 in press.

*7. Cai H, Shu XO, Xiang YB, Yang G, Li H, Ji BT, et al. Sleep duration and mortality: A prospective study of 113 138 middle-aged and elderly Chinese men and women. Sleep. 2014 in press.

8. Dettoni JL, Consolim-Colombo FM, Drager LF, Rubira MC, Souza SB, Irigoyen MC, et al. Cardiovascular effects of partial sleep deprivation in healthy volunteers. J Appl Physiol. 2012; 113:232–236. [PubMed: 22539169]
9. Ablin JN, Clauw DJ, Lyden AK, Ambrose K, Williams DA, Gracely RH, et al. Effects of sleep restriction and exercise deprivation on somatic symptoms and mood in healthy adults. Clin Exp Rheumatol. 2013; 31(6 Suppl 79):S53–9. [PubMed: 24373363]
10. Robertson MD, Russell-Jones D, Umpleby AM, Dijk DJ. Effects of three weeks of mild sleep restriction implemented in the home environment on multiple metabolic and endocrine markers in healthy young men. Metabolism. 2013; 62:204–211. [PubMed: 22985906]

*11. Knutson KL, Van Cauter E, Rathouz PJ, DeLeire T, Lauderdale DS. Trends in the prevalence of short sleepers in the USA: 1975–2006. Sleep. 2010; 33:37–45. [PubMed: 20120619]

12. Bin YS, Marshall NS, Glozier N. Secular trends in adult sleep duration: a systematic review. Sleep Med Rev. 2012; 16(3):223–230. [PubMed: 22075214]

*13. Bin YS, Marshall NS, Glozier N. Sleeping at the limits: the changing prevalence of short and long sleep durations in 10 countries. Am J Epidemiol. 2013; 177:826–833. [PubMed: 23524039]

*14. Rowshan Ravan A, Bengtsson C, Lissner L, Lapidus L, Björkelund C. Thirty-six-year secular trends in sleep duration and sleep satisfaction, and associations with mental stress and socioeconomic factors--results of the Population Study of Women in Gothenburg, Sweden. J Sleep Res. 2010; 19:496–503. [PubMed: 20477952]

*15. Bonke J. Trends in short and long sleep in Denmark from 1964 to 2009, and the associations with employment, SES (socioeconomic status) and BMI. Sleep Med. 2015 in press.

16. Matricciani L. Subjective reports of children's sleep duration: Does the question matter? A literature review Sleep Med. 2013; 14:303–311. [PubMed: 23481486]

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

17. Lauderdale DS. Survey questions about sleep duration: does asking separately about weekdays and weekends matter? Behav Sleep Med. 2014 Mar 4; 12(2):158–168. [PubMed: 23570614]

18. Means MK, Edinger JD, Glenn DM, Fins AI. Accuracy of sleep perceptions among insomnia sufferers and normal sleepers. Sleep Medicine. 2003; 4:285–296. [PubMed: 14592301]

19. Orff HJ, Drummond SPA, Nowakowski S, Perlis ML. Discrepancy between subjective symptomatology and objective neuropsychological performance in insomnia. Sleep. 2007; 30(9): 1205–1211. [PubMed: 17910392]

20. Ohayon MM, Carskadon MA, Guilleminault C, Vitiello MV. Meta-analysis of quantitative sleep parameters from childhood to old age in healthy individuals: Developing normative sleep values across the human lifespan. Sleep. 2004; 27:1255–1273. [PubMed: 15586779]

21. Van Cauter E1, Knutson KL. Sleep and the epidemic of obesity in children and adults. Eur J Endocrinol. 2008; 159(Suppl 1):S59–66. [PubMed: 18719052]

22. Adenekan B, Pandey A, McKenzie S, Zizi F, Casimir GJ, Jean-Louis G. Sleep in America: Role of racial/ethnic differences. Sleep Med Rev. 2013; 17:255–262. [PubMed: 23348004]

23. Kis A, Szakadát S, Simor P, Gombos F, Horváth K, Bódizs R. Objective and subjective components of the first-night effect in young nightmare sufferers and healthy participants. Behav Sleep Med. 2014; 12:469–80. [PubMed: 24294972]

24. Roenneberg T, Allebrandt KV, Merrow M, Vetter C. Social jetlag and obesity. Curr Biol. 2012; 22:939–43. [PubMed: 22578422]

25. Gubelmann C, Guessous I, Theler JM, Haba-Rubio J, Gaspoz JM, Marques-Vidal P. Trends and determinants of time in bed in Geneva, Switzerland. J Clin Sleep Med. 2014; 15:1129–1135. [PubMed: 25317094]

26. Moore M. Mexicans must say adios to the 3-hour siesta. Washington Post. 1999; 23

27. Wolf-Meyer M. Where have all our naps gone? Or Nathaniel Kleitman, the consolidation of sleep, and the historiography of emergence. Anthropology of Consciousness. 2013; 24:96–116.

*28. Wolf-Meyer, MJ. Sleep, Medicine, and Modern American Life. University of Minnesota Press; Minneapolis, MN: 2012. The Slumbering Masses.

29. Youngstedt SD, Kripke DF. Sleep duration and mortality: Rationale for sleep restriction. Sleep Med Rev. 2004; 8:159–174. [PubMed: 15144959]

30. Kripke DF, Langer RD, Elliott JA, Klauber MR, Rex KM. Mortality related to actigraphic long and short sleep. Sleep Med. 2011; 12:28–33. [PubMed: 20870457]

31. Moloney ME1, Konrad TR, Zimmer CR. The medicalization of sleeplessness: a public health concern. Am J Public Health. 2011; 101:1429–1433. [PubMed: 21680913]

32. Anderson C, Horne JA. Do we really want more sleep? A population-based study evaluating the strength of desire for more sleep. Sleep Med. 2008; 9(2):184–7. [PubMed: 17638588]

33. Bromet E, Andrade LH, Hwang I, et al. Cross-national epidemiology of DSM-IV major depressive episode. BMC Med. 2011; 9:10. [PubMed: 21281463]

34. Meerlo P, Havekes R, Steiger A. Chronically restricted or disrupted sleep as a causal factor in the development of depression. Curr Top Behav Neurosci. 2015 in press.

35. Perkins HW, Berkowitz AD. Perceiving the community norms of alcohol use among students: Some research implications for campus alcohol education programming. Int J Addict. 1986; 21(9 & 10):961–976. [PubMed: 3793315]

36. Matricciani LA, Olds TS, Blunden S, Rigney G, Williams MT. Never enough sleep: A brief history of sleep recommendations for children. Pediatrics. 2012; 129(3):548–56. [PubMed: 22331340]

37. Hartz I1, Furu K, Bratlid T, Handal M, Skurtveit S. Hypnotic drug use among 0–17 year olds during 2004–2011: a nationwide prescription database study. Scand J Public Health. 2012; 40(8): 704–711. [PubMed: 23108475]

*38. Matricciani L, Olds T, Petkov J. In search of lost sleep: secular trends in the sleep time of school-aged children and adolescents. Sleep Med Rev. 2012; 16(3):203–11. [PubMed: 21612957]

39. Children's Lives at the Turn of the Twentieth Century. [Accessed 13th February 2015] Library of Congress Teaching with Primary Sources. [Online] Available from: http://www.loc.gov/teachers/classroommaterials/primarysourcesets/childrens-lives/pdf/teacher_guide.pdf

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

40. Brownson RC, Boehmer TK, Luke DA. Declining rates of physical activity in the United States: What are the contributors? Annual Review of Public Health. 2005; 26:421–443.
41. http://www.huffingtonpost.com/susan-steinbrecher/why-our-247-connected-society-is-driving-us-farther-apart_b_5185925.html. Posted: 04/28/2014 6:50 pm EDT. Updated: 06/28/2014 5:59 am EDT
42. Gordon NP, Cleary PD, Parker CE, Czeisler CA. The prevalence and health impact of shiftwork. Am J Public Health. 1986; 76:1225–12288. [PubMed: 3752325]
43. McMenamin TM. A time to work. Recent trends in shiftwork and flexible schedules. Mon Labor Rev. 2007; 130:3–15.
44. Harris JD, Staheli G, LeClere L, Andersone D, McCormick F. What effects have resident work-hour changes had on education, quality of life, and safety? A systematic review. Clin Orthop Relat Res. 2014 in press.
45. Federal Motor Carrier Safety Administration. [Accessed 13th February 2015] Hours of Service. [Online] Available from: http://www.fmcsa.dot.gov/regulations/hours-of-service
46. http://www.cnn.com/2009/HEALTH/03/04/sleep.stress.economy/ Why We're Sleeping Less. updated 4:08 p.m. EST, Fri March 6, 2009
*47. Ekirch, AR. At Day's Close: Night in Times Past. W. W. Norton & Company; New York, NY: 2006.
48. Ekirch, AR. Email sent to: Alexandria M Reynolds. Jun 24. 2014
49. http://www.huffingtonpost.com/2013/06/01/electric-light-sleep-circadian-rhythm-cycle_n_3332920.html. How Electric Light Is Harming Our Normal Sleep Cycles. Posted: 06/01/2013 11:03 am EDT. Updated: 06/01/2013 11:03 am EDT
50. Worthman CM, Brown RA. Sleep budgets in a globalizing world: Biocultural interactions influence sleep sufficiency among Egyptian families. Soc Sci Med. 2013; 79:31–39. [PubMed: 22651897]
*51. Knutson KL. Sleep duration, quality, and timing and their associations with age in a community without electricity in Haiti. Am J Hum Biol. 2014; 26(1):80–86. [PubMed: 24243559]
52. Irwin MR. Why sleep is important for health: psychoneuroimmunology perspective. Annu Rev Psychol. 2015; 66:143–72. [PubMed: 25061767]
53. Irwin MR, Olmstead R, Carroll JE. Sleep disturbance, sleep duration, and inflammation: A systematic review and meta-analysis of cohort studies and experimental sleep deprivation. Biol Psychiat. In Press.
54. Robinson JP, Michelson W. Sleep as a victim of the "time crunch" – a multinational analysis. Int J Time Use Res (electronic). 2010; 7:61–72.
55. Feinberg I, Keresko RL, Heller N. EEG sleep patterns as a function of normal and pathological aging in man. J Psychiatr Res. 1967; 5(2):107–44. [PubMed: 6056816]
56. Kahn E, Fisher C, Lieberman L. Sleep characteristics of the human aged female. Compr Psychiatry. 1970; 11(3):274–8. [PubMed: 4315300]
57. Ryback RS, Lewis OF. Effects of prolonged bed rest on EEG sleep patterns in young, healthy volunteers. Electroencephalogr Clin Neurophysiol. 1971; 31(4):395–9. [PubMed: 4107974]
58. Williams RL, Karacan I, Thornby JI, Salis PJ. The electroencephalogram sleep patterns of middle-aged males. J Nerv Ment Dis. 1972; 154:22–30. [PubMed: 4332321]
59. Brezinova V. The number and duration of the episodes of the various EEG stages of sleep in young and older people. Electroencephalogr Clin Neurophysiol. 1975; 39(3):273–8. [PubMed: 50225]
60. Browman CP, Tepas DI. The effects of presleep activity on all-night sleep. Psychophysiology. 1976; 13(6):536–40. [PubMed: 186836]
61. Karacan I, Thornby JI, Anch M, et al. Dose-related sleep disturbances induced by coffee and caffeine. Clin Pharmacol Ther. 1976; 20(6):682–9. [PubMed: 186223]
62. Walker JM, Floyd TC, Fein G, et al. Effects of exercise on sleep. J Appl Physiol Respir Environ Exerc Physiol. 1978; 44(6):945–51. [PubMed: 670015]
63. Gaillard JM. Chronic primary insomnia: Possible physiopathological involvement of slow wave sleep deficiency. Sleep. 1978; 1(2):133–47. [PubMed: 227028]

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

64. Browman CP. Sleep following sustained exercise. Psychophysiology. 1980; 17(6):577–80. [PubMed: 7443925]
65. Adam K. Dietary habits and sleep after bedtime food drinks. Sleep. 1980; 3(1):47–58. [PubMed: 6894037]
66. Philipson L, Risberg AM, Ingvar DH. Normal sleep pattern analyzed statistically and studied by color “dormograms”. Sleep. 1980; 2(4):437–51. [PubMed: 7403743]
67. Nicholson AN, Stone BM. Heterocyclic amphetamine derivatives and caffeine on sleep in man. Br J Clin Pharmacol. 1980; 9(2):195–203. [PubMed: 6101960]
68. Coates TJ, George JM, Killen JD, et al. First night effects in good sleepers and sleep-maintenance insomniacs when recorded at home. Sleep. 1981; 4(3):293–8. [PubMed: 7302460]
69. Montgomery I, Trinder J, Paxton SJ. Energy expenditure and total sleep time: Effect of physical exercise. Sleep. 1982; 5(2):159–68. [PubMed: 7100746]
70. Trinder J, Bruck D, Paxton SJ, Montgomery I, Bowling A. Physical fitness, exercise, age and human sleep. Australian Journal of Psychology. 1982; 34(2):131–138.
71. Adam K. Sleep is changed by blood sampling through an indwelling venous catheter. Sleep. 1982; 5(2):154–8. [PubMed: 7100745]
72. Okuma T, Matsuoka H, Matsue Y, Toyomura K. Model insomnia by methylphenidate and caffeine and use in the evaluation of temazepam. Psychopharmacology (Berl). 1982; 76(3):201–8. [PubMed: 6124991]
73. Paxton SJ, Trinder J, Montgomery I. Does aerobic fitness affect sleep? Psychophysiology. 1983; 20(3):320–4. [PubMed: 6867225]
74. Bunnell DE, Bevier W, Horvath SM. Effects of exhaustive exercise on the sleep of men and women. Psychophysiology. 1983; 20(1):50–8. [PubMed: 6828612]
75. Horne JA, Staff LH. Exercise and sleep: Body-heating effects. Sleep. 1983; 6(1):36–46. [PubMed: 6844796]
76. Bixler EO, Kales A, Jacoby JA, Soldatos CR, Vela-Bueno A. Nocturnal sleep and wakefulness: Effects of age and sex in normal sleepers. Int J Neurosci. 1984; 23(1):33–42. [PubMed: 6724815]
77. Matsumoto K, Saito Y, Abe M, Furumi K. The effects of daytime exercise on night sleep. J Hum Ergol (Tokyo). 1984; 13(1):31–6. [PubMed: 6534955]
78. Paxton SJ, Trinder J, Shapiro CM, et al. Effect of physical fitness and body composition on sleep and sleep-related hormone concentrations. Sleep. 1984; 7(4):339–46. [PubMed: 6515249]
79. Reynolds CF 3rd, Kupfer DJ, Taska LS, et al. Slow wave sleep in elderly depressed, demented, and healthy subjects. Sleep. 1985; 8(2):155–9. [PubMed: 4012158]
80. Bonnet MH. Effect of sleep disruption on sleep, performance, and mood. Sleep. 1985; 8(1):11–9. [PubMed: 3992104]
81. Kupfer DJ, Sewitch DE, Epstein LH, et al. Exercise and subsequent sleep in male runners: Failure to support the slow wave sleep-mood-exercise hypothesis. Neuropsychobiology. 1985; 14(1):5–12. [PubMed: 4069348]
82. Carskadon MA, Dement WC. Sleep loss in elderly volunteers. Sleep. 1985; 8(3):207–21. [PubMed: 4048736]
83. Berry DT, Webb WB. Sleep and cognitive functions in normal older adults. J Gerontol. 1985; 40(3):331–5. [PubMed: 3989247]
84. Reynolds CF 3rd, Kupfer DJ, Hoch CC, et al. Sleep deprivation in healthy elderly men and women: Effects on mood and on sleep during recovery. Sleep. 1986; 9(4):492–501. [PubMed: 3809863]
85. Roehrs T, Kribbs N, Zorick F, Roth T. Hypnotic residual effects of benzodiazepines with repeated administration. Sleep. 1986; 9(2):309–16. [PubMed: 2905824]
86. Nakagawa Y. Sleep disturbances due to exposure to tone pulses throughout the night. Sleep. 1987; 10(5):463–72. [PubMed: 3685754]
87. James SP, Mendelson WB, Sack DA, Rosenthal NE, Wehr TA. The effect of melatonin on normal sleep. Neuropsychopharmacology. 1987; 1(1):41–4. [PubMed: 3509066]
88. Naifeh KH, Severinghaus JW, Kamiya J. Effect of aging on sleep related changes in respiratory variables. Sleep. 1987; 10(2):160–71. [PubMed: 3589328]

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

89. Libert JP, Di Nisi J, Fukuda H, et al. Effect of continuous heat exposure on sleep stages in humans. Sleep. 1988; 11(2):195–209. [PubMed: 3381060]

90. Hudson J, Lipinski J, Frankenburg F, Grochocinski V, Kupfer D. Electroencephaolgraphic sleep in mania. Arch Gen Psychiatry. 1988; 45(3):267–73. [PubMed: 3341881]

91. Schiavi RC, Schreiner-Engel P. Nocturnal penile tumescence in healthy aging men. J Gerontol. 1988; 43(5):M146–50. [PubMed: 3418036]

92. Hoch CC, Reynolds CF 3rd, Kupfer DJ, Berman SR. Stability of EEG sleep and sleep quality in healthy seniors. Sleep. 1988; 11(6):521–7. [PubMed: 3238255]

93. Mellman T, Uhde T. Electroencephalographic sleep in panic disorder. A focus on sleep-related panic attacks. Arch Gen Psychiatry. 1989; 46(2):178–84. [PubMed: 2913974]

94. Bonnet M. The effect of sleep fragmentation on sleep and performance in younger and older subjects. Neurobiol Aging. 1989; 10(1):21–5. [PubMed: 2755554]

95. Lydiard R, Zealberg J, Laraia M, et al. Electroencephalography during sleep of patients with panic disorder. J of Neuropsychiatry. 1989; 1(4):372–76.

96. Saletu B, Frey R, Grunberger J, et al. Sleep laboratory studies on single does effects of suriclone. Br J Clin Pharmacol. 1990; 30(5):703–10. [PubMed: 1980201]

97. Vitiello M, Prinz P, Avery D, et al. Sleep is undisturbed in elderly, depressed individuals who have not sought health care. Biol Psychiatry. 1990; 27(4):431–40. [PubMed: 2178692]

98. Brendel DH, Reynolds CF III, Jennings JR, et al. Sleep stage physiology, mood, and vigilance responses to total sleep deprivation in healthy 80-year-olds and 20-year-olds. Psychophysiology. 1990; 27(6):677–8. [PubMed: 2100353]

99. Hoch CC, Reynolds CF III, Monk TH, et al. Comparison of sleep disordered breathing among healthy elderly in the seventh, eighth, and ninth decades of life. Sleep. 1990; 13(6):502–11. [PubMed: 2126391]

100. Van Coevorden A, Mockel J, Laurent E, et al. Neuroendocrine rhythms and sleep in aging men. Am J Physiol. 1991; 260(4 Pt 1):E651–61. [PubMed: 2018128]

101. Lauer CJ, Riemann D, Wiegand M, Berger M. From early to late adulthood changes in EEG sleep of depressed patients and healthy volunteers. Biol Psychiatry. 1991; 29(10):979–93. [PubMed: 2065140]

102. Monk TH, Reynolds CF III, Buysee DJ, et al. Circadian characteristics of healthy 80-year-olds and their relationship to objectively recorded sleep. J Gerontol. 1991; 46(5):M171–5. [PubMed: 1890283]

103. Wauquier A, van Sweden B, Lagaay AM, Kemp B, Kamphuisen HA. Ambulatory monitoring of sleep-wakefulness patterns in healthy elderly males and females (greater than 88 years): The “Senieur” protocol. J Am Geriatr Soc. 1992; 40(2):109–14. [PubMed: 1740593]

104. Bonnet MH, Arand DL. Caffeine use as a model of acute and chronic insomnia. Sleep. 1992; 15(6):526–36. [PubMed: 1475567]

105. Hudson J, Lipinski J, Keck j, et al. Polysomnographic characteristics of young manic patients. Arch Gen Psychiatry. 1992; 49(5):378–83. [PubMed: 1586273]

106. Monk TH, Reynolds CF 3rd, Machen MA, Kupfer DJ. Daily social rhythms in the elderly and their relation to objectively recorded sleep. Sleep. 1992; 15(4):322–9. [PubMed: 1519007]

107. Buysse DJ, Browman KE, Monk TH, et al. Napping and 24-hour sleep/wake patterns in healthy elderly and young adults. J Am Geriatr Soc. 1992; 40(8):779–86. [PubMed: 1634721]

108. Hirshkowitz M, Moore CA, Hamilton CR 3rd, Rando KC, Karacan I. Polysomnography of adults and elderly: Sleep architecture, respiration, and leg movement. J Clin Neurophysiol. 1992; 9(1): 56–62. [PubMed: 1552008]

109. Montmayeur A, Buguet A. Sleep patterns of European expatriates in a dry tropical climate. J Sleep Res. 1992; 1(3):191–196. [PubMed: 10607050]

110. Dijk DJ, Czeisler CA. Body temperature is elevated during the rebound of slow-wave sleep following 40-h of sleep deprivation on a constant routine. J Sleep Res. 1993; 2(3):117–120. [PubMed: 10607081]

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

111. Hoch CC, Dew MA, Reynolds CF 3rd, et al. A longitudinal study of laboratory- and diary-based sleep measures in healthy “old old” and “young old” volunteers. Sleep. 1994; 17(6):489–96. [PubMed: 7809561]
112. Gillberg M, Åkerstedt T. Sleep restriction and SWS-suppression: Effects on daytime and night-time recovery. J Sleep Res. 1994; 3(3):144–151. [PubMed: 10607119]
113. Walsh JK, Hartman PG, Schweitzer PK. Slow-wave sleep deprivation and waking function. J Sleep Res. 1994; 3(1):16–25. [PubMed: 10607104]
114. Carrier J, Dumont M. Sleep propensity and sleep architecture after bright light exposure at three different times of day. J Sleep Res. 1995; 4(4):202–211. [PubMed: 10607160]
115. Buguet A, Montmayeur A, Pigeau R, Naitoh P. Modafinil, d-amphetamine and placebo during 64 hours of sustained mental work. II. Effects on two nights of recovery sleep. J Sleep Res. 1995; 4(4):229–241. [PubMed: 10607162]
116. Landolt HP, Werth E, Borbély AA, Dijk DJ. Caffeine intake (200 mg) in the morning affects human sleep and EEG power spectra at night. Brain Res. 1995; 675(1–2):67–74. [PubMed: 7796154]
117. Hajak G, Rodenbeck A, Bandelow B, et al. Nocturnal plasma melatonin levels after flunitrazepam administration in healthy subjects. Eur Neuropsychopharmacol. 1996; 6(2):149–53. [PubMed: 8791041]
118. Mann K, Bauer H, Hiemke C, et al. Acute, subchronic and discontinuation effects of zopiclone on sleep EEG and nocturnal melatonin secretion. Eur Neuropsychopharmacol. 1996; 6(3):163–8. [PubMed: 8880074]
119. Jean-Louis G, von Gizycki H, Zizi F, et al. Determination of sleep and wakefulness with the actigraph data analysis software (ADAS). Sleep. 1996; 19(9):739–43. [PubMed: 9122562]
120. Carrier J, Monk TH, Buysse DJ, Kupfer DJ. Inducing a 6-hour phase advance in the elderly: Effects on sleep and temperature rhythms. J Sleep Res. 1996; 5(2):99–105. [PubMed: 8795810]
121. Landolt HP, Roth C, Dijk DJ, Borbély AA. Late-afternoon ethanol intake affects nocturnal sleep and the sleep EEG in middle-aged men. J Clin Psychopharmacol. 1996; 16(6):428–36. [PubMed: 8959467]
122. Landolt HP, Dijk DJ, Achermann P, Borbély AA. Effect of age on the sleep EEG: Slow-wave activity and spindle frequency activity in young and middle-aged men. Brain Res. 1996; 738(2): 205–12. [PubMed: 8955514]
123. Vitiello MV, Larsen LH, Moe KE, et al. Objective sleep quality of healthy older men and women is differentially disrupted by nighttime periodic blood sampling via indwelling catheter. Sleep. 1996; 19(4):304–11. [PubMed: 8776788]
124. Ehlers CL, Kupfer DJ. Slow-wave sleep: Do young adult men and women age differently? J Sleep Res. 1997; 6:211–5. [PubMed: 9358400]
125. Haimov I, Lavie P. Circadian characteristics of sleep propensity function in healthy elderly: A comparison with young adults. Sleep. 1997; 20(4):294–300. [PubMed: 9231956]
126. Carrier J, Monk TH, Buysse DJ, Kupfer DJ. Sleep and morningness-eveningness in the ‘middle’ years of life (20–59 y). J Sleep Res. 1997; 6(4):230–7. [PubMed: 9493522]
127. Cajochen C, Kräuchi K, Möri D, Graw P, Wirz-Justice A. Melatonin and S-20098 increase REM sleep and wake-up propensity without modifying NREM sleep homeostasis. Am J Physiol. 1997; 272(4 Pt 2):R1189–96. [PubMed: 9140019]
128. Edinger JD, Fins AI, Sullivan RJ Jr, Marsh GR, Dailey DS, Hope TV, et al. Sleep in the laboratory and sleep at home: Comparisons of older insomniacs and normal sleepers. Sleep. 1997; 20(12):1119–26. [PubMed: 9493921]
129. Martin SE, Wraith PK, Deary IJ, Douglas NJ. The effect of nonvisible sleep fragmentation on daytime function. Am J Respir Crit Care Med. 1997; 155(5):1596–601. [PubMed: 9154863]
130. Hume KI, Van F, Watson A. A field study of age and gender differences in habitual adult sleep. J Sleep Res. 1998; 7(2):85–94. [PubMed: 9682179]
131. Cajochen C, Kräuchi K, Danilenko KV, Wirz-Justice A. Evening administration of melatonin and bright light: interactions on the EEG during sleep and wakefulness. J Sleep Res. 1998; 7(3):145–57. [PubMed: 9785269]

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

132. Blagrove M, Owens DS, MacDonald I, et al. Time of day effects in, and the relationship between, sleep quality and movement. J Sleep Res. 1998; 7(4):233–9. [PubMed: 9844849]
133. Härmä M, Suvanto S, Popkin S, et al. A dose-response study of total sleep time and the ability to maintain wakefulness. J Sleep Res. 1998; 7(3):167–74. [PubMed: 9785271]
134. Yassouridis A, Steiger A, Klinger A, Fahrmeir L. Modelling and exploring human sleep with event history analysis. J Sleep Res. 1999; 8(1):25–36. [PubMed: 10188133]
135. Rao U, Poland RE, Lutchmansingh P, et al. Relationship between ethnicity and sleep patterns in normal controls: Implications for psychopathology and treatment. J Psychiatr Res. 1999; 33(5): 419–26. [PubMed: 10504010]
136. Lushington K, Dawson D, Kennaway DJ, Lack L. The relationship between 6-sulphatoxymelatonin rhythm phase and age in self-reported good sleeping controls and sleep maintenance insomniacs aged 55–80 years. Psychopharmacology (Berl). 1999; 147(1):111–2. [PubMed: 10591877]
137. Stone BM, Turner C, Mills SL, Nicholson AN. Hypnotic activity of melatonin. Sleep. 2000; 23(5):663–9. [PubMed: 10947034]
138. Naylor E, Penev PD, Orbeta L, et al. Daily social and physical activity increases slow-wave sleep and daytime neuropsychological performance in the elderly. Sleep. 2000; 23(1):87–95. [PubMed: 10678469]
139. Hindmarch I, Rigney U, Stanley N, et al. A naturalistic investigation of the effects of day-long consumption of tea, coffee and water on alertness, sleep onset and sleep quality. Psychopharmacology (Berl). 2000; 149(3):203–16. [PubMed: 10823400]
140. Youngstedt SD, O'Connor PJ, Crabbe JB, Dishman RK. The influence of acute exercise on sleep following high caffeine intake. Physiol Behav. 2000; 68(4):563–70. [PubMed: 10713298]
141. Armitage R, Hoffmann R, Fitch T, Trivedi M, Rush AJ. Temporal characteristics of delta activity during NREM sleep in depressed outpatients and healthy adults: Group and sex effects. Sleep. 2000; 23(5):607–17. [PubMed: 10947028]
142. Carrier J, Land S, Buysse DJ, Kupfer DJ, Monk TH. The effects of age and gender on sleep EEG power spectral density in the middle years of life (ages 20–60 years old). Psychophysiology. 2001; 38(2):232–42. [PubMed: 11347869]
143. Nicolas A, Petit D, Rompre S, Montplaisir J. Sleep spindle characteristics in healthy subjects of different age groups. Clin Neurophysiol. 2001; 112(3):521–7. [PubMed: 11222974]
144. Edinger J, Glenn M, Bastain L, et al. Sleep in the laboratory and sleep at home II: Comparison of middle-aged insomnia sufferers and normal sleepers. Sleep. 2001; 24(7):761–70. [PubMed: 11683479]
145. Pires ML, Benedito-Silva AA, Pinto L, et al. Acute effects of low doses of melatonin on the sleep of young healthy subjects. J Pineal Res. 2001; 31(4):326–32. [PubMed: 11703562]
146. Roky R, Chapotot F, Hakkou F, Benchekroun MT, Buguet A. Sleep during Ramadan intermittent fasting. J Sleep Res. 2001; 10(4):319–27. [PubMed: 11903862]
147. Sharkey KM, Fogg LF, Eastman CI. Effects of melatonin administration on daytime sleep after simulated night shift work. J Sleep Res. 2001; 10(3):181–92. [PubMed: 11696071]
148. Onen SH, Alloui A, Gross A, Eschallier A, Dubray C. The effects of total sleep deprivation, selective sleep interruption and sleep recovery on pain tolerance thresholds in healthy subjects. J Sleep Res. 2001; 10(1):35–42. [PubMed: 11285053]
149. Jean-Louis G, Kripke DF, Cole RJ, Assmus JD, Langer RD. Sleep detection with an accelerometer actigraph: comparisons with polysomnography. Physiol Behav. 2001; 72(1–2):21–8. [PubMed: 11239977]
150. Jean-Louis G, Kripke DF, Mason WJ, Elliott JA, Youngstedt SD. Sleep estimation from wrist movement quantified by different actigraphic modalities. J Neurosci Methods. 2001; 105(2):185–91. [PubMed: 11275275]
151. Gaudreau H, Carrier J, Montplaisir J. Age-related modifications of NREM sleep EEG: From childhood to middle age. J Sleep Res. 2001; 10(3):165–72. [PubMed: 11696069]
152. Crowley K, Trinder J, Kim Y, Carrington M, Colrain IM. The effects of normal aging on sleep spindle and K-complex production. Clin Neurophysiol. 2002; 113(10):1615–22. [PubMed: 12350438]

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

153. Huber R, Treyer V, Borbély AA, et al. Electromagnetic fields, such as those from mobile phones, alter regional cerebral blood flow and sleep and waking EEG. J Sleep Res. 2002; 11(4):289–95. [PubMed: 12464096]

154. Baskett JJ, Broad JB, Wood PC, et al. Does melatonin improve sleep in older people? A randomised crossover trial. Age Ageing. 2003; 32(2):164–70. [PubMed: 12615559]

155. Mukai J, Uchida S, Miyazaki S, Nishihara K, Honda Y. Spectral analysis of all-night human sleep EEG in narcoleptic patients and normal subjects. J Sleep Res. 2003; 12(1):63–71. [PubMed: 12603788]

156. Brandenberger G, Viola AU, Ehrhart J, et al. Age-related changes in cardiac autonomic control during sleep. J Sleep Res. 2003; 12(3):173–80. [PubMed: 12941056]

157. Waters WF, Magill RA, Bray GA, et al. A comparison of tyrosine against placebo, phertermine, caffeine, and D-amphetamine during sleep deprivation. Nutr Neurosci. 2003; 6(4):221–35. [PubMed: 12887139]

158. Yoon IY, Kripke DF, Youngstedt SD, Elliott JA. Actigraphy suggests age-related differences in napping and nocturnal sleep. J Sleep Res. 2003; 12(2):87–93. [PubMed: 12753345]

159. Means M, Edinger J, Glenn DM, Fins A. Accuracy of sleep perceptions among insomnia sufferers and normal sleepers. Sleep Med. 2003; 4(4):285–96. [PubMed: 14592301]

160. Edinger JD, Glenn DM, Bastian LA, Marsh GR, Dailey D, Hope TV, et al. Daytime testing after laboratory or home-based polysomnography: Comparisons of middle-aged insomnia sufferers and normal sleepers. J Sleep Res. 2003; 12(1):45–52.

161. de Souza L, Benedito-Silva AA, Pires ML, et al. Further validation of actigraphy for sleep studies. Sleep. 2003; 26(1):81–5. [PubMed: 12627737]

162. Youngstedt SD, Perlis ML, O'Brien PM, et al. No association of sleep with total daily physical activity in normal sleepers. Physiol Behav. 2003; 78(3):395–401. [PubMed: 12676274]

163. Kato T, Montplaisir JY, Lavigne GJ. Experimentally induced arousals during sleep: A cross-modality matching paradigm. J Sleep Res. 2004; 13(3):229–38. [PubMed: 15339258]

164. Benson K, Friedman L, Noda A, et al. The measurement of sleep by actigraphy: Direct comparison of 2 commercially available actigraphs in a nonclinical population. Sleep. 2004; 27(5):986–9. [PubMed: 15453559]

165. Beaumont M, Batéjat D, Piérard C, et al. Caffeine or melatonin effect on sleep and sleepiness after rapid eastward transmeridian travel. J Appl Physiol (1985). 2004; 96(1):50–8. [PubMed: 12959951]

166. LaJambe CM, Kamimori GH, Belenky G, Balkin TJ. Caffeine effects on recovery sleep following 27 h total sleep deprivation. Aviat Space Environ Med. 2005; 76(2):108–13. [PubMed: 15742825]

167. Drapeau C, Hamel-Hébert I, Robillard R, et al. Challenging sleep in aging: The effects of 200 mg of caffeine during the evening in young and middle-aged moderate caffeine consumers. J Sleep Res. 2006; 15(2):133–41. [PubMed: 16704567]

168. Monk T, Thompson W, Buysse D, et al. Sleep in healthy seniors: A diary study of the relation between bedtime and the amount of sleep obtained. J Sleep Res. 2006; 15(3):256–60. [PubMed: 16911027]

169. Penev PD. Association between sleep and morning testosterone levels in older men. Sleep. 2007; 30(4):427–32. [PubMed: 17520786]

170. Hornyak M, Feige B, Voderholzer U, Philipsen A, Riemann D. Polysomnography finding in patients with restless legs syndrome and in healthy controls: A comparative observational study. Sleep. 2007 Jul; 30(7):861–5. [PubMed: 17682656]

171. Robertson JA, Broomfield NM, Espie CA. Prospective comparison of subjective arousal during the pre-sleep period in primary sleep-onset insomnia and normal sleepers. J Sleep Res. 2007; 16(2):230–8. [PubMed: 17542954]

172. Carrier J, Fernandez-Bolanos M, Robillard R, et al. Effects of caffeine are more marked on daytime recovery sleep than on nocturnal sleep. Neuropsychopharmacology. 2007; 32(4):964–72. [PubMed: 16936703]

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

173. Mahlberg R, Kunz D. Melatonin excretion levels and polysomnographic sleep parameters in healthy subjects and patients with sleep-related disturbances. Sleep Med. 2007; 8(5):512–6. [PubMed: 17581781]
174. Bonnet M, Arand D. EEG arousal norms by age. J Clin Sleep Med. 2007; 3(3):271–4. [PubMed: 17561594]
175. Peters KR, Ray L, Smith V, Smith C. Changes in the density of stage 2 sleep spindles following motor learning in young and older adults. J Sleep Res. 2008; 17(1):23–33. [PubMed: 18275552]
176. Wong KK, Marshall NS, Grunstein RR, Dodd MJ, Rogers NL. Comparing the neurocognitive effects of 40 h sustained wakefulness in patients with untreated OSA and healthy controls. J Sleep Res. 2008; 17(3):322–30. [PubMed: 18522688]
177. Schmid SM, Hallschmid M, Jauch-Chara K, Born J, Schultes B. A single night of sleep deprivation increases ghrelin levels and feelings of hunger in normal-weight healthy men. J Sleep Res. 2008; 17(3):331–4. [PubMed: 18564298]
178. O'Donnell D, Silva EJ, Münch M, et al. Comparison of subjective and objective assessments of sleep in healthy older subjects without sleep complaints. J Sleep Res. 2009; 18(2):254–63. [PubMed: 19645969]
179. Cote KA, Milner CE, Smith BA, et al. CNS arousal and neurobehavioral performance in a short-term sleep restriction paradigm. J Sleep Res. 2009; 18(3):291–303. [PubMed: 19552702]
180. Bixler EO, Papaliaga MN, Vgontzas AN, et al. Women sleep objectively better than men and the sleep of young women is more resilient to external stressors: Effects of age and menopause. J Sleep Res. 2009; 18(2):221–8. [PubMed: 19302341]
181. Paterson LM, Nutt DJ, Ivarsson M, Hutson PH, Wilson SJ. Effects on sleep stages and microarchitecture of caffeine and its combination with zolpidem or trazodone in healthy volunteers. J Psychopharmacol. 2009; 23(5):487–94. [PubMed: 19351801]
182. Robillard R, Massicotte-Marquez J, Kawinska A, et al. Topography of homeostatic sleep pressure dissipation across the night in young and middle-aged men and women. J Sleep Res. 2010; 19(3): 455–65. [PubMed: 20408933]
183. Morgan PT, Kehne JH, Sprenger KJ, Malison RT. Retrograde effects of triazolam and zolpidem on sleep-dependent motor learning in humans. J Sleep Res. 2010; 19(1 Pt 2):157–64. [PubMed: 19682231]
184. Marzano C, Ferrara M, Curcio G, De Gennaro L. The effects of sleep deprivation in humans: Topographical electroencephalogram changes in non-rapid eye movement (NREM) sleep versus REM sleep. J Sleep Res. 2010; 19(2):260–8. [PubMed: 19845849]
185. Ferri R, Drago V, Arico D, et al. The effects of experimental sleep fragmentation on cognitive processing. Sleep Med. 2010; 11(4):378–85. [PubMed: 20226732]
186. Herbst E, Metzler T, Lenoci M, et al. Adaptation effects to sleep studies in participants with and without chronic posttraumatic stress disorder. Psychophysiology. 2010; 47(6):1127–33. [PubMed: 20456661]
187. Vandekerckhove M, Weiss R, Schotte C, et al. The role of presleep negative emotion in sleep physiology. Psychophysiology. 2011; 48(12):1738–44. [PubMed: 21895689]
188. Brower K, Hoffmann R, Conroy D, Arnedt JT, Armitage R. Sleep homeostasis in alcohol-dependent, depressed and healthy control men. Eur Arch Psychiatry Clin Neurosci. 2011; 261(8): 559–66. [PubMed: 21312040]
189. Rahman K, Burton A, Galbraith S, Lloyd A, Vollmer-Conna U. Sleep-wake behavior in chronic fatigue syndrome. Sleep. 2011; 34(5):671–8. [PubMed: 21532961]
190. Kogure T, Shirakawa S, Shimokawa M, Hosokawa Y. Automatic sleep/wake scoring from body motion in bed: Validation of a newly developed sensor placed under a mattress. J Physiol Anthropol. 2011; 30(3):103–9. [PubMed: 21636953]
191. Myllymäki T, Kyröläinen H, Savolainen K, et al. Effects of vigorous late-night exercise on sleep quality and cardiac autonomic activity. J Sleep Res. 2011; 20(1 Pt 2):146–53. [PubMed: 20673290]
192. Gooneratne NS, Bellamy SL, Pack F, et al. Case-control study of subjective and objective differences in sleep patterns in older adults with insomnia symptoms. J Sleep Res. 2011; 20(3): 434–44. [PubMed: 20887395]

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

193. Nissen C, Kloepfer C, Feige B, et al. Sleep-related memory consolidation in primary insomnia. J Sleep Res. 2011; 20(1 Pt 2):129–36. [PubMed: 20673291]

194. Hébert S, Fullum S, Carrier J. Polysomnographic and quantitative electroencephalographic correlates of subjective sleep complaints in chronic tinnitus. J Sleep Res. 2011; 20(1 Pt 1):38–44. [PubMed: 20561177]

195. Danker-Hopfe H, Dorn H, Bahr A, Anderer P, Sauter C. Effects of electromagnetic fields emitted by mobile phones (GSM 900 and WCDMA/UMTS) on the macrostructure of sleep. J Sleep Res. 2011; 20(1 Pt 1):73–81. [PubMed: 20561179]

196. Marzano C, De Simoni E, Tempesta D, Ferrara M, De Gennaro L. Sleep deprivation suppresses the increase of rapid eye movement density across sleep cycles. J Sleep Res. 2011; 20(3):386–94. [PubMed: 20819146]

197. Gonzalez JLB, Fernandez TVS, Rodriguez LA, et al. Sleep architecture in patients with fibromyalgia. Psicothema. 2011; 23(3):368–73. [PubMed: 21774887]

198. Bianchi M, Wang W, Klerman E. Sleep misperception in healthy adults: Implications for insomnia diagnosis. J Clin Sleep Med. 2012; 8(5):547–54. [PubMed: 23066367]

199. Schmid MR, Murbach M, Lustenberger C, et al. Sleep EEG alterations: Effects of pulsed magnetic fields versus pulse-modulated radio frequency electromagnetic fields. J Sleep Res. 2012; 21(6):620–9. [PubMed: 22724534]

200. Ferri R, Bruni O, Fulda S, Zucconi M, Plazzi G. A quantitative analysis of the submentalis muscle electromyographic amplitude during rapid eye movement sleep across the lifespan. J Sleep Res. 2012; 21(3):257–63. [PubMed: 21955170]

201. Jaehne A, Unbehaun T, Feige B, et al. How smoking affects sleep: A polysomnographical analysis. Sleep Med. 2012; 13(10):1286–92. [PubMed: 23026505]

202. Frey S, Birchler-Pedross A, Hofstetter M, et al. Challenging the sleep homeostat: Sleep in depression is not premature aging. Sleep Med. 2012; 13(7):933–45. [PubMed: 22609025]

203. Schmid MR, Loughran SP, Regel SJ, et al. Sleep EEG alterations: Effects of different pulse-modulated radio frequency electromagnetic fields. J Sleep Res. 2012; 21(1):50–8. [PubMed: 21489004]

204. Wulff K, Dijk DJ, Middleton B, Foster R, Joyce E. Sleep and circadian rhythm disruption in schizophrenia. Br J Psychiatry. 2012; 200(4):308–16. [PubMed: 22194182]

205. Scatena M, Dittoni S, Maviglia R, et al. An integrated video-analysis software system designed for movement detection and sleep analysis. Validation of a tool for the behavioural study of sleep. Clin Neurophysiol. 2012; 123(2):318–23. [PubMed: 21873109]

206. Flausino NH, Da Silva Prado JM, de Queiroz SS, Tufik S, de Mello MT. Physical exercise performed before bedtime improves the sleep pattern of healthy young good sleepers. Psychophysiology. 2012; 49(2):186–92. [PubMed: 22092095]

207. Kobayashi I, Huntley E, Lavela J, Mellman TA. Subjectively and objectively measured sleep with and without posttraumatic stress disorder and trauma exposure. Sleep. 2012; 35(7):957–65. [PubMed: 22754042]

208. Shambroom JR, Fábregas SE, Johnstone J. Validation of an automated wireless system to monitor sleep in healthy adults. J Sleep Res. 2012; 21(2):221–30. [PubMed: 21859438]

209. Holz J, Piosczyk H, Feige B, et al. EEG Σ and slow-wave activity during NREM sleep correlate with overnight declarative and procedural memory consolidation. J Sleep Res. 2012; 21(6):612–9. [PubMed: 22591117]

210. Robertson MD, Russell-Jones D, Umpleby AM, Dijk DJ. Effects of three weeks of mild sleep restriction implemented in the home environment on multiple metabolic and endocrine markers in healthy young men. Metabolism. 2013; 62(2):204–11. [PubMed: 22985906]

211. Rosipal R, Lewandowski A, Dorffner G. In search of objective components for sleep quality indexing in normal sleep. Biol Psychol. 2013; 94(1):210–20. [PubMed: 23751915]

212. Ferri R, Zucconi M, Marelli S, et al. Effects of long-term use of clonazepam on nonrapid eye movement sleep patterns in rapid eye movement sleep behavior disorder. Sleep Med. 2013; 14(5): 399–406. [PubMed: 23490738]

213. Chellappa SL, Steiner R, Oelhafen P, et al. Acute exposure to evening blue-enriched light impacts on human sleep. J Sleep Res. 2013; 22(5):573–80. [PubMed: 23509952]

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

214. Ju Y, McLeland J, Toedebusch C, et al. Sleep quality and preclinical Alzheimer disease. JAMA Neurol. 2013; 70(5):587–93. [PubMed: 23479184]

215. Winser MA, McBean AL, Montgomery-Downs HE. Minimum duration of actigraphy-defined nocturnal awakenings necessary for morning recall. Sleep Med. 2013; 14(7):688–91. [PubMed: 23746600]

216. Lombardi C, Meriggi P, Agostoni P, et al. High-altitude hypoxia and periodic breathing during sleep: Gender-related differences. J Sleep Res. 2013; 22(3):322–30. [PubMed: 23294420]

217. Robey E, Dawson B, Halson S, et al. Effect of evening postexercise cold water immersion on subsequent sleep. Med Sci Sports Exerc. 2013; 45(7):1394–402. [PubMed: 23377833]

218. Petersen H, Kecklund G, D'Onofrio P, Nilsson J, Åkerstedt T. Stress vulnerability and the effects of moderate daily stress on sleep polysomnography and subjective sleepiness. J Sleep Res. 2013; 22(1):50–7. [PubMed: 22835074]

219. Richards A, Metzler TJ, Ruoff LM, et al. Sex differences in objective measures of sleep in post-traumatic stress disorder and healthy control subjects. J Sleep Res. 2013; 22(6):679–87. [PubMed: 23763708]

220. Saxvig IW, Wilhelmsen-Langeland A, Pallesen S, et al. Objective measures of sleep and dim light melatonin onset in adolescents and young adults with delayed sleep phase disorder compared to healthy controls. J Sleep Res. 2013; 22(4):365–72. [PubMed: 23363423]

221. Tonetti L, Cellini N, de Zambotti M, et al. Polysomnographic validation of a wireless dry headband technology for sleep monitoring in healthy young adults. Physiol Behav. 2013; 118:185–188. [PubMed: 23714587]

222. O'Hare E, Flanagan D, Penzel T, et al. A comparison of radio-frequency biomotion sensors and actigraphy versus polysomnography for the assessment of sleep in normal subjects. Sleep Breath. 2014 in press.

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

Practice Points

1. Systematic reviews of the literature have generally not shown that average self-reported sleep duration has declined, nor that the prevalence of short sleep duration (< 6 h) has increased over the past few decades [11–15].
2. Limitations of the objective-recording literature include unrepresentative samples; assessment of sleep mostly with PSG under laboratory conditions; and almost no studies of 24-hr sleep patterns.
3. The data indicate no significant change in objective TST over the last 50+ years.
4. Reasons for persistent assumptions about a temporal decline in societal sleep duration could include greater knowledge about sleep and the risks of inadequate sleep; increased prevalence of depression; misperceptions about population norms; and persistent claims in the popular and scientific literature regarding a so-called modern epidemic of insufficient sleep.

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

Research Agenda

1. A similar analysis of temporal trends in objective sleep duration in children and adolescents should be undertaken. A recent review indicated a decline in reported sleep duration of about 70 min per night among children and adolescents over the last century [38], which should be confirmed with objective data.
2. A similar analysis of temporal changes in other measures of objective sleep, such as sleep latency and sleep efficiency, should be conducted to address whether the quality of sleep has changed over time.
3. Further historical studies focused specifically on sleep duration and other sleep variables might uncover more information about sleep changes over time.
4. Future large-scale prospective, representative, multi-national studies of objective sleep (using actigraphy) could address whether there are future population changes in sleep.

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

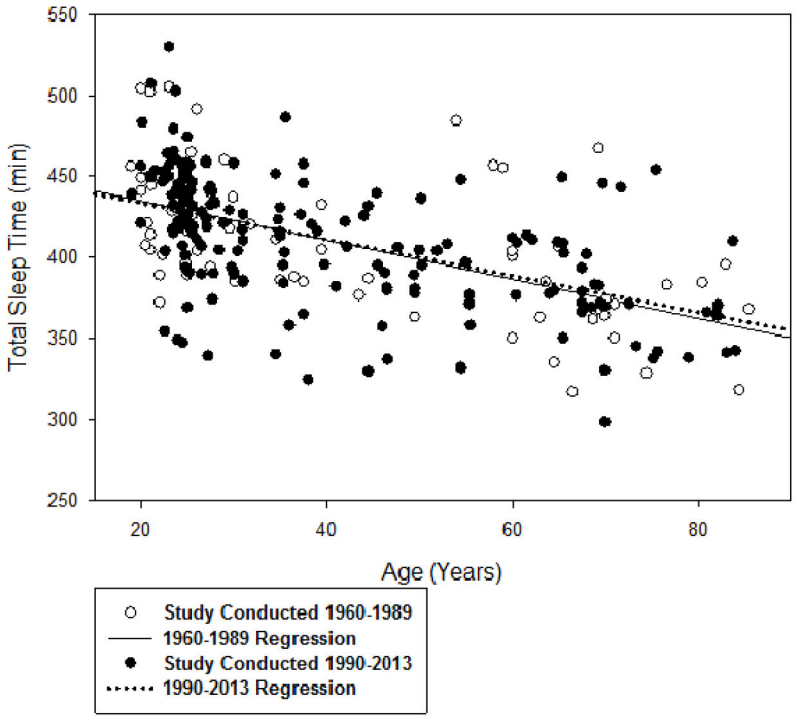


Figure 1.

Association of mean age of participants with total sleep time (min) for studies conducted between 1960–1989 (open circles) and 1990–2013 (closed circles).

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

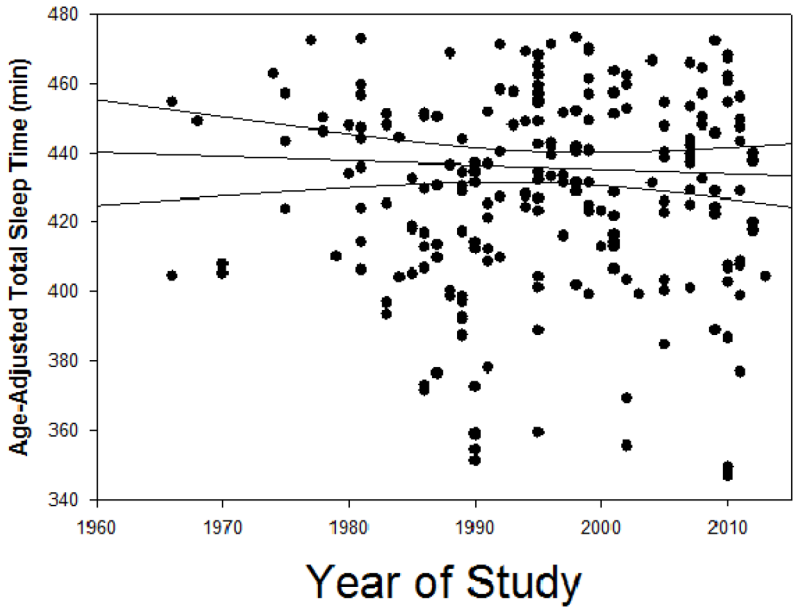


Figure 2.

Association of year of study with age-adjusted total sleep time (min) for all data points. The regression line and 95% confidence intervals are displayed.

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

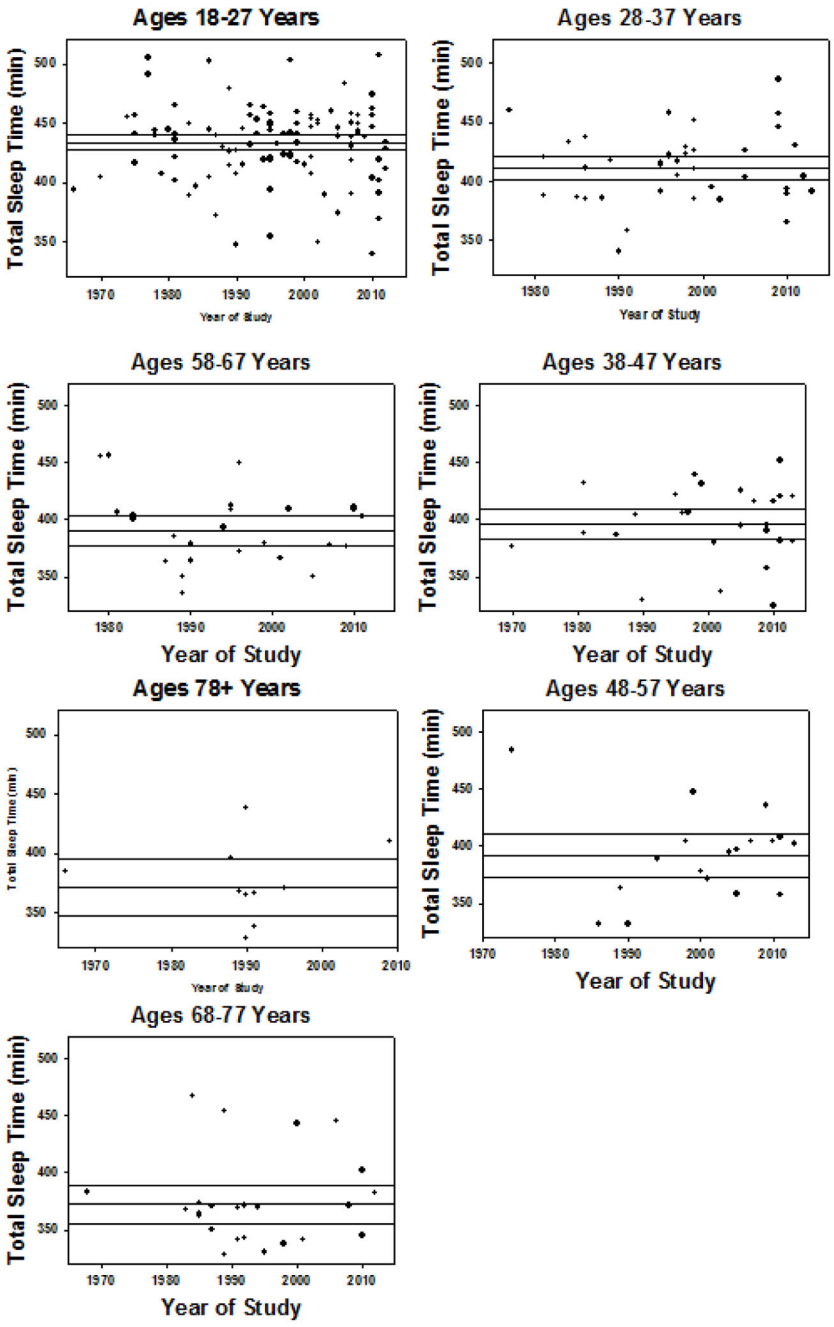


Figure 3.

Association of year of study with total sleep time (with regression line and 95% confidence intervals) for participants ages 18–27 years (a), 28–37 years (b), 38–47 years (c), 48–57 years (d), 58–67 years (e), 68–77 years (f), and ≥78 years (g).

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

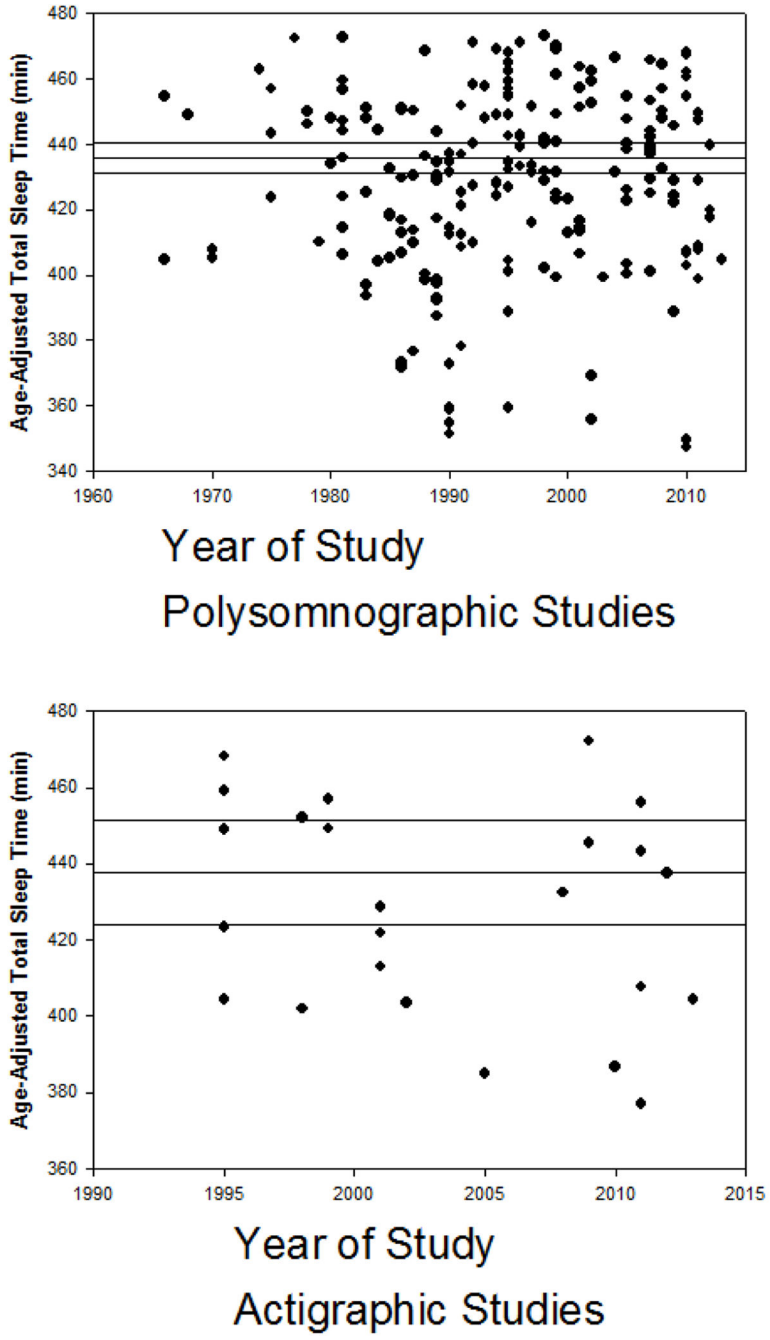


Figure 4.

Association of year of study with age-adjusted total sleep time (min) for polysomnographic data (a) and actigraphic data (b). The regression line and 95% confidence intervals are displayed.

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

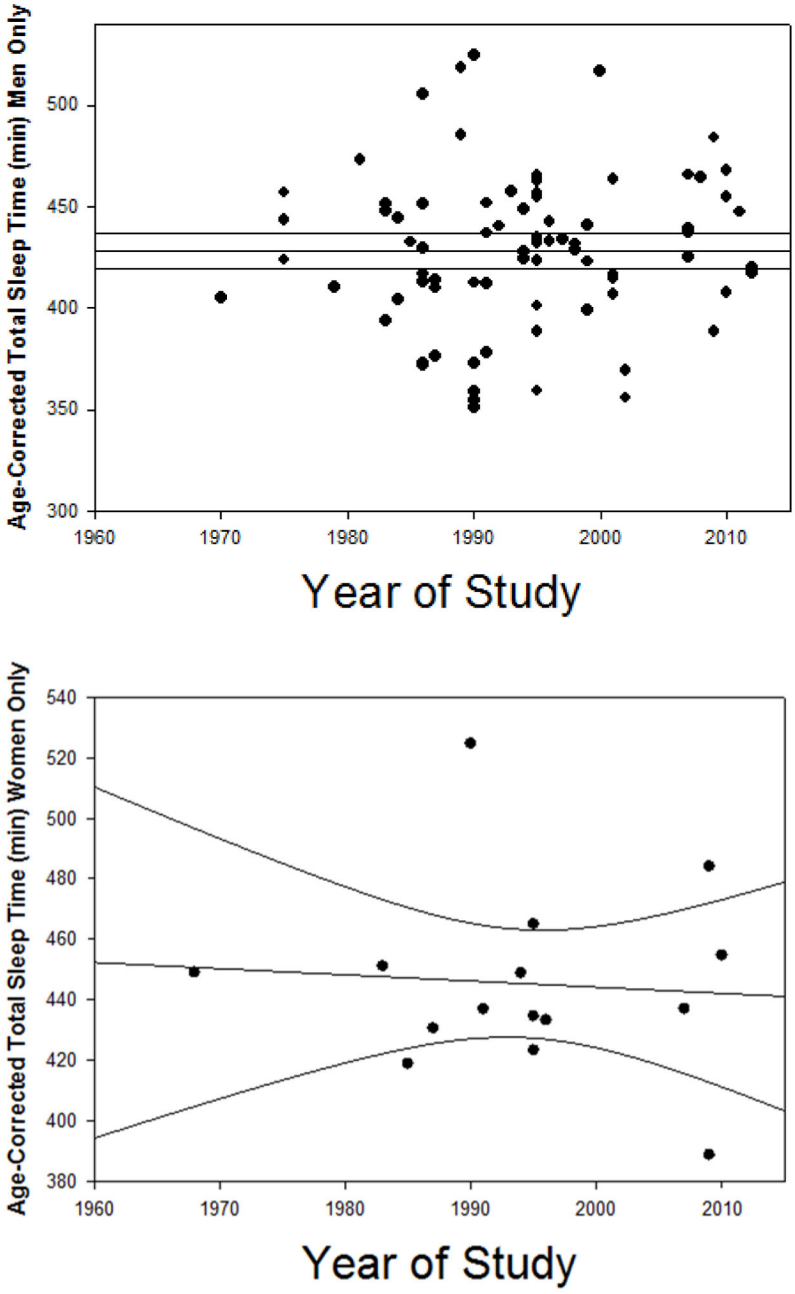
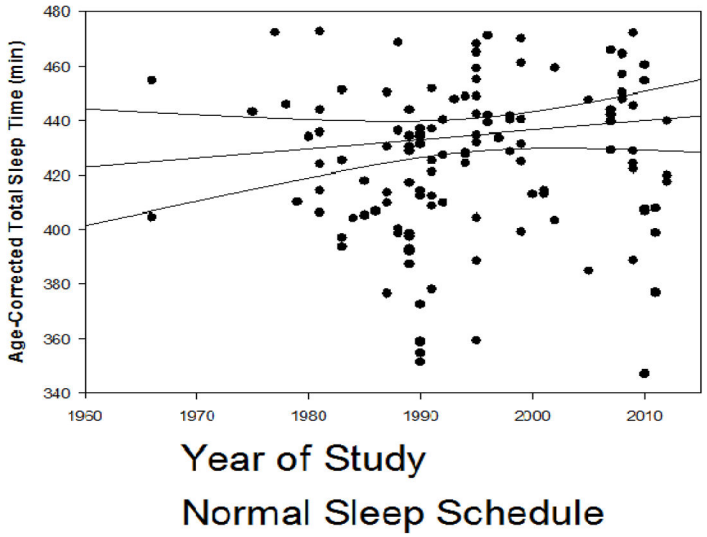


Figure 5.

Association of year of study with age-adjusted total sleep time (min) for women subjects only. The regression line and 95% confidence intervals are displayed.

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

a.)



b.)

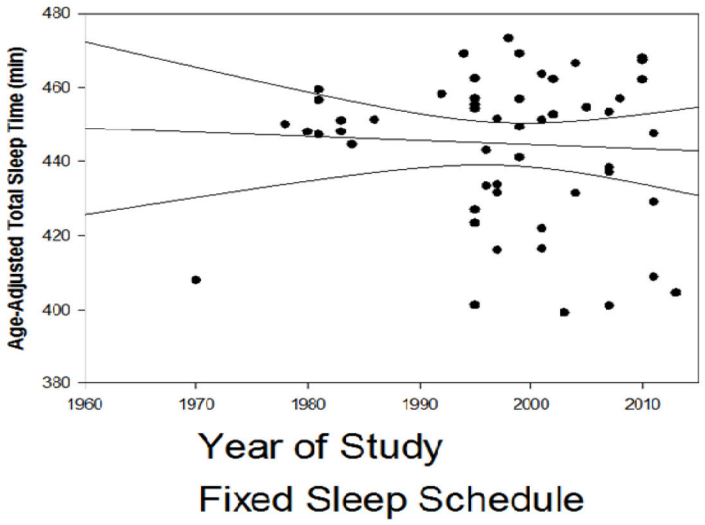


Figure 6.

Association of year of study with age-adjusted total sleep time (min) for studies in which subjects followed their usual sleep schedule (a), and for studies in which subjects followed a fixed sleep schedule of 470–480 min (b). The regression line and 95% confidence intervals are displayed.

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

Sleep Med Rev. Author manuscript; available in PMC 2017 August 01.

Table 1

Polysomnography studies reviewed for the present paper.

Polysomnography Studies									
Fixed Sleep Schedule									
Authors	**Year Published**	**Estimated Year of Study**	**Sample Size**	**Sample Age Years**	**Gender**	**Total Sleep Time (± SD) min**	**Time in Bed (± SD) min**	**Excluded First Night**	**Comments**
Ryback, Lewis	1971	1970	n= 8	18–24	not stated	404.5	480	Yes	Baseline data only
Brezinova	1975	1974	n=24	42–66	M-5 F-9	484 ± 22	540	Yes	
				20–30	M-6 F-4	455 ± 31			
Nicholson, Stone	1980	1978	n=6	24	not stated	443.3	480	Not Stated	Placebo data only
Okuma et al.	1982	1982	n= 8	21.1	M-8	444.4	480	Not Stated	Baseline data only
Bixler et al.	1984	1984	n=100	19–29	M-10 F-11	440.4	480	Yes	
				30–49	M-16 F-21	432.4			
				50–80	M-14 F-28	406.6			
Carskadon, Dement	1985	1985	n= 10	69.3	M-2 F-8	467 ± 54	600	Yes	Baseline data only
Roehrs et al.	1986	1986	n= 12	28	M-12	433.2	480	Yes	Placebo group only
Libert et al.	1988	1988	n= 6	20–29	M-6	444.4 ±19.7	480	Yes	Baseline data only
Gillberg, Akerstedt	1994	1993	n= 7	19–21	No Data	456 ±6.4	480	Yes	8-hour treatment data only
Walsh et al.	1994	1993	n= 12	23.5	M-9 F-3	465	510	Not Stated	ND (no sleep disruption condition) night two data only
Carrier, Dumont	1995	1995	n= 23	22.8	M-18 F-5	463.68	480	Not Stated	Baseline data only
Landolt et al.	1995	1995	n= 9	22.4	M-9	452.67	480	Yes	Placebo, baseline night data only
Mann et al.	1996	1995	n= 11	24.8	M-11	393.5 ±19	480	Yes	Baseline data only
Landolt et al.	1996	1994	n= 10	61.6	M-10	413.4	480	Yes	Baseline data only
Landolt et al.	1996	1995	n=16	20–26	M-8	449.7 ±4.7	480	Yes	
				57–64	M-8	409.2 ±7.9	480		
Cajochen et al.	1997	1995	n= 8	23–32	M-8	443.6 ±10.6	480	Yes	Placebo, pretreatment night data only

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

Polysomnography Studies									
Fixed Sleep Schedule									
Authors	**Year Published**	**Estimated Year of Study**	**Sample Size**	**Sample Age Years**	**Gender**	**Total Sleep Time (± SD) min**	**Time in Bed (± SD) min**	**Excluded First Night**	**Comments**
Martin et al.	1997	1996	n= 12	25	M-7	419.0 ±27.4	450	Yes	Disregarding data from fragmented sleep night
Rao et al	1998	1998	n= 17	African American 30.9	M-6 F-11	416.9 ±45.7	480	Not Stated	
			n= 10	Asian 28.4	M-6 F-4	404.3 ±29.2	480		
			n= 30	Caucasian 42.2	M-16 F-14	406.4 ±52.5	480		
			n= 16	Hispanic 27.7	M-7 F-9	440.6	480		
Harma et al.	1998	1996	n= 2	28.9	F-2	421 ± 24	480	Yes	Controls only
Yassouridis et al.	1999	1997	n= 30	27.5	M-30	432.21 ±16.5	480	Yes	
Sharkey et al.	2001	2000	n= 21	27	M-12 F-9	459 ± 12	480	Yes	Baseline, placebo data only
Onen et al.	2001	2000	n= 9	31	M-9	426.3 ±11.7	480	Yes	Baseline data only
Gaudreau et al.	2001	1999	n=54	19–29	M-10 F-5	502.53 ±46.32	570	Yes	> 18 year old data plotted only
				36–60	M-10 F-5	439.49 ±34.54	480		
Huber et al.	2002	2002	n= 16	22.3	M-16	446.4 ±3	480	Yes	Sham data only
Mukai et al.	2003	2001	n= 8	24.5	M-8	456.3 ±15.7	480	Yes	Normal sleepers only
Brandenberger et al.	2003	2002	n= 24	21.1	M-10 F-2	449.2 ±4	480	Yes	
				64.9	M-10 F-2	409.5 ±85			
Waters et al.	2003	2002	n= 77	26.5	M-77	406.8	480	Yes	Placebo data only
LaJambe et al.	2005	2004	n= 8	18–35	no data per group	389.6 ±24	480	Yes	Placebo data only
Drapeau et al.	2006	2005	n= 12	23.8	M-6 F-6	460 ± 12	480	Yes	Placebo data only
			n= 12	50.3	M-5 F-7	395 ± 15			
Hornyak et al.	2007	2006	n= 35	19–69	M-16 F-29	425.4 ±34.3	480 ±30	Yes	Controls only
Wong et al.	2008	2007	n= 9	27.8	M-9 F-1	390	480	Yes	Control data only
Schmid et al.	2008	2007	n= 9	24.2	M-9	418 ± 11	420	Not Stated	Seven hour TIB data only
Cote et al.	2009	2008	n= 12	21	M-4 F-13	450	480	Yes	Baseline data only
Bixler et al.	2009	2007	n= 66	23.5	M-32	432	480	Yes	Baseline data only

Sleep Med Rev. Author manuscript; available in PMC 2017 August 01.

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

Polysomnography Studies									
Fixed Sleep Schedule									
Authors	**Year Published**	**Estimated Year of Study**	**Sample Size**	**Sample Age Years**	**Gender**	**Total Sleep Time (± SD) min**	**Time in Bed (± SD) min**	**Excluded First Night**	**Comments**
				24.2	F-34	430	480		
Vandekerckhove et al.	2011	2010	n= 13	19–56	M-6 F-7	457.42 ±32.65 445.46 ±45.77	480	Yes	Baseline (first data point) neutral data (second data point)
Brower et al.	2011	2010	n= 10	20–40	no data	389.3 ±10.3	420	Yes	Baseline data only for healthy control
Schmid et al.	2012	2011	n= 23	23.2	M-23	462.1 ±1.3	480	Yes	Sham data only
Schmid et al.	2012	2011	n= 30	23	M-30	456.5 ±2.4	480	Screening night included	Sham data only
Flausino et al.	2012	2011	n= 18	27.2	M-18	339.1 ±54.9	480	Not Stated	Baseline data only. Data deleted as outlier
Holz et al.	2012	2012	n= 20	27.1	M-10 F-10	418.7	480	Yes	Baseline data only
Rosipal et al.	2013	2012	n=148	20–86	M-67 F-81	384 408	474 474	Yes	Data from two nights; used only 2nd night
Tonetti et al.	2013	2012	n= 11	24.75	M-4 F-7	401.18 ±47.96	480	Not Stated	PSG data only, WS device data not included
Normal Sleep Schedule									
Feinberg et al.	1967	1966	n=30	19–36	M-9 F-6	393.9 ±28.1	420.7 ±2.0	Yes	Healthy control data only
				65–96	M-9 F-6	384.4 ±36.5	468.9 ±38.3		
Walker et al.	1977	1975	n= 10	18–22	M-10	441.0 ±27.5	478.6 ±3	Yes	Nonrunner, baseline data only
Gaillard	1978	1977	n= 40	19–21	n=12	504 ± 36	529 ± 38	Yes	
				22–24	n=11	505 ± 45	525 ±38		
				25–27	n=11	491 ±49	517 ± 43		
				28–30	n=6	460 ± 49	507 ± 40		
Browman	1980	1979	n= 8	19–22	M-8	407.3 ±43.1	418.57 ±50.89	Yes	Baseline data only
Adam	1980	1979	n= 16	59	M-6 F-10	455.1±24.8	Normal Sleep Patterns	Yes	Placebo capsule data
Philipson et al.	1980	1978	n= 46	24	M-37 F-9	439.3	481.3	Yes	
Coates et al.	1981	1981	n= 12	23–60	M-6 F-6	388 ±55.4	Normal Sleep Patterns	Yes	Night two data only

Sleep Med Rev. Author manuscript; available in PMC 2017 August 01.

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

Polysomnography Studies									
Fixed Sleep Schedule									
Authors	**Year Published**	**Estimated Year of Study**	**Sample Size**	**Sample Age Years**	**Gender**	**Total Sleep Time (± SD) min**	**Time in Bed (± SD) min**	**Excluded First Night**	**Comments**
Montgomery et al.	1982	1982	n= 12	23.3	M-4 F-4	428. 4	455.3	Yes	Unfit subjects, however still fit healthy criteria
Trinder et al.	1982	1982	n= 6	22.3	not stated	401.4	452.3	Yes	Unfit subjects, however still fit healthy criteria
			n= 6	31.8	not stated	420.2	449.4		
Paxton et al.	1983	1983	n= 9	20.67	M-9	416	446	Yes	Normal, unfit data only. Used average of 2 nights
						426	454		
Bunnell et al.	1983	1983	n= 9	25	M-4 F-5	436.2 ± 11.1	Normal Sleep Patterns	Not Stated	Baseline data only
Horne, Staff	1983	1983	n= 8	25.4	M-8	464.5 ± 20.5	Normal Sleep Patterns	Yes	Baseline data only
Matsumoto et al.	1984	1984	n= 6	20–24	M-6	389.0 ± 11.5	Normal Sleep Patterns	Not Stated	No exercise group
Paxton et al.	1984	1984	n= 17	20	M-17	449 ± 49.5	489 ± 25.2	Yes	Non-athlete. Baseline data only
Reynolds et al.	1985	1985	n= 24	69.5	M-8 F-16	367.4 ± 45	Normal Sleep Patterns	Yes	Healthy control data only
Bonnet	1985	1985	n= 11	18–32	not stated	389	Normal Sleep Patterns	Yes	Baseline data only
Kupfer et al.	1985	1985	n= 10	24.8	M-10	396.6 ± 47.6	Normal Sleep Patterns	Yes	No exercise group
Nakagawa	1987	1987	n= 6	19– 23	M-6	501.8 ± 28.2	523.0 ± 30.7	Yes	Baseline data only
Naifeh et al.	1987	1987	n=23	30–40	M-6 F-6	386 ± 40	404 ± 46	Not Stated	
				60 +	M-5 F-6	364 ± 47	422 ± 58		
Hudson et al.	1988	1988	n=18	20–55	M-8 F-10	384.9 ± 30.7	421.1 ± 27.5	Yes	Controls only
Schiavi, Schreiner-Engel	1988	1988	n=40	23–29	M-11	404 ± 36	441 ± 36	Yes	
				30–39	M-5	411 ± 34	448 ± 41		
				40–49	M-8	387 ± 42	434 ± 26		
				50–59	M-7	332 ± 51	398 ± 39		
				60–73	M-9	317 ± 53	397 ± 39		
Hoch et al.	1988	1988	n=19	60–82	M-9 F-10	350.1 ± 64.9	467.3	Yes	
						370.9± 29.6	455.8		
Mellman, Uhde	1989	1989	n=7	26–49	M-5 F-2	439.6 ± 45.3	Normal Sleep Patterns	Yes	Controls only

Sleep Med Rev. Author manuscript; available in PMC 2017 August 01.

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

Polysomnography Studies									
Fixed Sleep Schedule									
Authors	**Year Published**	**Estimated Year of Study**	**Sample Size**	**Sample Age Years**	**Gender**	**Total Sleep Time (± SD) min**	**Time in Bed (± SD) min**	**Excluded First Night**	**Comments**
Bonnet	1989	1989	n=24	22	M-12	372	411	Yes	
				63	M-12	363	430		
Lydiard et al	1989	1989	n=14	30.1	No Data	384.9 ± 31.4	Normal Sleep Patterns	Yes	Controls only
Saletu et al	1990	1990	n=16	23–39	M-8 F-8	385.66 ± 78.55	426.65 ± 19.4	Yes	Baseline data only
Vitiello et al.	1990	1990	n= 24	63.6	M-11 F-13	385.1	456.5	Yes	Controls only
Brendel et al	1990	1990	n=10	83	M-6 F-4	395.5 ± 70.1	491.5 ± 55.7	Yes	Nights two and three
			n=14	23.9	M-10 F-4	429.8 ± 31.4	445.0 ± 42.4		
Hoch et al	1990	1990	n=34	60–69	M-21 F-13	335.1 ± 62.3	430.6	Yes	
			n=33	70–79	M-17 F-16	328.5 ± 56.4	431.9		
			n=38	80–89	M-19 F-19	318.1 ± 81.4	437.3		
Lauer et al.	1991	1991	n=13	18–24	M-26 F-25 total Not specified for age groups	413.9 ± 16	422.3	Not Stated	Controls only
			n= 10	25–34		417.6 ± 23.6	428.8		
			n= 10	35–44		404.6 ± 34.2	424.1		
			n= 9	45–54		363.1 ± 44.5	397.2		
			n= 9	55–65		350.0 ± 36.3	385.8		
Monk et al.	1991	1991	n=34	80–91	M-16 F-18	368 ± 50	478	Yes	
			n=30	21–30	M-21 F-9	426 ± 39	507		
Van Coevorden et al.	1991	1990	n= 8	20–27	M-8	479 ± 48	Normal sleep Patterns	Yes	Non-catheter data only
			n= 8	67–84	M-8	454 ± 53			
Wauquier et al.	1992	1992	n= 7	88–102	F-7	438 ± 27.6	566 ± 22.8	Yes	
			n= 7	88–98	F-7	328 ± 14.1	462 ± 14.6		
Bonnet, Arand	1992	1992	n= 12	18–30	M-12	445	472	Yes	Baseline data only
Hudson et al	1992	1992	n= 19	24.5	M-7 F-12	407 ± 35	437 ± 32	Yes	Controls only
Monk et al.	1992	1992	n= 25	71–91	F-25	366 ± 37	Normal Sleep Patterns	Not Stated	
			n= 20	71–97	M-20	338 ± 48			
			n= 21	19–28	M-10 F-11	415 ± 47			

Sleep Med Rev. Author manuscript; available in PMC 2017 August 01.

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

Polysomnography Studies									
Fixed Sleep Schedule									
Authors	**Year Published**	**Estimated Year of Study**	**Sample Size**	**Sample Age Years**	**Gender**	**Total Sleep Time (± SD) min**	**Time in Bed (± SD) min**	**Excluded First Night**	**Comments**
Buysse et al	1992	1992	n=45	> 78	M-21 F-24	365.0 ± 62.0	Normal Sleep Patterns	Yes	
			n=33	20–30	M-20 F-13	426.5 ± 36.4			
Hirshkowitz et al.	1992	1992	n=44	20–29	M-44	347.3 ± 62.5	404.9 ± 44.1	Yes	
			n=23	30–39	M-23	340.0 ± 70.8	393.1 ± 58.2		
			n=49	40–49	M-49	329.4 ± 54.6	404.2 ± 49.4		
			n=41	50–59	M-41	331.6 ± 63.6	393.0 ± 51.1		
			n=29	>60	M-29	298.4 ± 61.3	395.7 ± 42.8		
Montmayeur, Buguet	1992	1992	n= 6	36	M-6	357.8 ± 16.2	Normal Sleep Patterns	Not Stated	Data from intermediate temperature only (March)
Dijk, Czeisler	1993	1993	n= 9	21–30	M-9	431.8 ± 6.3	Normal Sleep Patterns	Yes	Baseline data only
Hoch et al.	1994	1994	n=27	<75	M-21 F-29	378.6 ± 40.5	Normal Sleep Patterns	Yes	Baseline data
			n=23	≥75		363.9 ± 57.4			
Buguet et al.	1995	1994	n= 6	24	No data	441.2 ± 4.9	489.1 ± 2.3	Not Stated	Placebo, baseline night data only
Hajak et al.	1996	1995	n= 10	25.6	M-5	419.1 ± 62.1	483 ± 16	Yes	Placebo data only
				49.4	M-5	389 ± 44.6	455 ± 20 min		
Carrier et al.	1996	1995	n= 24	82.2	M-10 F-14	370.3 ± 7.9	460	Yes	Baseline data only
Vitiello et al.	1996	1995	n= 68	55–80+	F-68	393.2 ± 6	465.8 ± 5.9	Yes	Non-catheter data only
			n= 45	60–80+	M-45	369.8 ± 7.3	445.3 ± 8.5		
Ehlers, Kupfer	1997	1996	n=61	20–29	M-18	447.83	477.58	Yes	
					F-14	457.71	483.43		
				30–40	M-15	413	445.57		
					F-14	415.5	439.4		
Haimov, Lavie	1997	1996	n=17	65–75	M-17	330.2 ± 33.4	Normal Sleep Patterns	Yes	
			n=8	19–26	M-8	354.3 ± 38.4			
Carrier et al.	1997	1997	n= 39	29.99	M-52 F-58	457.73 ± 44.36	460.6 ± 4.3	Yes	

Sleep Med Rev. Author manuscript; available in PMC 2017 August 01.

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

Polysomnography Studies									
Fixed Sleep Schedule									
Authors	**Year Published**	**Estimated Year of Study**	**Sample Size**	**Sample Age Years**	**Gender**	**Total Sleep Time (± SD) min**	**Time in Bed (± SD) min**	**Excluded First Night**	**Comments**
			n= 37	34.79		423.05 ± 36.4			
			n= 33	47.64		405.96 ± 37.52			
Edinger et al.	1997	1997	n=32	67.5	M-16 F-16	363.6 (Home)	Normal Sleep Patterns	No	Used only night 2 in the lab
						347.5 (Home)			
						371.8 (Lab)			
						361.1 (Lab)			
Cajochen et al.	1998	1997	n= 10	27	M-10	423.5 ± 5	Normal Sleep Patterns	Yes	Placebo, treatment night data only
Lushington et al.	1999	1997	n= 16	65.4	M-5 F-11	449.3 ± 8	530 ± 6	Yes	
Armitage et al.	2000	1999	n=23	22–40	M-15	384.5	Normal Sleep Patterns	Yes	Controls only
					F-8	410.3			
Carrier et al.	2001	1999	n=100	20–39	M-31 F-27	428.9	Normal Sleep Patterns	Yes	
				40–60	M-22 F-20	404.3			
Nicolas et al.	2001	2000	n=30	20–29	M-3 F-3	433.07 ± 32.99	Normal Sleep Patterns	Yes	
				30–39	M-3 F-3	451.53 ± 47.45			
				40–49	M-3 F-3	431.47 ± 22.09			
				50–59	M-3 F-3	447.65 ± 39.00			
				60–69	M-2 F-4	379.12 ± 41.28			
Edinger et al.	2001	2000	n= 35	40–59	M-17 F-18	377.6 ± 10.5	Normal Sleep Patterns	Yes	Controls only (Home)
Roky et al.	2001	1999	n= 8	20–28	M-8	422 ± 9	Normal Sleep Patterns	Yes	Baseline data only
Means et al.	2003	2002	n= 49	55.4	M-27 F-22	376.9 ± 46.5 (Home)	452.0 ± 63.3	Yes	Disregarded insomnia patient data
						371.2 ± 41.2 (Lab)	430.7 ± 45.8		
Kato et al.	2004	2003	n= 10	24.6	M-4 F-6	452 ± 17	Normal Sleep Patterns	Yes	Baseline data only
Penev	2007	2006	n=12	68.9	M-12	383 ± 58	436	Yes	
Carrier et al.	2007	2006	n= 17	37.2	M-7 F-10	426.1 ± 16	504	Not Stated	Placebo data only
Peters et al.	2008	2007	n= 28	20.14	M-7 F-7	483.12 ± 35.32	Normal Sleep Patterns	Yes	Baseline data only

Sleep Med Rev. Author manuscript; available in PMC 2017 August 01.

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

Polysomnography Studies									
Fixed Sleep Schedule									
Authors	**Year Published**	**Estimated Year of Study**	**Sample Size**	**Sample Age Years**	**Gender**	**Total Sleep Time (± SD) min**	**Time in Bed (± SD) min**	**Excluded First Night**	**Comments**
				69.79	M-7 F-7	445. 43 ± 71.7			
O'Donnell et al.	2009	2008	n= 24	64	M-11 F-13	377.5 ± 37.6	Normal Sleep Patterns	Yes	Baseline data only
Paterson et al.	2009	2008	n= 12	24.9	M-12	458 ± 12	Normal Sleep Patterns	Yes	Placebo data only
Robillard et al.	2010	2008	n= 87	23.3	M-26 F-22	438	Normal Sleep Patterns	Not Stated	
				51.9	M-18 F-21	404			
Morgan et al.	2010	2008	n= 12	39	M-12	416 ± 15	Normal Sleep Patterns		Placebo data only
Marzano et al.	2010	2009	n= 10	23.8	M-10 F-10	441.4 ± 38	484.8 ± 63	Yes	Baseline data only
Ferri et al.	2010	2009	n= 15	24.6	M-12 F-3	449.6 ± 18.41	483.0 ± 16	Not Stated	
Herbst et al	2010	2009	n= 26	39.8	M-13 F-13	386.56 ± 83.95	Normal Sleep Patterns	Yes	Night one and night two data
						395.27 ± 68.49			
Nissen et al.	2011	2009	n= 26	46.3	M-14 F-12	390.4	Normal Sleep Patterns	Not Stated	Controls only
Hebert et al.	2011	2009	n= 22	60.4	M-8 F-14	376.6 ± 59.6	Normal Sleep Patterns	No	Controls only
Danker-Hopfe et al.	2011	2009	n= 30	25.3	M-30	456.3 ± 16.6	Normal Sleep Patterns	Yes	Sham data only
Marzano et al.	2011	2009	n= 50	24.3	M-29 F-21	443.26	Normal Sleep Patterns	Yes	Baseline data only
Gonzalez et al.	2011	2010	n= 20	28–64	F-20	357.31 ± 41.5	420.59 ± 20.74	Not Stated	Control data only
Bianchi et al.	2012	2011	n= 32	18–32	M-16 F-16	474 ± 48	516	Recorded as baseline	Baseline data only
			n= 12	60–76	M-5 F-7	402 ± 48	485		
Ferri, Bruni et al.	2012	2011	n= 98	29.7	M-12 F-13	393.7	438.5	Not Stated	> 18 year old data only
				62.2	M-4 F-6	410.8	526.6		
				73.4	M-3 F-6	345.1	487.7		
Frey et al.	2012	2011	n= 8	20–31	F-8	446.2 ± 26.9	Normal Sleep Patterns	Yes	Disregarded depression data, baseline data only.
			n= 8	57–74	F-8	408.5 ± 42.5			
Kobayashi et al.	2012	2011	n=22	22.6	M-15 F-8	373.1 ± 136.2	Normal Sleep Patterns	Yes	Non-PTSD subjects Only used
						408.1 ± 81.7			
Ferri et al.	2013	2012	n=18	69.4	M-10 F-8	382.5± 53.11	517.2 ± 64.31	Yes	
Chellappa et al.	2013	2012	n= 30	25.2	M-16 F-14	390.7 ± 3.1	Normal Sleep Patterns	Not Stated	Classic light data only

Sleep Med Rev. Author manuscript; available in PMC 2017 August 01.

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

Polysomnography Studies									
Fixed Sleep Schedule									
Authors	**Year Published**	**Estimated Year of Study**	**Sample Size**	**Sample Age Years**	**Gender**	**Total Sleep Time (± SD) min**	**Time in Bed (± SD) min**	**Excluded First Night**	**Comments**
Robey et al.	2013	2012	n= 11	26	M-11	410.9 ± 14.3	438.9 ± 8	Yes	Control data only
Richards et al.	2013	2012	n= 43	30.39	M-22 F-21	403.66	Normal Sleep Patterns	Not Stated	Control data only
Saxvig et al.	2013	2012	n= 19	21.1	M-5 F-14	507 ± 68.8	551 ± 67.2	Yes	Control data only
Sleep Schedule Not Stated									
Kahn et al.	1970	1968	n=10	76.7	F-10	383 ± 46.6	Not stated	Yes	
Williamset al.	1972	1970	n=10	41–46	M-10	376.6 ± 35.7	Not stated	Yes	
Browman, Tepas	1976	1975	n= 9	18.89	M-9	456	Not stated	Yes	Relaxation data group only
Karacan et al.	1976	1975	n= 18	20–30	M-18	416	Not stated	Yes	Baseline data only
Adam	1982	1982	n= 7	58	M-4 F-3	456.5 ± 29.7	Not stated	Yes	Non-catheter night only
Berry, Webb	1985	1985	n=119	50–70	M-55	400.7	Not stated	Yes	
					F-64	403.8			
Reynolds et al.	1986	1986	n= 20	70.1	M-10	374 ± 48	Not stated	Yes	Baseline data only
				68.7	F-10	361.8 ± 42.6			
James et al.	1987	1987	n= 10	29.9	M-7 F-3	436.9 ± 32.8	Not stated	Yes	Placebo group only
Stone et al.	2000	1999	n= 7	23.4	M-7	417.0 ± 26.6	Not stated	Yes	
Youngstedt et al.	2000	1998	n=8	24.5	M-8	424.3 ± 14.4	Not stated	Yes	
Crowley et al.	2002	2001	n=34	18–25	M-8 F-6	453.3 ± 92.7	Not stated	Yes	
				74.6	M-11	341.7 ± 65.5	Not stated		
				76.7	F-9				
Edinger et al.	2003	2003	n=34	46.5	M-16 F-18	370.5 ± 10.1 (Lab)	Ad Lib	Yes	Normal patient data only
						379.6 ± 11.3 (Home)			
De Souza et al.	2003	2001	n= 21	18–33	M-7 F-14	414.8 ± 43.2	Not stated	Yes	
Beaumont et al.	2004	2002	n= 9	35.3	M-6 F-3	395 ± 25	Not stated	Yes	Placebo data only
Mahlberg, Kunz	2007	2006	n= 29	24–86	M-13 F-16	396.8 ± 50.2	Not stated	Yes	Healthy subject only

Sleep Med Rev. Author manuscript; available in PMC 2017 August 01.

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

Polysomnography Studies									
Fixed Sleep Schedule									
Authors	**Year Published**	**Estimated Year of Study**	**Sample Size**	**Sample Age Years**	**Gender**	**Total Sleep Time (± SD) min**	**Time in Bed (± SD) min**	**Excluded First Night**	**Comments**
Bonnet, Arand	2007	2006	n= 12	18–20	M-3 F-9	439	Not stated	No	Data corrected for arousals associated with limb movements and apnea
			n= 13	21–30	M-7 F-6	446			
			n=13	31–40	M-7 F-6	403			
			n=10	41–50	M-6 F-4	395			
			n=14	51–60	M-12 F-2	358			
			n=14	61–70	M-12 F-2	350			
Jaehne et al	2012	2011	n= 44	18–52	M-29 F-15	430.5 ± 17.06	Not stated	Yes	Smoker data disregarded

Sleep Med Rev. Author manuscript; available in PMC 2017 August 01.

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

Sleep Med Rev. Author manuscript; available in PMC 2017 August 01.

Table 2

Actigraphic studies reviewed for the present paper.

Actigraphic Studies									
Fixed Sleep Schedule									
Authors	**Year Published**	**Estimated Year of Study**	**Sample Size**	**Sample Age Years**	**Gender**	**Total Sleep Time (± SD) min**	**Time in Bed (± SD) min**	**Excluded First Night**	**Comments**
Blagrove et al.	1998	1996	n= 9	20	F-9	421 ± 12.2	480	Yes	
Hindmarch et al.	2000	1998	n= 30	27.3	M-15 F-15	441.6	510	Yes	Placebo data only
Jean-Louis et al.	2001	1999	n= 11	25.36	M-4 F-7	441	480	Yes	
Jean-Louis et al.	2001	1999	n=5	25	no data	449 ± 19	480	Yes	
Baskett et al.	2003	2001	n= 20	71.7	M-4 F-16	443	480	Yes	Baseline data only
Yoon et al.	2003	2002	n=133	18–32	M-26 F-47	420.8 ± 48.2	474.5 ± 54.5	Yes	
				60–75	M-22 F-38	366.1 ± 53.2	475.9 ± 64.3		
O'Hare et al.	2014	2013	n=20	30	M-11 F-9	391 ± 49	450	Not Stated	
Normal Sleep Schedule									
Jean-Louis et al.	1996	1996	n= 20	29.95	M-11 F-9	391 ± 57	Normal Sleep Patterns	Not Stated	Validation night only
Hume et al.	1998	1997	n= 190	20–34	M-39 F-23	458 ± 54	Normal Sleep Patterns	Yes	
				35–49	M-22 F-42	422 ±60			
				50–70	M-26 F-38	412 ± 55			
Pires et al.	2001	2000	n= 6	22–24	M-6	558.7 ±73	Normal Sleep Patterns	Yes	Placebo data only. Data from PSG
						511.5 ± 101			
						517.7 ± 39			
Youngstedt et al.	2003	2002	n= 71	18–75	no data	380.95 ± 5.8	Not stated	No, because at home	
Benson et al.	2004	2003	n= 20	35.35	M-7 F-13	383.93 ±70.29	Normal Sleep Patterns	No, because at home	
Monk et al	2006	2005	n= 128	70–92	M-65 F-63	413 ± 83	449 ± 76	Not Stated	
Robertson et al.	2007	2006	n= 15	27.7	M-7 F-8	374 ± 56.8	Normal Sleep Patterns	Not Stated	Normal sleepers only.
Rahman et al.	2011	2010	n=15	35.6	M-5 F-10	486 ±54	Normal Sleep Patterns		Control data only.
Kogure et al.	2011	2010	n= 45	50.2	M-16 F-17	436 ± 69	Normal Sleep Patterns	No, because at home	
				83.8	F-12	410 ± 72.9			
Myllymäki et al.	2011	2010	n= 11	25	M-7 F-4	437.7 ± 45	486	Yes	Control data only

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

Actigraphic Studies									
Fixed Sleep Schedule									
Authors	**Year Published**	**Estimated Year of Study**	**Sample Size**	**Sample Age Years**	**Gender**	**Total Sleep Time (± SD) min**	**Time in Bed (± SD) min**	**Excluded First Night**	**Comments**
Scatena et al.	2012	2011	n= 25	44.3	M-13 F-12	736.7 ± 121.8	Normal Sleep Patterns	Not Stated	Data deleted as outlier
Robertson et al.	2013	2012	n= 19	20–30	M-19	369 ± 40.5	Not stated	Not Stated	Baseline data only.
Petersen et al.	2013	2012	n= 28	41	M-7 F-21	381.81 ± 11.3	491	Yes	Low sensitivity, low stress data only
Sleep Schedule Not Stated									
Naylor et al.	2000	1999	n= 14	75.2	M-5 F-9	337.6 ± 19.5	Not stated	Yes	Controls only
Gooneratne et al.	2011	2009	n= 100	72.5	M-37 F-63	371.1	Not stated	Yes	> 18 year old data only
Wulff et al.	2012	2010	n= 21	37.5	M-13 F-8	364.8 ± 37.2	Not stated	Not Stated	Control data only.
Shambroom et al.	2012	2010	n=26	38	M-13 F-13	324.6 ± 11.2	Not stated	Yes	
Ju et al	2013	2012	n=142	65.6	M-58 F-84	402.6±44.6	486.4 ±49.8	Not Stated	
Winser et al.	2013	2012	n=39	26.5	M-12	428 ± 55.2	Not Stated	Not stated	
				27.9	F-27	434.1 ± 40			
Lombardi et al	2013	2012	n= 23	40.6	M-23	420	Not Stated	Not stated	Sea level data only
			n= 14	36.1	F-14				

Author Manuscript

Author Manuscript

Author Manuscript

Author Manuscript

Table 3

Studies located which assessed sleep objectively both at home and in the laboratory.

Authors /Year	n	Home TST	Lab TST	Comments
Coates et al., 1979	8	380.8	364.1	
Riley, Peterson, 1983	10	378	408	
Edinger et al. 1997	32	Nt 2,3: 371.8	Nights 2–3: 361.1	
Edinger et al., 2001	35	Nt 2,3: 377.6	Nights2–3: 376.5	
Edinger et al, 2003	35	379.6	370.5	
Means et al, 2003	49	376.6	371.2	
Penev, 2007	12	381	383	
Kobayashi, et al., 2012	22	373.1	403.7	Actigraphy home PSG lab