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EARLY TO BED AND EARLY TO RISE MAKES A PERSON HEALTHY: RELATIONSHIPS BETWEEN SLEEP PATTERNS AND PHYSICAL HEALTH

A Thesis in

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by

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ABSTRACT

Chronic lack of sleep and sleep disorders are becoming increasingly more prevalent in the United States, and evidence suggests that severe lack of sleep is detrimental to the functioning of individuals and society. This study uses an ecologically-valid daily diary protocol to investigate the interactive effects of sleep duration, wake-up time, and night-to-night sleep variability on physical health, operationalized as global self-rated health, daily health symptoms, and a biomarker of health (daily profile of the hormone cortisol). Variable-oriented and person-oriented methodologies – hierarchical regression analyses and hierarchical cluster analyses – were employed to explore the research questions. Both methods provided consistent findings, underscoring the importance of the moderating influence of wake-up time and sleep variability on the relationship between sleep duration and health. Results suggest that participants receiving longer sleep, characterized by early wake-up time and consistent night-to-night sleep schedule, demonstrate the best health outcomes. Findings illustrate that sleep is a complex phenomenon, and that the amount of sleep one receives per night is important for physical health only when coupled with additional sleep-related factors.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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EPIGRAPH

"Sleep is the golden chain that ties health and our bodies together."

Thomas Dekker

English dramatist (1572 - 1632)

Chapter 1

Introduction

Specific Aims

Chronic lack of sleep and sleep problems are increasing in prevalence in the United States society and recent empirical work has confirmed the lay wisdom in the importance of sleep for healthy functioning. The National Sleep Foundation estimates that 71% of the population sleep less than eight hours on weekdays (with 40% sleeping less than seven hours), 58% experience at least one symptom of insomnia at least a few times a week, and over one-quarter classify their sleep as either “fair” or “poor” (Sleep in America Poll, 2005). Conversely, those who sleep at least seven hours on weekdays tend to be more likely to rate both their sleep quality and their overall health as either “excellent” or “very good” (Sleep in America Poll, 2002). Although some sleep is crucial for functioning, research is unclear on the precise effects of how much and how people sleep on health. This thesis explores how several sleep parameters (duration, wake-up time, variability in duration and wake-up time) in combination are related to physical health.

Experimental evidence illustrates that sleep is necessary for cognitive, affective, mental and physical well-being (e.g., Dawson & Reid, 1997; Haack & Mullington, 2005; Breslau, Roth, Rosenthal, & Andreski, 1996; Ayas, White, Manson, Stampfer, Speizer, Malhotra, & Hu, 2003, respectively). The estimated report of typical sleep duration, however, is not a consistent predictor of health. Whereas some studies show that unhealthy outcomes are predicted by shorter sleep duration (e.g., Haack and Mullington, 2005), others find long sleep to be associated with illness (e.g., Wingard & Berkman, 1983; for review, see Youngstedt & Kripke, 2004). Finally, several studies illustrate that sleep duration has no direct effect on health (e.g., Pilcher, Ginter, & Sadowsky, 1996).

Such a lack of consistency among findings indicates that sleep duration may influence health under certain conditions, but not under others; that other factors may moderate the relationship between sleep and health. Research on biomarkers, or the micro features of health, suggests that other sleep indicators are important predictors for areas of functioning that may be indirectly related to healthy functioning. Studies examining endocrine functioning indicate that wake-up time may be an important predictor of physical health (Edwards, Evans, Hucklebridge, & Clow, 2001; Schlotz, Hellhammer, Schultz, & Stone, 2004). In addition, sleep parameters fluctuate from night-to-night. For example, several studies have found that sleep onset latency, sleep duration, time in bed, and sleep efficiency demonstrate substantial within-person night-to-night variability (e.g., Knutson, Rathouz, Yan, Liu, & Lauderdale, 2007; Wohlgemuth, Edinger, Fins, & Sullivan, 1999). High night-to-night variability in sleep duration has been found to be an important for health across the life-span. More variable sleep duration is associated with poorer preschool adjustment among children (Bates, Viken, Alexander, Beyers, & Stockton, 2002), worse psychological well-being among adolescents (Fuligni & Hardway, 2006), and lower performance and positive affect among adults (Taub, 1978; Taub & Berger, 1976). These two lines of research indicate that in addition to the effects of sleep duration, wake-up time and the night-to-night pattern of sleep may be important for healthy functioning.

The current thesis examines the moderating effects of wake-up time and night-to-night variability in sleep duration and wake-up time on the relationship between sleep duration and physical health among a national sample of participants. The main research goal is to use an ecologically-valid protocol to examine the interactive influence of sleep duration, wake-up time, and variability in sleep duration and wake-up time on health. Health is operationalized in three ways, as global self-rated health, daily health symptoms, and healthy endocrine functioning. Finally, this study uses both hierarchical regression and cluster analyses. Thus, the study questions were examined with both variable- and person-centered approaches, providing a more rigorous test of the moderation hypotheses. Consistent results from both methods allow for a more robust conclusion than either of the two methods would on their own.

The Costs of Severe Lack of Sleep

A recent rise in investigations of sleep illustrates the importance of sleep for the functioning of individuals and society. The individual and societal costs of sleep-related problems are vast. On the individual level, sleep deprivation compromises cognitive performance, and these cognitive deficits have even been compared to the deficits resulting from alcohol consumption. For example, 17 hours of wakefulness produced cognitive impairments equivalent to those of individuals with blood alcohol concentration (BAC) of .05%; moreover, 24 hours of wakefulness produced impairments equivalent to those of persons with .10% BAC (Dawson & Reid, 1997). An experimental random assignment of participants to sleep 8, 6 or 4 hours per night for 14 nights demonstrated that even moderate, but chronic sleep restriction seriously impairs cognitive performance (Van Dongen, Maislin, Mullington, & Dinges, 2003). Fourteen days of sleep restriction to 6 hours per night produced cognitive deficits observed after 1 night of total sleep deprivation, and 14 days of sleep restriction to 4 hours produced cognitive deficits equivalent to 2 nights without sleep. The most alarming result, arguably, was the fact that sleepiness ratings quickly adapted to partial sleep deprivation, such that by the end of a fortnight, participants sleeping 4 or 6 hours per night reported feeling only slightly sleepy, which was in contrast to their steadily deteriorating cognitive functioning. The authors posit that this adaptation in sleepiness to lack of sleep and a lack of reliable introspection regarding actual sleepiness and performance may explain why chronic lack of sleep is so common and undertreated.

Severe lack of sleep also has an impact on physical and mental health. Studies testing the causal relationship between sleep loss and health among laboratory animals have found that sleep loss can be a causal factor in negative health outcomes, such as hypothermia, weight loss, and, ultimately, death in rats (Everson, 1993; Everson & Toth, 2000; Rechtschaffen, Gilliland, Bergmann, & Winter, 1982). Among humans, reduction of sleep to 5 hours per night during a 7-day hospital stay is associated with robust mood disturbances (Dinges, et al., 1997). In another study, participants were randomly assigned into groups that were allowed to sleep either 4 or 8 hours for 12 consecutive nights. Participants in the short sleep condition reported increases in pain, such as severity of backaches, upset stomachs, and muscular pain, as well as reductions in affective well-being, such as lower reports of happiness, sociability and cheerfulness (Haack & Mullington, 2005).

The ramifications of poor sleep are not restricted to the individual and can affect members of one’s family. For example, a child’s illness may impair the parents’ sleep, and a disturbed sleep on the part of the child may damage the parents' well-being. Germo, Chang, Keller and Goldberg (2007) found that mothers who report higher problems with their child's sleep behavior (e.g., resistance to being alone at bedtime) also exhibit lower marital quality and higher depressive symptoms. Another recent study found that parents of children with multiple sleep disorders experience more daytime sleepiness than parents of children with one sleep disorder (Boergers, Hart, Owens, Streisand, & Spirito, 2007). This association was particularly strong among women, indicating that a child's sleep-related illnesses affect the mother's sleepiness more than the father's.

The societal costs of insufficient sleep length are also profound. The risk of car and ship accidents peaks around 3:00 am – the time when individuals are most sleepy (Folkard, 1997). Anonymous surveys reveal that fatigue is the second most important reason attributed to medical errors among on-call physicians (Wu, Folkman, McPhee, & Lo, 1991) and that fatigue is also the single most important cause of dosage- and control-related mistakes among anesthesiologists (Nocera & Khursandi, 1998; Cooper, Newbower, & Kitz, 1984). On the broadest scale, lack of sleep and fatigue were significant causes of major global-scale accidents, impacting human quality of life and environmental safety. The Three Mile Island reactor accident in Pennsylvania and the Chernobyl nuclear plant meltdown in Ukraine both occurred in the very early morning hours, both caused, in part, by employees' severe lack of sleep and work scheduling problems (Mitler, Carskadon, Czeisler, Dement, Dinges, & Graeber, 1988; Akerstedt, 2007). Lack of sleep was partly to blame for the Exxon Valdez oil spill in Alaska and the Challenger Space Shuttle disaster (Dement, 1999).

The Mechanism of the Relation between Sleep and Health

Lay wisdom advises to get a good night's sleep every night to ward off sickness, and to get as much rest as possible to speed recovery from illness. Several hypotheses have been proposed to explain the causal direction between sleep and illness (for review see Toth & Jhaveri, 2003). The disease process itself influences sleep in predictable ways. Conversely, sleep deprivation may be implicated in health by rendering healthy individuals more susceptible to disease, and by impairing one's ability to recover from an illness (Everson & Toth, 2000; Toth & Jhaveri, 2003).

A series of studies by Toth and colleagues have provided experimental evidence for the influence of disease on sleep. Following an infection, rabbits show a consistent increase in sleep duration. Rabbits that experience a more robust increase in sleep length following infection are more likely to survive than rabbits that show little or no increase in sleep duration (Toth, Tolley, & Krueger, 1993). Thus, an evolutionary advantage may be attributed to an increase in sleep following infections because inactivity and lower metabolic rate may save the energy required for the metabolically costly process of disease resistance (Zepelin, 2000). Some researchers proposed, that in addition to metabolic aims, sleep assists the immune response (Krueger, Majde, & Obal, 2003) because peak levels in circulating levels of inflammatory cytokines (e.g., IL-1, IL-6, TNF) – proteins and peptides produced predominantly by an activated immune system – are reached during nocturnal sleep (Born, Lange, Hansen, Molle, & Fehm, 1997). Furthermore, a pronounced phase of reduced sleep follows the increase in sleep that results from an illness (Toth & Krueger, 1988, 1989, 1990). This time is associated with a rise in the anti-inflammatory cytokines, which proliferate at the late stages of the disease process.

Although pain, fever, or other symptoms of illnesses can prevent sleep onset or cause fragmented sleep, research also suggests that lack of sleep, in turn, may cause pain and illnesses. An experiment examining pain tolerance following sleep restrictions may shed light on whether sleep duration may cause or increase the experience of pain. One experiment found that sleep deprivation shortened the time to finger-withdrawal from a radiant heat source among healthy participants. Finger-withdrawal latency was 25% shorter on nights when participants slept 4 hours, as compared to when they slept 8 hours (Roehrs, Hyde, Blaisdell, Greenwald, & Roth, 2006). Another carefully controlled experiment found a night of sleep deprivation decreased the threshold for pressure pain, but had no effect on the threshold of thermal pain resulting from heat (Onen, Alloui, Gross, Eschallier, & Dubray, 2000). Using the same method for testing thermal pain thresholds, Kundermann and colleagues, however, found that a night of sleep deprivation leads to significant decreases in pain threshold to both cold and heat (Kundermann, Spernal, Huber, Krieg, & Lautenbacher, 2004). Finally, one experiment did not find a significant link between sleep restriction and pain tolerance. The authors found that reducing sleep to 4.5 hours per night does not lead to reduced pressure pain threshold (Smith, Edwards, McCann, & Haythornthwaite, 2007).

Sleep deprivation experiments on animals have been able to investigate the onset of the disease process during sleep deprivation more closely than experiments with human participants. For example, experiments on humans (e.g., Naitoh, Kelly, & Englund, 1990) show that sleep deprivation causes signs of illness that are of a nonspecific origin. Everson and Toth's (2000) clarified these findings with an experiment on rats; their principal finding explains a mechanism whereby sleep deprivation induces nonspecific illness without an infectious focus. They reviewed that the proximal cause of illness occurs because of a weakening of the inflammatory immune response coupled with a bloodstream infection by anaerobic bacteria from the gut. The authors found that following a weakening of the immune system, the bacteria translocated from the rats' intestines to normally sterile extraintestinal sites, such as the lymph nodes and bloodstream. Bacterial migration to organs normally ill-adapted to fight gut bacteria, particularly when coupled with hypothermia, create a state of sepsis in the body, or a life-threatening whole-body inflammatory state. The authors conclude that

> "… it may be considered that abnormalities of host defenses including immune suppression and chronic antigenic challenge would render ordinary sleep-deprived individuals susceptible to disease and exacerbate existing disease and complicate recovery in sleep-deprived patients" (pg. R914).

This study suggests that even in a sterile laboratory environment, sleep deprivation causes illness by weakening the immune system and allowing intestinal bacteria to infect extraintestinal sites.

The Effect of Sleep Duration on Health

The relationship between health and the normative range of sleep length is less evident. Although sleep deprivation and severe lack of sleep may cause critical declines in health and performance, studies examining the implications of mild to moderate lack of sleep do not provide unequivocal conclusions. Epidemiologic studies rarely find a linear effect of sleep duration on health. Slight differences and variations in sleep that typically occur among people are often much less extreme than lab-induced manipulations. These normative between- and within-person differences in sleep length and timing may be adaptive for daily functioning and harmless to health. Some studies find no significant relationship between average nightly sleep duration and health, while others show that both short and long sleep are linked to negative health outcomes.

Sleep of a relatively short length has been linked to depression (Breslau, Roth, Rosenthal, & Andreski, 1996), incidence of coronary heart disease (Ayas, White, Manson, Stampfer, Speizer, Malhotra, & Hu, 2003), and even mortality (Dew, Hoch, Buysse, Monk, Begley, Houck, Hall, Kupfer, & Reynolds III, 2003; Heslop, Smith, Metcalfe, Macleod, & Hart, 2002; Kripke, Garfinkel, Wingard, Klauber, & Marler, 2002; Wingard, Berkman, & Brand, 1982; Wingard & Berkman, 1983). Wingard and Berkman (1983) have found that report of sleeping 6 hours or less was associated with 1.7 and 1.6 times the death rate for men and women, respectively, 9 years later. A National Health and Nutrition Examination Survey have found that a report of usually sleeping less than 5 hours per night is linked with an increased rate of an objectively measured illness – hypertension – over the next 8 to 10 years (hazard ratio, 2.10) (Gangwisch, et al., 2006).

Sleep of a very long duration also has negative consequences for physical and mental health, such that hypersomniacs are at a greater risk of major depression (Breslau, Roth, Rosenthal, & Andreski, 1996). Those who report typically sleeping longer than 8 hours of sleep are at a greater risk of stroke (Qureshi, Giles, Croft, & Bliwise, 1997). Moreover, those who report typically sleeping longer than 9 hours per night are at a greater risk for coronary disease (Ayas, White, Manson, et al., 2003) and symptomatic diabetes (Ayas, White, Al-Delaimy, Manson, Stampfer, Speizer, Patel, & Hu, 2003). The

Alameda County study of health practices (Wingard & Berkman, 1983) and its replication in Michigan (Brock, Haefner, & Noble, 1988), found typical sleep of 9 hours or longer was associated with an increased risk of all-cause mortality, and poor health, respectively. The best outcomes occured among participants who reported typically sleeping between 7 and 8 hours per night in both studies. Kripke and colleagues have found that the risk of mortality increases even for participants reporting 8 or more hours of sleep (Kripke, Garfinkel, Wingard, Klauber, & Marler, 2002). The above-cited research illustrates that although a drastic reduction in sleep hours causes illnesses, an estimated report of how long one sleeps on a typical night is not a consistent predictor of health, and that other factors may be important to consider in concert with sleep duration. Furthermore, the relationship between sleep duration and health may be curvilinear, such that the best outcomes may be associated with moderate levels of sleep. In addition to testing moderators of the relationship between sleep length and health, the current thesis investigates the possibility that sleep duration is not linearly related to health outcomes.

The Importance of Wake-Up Time: Studies of Endocrine System Functioning

Studies examining micro features of health, such as endocrine functioning, indicate that wake-up time may be an important predictor for physical health, in addition to sleep duration. Salivary cortisol, a biological marker of activity of the hypothalamic-pituitary-adrenal (HPA) axis, is essential to healthy functioning. A wealth of studies has documented elevated cortisol levels in response to laboratory-controlled acute psychological stressors (for review see Dickerson & Kemeny, 2004). Unfortunately, much less is known about naturally-occurring cortisol, as the HPA axis regulates itself outside of the laboratory. The data used for analyses come from participants who were instructed to collect their saliva at home with minimal modifications to their daily routines.

Levels of cortisol typically peak 30-45 minutes after waking in the morning and gradually decline throughout the rest of the day. A disruption in the cortisol rhythm, as exhibited by a relatively low morning rise peak (MR), or a relatively flat afternoon decline (AD), or both, may indicate that other biological rhythms are also dysregulated, such as lymphocyte production and basal body temperature (Cugini et al., 1990). Examining patterns of cortisol throughout the day provides a window into the extent to which the HPA-axis is responding to the external environment. Failure to activate the HPA axis in the morning and deactivate it in the evening may indicate a difficulty in disengaging from external demands, leading to inhibition of restoration and recovery processes (Sapolsky, et al., 1986).

A series of studies show that an earlier wake-up time is associated with a healthier, more robust MR profile of cortisol (e.g., Edwards, Evans, Hucklebridge, & Clow, 2001; Kudielka & Kirschbaum, 2003; Federenko, Wüst, Hellhammer, Dechoux, Kumsta, & Kirschbaum, 2004; Schlotz, Hellhammer, Schultz, & Stone, 2004). Early studies examining a similar question, however, have found no consistent effect of wake-up time on the profile of cortisol (Pruessner, Wolf, Hellhammer, Buske-Kirschbaum, von Auer, Jobst, Kaspers, & Kirschbaum, 1997; Wüst, Wolf, Hellhammer, Federenko, Schommer, & Kirschbaum, 2000). Pruessner and colleagues (Pruessner, et al., 1997) had tested three small datasets to explore the correlates of the MR. Time of awakening was not associated with the MR of cortisol, but neither was age, weight, smoking, or alcohol consumption – all factors that were since found to affect cortisol levels. An analysis of

509 adult participants pooled from four separate laboratory-based studies has investigated the relationship between awakening time, sleep length and cortisol MR after each construct was aggregated across two days (Wüst, Wolf, Hellhammer, Federenko, Schommer, & Kirschbaum, 2000). Shorter sleep length was related to a more robust MR, but wake-up time did not have a direct effect on MR or total cortisol levels. Unfortunately, the authors did not test the statistical interaction between sleep duration and wake-up time.

Most studies, however, suggest that earlier wake-up time is indeed related to a healthier, more robust cortisol MR. A very recent study by Wilhelm and colleagues (Wilhelm, Born, Kudielka, Schlotz, & Wüst, 2007) found that the morning increase in cortisol is not simply a biologically entrained circadian rhythm that would occur regardless of whether one is awake or not. Cortisol serum levels were traced throughout the night until one hour after awakening. The results displayed a linear increase of serum cortisol throughout the night, coupled with a much steeper spike following awakening. In other words, the results demonstrated that in addition to being a circadian rhythm, the cortisol MR is a response to awakening, rather than just a hormonal spike that also happens to occur at the time that one wakes up.

Edwards, Evans, Hucklebridge and Clow's (2001) data on 40 university students and staff aggregated across two days show that an early wake-up time is associated with larger cortisol response to awakening, as well as a more marked afternoon decline. Similarly, Kudielka and Kirschbaum (2003) found in their study of 179 community dwelling participants that earlier wakers (mean wake-up time: 06:49) have a steeper MR than late wakers (mean wake-up time: 09:43) do. This study is particularly interesting because the authors used home collection of salivary cortisol rather than the typical laboratory collection. The authors did not, however, assess cortisol past one hour post-waking, so whether wake-up time affects AD is unclear from this study. Federenko, Wüst, Hellhammer, Dechoux, Kumsta and Kirschbaum (2004) also showed a significant association between wake-up time with MR. The authors aggregated data across two days and compared the MR among 24 nurses working on early (06:00–1400), late (13:30–20:00), and night (20:00–06:00) shifts. Earlier wake-up time was associated with higher cortisol level at 60 minutes post waking, and total sleep time was not directly related to MR. The absence of the main effect of sleep duration, however, does not preclude the possibility that wake-up time and sleep duration may interact to influence MR. Lack of cortisol collection in the afternoon and a very low sample size did not permit the examination of AD and the interaction of sleep duration with wake-up time, respectively. Furthermore, a small sample size may have increased the possibility of Type II error.

The Importance of Variability: Within-Person Variability in Sleep Duration and Wake-Up Time

Sleep is an adaptive phenomenon, fitting the physical, cultural and biotic proximal factors (Worthman & Melby, 2002). Although adaptive behavior promotes survival in most cases, too much stress in the environment to vary sleep from night-to-night may make sleep too irregular than is beneficial for typical health functioning. Not surprisingly, researchers find that sleep duration and wake-up time vary within each person from night-to-night. Wohlgemuth and colleagues (Wohlgemuth, Edinger, Fins, & Sullivan, 1999) found that people show substantial within-person night-to-night variability on various sleep parameters, such as sleep onset latency, total sleep time, wake-up time after sleep onset, time in bed, and sleep efficiency.

A series of analyses of the CARDIA sample (Coronary Artery Risk Development in Young Adults) yielded an interesting picture of night-to-night variability in sleep. A subsample of CARDIA respondents (n = 669) were recruited to participate in a longitudinal sleep study (Knutson, Rathouz, Yan, Liu, & Lauderdale, 2007). Participants were instructed to wear wrist actigraphy watches and keep sleep logs for three consecutive nights of at-home collection during two waves of data collection, which were spaced apart by approximately one year. Although the wake-up time data was not analyzed, the authors decomposed the variance of sleep duration, as measured by wrist actigraphy, into between-person, within-person day-to-day, and within-person year-to-year variance. Results suggest that the most variability in sleep duration comes from within-person day-to-day variance, while between-person differences in sleep duration are the most stable. On average, participants varied by 42 minutes from each other, 23.4 minutes from year-to-year, and 75.6 minutes from night-to-night.

Evidence suggests that an inconsistent sleeping schedule may be just as detrimental as sleep deprivation for health and well-being. High night-to-night variability in sleep duration predicts psychological well-being among adolescents (Fuligni & Hardway, 2006) and lower positive affect, and higher reaction times and negative affect among adults (Taub, 1978). High variability in sleep duration is also associated with other important outcomes, which may or may not indicate poor physical functioning. For example, Taub and Hawkins (1979) showed that irregular sleepers score higher on a scale of flexibility, but lower on scales of dominance, sociability, self-acceptance, self-control, achievement via conformance, and intellectual efficiency, than control subjects. Among children, high night-to-night variability in sleep duration is associated with an experience of poor preschool adjustment (Bates, Viken, Alexander, Beyers, & Stockton, 2002), whereas higher bedtime irregularity is associated with poorer school functioning (Acebo & Carskadon, 1993). Finally, experimental irregularization of sleep schedules causes mood deficits and performance reduction among college students (Taub & Berger, 1976). Although no previous studies known to the author of this thesis examined the influence of high variability in sleep duration and wake-up time on self-reported health and the daily cortisol profile, previous literature on the significance of sleep variability for school functioning, affect, and performance indicates that this kind of variability may have important implications for health.

The Current Study

The first purpose of this study is to explore the distribution of sleep duration, wake-up time, and variability in sleep duration and wake-up time among a national sample of participants residing in the United States. The national sample of this study will contribute generalizability to the findings of in-depth sleep studies, which have often recruited small, unrepresentative samples. Large-scale epidemiological studies are often confined to a one-time assessment of typical sleep practices, whereas this study administers sleep questions that pertain specifically to the previous night, for 8 consecutive days. In addition to providing a picture of the normative distribution of Americans on sleep duration, wake-up time, and variability in sleep duration and wake-up time, this study will use cluster analysis to establish typical person-specific patterns among the above-mentioned sleep variables.

The second aim of the study is to examine the main effects of sleep duration, wake-up time, and variability in sleep duration and wake-up time on the indicators of health. According to previous research, we can expect that longer sleep duration, earlier wake-up time, and lower variability in sleep duration and wake-up time will be positively related to better health.

The final goal and primary function of this study is to test whether sleep duration affects health in concert with other sleep variables, such as wake-up time, and variability in sleep duration and wake-up time. Furthermore, this study will distinguish the effects of sleep on three types of health indicators: self-rated global health, self-rated daily health, and an objective indicator HPA functioning.

Chapter 2

Method

Participants

The sample comes from the second wave of respondents (N = 4,963) who took part in the National Survey of Midlife in the United States (MIDUS II) – a nationally-representative survey of noninstitutionalized, English-speaking adults of the coterminous United States. During the first wave of data collection, which spanned between 1995 and 1996, over 7,000 individuals between the ages of 25 and 74 participated in the original MIDUS survey. Phone numbers were selected from working telephone banks. For each household contacted, a list was generated of all people between the ages of 25 and 74, and a random respondent was selected. No other person in the household was selected if the selected respondent did not complete the interview. Respondents were re-interviewed 9-10 years later (2004-2006).

Analyses are based on a randomly-selected subsample of unrelated Wave 2 MIDUS participants (n = 1042) who also agreed to take part Wave 2 of the National Study of Daily Experiences (NSDE II), an eight-day daily diary satellite of the MIDUS project. Among the NSDE II participants, over two thirds of the subsample (n = 791) were part of the nationally-representative sample, contacted through random digit dialing procedures, while the remaining third were part of the randomly selected subsamples of United States unrelated twins (n = 174), unrelated siblings (n = 77).

A randomly-selected subsample of MIDUS II participants is currently being surveyed by the NSDE II team of researchers. The results of the current study are based on the preliminary sample of 1042 participants that have been interviewed so far; this sample represents approximately 63% of the NSDE II eventual participant sample goal.

Procedure

The MIDUS sample. Upon re-contact of MIDUS I, consenting participants were administered a telephone interview and an extensive self-administered mail-in questionnaire as part of the MIDUS II battery. Both the telephone and the mail-in surveys, assessed behavioral, psychological and social factors (e.g., cognitive functioning, coping, stressful life events, features of work and family functioning, caregiving), as well as facets of health and well-being (e.g., physical functioning, chronic conditions, depressive symptoms, satisfaction with life). The response rate for both parts of the survey was 60.8%.

The NSDE subsample. A randomly selected sample of participants were contacted approximately 90 days after the completion of the MIDUS battery and invited to participate in the NSDE II. NSDE II respondents completed eight consecutive evening telephone interviews regarding their experiences during the previous day, including questions on stress, positive events, sleep, daily health symptoms, psychological distress, and time use. The interviews were conducted by trained interviewers from the Penn State's Survey Research Center during a convenient time, as indicated by the participant, with the computer-aided telephone interview system (CATI). The CATI consists of a keypunch data entry and skip patterns to keep the interview efficient and make better use of interview time. On the final day of data collection, each participant also responded to several questions regarding the previous week's experiences overall.

Cortisol is assayed through saliva for day 2 through 5 of the study period. As part of recruitment, respondents receive a Home Saliva Collection Kit one week prior to their initial phone call. Sixteen numbered and color-coded salivettes are included in the collection kit, each containing a small absorbent wad, about 3/4 of an inch long, as well as a detailed instruction sheet. In addition to written instructions, telephone interviewers review the collection procedures and answer any questions. When all 16 tubes are ready to be sent, participants use a pre-addressed, paid courier package for the return mailing. The enclosed salivettes are shipped to the MIDUS Biological Core at the University of Wisconsin, where they are stored in an ultracold freezer at -60 ^{o}C. For analysis, the salivettes are thawed and centrifuged at 3000 rpm for 5 min yielding a clear fluid with low viscosity. Cortisol concentrations are quantified with a commercially available luminescence immunoassay (IBL, Hamburg, Germany), with intra-assay and inter-assay coefficient of variations below 5% based on our prior experience (e.g., Dressendorfer, Kirschbaum, Rohde, Stahl, & Strasburger, 1992).

Measures

Covariates. Demographic characteristics – age, gender, education, and household income – were entered to control for the confounding effects of age differences, sex, and socioeconomic status. A nominal education scale, ranging from 1 to 12, was developed for the MIDUS project. Total household income was a sum of earnings and government assistance of all members of the household (for a detailed review of the MIDUS measures see Brym, Ryff, & Kessler, 2004).

Sleep. The NSDE daily interview included questions on sleep and wake-up time. Participants answered two questions: “Since yesterday, how long did you spend sleeping, not including the time you may have spent napping," and "At what time did you wake up today?" Responses to these questions from eight consecutive evenings were used to compute four independent variables: average sleep duration, average wake-up time, and average night-to-night individual variability (within-person Standard Deviation) in sleep and wake-up time. All 4 sleep variables were centered. Finally, interactions between sleep duration and each of the other 3 sleep variable was created.

Global health. Self-rated global health was assessed by the original MIDUS II telephone survey, where participants were asked to estimate their general health on the scale ranging from and 5 (*poor)*, 4 (*fair*), 3 (*good*), 2 (*very good*), 1 (*excellent*). The responses were reverse-coded for all analyses, such that a higher number corresponds to better health. This one-item measure among the MIDUS sample of participants has been successfully used in various studies to assess health status (e.g., Lachman & Weaver, 1998; Almeida, Neupert, Banks, & Serido, 2005)

Daily health symptoms. Health symptoms were assessed daily with an adapted version of Symptom Checklist (Larsen & Kasimatis, 1991). An interviewer prompted each participant with a *Yes* or *No* response to a checklist of symptoms and conditions including aches (e.g., headache, joint pain), gastrointestinal symptoms (e.g., nausea/upset stomach), and upper respiratory symptoms (e.g., allergies, flu symptoms), as well as one open-ended item. Following an affirmative response to any of the symptoms, participants were asked to rate the subjective severity of the symptom on a scale ranging from 1 (*very mild*) to 10 (*very severe*). Male participants were asked to report on 25 symptoms, whereas the checklist for female participants included two additional items (menstrual-related symptoms, hot flashes or flushes). These two extra items were excluded from analyses, to ensure equivalence of symptom scales among male and female participants. Two measures of daily health – symptom number and symptom severity – were created. Number of symptoms were created by averaging the number of daily symptoms across 8 days and symptom severity was a sum or all symptom severity ratings across 8 days.

Cortisol. Respondents provide 4 saliva samples per day on days 2 through 5 of the 8-day period to be assayed for cortisol. On each of the four saliva collection days, respondents produced saliva samples upon awakening, 30 minutes after getting out of bed, before lunch, and before bed time. Data on the exact time respondents provide each saliva sample was obtained from the nightly telephone interviews and from a paper-pencil log sent with the collection kit.

Plan of Analyses

The first set of analyses examined the effects of sleep on health using hierarchical regression analysis. Five regressions were ran, each predicting global self-rated health, number of daily symptoms, severity of daily symptoms, cortisol morning rise, and cortisol afternoon decline. Control variables – age, gender, education, and total household income – were entered at Step 1 of the regression. The four constructed sleep variables – sleep duration, wake-up time, within-person variation in sleep duration, and within-person variation in wake-up time – were entered at Step 2. Finally, Step 3 examined the moderating effects of the latter three sleep variables on the relationship between sleep duration and health.

The second set of analyses examined the research question using cluster analysis, a person-specific analytic approach. Profiles of sleep duration, wake-up time, within-person variation in sleep duration and within-person variation in wake-up time were created using the hierarchical agglomerative technique with centroid clustering and cosign similarity measure. In addition to providing an exploration of meaningful person-specific patterns of sleep, cluster analysis allows a test of nonlinear relationships among variables, as well as an examination of complex three- and four-way interactions that are difficult to conduct in regression, due to collinearity and difficulty in interpretation of complex interactions. After the profiles of sleep were created with cluster analyses, five one-way ANOVAs were ran, with sleep profiles predicting global self-rated health, number of daily symptoms, severity of daily symptoms, cortisol morning rise, and cortisol afternoon decline.

Chapter 3

Results

Descriptive Statistics

A total of 1,042 NSDE respondents were included in the analyses. On average, participants were 57.57 years old (age range: 34-84), reported receiving around 3 years of post high-school education, and a total household income of nearly 68,000 dollars. The descriptive statistics and averages for self-reported variables of the sample are presented in Table 1. NSDE participants were approximately two years older, slightly more likely to be female, reported a slightly lower total household income and a slightly higher self-rated global health than the original, nationally-representative MIDUS sample.

Table 1 illustrates that U.S. Americans report “good” to “very good” health. Despite this optimistic picture, the participants reported considerable variability in their responses. For most people in the sample (within one standard deviation of the mean), health ranged between “fair” and “excellent,” and the average number of daily physical symptoms typically ranged from approximately 0 to 4 per day.

Respondents reported sleeping a little over 7 hours per night, an average wake-up time of 6:45 am, and “good” to “very good” health. Participants varied among each other in sleep, such that most participants (within one standard deviation of the mean) slept approximately 6 to 8 hours per night, and woke up between approximately 5:30 and 8:00 am. The average within-person night-to-night variation in sleep duration was approximately one hour.

The baseline correlations of dependent variables with covariates are presented in Table 2. The first four rows of this table present correlations among control variables and health outcomes. Older participants reported lower self-rated global health and experienced slightly flatter cortisol afternoon declines. Women were more likely to report a greater number of daily physical symptoms and higher total severity of physical symptoms across 8 days. Lower levels of education and household income were both risk factors for poor health, as measured by self-rated global health, greater report of symptom number and severity, and flatter afternoon decline of cortisol. Lower education was also weakly associated with a steeper morning rise of cortisol.

In general, longer sleep duration, earlier wake-up time, and lower night-to-night variability in sleep duration and wake-up time were associated with positive health outcomes. Specifically, better self-rated health was associated with longer and less variable sleep duration, better daily health, as measured by daily symptom number and severity, was associated with longer and less variable sleep duration and earlier wake up time. Finally, more robust afternoon decline in cortisol was associated with lower variability in sleep duration and wake-up time, and longer sleep duration. Conversely, a more robust morning rise in cortisol was associated with higher variability in sleep duration and wake-up time, and shorter sleep duration. Thus, duration and variability of last night's sleep were consistent predictors of all five outcomes, wake-up time was associated with daily reports of health, and variability in wake-up time was related to cortisol outcomes.

Table 3 presents associations between independent variables. Older participants reported lower education, household income, and variability in sleep duration and wake-up time across 8 days. Women also tended to report less education and income, but a greater night-to-night variability in sleep duration. Although sleep variables were all significantly associated, the correlations were modest, never rising above r = .35. The associations between control variables with each other and sleep variables were non-significant to small (Cohen, 1988).

Hierarchical Regression Analyses

Hierarchical regression analyses were first used to account for the effect of control variables, followed by an examination of the main effects of sleep on health, and concluding with the exploration of the moderating effects of wake-up time, and variability in sleep and wake-up time on the relationship between sleep duration and health. Five regressions were conducted, with self-rated global health, number of daily symptoms, sum of daily symptom severity, morning rise in cortisol, and afternoon decline in cortisol as dependent variables, respectively. Age, gender, education and household income were entered in the first block as control variables in all analyses. The main effects of four sleep variables were entered into the second step of each regression. The interactive effects of sleep duration with wake-up time and variability in sleep duration and wake-up time were entered as a final step of each regression. The interactions were entered simultaneously to reduce the likelihood of Type I error in light of multiple comparisons.

Main Effects. Models 2 in Tables 4 through 8 describe the effects of four created sleep variables on health after the effects of control variables were partialed out. Wake-up time was the only sleep factor that had a significant main effect on self-rated global health (Table 4), showing that earlier wake-up time is associated with better global self-rated health. Lower average number of physical symptoms (Table 5) was predicted by an earlier wake-up time and a lower night-to night variability in sleep duration. Similarly, lower total weekly severity of physical symptoms (Table 6) was predicted by an earlier wake-up time and a lower night-to night variability in sleep duration. Contrary to predictions, a healthier, more robust cortisol morning rise (Table 7) was associated with greater variability in wake-up time; however, in agreement with predictions, a more robust cortisol morning rise was associated with a longer sleep duration. Finally, contrary to expectations, a healthier, steeper cortisol afternoon decline (Table 8) was predicted by a shorter sleep duration.

Interactive Effects. Figures 1 and 2 illustrate the interactive effects of sleep variables on self-rated global health. Wake-up time and variability in wake-up time moderated the relation between sleep duration and self-rated global health. Simple slope analyses revealed that compared to shorter sleep, long sleep was only beneficial in light of an earlier wake-up time, furthermore, earlier wake-up time was only beneficial for self-rated global health in light of a longer sleep duration (Figure 1). Variability in wake-up time had a similar moderating effect on the relationship between sleep duration and self-rated global health, such that long sleep was only beneficial within the context of lower wake-up time variability, and lower variability in wake-up time was only beneficial within the context of longer sleep (Figure 2). The three-way interaction between sleep duration, wake-up time and variability in wake-up time self-rated global health was not significant (results not shown).

Figure 3 through 5 show the interactive effects of sleep variables on self-rated daily health, demonstrating that wake-up time and low variability in sleep duration moderated the relation between sleep duration and self-rated daily health. Long sleep duration predicted fewer number of daily physical symptoms in light of an earlier wake-up time, and earlier wake-up time predicted fewer number of physical symptoms within the context of longer sleep duration (Figure 3). An identical moderation of wake-up time was observed in the relation between sleep duration and daily physical symptom severity, such that long sleep in combination with early wake-up time, and visa versa, predicted low symptom severity (Figure 4). Low sleep duration variability moderated the relation between sleep duration and daily physical symptom severity (Figure 5). As in previous cases, longer sleep duration predicts lower total symptom severity only in the context of lower variability in sleep duration. In contrast to the above-described interactions, lower variability in sleep duration provided a statistically significant benefit to physical symptom severity of all participants, regardless sleep duration. However, the benefits of lower variability in sleep duration were stronger in light of a longer sleep duration. The three-way interaction between sleep duration, wake-up time and variability in sleep duration on symptom severity was not significant (results not shown).

No interactions were significant in Model 3 of cortisol morning rise and afternoon decline, indicating that the second model of these regressions are the final models to be interpreted.

Cluster Analyses

The four sleep variables were grouped by using cluster analysis to explore whether there may be meaningful person-specific patterns of sleep length, wake-up time and variability in sleep and wake up time. Cluster analysis approach also allows to examine non-linear relationships between variables that would have been difficult to test in regression because of issues of collinearity. Moreover, examination of within-person patterns across all variables allows for a test of complex three- and four-way interactions, which would have been difficult to interpret as regression coefficients. Hierarchical agglomerative technique with centroid clustering and cosine similarity measure was used, as this method produced the groups that were the most equal in size, while still constructing groups that were sufficiently different from each other. Cosine similarity measure emphasizes the scatter of scores on the variables (Blashfield & Aldenderfer, 1988), and stresses the shape, as well as level of similarity within variables across cluster groups. Various number of clusters were tested, with the four cluster solution yielding the best prediction of health outcomes.

Six hundred and thirty participants had available data on all four sleep variables. Figures 6 and 7 illustrate raw and standardized scores for sleep duration, wake-up time, and variability in sleep duration and wake-up time for each of the four clusters. Clusters 1 and 2 included the largest number of participants and were both within .5 standard deviation of the mean for each of the four variables. Participants in Cluster 1 (49.2% of respondents) slept slightly longer, woke up earlier, and experienced less inconsistency in sleep duration and wake-up time, than participants in Cluster 2 (30.5%), indicating that participants in Cluster 1 may report the healthiest sleep patterns. The greatest the difference between these clusters was in wake-up time; therefore Clusters 1 and 2 were named "Consistent Sleepers and Risers" and "Consistent Sleepers, Later Risers," respectively. The average scores of respondents in Clusters 3 and 4 were strikingly different from the average scores. Cluster 3 (11.4%) experienced the shortest sleep duration, latest wake-up time, and a relatively high night-to-night variability in sleep duration; this group was called "Inconsistent Short Sleepers, Latest Risers." The sleep pattern of participants belonging to Cluster 4 (8.8%) was characterized by the highest variability in both night-to-night variability in sleep duration and wake-up time; this group was named "Inconsistent Sleepers and Risers." Upon closer comparison of regression and cluster analysis results participants in Cluster 1 are similar to the healthiest group found by regression analyses: early wakers who slept longer.

A series of one-way ANOVAs with Tukey post hoc comparisons were conducted to test whether there were between-cluster differences in health. Table 9 shows how participants in each cluster varied from participants in other clusters on health outcomes, whereas Figures 8 though 12 graphically illustrate these differences. Consistent Sleepers and Risers experienced the best health on most outcomes whereas Inconsistent Short Sleepers, Latest Risers showed the worst self-reported health outcomes. There was a significant difference between Consistent Sleepers and Risers and Inconsistent Short Sleepers, Latest Risers on self-rated global health (Figure 8); these groups had the best and worst self-rated global health, respectively. Consistent Sleepers, Later Risers and Inconsistent Sleepers and Risers did not differ significantly from the above-mentioned participants in Clusters 1 and 3.

Inconsistent Short Sleepers, Latest Risers reported experiencing the greatest number of daily physical symptoms, when compared to participants in each of the other three clusters (Figure 9). Similarly, Inconsistent Short Sleepers, Latest Risers reported experiencing greater total symptom severity, when compared to participants in each of the other three clusters (Figure 10).

Figure 11 demonstrates cortisol afternoon decline as a function of cluster membership. Consistent Sleepers and Risers had a more robust afternoon decline in cortisol than the Inconsistent Short Sleepers and Latest Risers and than the Inconsistent Sleepers and Risers. Consistent Sleepers, Later Risers experienced steeper cortisol afternoon declines than Inconsistent Sleepers and Risers.

Table 1

Descriptive Statistics

	Means (*SD*) NSDE (*n*=1,042)	Means (*SD*) MIDUS (*N*=4,963)	*t*	df
Gender (0 = male, 1 = female)	0.57	0.53	2.48*	1,646.7
Age	57.57 (12.51)	55.43 (12.45)	6.25***	4,960
Education	7.25 (2.46)	7.20 (2.52)	0.76	4,954
Total Household Income (dollars)	67,924 (57,579)	71,322 (61,257)	-2.10*	1,898.5
Self-Rated Health	3.59 (.98)	3.54 (1.02)	1.98*	1,706.9
Sleep Duration	7.10 (1.02)			
Wake-up Time	6.74 (1.29)			
Sleep Duration Variability	0.97 (.62)			
Wake-up Time Variability	1.00 (.87)			
Number of Symptoms	1.72 (1.76)			
Total Symptom Severity	9.00 (8.78)			

*$p < .05$, **$p < .01$, ***$p < .001$.

Table 2

Correlation Table

Variables	Self-Rated Health	Number of Symptoms	Total Symptom Severity	Morning Rise	Afternoon Decline
Age	-.09**	.03	.01	.03	.10*
Gender (0 = male, 1 = female)	-.01	.15***	.16***	.03	-.04
Education	.22***	-.09**	-.13***	-.07*	-.11**
Household Income	.26***	-.17***	-.18***	-.01	-.12**
Sleep Duration	.10**	-.10**	-.14**	-.07*	-.16***
Wake-up Time	-.08	.13**	.11**	.02	.00
Sleep Duration Variability	-.11***	.18***	.24***	.15***	.12**
Wake-up Time Variability	-.04	.02	.06	.15**	.11*

*$p < .05$, **$p < .01$, ***$p < .001$.

Table 3

Correlations Among Independent Variables

Variables	Age	Gender	Education	Household Income	Sleep Duration	Wake-Up Time	Sleep Duration Variability
Age							
Gender (0 = male, 1 = female)	-.04						
Education	-.07*	-.14***					
Household Income	-.28***	-.08**	.31***				
Sleep Duration	.04	.02	.10**	.05			
Wake-up Time	-.03	.08	.05	.03	.20***		
Sleep Duration Variability	-.15***	.11**	-.07*	-.03	-.22***	.15***	
Wake-up Time Variability	-.22***	.06	-.04	.12**	-.13**	.25***	.34***

**p* < .05, ***p* < .01, ****p* < .001.

Table 4

Hierarchical Regression Analysis for Variables Predicting Self-Rated Health

	Model 1 (β)	Model 2 (β)	Model 3 (β)
Age	-.030	-.054	-.047
Gender	-.031	-.018	-.017
Education	.112**	.104*	.112**
Household Income	.228***	.223***	.217***
Sleep Duration		.054	.084*
Wake-Up Time		-.092*	-.122**
Sleep Duration Variability		-.075	-.070
Wake-up Time Variability		-.010	-.032
Sleep Duration × Wake-up Time			-.087*
Sleep Duration × Sleep Duration Variability			<.001
Sleep Duration × Wake-up Time Variability			-.121**
Adjusted R^2	.082	.096	.121
F for change in R^2	14.817***	3.289*	6.747***
Valid N			615

$^*p < .05$, $^{**}p < .01$, $^{***}p < .001$.

Table 5

Hierarchical Regression Analysis for Variables Predicting Average Number of Physical Symptoms

	Model 1 (β)	Model 2 (β)	Model 3 (β)
Age	-.024	-.003	-.004
Gender	.177***	.153***	-.155***
Education	.011	.018	.014
Household Income	-.170***	-.151**	-.142**
Sleep Duration		-.045	-.089*
Wake-Up Time		.126**	.158***
Sleep Duration Variability		.181***	.189***
Wake-up Time Variability		-.082	-.077
Sleep Duration × Wake-up Time			.092*
Sleep Duration × Sleep Duration Variability			.077
Sleep Duration × Wake-up Time Variability			.040
Adjusted R^2	.055	.097	.116
F for change in R^2	9.983***	8.082***	5.285**
Valid *N*			615

$*p < .05$, $**p < .01$, $***p < .001$.

Table 6

Hierarchical Regression Analysis for Variables Predicting Total Weekly Severity of Physical Symptoms

	Model 1 (β)	Model 2 (β)	Model 3 (β)
Age	-.043	-.011	.016
Gender	.179***	.148***	.153***
Education	-.026	.002	<.001
Household Income	-.186***	-.171***	-.164***
Sleep Duration		-.018	-.076
Wake-Up Time		.082*	.121**
Sleep Duration Variability		.289***	.304***
Wake-up Time Variability		-.062	-.063
Sleep Duration × Wake-up Time			.112*
Sleep Duration × Sleep Duration Variability			.112*
Sleep Duration × Wake-up Time Variability			.015
Adjusted R^2	.066	.144	.171
F for change in R^2	11.215***	13.996***	7.255***
Valid *N*		578	

*$p < .05$, **$p < .01$, ***$p < .001$.

Table 7

Hierarchical Regression Analysis for Variables Predicting Cortisol Morning Rise

	Model 1 (β)	Model 2 (β)	Model 3 (β)
Age	.032	.087	.091*
Gender	-.009	<.001	-.005
Education	-.111*	-.093*	-.095*
Household Income	.024	.014	.015
Sleep Duration		.004	.025
Wake-Up Time		-.012	.016
Sleep Duration Variability		.059	.059
Wake-up Time Variability		.140**	.165**
Sleep Duration × Wake-up Time			.080†
Sleep Duration × Sleep Duration Variability			.036
Sleep Duration × Wake-up Time Variability			.066
Adjusted R^2	.006	.025	.037
F for change in R^2	1.910	3.617**	3.342*
Valid *N*		557	

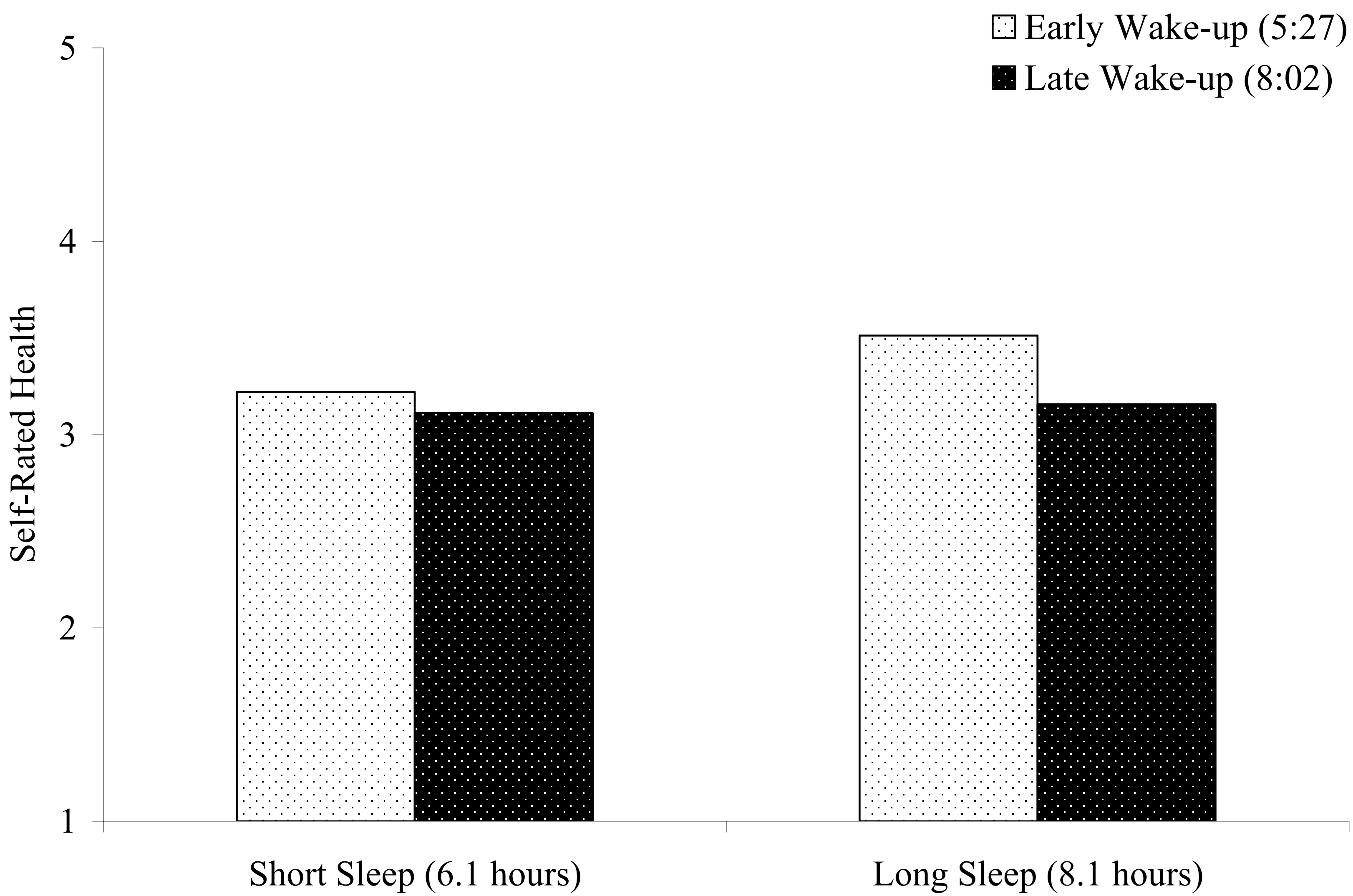
†$p < .10$, *$p < .05$, **$p < .01$, ***$p < .001$.

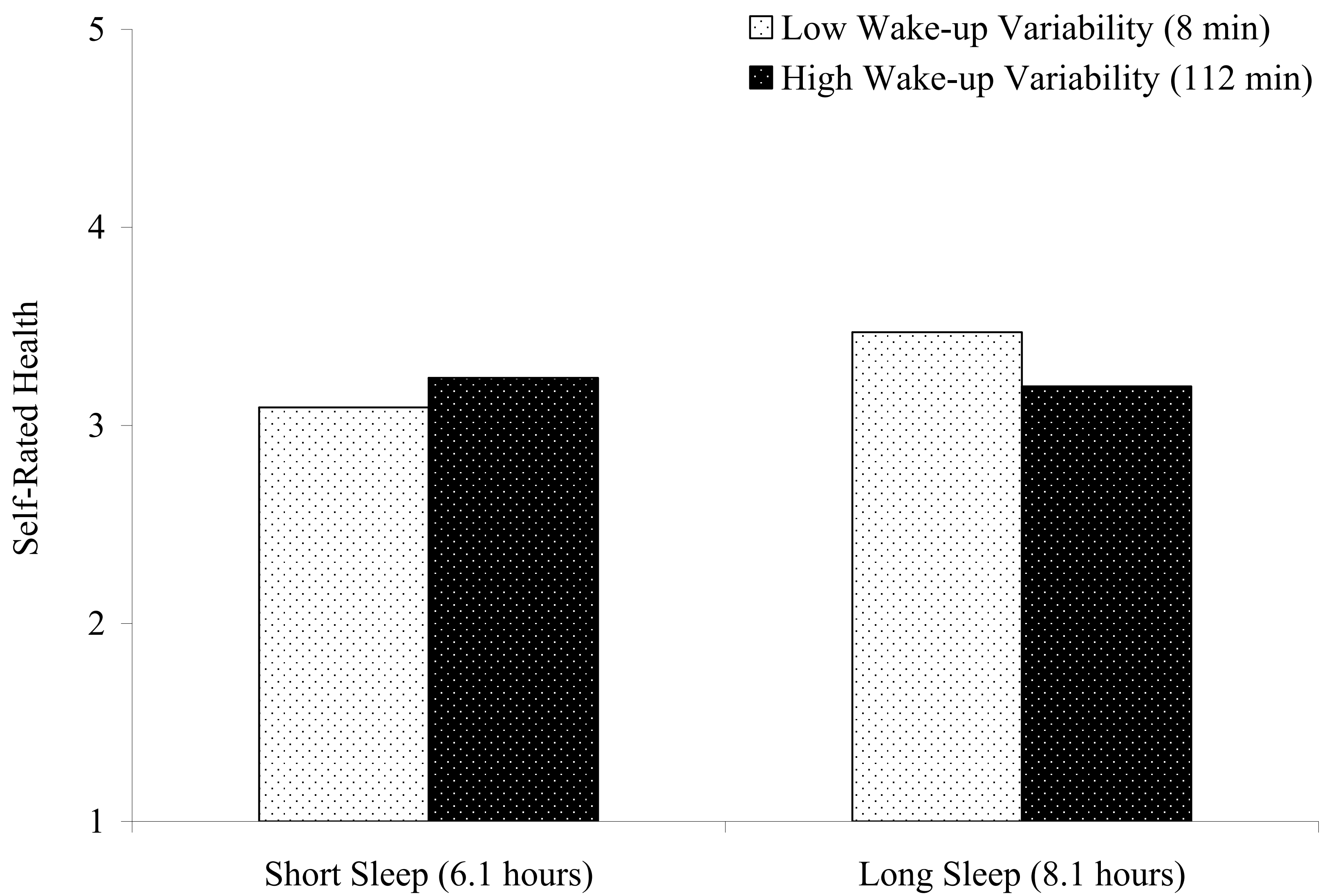
Table 8

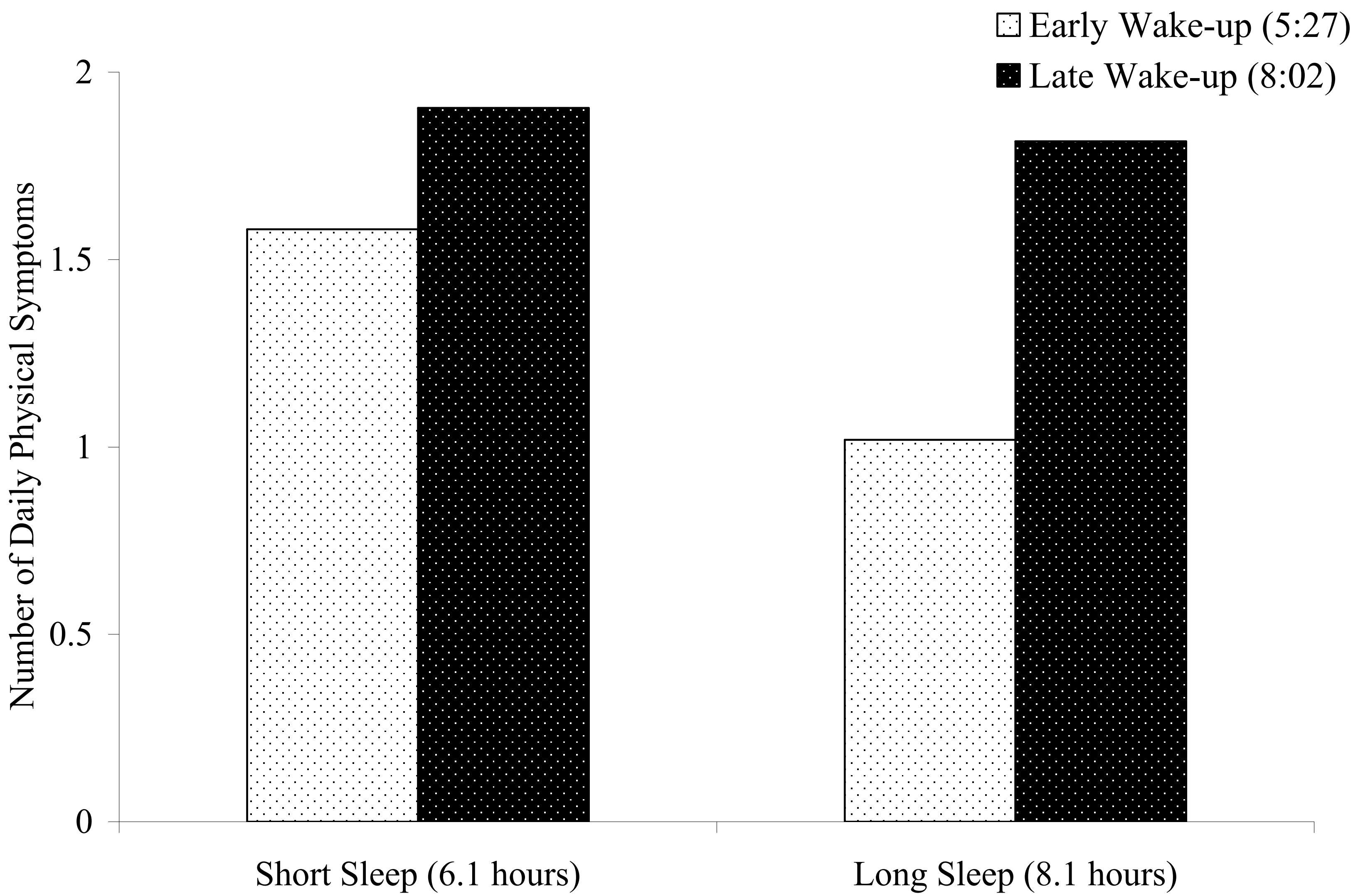
Hierarchical Regression Analysis for Variables Predicting Cortisol Afternoon Decline

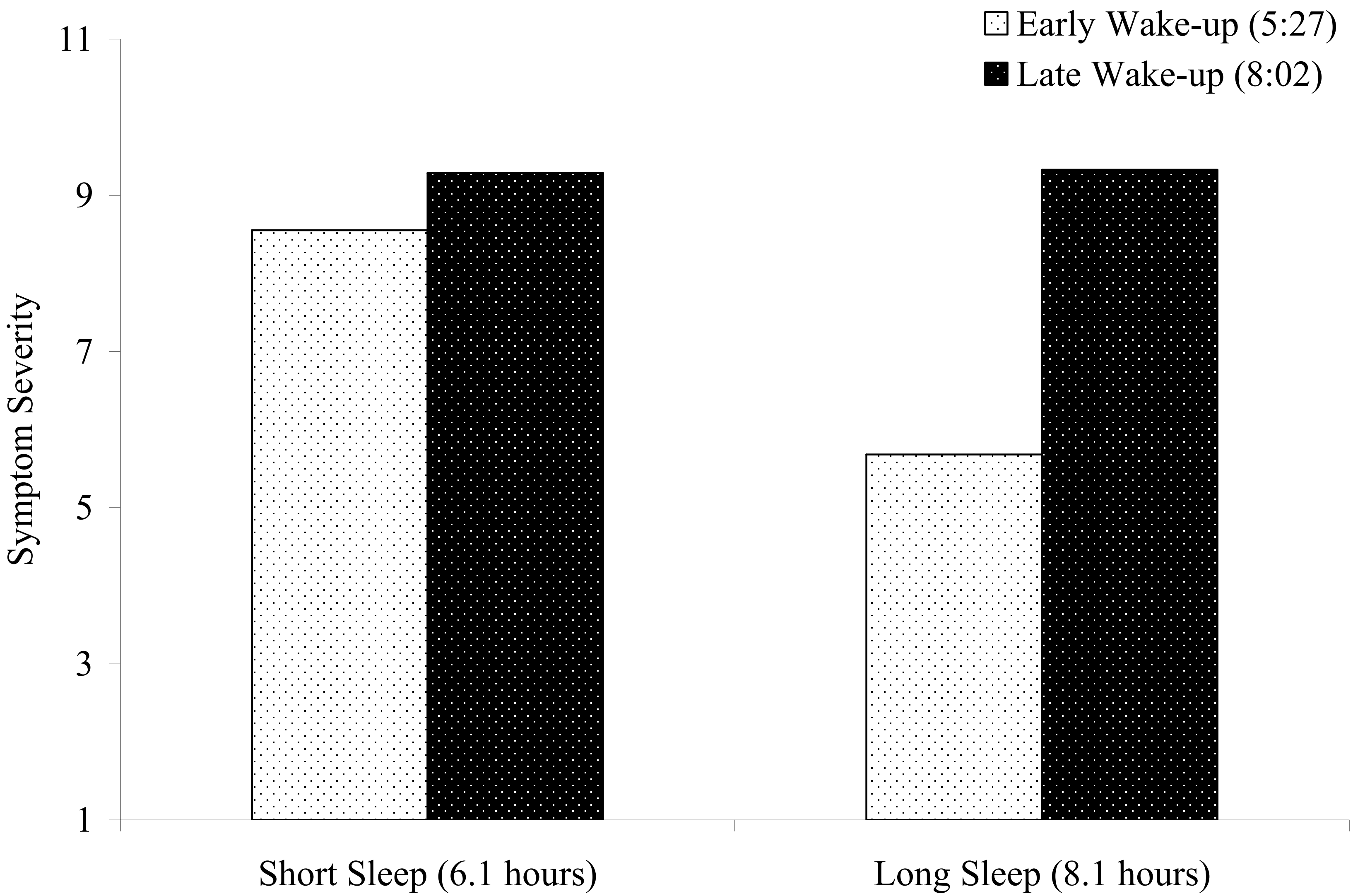
	Model 1 (β)	Model 2 (β)	Model 3 (β)
Age	.042	.088*	.085
Gender	-.014	-.009	-.011
Education	-.048	-.012	.014
Household Income	-.104*	-.106*	-.102*
Sleep Duration		-.170***	-.180***
Wake-Up Time		.001	.019
Sleep Duration Variability		.053	.051
Wake-up Time Variability		.105*	.107*
Sleep Duration × Wake-up Time			.086†
Sleep Duration × Sleep Duration Variability			-.003
Sleep Duration × Wake-up Time Variability			.006
Adjusted R^2	.014	.059	.061
F for change in R^2	.770	7.635***	1.442*
Valid *N*			559

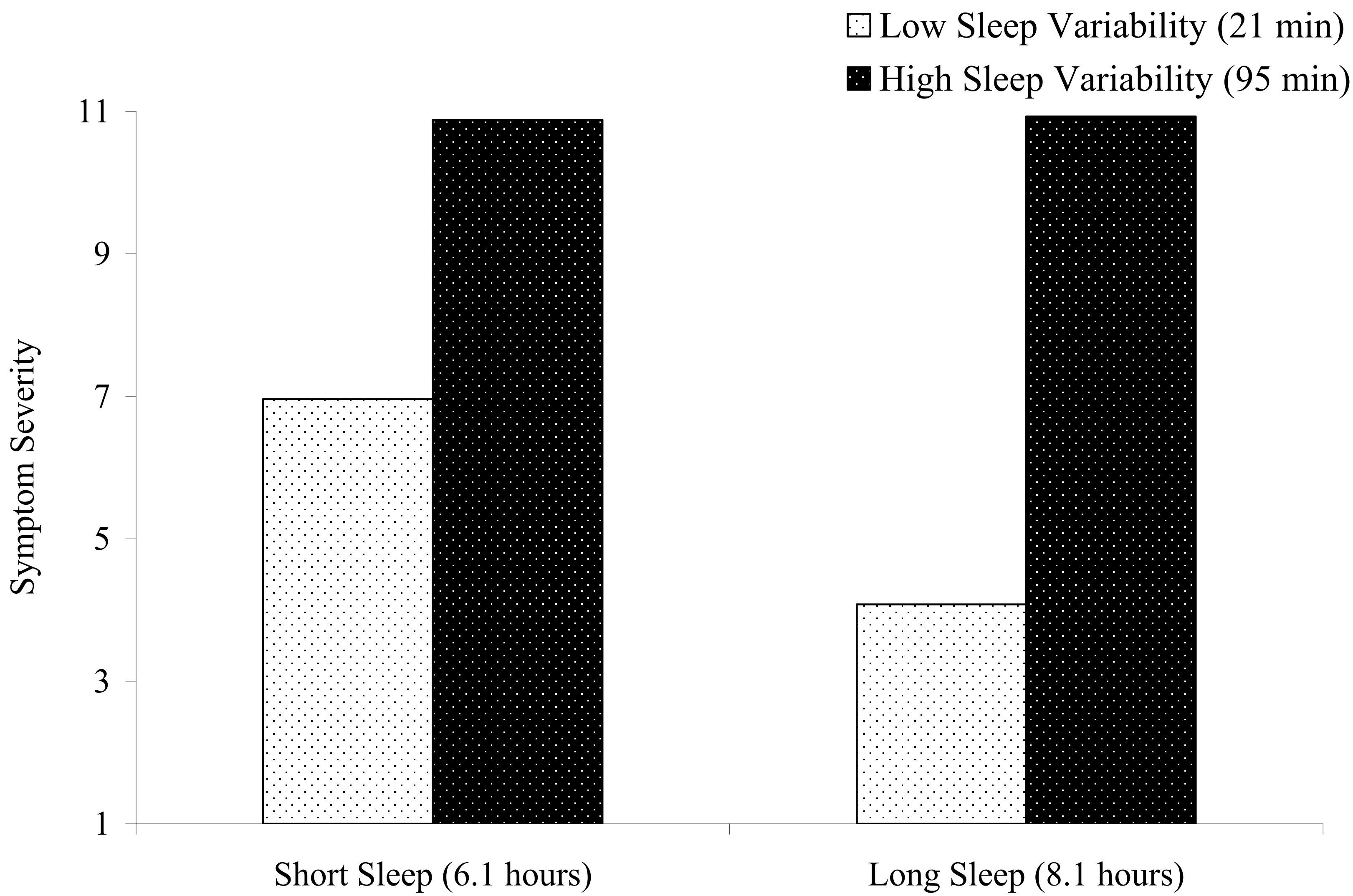
†*p* < .10, **p* < .05, ***p* < .01, ****p* < .001.

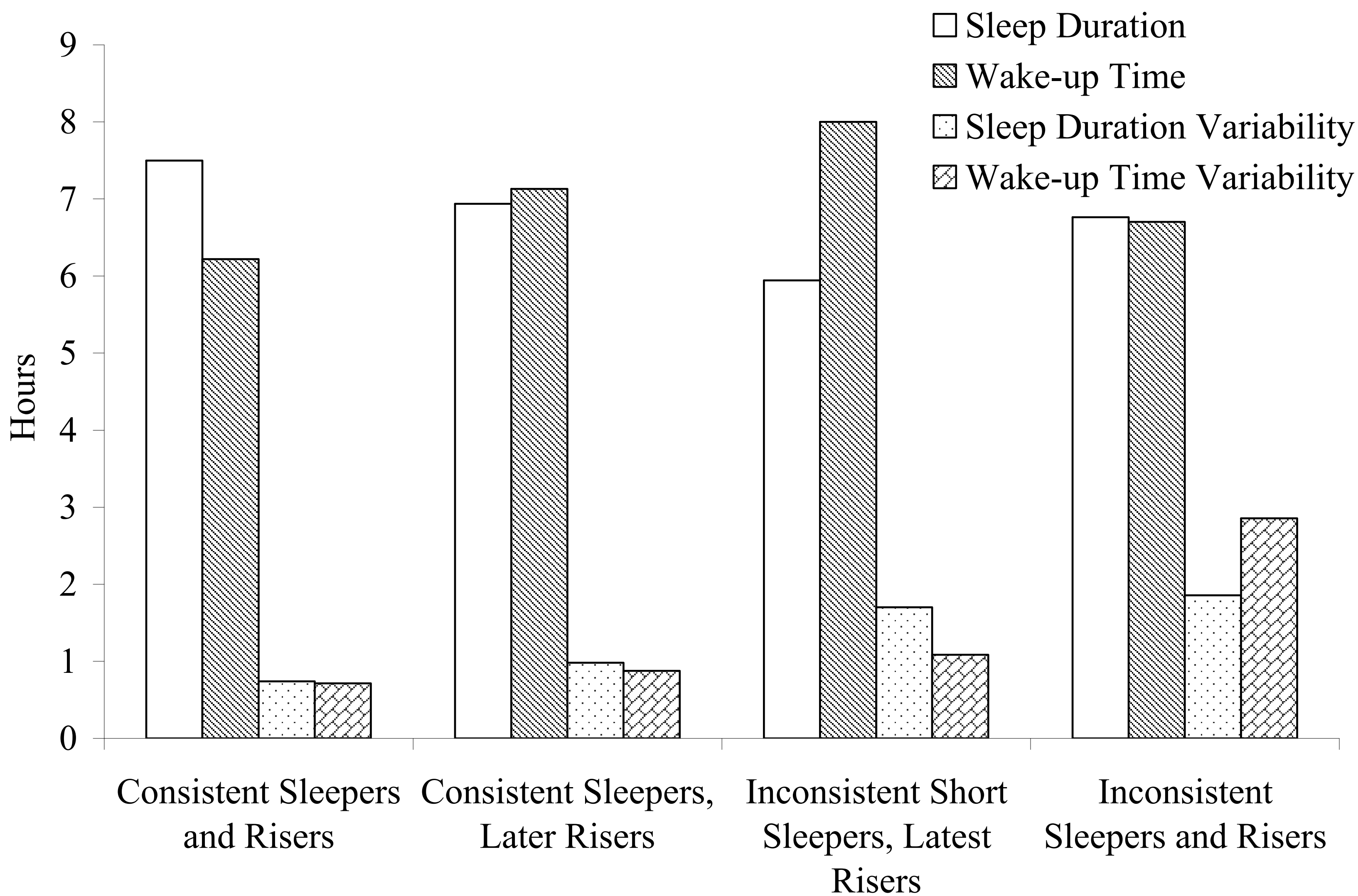

Early Wake-up (5:27)
Late Wake-up (8:02)
5
4
3
2
1
Self-Rated Health
Short Sleep (6.1 hours)
Long Sleep (8.1 hours)


Low Wake-up Variability (8 min)
High Wake-up Variability (112 min)
Self-Rated Health
5
4
3
2
1
Short Sleep (6.1 hours)
Long Sleep (8.1 hours)


Early Wake-up (5:27)
Late Wake-up (8:02)
Number of Daily Physical Symptoms
2
1.5
1
0.5
0
Short Sleep (6.1 hours)
Long Sleep (8.1 hours)


Early Wake-up (5:27)
Late Wake-up (8:02)
Symptom Severity
11
9
7
5
3
1
Short Sleep (6.1 hours)
Long Sleep (8.1 hours)


Low Sleep Variability (21 min)
High Sleep Variability (95 min)
Symptom Severity
11
9
7
5
3
1
Short Sleep (6.1 hours)
Long Sleep (8.1 hours)


Sleep Duration
Wake-up Time
Sleep Duration Variability
Wake-up Time Variability
Hours
9
8
7
6
5
4
3
2
1
0
Consistent Sleepers and Risers
Consistent Sleepers, Later Risers
Inconsistent Short Sleepers, Latest Risers
Inconsistent Sleepers and Risers

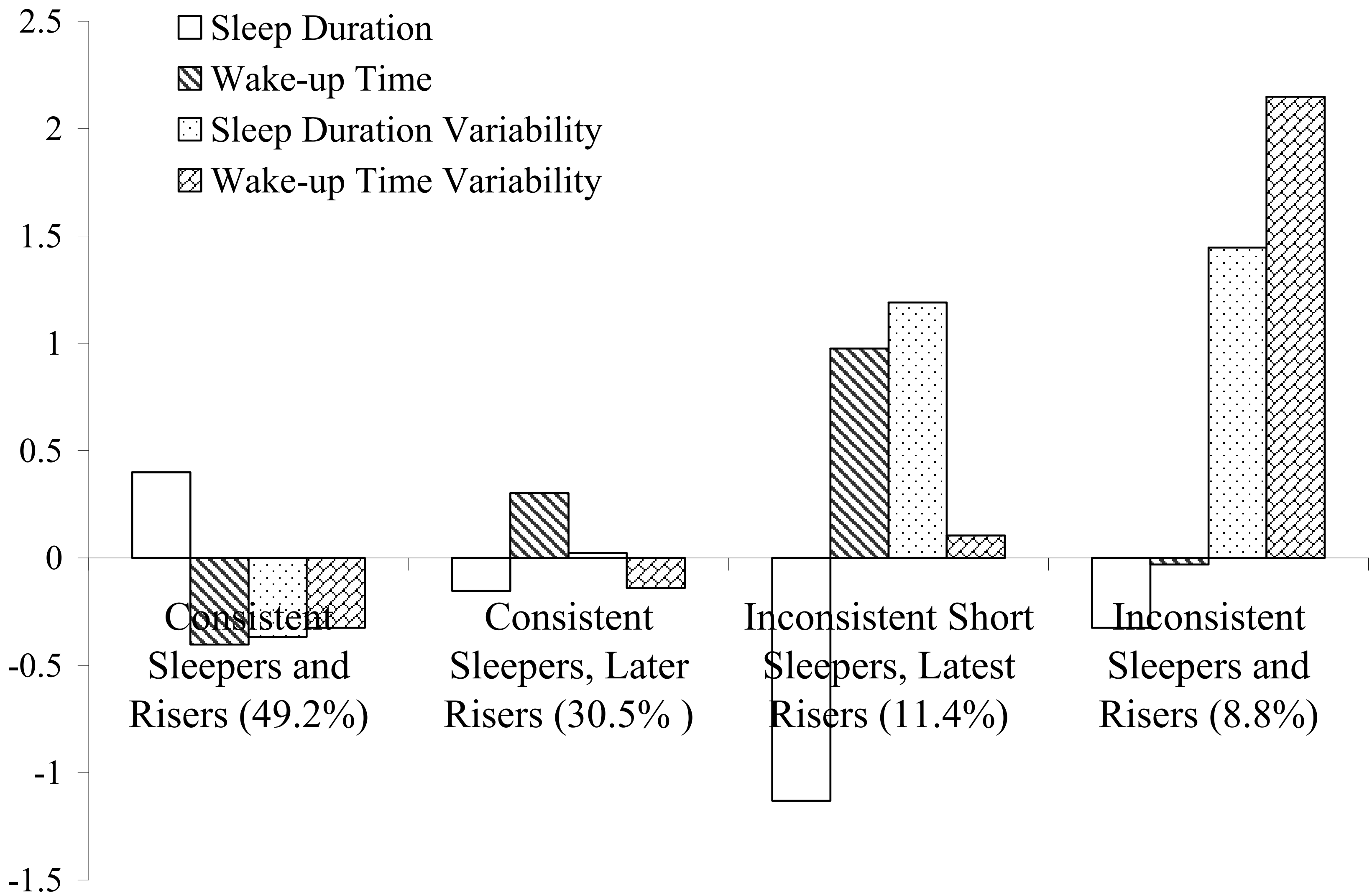
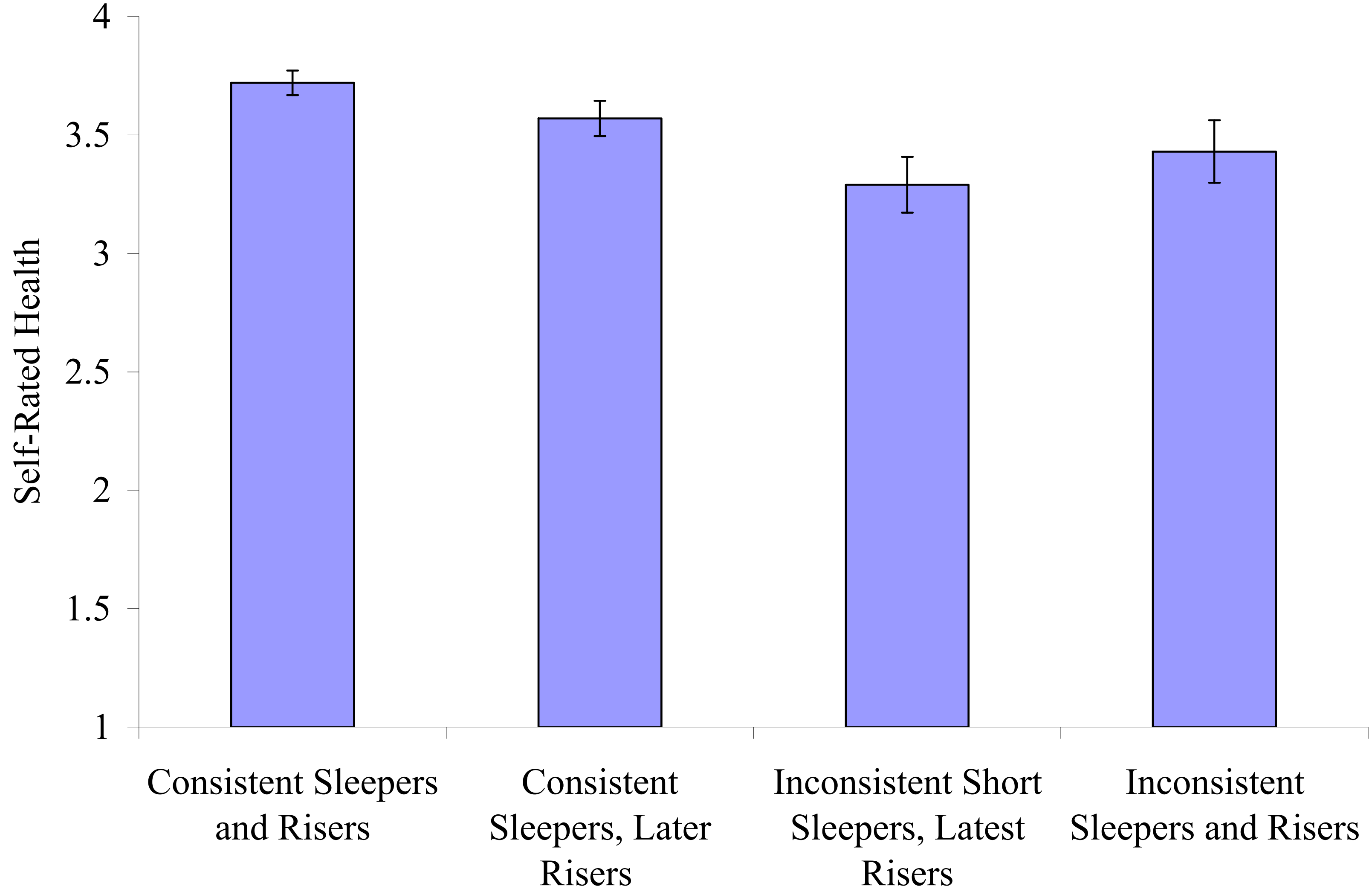

2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
Sleep Duration
Wake-up Time
Sleep Duration Variability
Wake-up Time Variability
Consistent Sleepers and Risers (49.2%)
Consistent Sleepers, Later Risers (30.5%)
Inconsistent Short Sleepers, Latest Risers (11.4%)
Inconsistent Sleepers and Risers (8.8%)

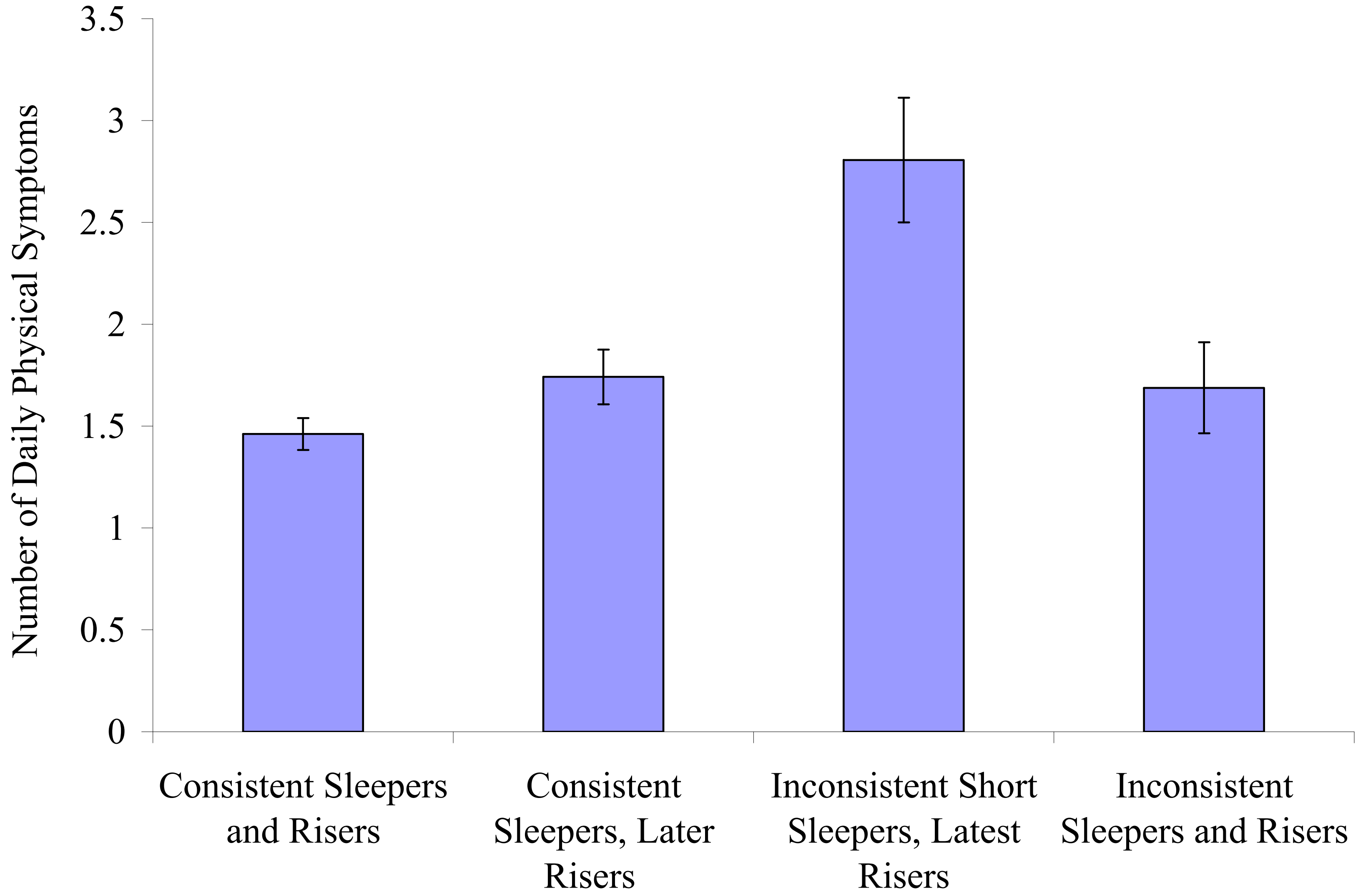
Table 9

Means (SD) for Self-Rated Health, Daily Physical Symptoms and Cortisol Slopes as a Function of Cluster Membership

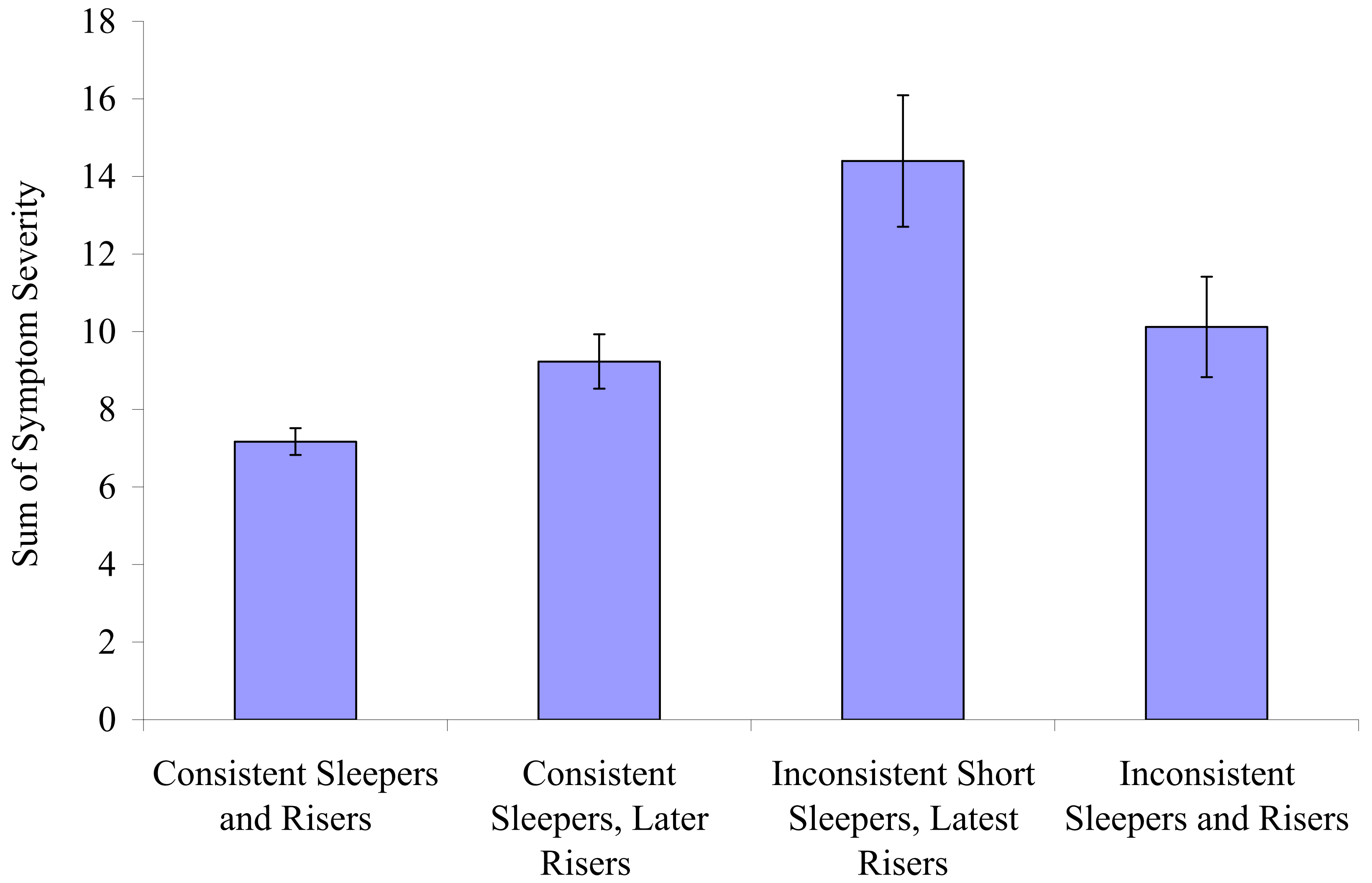
	Consistent Sleepers and Risers (*n* = 310)	Consistent Sleepers, Later Risers (*n* = 192)	Inconsistent Short Sleepers, Latest Risers (n = 72)	Inconsistent Sleepers and Risers (*n* = 56)
Self-Reported Health	$3.72\ (0.92)_a$	3.57 (1.03)	$3.29\ (1.00)_b$	3.43 (0.99)
Number of Physical Symptoms	$1.46\ (1.39)_a$	$1.74\ (1.86)_a$	$2.81\ (2.60)_b$	$1.69\ (1.67)_a$
Severity of Physical Symptoms	$7.17\ (5.88)_c$	$9.23\ (9.49)_c$	$14.40\ (14.30)_d$	$10.12\ (9.43)_c$
Cortisol Morning Rise	0.24 (0.77)	0.34 (0.73)	0.34 (0.75)	0.48 (0.86)
Cortisol Afternoon Decline	$0.12\ (0.05)_e$	$-0.11\ (0.04)_f$	$-0.10\ (0.06)_g$	$-0.09\ (0.06)_h$

$_{a,\ b}$ Across each row, different subscripts indicate significant cluster differences, $p < .01$
$_{c,\ d}$ Across each row, different subscripts indicate significant cluster differences, $p < .05$
$_{e,\ f,\ g,\ h}$ Across each row, different subscripts indicate significant cluster differences, $p < .05$; $_e$ is different from $_g$ and $_h$; $_f$ is differen from $_h$; $_g$ is different from $_e$; and $_h$ is different from $_e$ and $_g$.

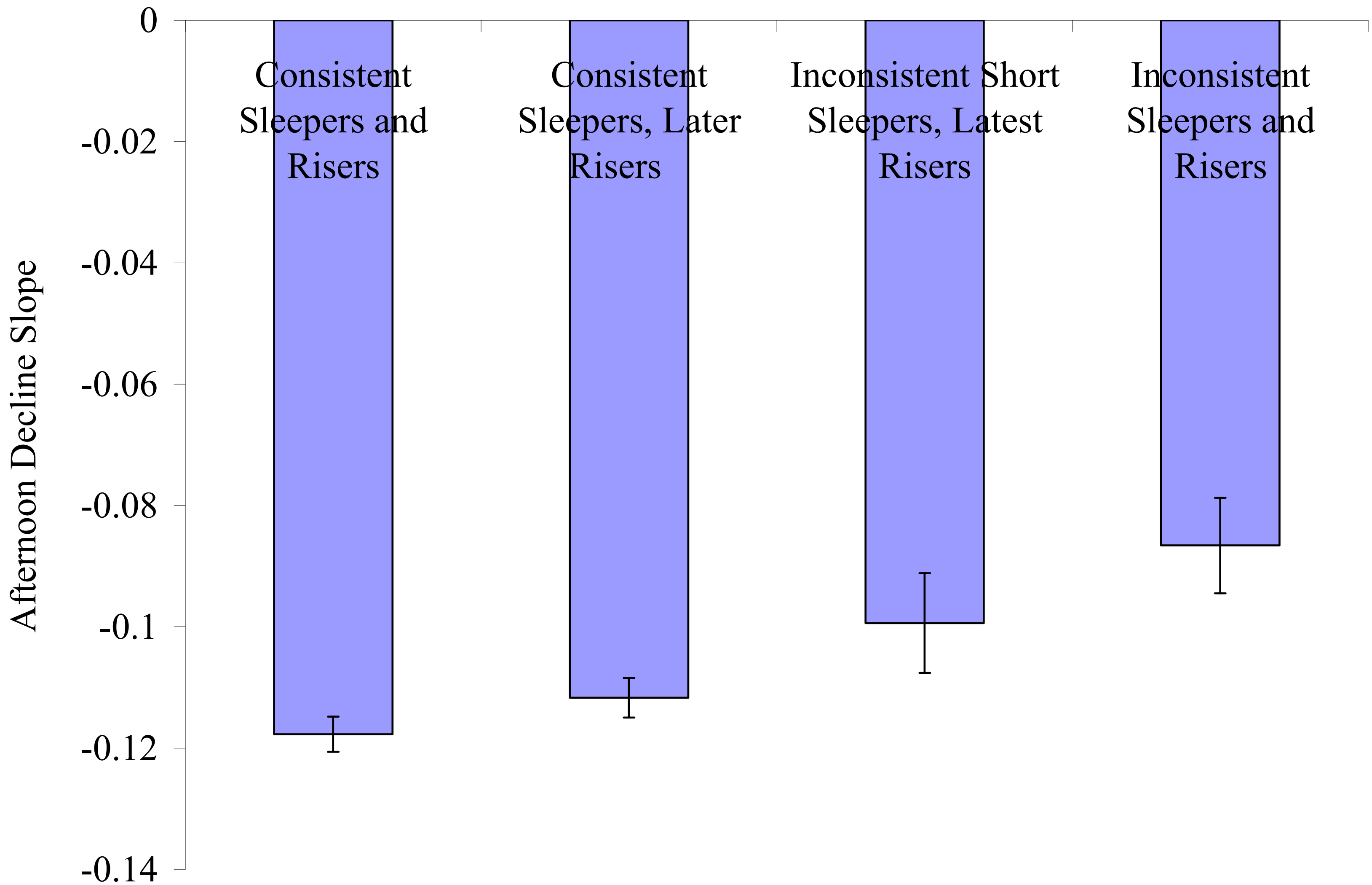

4
3.5
3
2.5
2
1.5
1
Self-Rated Health
Consistent Sleepers and Risers
Consistent Sleepers, Later Risers
Inconsistent Short Sleepers, Latest Risers
Inconsistent Sleepers and Risers



3.5
3
2.5
2
1.5
1
0.5
0
Number of Daily Physical Symptoms
Consistent Sleepers and Risers
Consistent Sleepers, Later Risers
Inconsistent Short Sleepers, Latest Risers
Inconsistent Sleepers and Risers



Sum of Symptom Severity
0
2
4
6
8
10
12
14
16
18
Consistent Sleepers and Risers
Consistent Sleepers, Later Risers
Inconsistent Short Sleepers, Latest Risers
Inconsistent Sleepers and Risers


0
-0.02
-0.04
-0.06
-0.08
-0.1
-0.12
-0.14
Afternoon Decline Slope
Consistent Sleepers and Risers
Consistent Sleepers, Later Risers
Inconsistent Short Sleepers, Latest Risers
Inconsistent Sleepers and Risers

Chapter 4

Discussion

Study Findings and Contributions

Variable-specific and person-specific methods were utilized to explore the impact of daily sleep patterns on physical health. The aims were three-fold: (1) to establish typical sleep patterns among a national sample of participants, (2) to examine the main effects of sleep duration, wake-up time, and variability in sleep duration and wake-up time on self-reported and objective indicators of health, and (3) to ascertain whether there are interactive effects of sleep duration, wake-up time, and variability in sleep duration and wake-up time on physical health. The study also contributed to previous research by distinguishing between three types of health indicators: global health, daily health, and an objective indicator of HPA functioning.

On average, participants slept approximately 7 hours, woke up around 6:45 am, and reported approximately 1 hour of variability in sleep duration and wake-up time across 8 days. The average participant perceived being in good to very good health, and reported fewer than 2 physical symptoms per day. Older participants reported less variability in sleep duration and wake-up time across 8 days, indicating that sleeping patterns become more established with age. Older respondents also reported slightly lower self-reported global health and experienced slightly flatter cortisol afternoon decline, demonstrating the physiological toll of aging on both one's perception of age, as well as on objective indicators of health. The small associations, however, confirm that older age is not a deterministic predictor of ill health. Furthermore, older age was unassociated with poor daily health, signifying the adaptability of perceptions of well-being in day-to-day life. Consistent with previous research, female participants were more likely to report a greater number and severity of symptoms (for a review see Verbrugge, 1985), whereas education and household income were positive predictors of self-reported health (e.g., Lantz, House, Mero, & Williams, 2005).

Baseline correlations showed that sleep was associated with indicators of health. Longer and less variable sleep duration were associated with higher self-rated global health, fewer number and lower severity of daily symptoms, a flatter cortisol morning rise, and a steeper cortisol afternoon decline. Wake-up time and variability were less consistently associated with health than sleep duration and variability were. Earlier wake-up time was associated with fewer number and lower severity of daily symptoms, and less variable wake-up time was associated with a flatter cortisol morning rise and steeper cortisol afternoon decline. All results, except in the case of cortisol afternoon decline as an outcome, were consistent with previous research and the study's hypotheses, confirming that longer sleep duration, earlier wake-up time, and less variable sleep duration and wake-up time are positively associated with healthier functioning. Unexpectedly, there was a small negative correlation between a more robust cortisol morning rise with more variable sleep duration and wake-up time, which will be discussed further below.

After accounting for the effects of control variables, regression analyses showed that there were unique effects of sleep duration, wake-up time, and variability in sleep duration and wake-up time on health. Although sleep duration was consistently significantly associated with positive health outcomes when looking at a simple correlational table, the direct association became non-significant for most regressions after the effects of control variables were partialed out. Sleep duration was only related to afternoon decline of cortisol and self-reported health, such that longer sleep was associated with a healthier, more robust decline in cortisol, and higher reports of global health. Thus, there were only two significant unique effects of sleep duration out of five health variables, indicating that sleep duration alone is not the best predictor of health, and that other sleep-related factors are important to examine in order to construct a definitive picture of the relationship between sleep and health.

The unique effect of wake-up time was important for all self-reported health variables. Consistent with previous research (e.g., Edwards, Evans, Hucklebridge, & Clow, 2001; Kudielka & Kirschbaum, 2003), results suggest that waking up earlier is better for health; earlier wake-up time was associated with fewer number and severity of daily symptoms and better self-rated global health. Variability in sleep parameters also emerged as an important factor for health. Higher variability in sleep duration was associated with a greater number and severity of daily physical symptoms, indicating that variability in sleep duration is associated with poorer health. Results for variability in wake-up time were less consistent, such that greater variability in wake-up time was associated with a more robust cortisol morning rise, but a flatter cortisol afternoon decline. Thus, among all sleep variables tested, no sleep-related factor emerged as the most important and consistent predictor of health.

The moderating effects were tested with two methodologies. Variable-specific and person-specific methods produced slightly different results in their tests of interactive relationships of sleep-related variables on health. Both methods have underscored the importance of earlier awakening time in light of relatively long sleep, and provided some evidence for the importance of a consistent sleeping schedule for self-reported health. In terms of self-reported health, Cluster 1 participants were similar to the healthiest group found by regression analyses: earlier wakers who also slept longer. Participants in Cluster 3 resembled the least healthy participants according to regression analyses: late wakers who slept less.

Specifically, regression analyses showed that participants with the best self-reported global and daily health tended to sleep longer and wake-up earlier than the average participant. Furthermore, self-reported health was also higher among participants with longer sleep duration and less variable awakening time, and symptom severity was lower among participants with longer sleep duration and less variable sleep duration. Wake-up time and variability in sleep duration and wake-up time did not moderate the relationship between sleep duration and endocrine functioning. Surprisingly, later wake-up time and shorter sleep duration were related to steeper cortisol morning rise and cortisol afternoon decline, respectively. Short sleep that is also characterized by a late wake-up time, may indicate the experience of high demands. Experience of stressors is associated with a spike in cortisol (for review see Dickerson & Kemeny, 2004) and may lead to more pronounced diurnal spikes in cortisol across the day. The experience of particularly steep intense cortisol slopes, due to high stress, may lead to an increased wear and tear of the HPA axis, resulting in hypocortisolism later in life, or the inability to engage the HPA axis, characterized by robust cortisol morning rise and afternoon decline. Indeed, the results show that older age was associated with a flatter cortisol afternoon decline. Thus, it is possible that the positive relations between wake-up time and short sleep length with the steepness of cortisol slopes will reverse direction later in life. Further exploration of these relations within different age groups is required to test this hypothesis. In general, regression analyses underscored the importance of earlier awakening time in light of relatively long sleep, and provided some evidence for the importance of a consistent sleeping schedule for self-reported health.

Regression analyses were limited to testing linear relationships and two-way interactions. Although the results were significant and intriguing, they did not provide a consistent and easily interpretable picture of the overall healthiest sleep pattern. The results provided by cluster analysis consistently showed that one particular type of sleepers experienced the best health – those who slept longer and woke up earlier on a consistent schedule. The results indicated that the best health was experienced by this largest cluster (49.2% of respondents); they slept approximately 7.5 hours per night, woke up around 6:15 am and reported their variability in sleep duration and wake-up time across 8 days to be slightly under 45 minutes. In contrast, Inconsistent Short Sleepers, Latest Risers (11.4% of respondents) consistently experienced the worst self-reported health. On average, this group slept 6 hours per night, and their sleeping duration varied approximately 1 hour and 45 minutes across 8 days. They woke up later than most respondents – around 8:00 am, and their awakening time varied approximately 1 hour across 8 days. This group, along with the smallest cluster, Inconsistent Sleepers and Risers (8.8% of respondents), experienced the flattest cortisol morning rise. On the whole, cluster analyses agree with previous research that sleeping 7 to 8 hours per night amounts is healthiest (e.g., Kripke, Garfinkel, Wingard, Klauber, & Marler, 2002), particularly when coupled with early awakening time and high consistency in sleeping schedules.

This study has taken important steps in underscoring the complexity of the relationship between sleep and health. The study has employed person-specific data analysis to find common patterns of sleep within individuals, rather than across variables in entire samples. Results are in agreement with recent research, which points to the importance of expanding the construct of sleep beyond sleep duration, to include the time of awakening and consistency of sleep schedules.

Limitations and Future Directions

Similar to the national distribution, the sample consisted of relatively ethnically homogeneous, Caucasian participants. Future research should confirm the relationships found in this study within samples that are more ethnically diverse. Furthermore, we have seen that both sleep and health parameters vary for people of different age groups in this sample. Future work should explore the consistency of relationships found in this study across the life-span.

The study is innovative in testing the relationship between various sleep parameters and diurnal cortisol among a national sample of participants, but the inclusion of more health biomarkers (e.g., markers of immune and cardiovascular functioning) would expand the results. The study is further limited by the self-reported feature of sleep measures. Objective measures of sleep, such as sleep actigraphs, may be easily implemented by participants at home and would greatly expand the current findings.

The significant results of the study need to be evaluated in light of the relatively small effect sizes. For example, of the five regression models that were ran, the addition of the four independent sleep variables to control variables increased the variance explained by the model from 1.4 to 7.8 percent, depending on the model. The inclusion of the interactive relationships improved the variance explained by the model from 0.2 to 2.7 percent, depending on the model.

The results of the study should also be extended with additional methodologies. The findings are based on a cross-sectional sample, and health could be partially or completely driving the directionality of results. Future work will employ multi-level modeling to utilize the information from participants that are missing some of the data and to make better use of the short-term and long-term longitudinal design of data than traditional regression analysis allows. Structural Equation Modeling will be used to determine the directionality of results. Cluster analysis is inherently exploratory and dependent on the sample under study. Future work should examine whether the clusters found in this study replicate to other samples. In addition, future work should utilize the current methodological advances in model-based cluster analysis, which provides a Bayesian Information Criterion to inferentially select the most parsimonious number of clusters in a sample.

Conclusion

The results of the study indicate that a consistent “early to bed and early to rise” pattern of sleep indeed makes one healthy. Previous studies have been unable to arrive at a conclusive picture of the relationship between the normative sleep range and health because they did not account for the multidimensional nature of the sleep construct. The results underscore the need to expand the construct of sleep beyond sleep duration to also include the time of awakening and consistency of sleep schedule.

The study suggests that a work schedule requiring a shifting sleep schedule may be particularly detrimental to health (e.g., Fenwick & Tausig, 2001). This type of work schedule requires individuals to alternate between night-time and day-time sleep, often forcing the wake-up time to occur well in the afternoon. Findings on flatter cortisol afternoon declines among participants in Clusters 3 and 4 demonstrate the biological toll taken by individuals with inconsistent sleep patterns; a toll that may result in additional health problems later in life.

The recent increase in popular media interest in sleep is important to note. Articles often advise readers to increase sleep duration to 8 hours per night. Unfortunately, many people may not have the option to increase sleep because of other pressing responsibilities. This study illustrates that it is important to get moderate amounts of sleep (approximately 7.5 hours), but in the instance of a shorter sleep duration, an earlier awakening time and a consistent sleeping schedule may be beneficial.

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