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Original Article

Poor sleep quality is associated with worse self-rated health in long sleep duration but not short sleep duration

Anna Andreasson [a, b, c], John Axelsson [a, d], Jos A. Bosch [e], Leonie JT. Balter [a, d, *]

[a] Stress Research Institute, Psychology Department, Stockholm University, Stockholm, Sweden
[b] Department of Medicine Solna, Division of Clinical Medicine, Karolinska Institutet, Stockholm, Sweden
[c] Department of Psychology, Macquarie University, NSW, Australia
[d] Department of Clinical Neuroscience, Division of Psychology, Stockholm, Karolinska Institutet, Stockholm, Sweden
[e] Clinical Psychology, Psychology Department, University of Amsterdam, Amsterdam, the Netherlands

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ABSTRACT

Unhealthy sleep duration, either short or long, is associated with worse health and central subjective dimensions of sleep and health such as fatigue. It has been argued that the link between sleep duration and health may depend on the quality of the slept hours, and on its functional impact (ie, fatigue). The present study therefore assessed whether the relationship between last night's sleep duration and general self-rated health (SRH) differs as a function of sleep quality, and secondly, whether current fatigue and sleep quality are factors linking sleep duration and SRH.

The present cross-sectional dataset involved 1304 individuals (57% female, $M_{age} = 28.8$, range 18–79). Participants completed surveys for general SRH, previous night's sleep duration and sleep quality, and current fatigue.

Results showed the expected inverted U-shaped (ie, quadratic) relation between last night's sleep duration and SRH and a linear relation between last night's sleep quality and SRH. However, long sleep duration was only associated with poorer SRH in individuals who also reported poor sleep quality. Further, the quadratic relationship between sleep duration and SRH was partially mediated by fatigue and sleep quality.

The results of this multi-study analysis suggest that SRH is particularly poor in those who slept both long and with poor quality the night before, while good sleep quality may protect those with a long sleep duration from poor SRH. Thus, last night's long sleep does not seem to be associated with poor subjective health unless it is coupled with poor sleep quality. Furthermore, fatigue and sleep quality are potential pathways linking short and long sleep duration with SRH. Different dimensions of sleep interact in their association with health, and future research will benefit from an integrative approach.

1. Introduction

Self-rated (subjective) health (SRH), assessed via a single item response is related to future objective health such as mortality, even after taking into account objective health-related measures that cover medical, physical, and socio-emotional status [1,2]. SRH is a measure where subjects integrate many aspects of their health, reflecting comorbidity better than any additive measure of disease status [2]. In addition to SRH's function as an indicator of future objective health, it also reflects functional health outcomes such as sick leave, health care use, and medication intake. Taking into account the brevity of SRH, it gives potent information highly relevant for health care. Notably, poor SRH is associated with fatigue, disturbed sleep, and short and long sleep duration [3–5], suggesting that several dimensions of sleep health may influence SRH.

Sleep is dynamic and influences health in several ways. One central dimension of sleep health is sleep duration. Short and long sleep duration, compared to normal or mid-range sleep, have both been linked to poorer health, either clinically determined, assessed

* Corresponding author. Stress Research Institute, Stockholm University, 106 91, Stockholm, Sweden.
E-mail address: leonie.balter@su.se (L.JT. Balter).

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by various risk markers, or as self-rated (subjective) health (SRH) [6–11]. It has been postulated that the pathways linking short sleep duration to morbidity involve immune activation, and altered sympathetic nervous system activity and hormone release [12,13]. In contrast, the mechanisms involved in the association of long sleep duration with morbidity are less well-defined. One suggestion is that long sleep duration is a surrogate marker of other factors that predispose to higher morbidity rates, such as undiagnosed medical diseases [14,15].

Sleep quality is another central dimension of sleep health, and has likewise been associated with health [16]. For example, worse mental, cognitive, or physical health has been reported in those with low sleep quality and even after as little as a single night of modest sleep disturbance [17,18]. Sleep quality may even be a stronger predictor than sleep duration for some health domains such as overall health, affective disorders, and hypertension risk [19–24]. These studies highlight the relevance of both sleep duration and sleep quality for health as independent entities, but only a limited number of studies report the effects of sleep duration and sleep quality in combination [19], and both additive and interactive effects have been reported. A combination of short sleep duration and poor sleep quality has been associated with the highest risk of physical disorders and number of comorbidities (with some studies reporting sex-specific results), while other studies suggest independent associations of short sleep and poor sleep quality with physical disorders and mental disorders [24–27]. In long sleepers, a higher risk of cardiovascular disease (CVD) and all-cause and CVD mortality has been shown to be associated with poor sleep quality or frequent insomnia [28,29], but another study, assessing CVD incidence in more than 20,000 participants, did not find such a negative relationship in long sleepers with poor sleep quality [26]. While lower SRH has been reported by short and long sleep sleepers as well as by those with poor sleep health or sleep quality [7,30,31], it is at present unclear whether the inverted U-shaped relationship of sleep duration with SRH is dependent on the quality of these sleep hours.

Fatigue is a third dimension of sleep health that is strongly associated with poor sleep quality and poor SRH [4,32]. There are reports that those with aberrant sleep duration are also most likely to report sleep disturbances and fatigue [33–35], tentatively suggesting that poor sleep quality and fatigue may be partly responsible for the inverted U-shaped association of sleep duration with health, something that has been proposed earlier [19]. In line with this, an experimental sleep restriction study showed that fatigue mediated the relationship between short sleep and SRH [36]. However, absence of a long sleep duration group limited the findings to short sleep only. The notion that sleep quality and fatigue are mediators of the link between sleep duration and SRH is thus preliminary. In all, there is limited understanding of how different dimensions of sleep are associated with SRH. Therefore, the current study focused on three central dimensions of sleep health, ie, sleep duration, sleep quality, and fatigue. Based on the literature, we expected that sleep duration would show an inverted U-shaped relationship with SRH, and that sleep quality would show a linear relationship with SRH. The aim was twofold. Firstly, to assess whether the inverted U-shaped association of sleep duration with SRH differed as a function of sleep quality. We hypothesized that sleep duration and sleep quality would interact so that long sleep duration would be associated with lower SRH when sleep quality is poor. The second aim was to assess subjective sleep quality and current fatigue as factors linking sleep duration and SRH. We hypothesized that the inverted U-shaped relationship of sleep duration with SRH would be mediated by sleep quality and fatigue in crosssectional mediation analysis.

2. Methods

2.1. Participants

A total of 1304 individuals (57% female, M_{age} = 28.8, range 18–79) were included in the present individual person data meta-analysis. Inclusion criteria were 18 years or older and fluent in English (study 2 and 4) or Dutch (study 1, 3, 5). In study 2, young (21–35) and older (63–80) participants without neurological or inflammatory disorder were recruited. In study 1 and 2, participants had either a high BMI (>30 in study 1 or > 27 in study 2) or a normal BMI (≤25). Data were collected between 2016 and 2020 in five independent cross-sectional studies examining relationships between health, inflammation, and cognitive functioning. Data on sex was available for 826 (63.3%) participants.

2.2. Procedure

All participants completed questions on self-rated health ("How would you rate your health in general?", scale 1 = very bad to 10 = excellent), sleep duration ("How many hours did you sleep last night?" in studies 1, 2, 3, and 5, or calculated by subtracting bed time + minutes to fall asleep from waking up time in study 4), and subjective seep quality ("How was your sleep quality last night?" rated on a 5-point scale from 1 ("very bad") to 5 ("very good")). Fatigue ("I feel tired") was rated on a scale from 1 ("disagree") to 5 ("agree"). Data on fatigue was collected in study 3, 4, and 5 and was available for 1149 (88.1%) participants. Current medical conditions, disorders, or diseases were reported using an open-entry question in all studies except for study 1 where no medical data was obtained. The studies were completed during a laboratory visit (study 1, 2, 3, and 5) or via an online survey (study 4). The separate studies were approved by the University of Birmingham Research Ethics Committee (study 1 and 2), the Faculty Ethics Review Board of the University of Amsterdam (Department of Psychology) (study 3 and 5), and the Swedish Ethical Review Authority (study 4). In all studies, participants provided informed consent at the start of the study.

2.3. Statistical analysis

Data from five studies was pooled in this individual person meta-analysis. Data analyses were performed using Stata 15 (StataCorp LLC, College Station, Texas, USA). All analyses adjust for the clustered nature of the data by clustering the models on study. For the purpose of the study, last night's sleep duration was categorized in three categories: <7 h (short sleep), 7–9 h (normal sleep), and ≥9 h (long sleep) [10,11,14], although there is no complete consensus regarding unhealthy sleep durations in adults [37]. Those who rated their sleep quality as 1 or 2 were categorized as having low-quality sleep, a rating of 3 was referred to as moderate-quality sleep, and a rating of 4 or 5 as high-quality sleep.

Quadratic and linear relationships of sleep duration and sleep quality with SRH. The relationships of sleep quality and sleep duration with SRH were assessed using mixed effects models with SRH as dependent variable and sleep quality (poor, intermediate, good) or sleep duration (short, normal, long) as independent variables. To further test the hypothesis of an inverted U-shaped relationship between sleep duration and SRH, the quadratic term of sleep duration was added to the linear model and the model was compared to the model with the linear term only. The same approach was taken for the relationship of sleep quality with SRH.

Sleep duration and sleep quality interactions. A mixed effects multilevel model was used to test interactive effects of sleep quality and sleep duration on SRH. Moderation was tested using the mixed

command. Variables were centered before analysis to avoid collinearity.

Mediating role of fatigue and sleep quality. Generalized structural equation model (GSEM) was used to test sleep quality and fatigue as mediator linking sleep duration and self-rated health. Formal mediation was tested using the nlcom command. Because the clustered mediation analysis did not converge for fatigue, the mediation analysis assessing fatigue as a mediator for the correlation between sleep duration and SRH was performed on the largest study only (study 4, $n = 858$).

3. Results

3.1. Self-rated health

In the current sample of individuals (M SRH = 7.6, SD = 1.6), SRH was similar for women ($M = 7.7$, SD = 1.6) and men (b = −0.15, 95% CI = −0.38, 0.08, $p = 0.192$) and age was not significantly associated with SRH (b = −0.00, 95% CI = −0.01, 0.01, $p = 0.449$). Participant characteristics and sleep data are summarized in Table 1.

3.2. Sleep duration, sleep quality, and self-rated health

Sleep duration. As shown in Fig. 1a, both the linear term (b = 0.70, 95% CI = 0.35, 1.05, $p < 0.001$) and the quadratic term (b = −0.04, 95% CI = −0.06, −0.02, $p < 0.001$) of sleep duration were associated with SRH, the quadratic model being a significantly better model than the linear model (b = 0.09, 95% CI = 0.03, 0.15, $p = 0.005$). Both short (b = −0.51, 95% CI = −0.72, −0.29, $p < 0.001$) and long sleepers (b = −0.27, 95% CI = −0.50, −0.03, $p = 0.029$) reported significantly lower SRH than normal sleepers ($M = 7.81$, $SE = 0.14$).

Sleep quality. As shown in Fig. 1b, the linear term (b = 0.46, 95% CI = 0.37, 0.55, $p < 0.001$) of sleep quality is associated with SRH. Adding the quadratic term to the linear model did not significantly improve the model (b = 0.06, 95% CI = −0.02, 0.13, $p = 0.119$), suggesting that the linear model is a better model. The mean SRH in those with intermediate sleep quality was 7.30 ($SE = 0.15$) (95% CI = 7.02, 7.59). Those with poor sleep quality reported significantly lower SRH than individuals with intermediate sleep quality (b = −0.29, 95% CI = 0.56, −0.03, $p = 0.032$). Those with good sleep quality reported significantly higher SRH than those with intermediate sleep quality (b = 0.68, 95% CI = 0.48, 0.89, $p < 0.001$).

Sleep duration and sleep quality interaction. As shown in Fig. 1c, the linear term of sleep quality moderated the quadratic relationship of sleep duration with SRH (b = 0.01, 95% CI = 0.00, 0.01, $p = 0.001$). The simple slopes of sleep duration predicting SRH at different levels of sleep quality show that long sleep duration is associated with worse SRH in individuals with poor sleep quality. Poorer SRH in individuals with short sleep duration was largely independent of sleep quality.

3.3. Sleep quality and fatigue mediate the relationship between sleep duration and SRH

Results of the GSEM indicate that the quadratic relationship of sleep duration with SRH (b = 0.66, 95% CI 0.33, 0.98, $p < 0.001$) was partly mediated by sleep quality (b = 0.30, 95% CI 0.20, 0.40, $p < 0.001$). When sleep quality was entered as a mediating variable, the quadratic relationship between sleep duration and SRH became weaker (b = 0.36, 95% CI 0.04, 0.68, $p = 0.029$), indicating that sleep quality partially mediated the quadratic relationship between sleep duration and SRH.

Subsequently, in model 2 it was shown that the quadratic relationship of sleep duration with SRH (b = 0.76, 95% CI 0.36, 1.17, $p < 0.001$) was significantly mediated by fatigue (b = 0.27, 95% CI 0.12, 0.41, $p < 0.001$). Sleep duration remained significantly associated with SRH (b = 0.50, 95% CI 0.11, 0.88, $p < 0.001$), supporting that fatigue partially mediated the quadratic relationship between sleep duration and SRH.

4. Discussion

Confirming previous reports, an unhealthy sleep duration, ie, both shorter and longer than 7–9 h sleep, and poor sleep quality in the night prior to assessment were associated with poorer SRH. This multi-study analysis extends these findings by showing that the association between long sleep and poorer SRH was augmented

Table 1
Descriptive characteristics and sleep duration, sleep quality, and fatigue data of the study population separated by study, given as median (interquartile range; IQR) or *n* (%); hyphen (–) indicates missing data; *p*-values indicate a main effect of study. Note: Sleep duration data was missing for 1 participant (Study 2).

Study	1	2	3	4	5	p-value
N	65	90	97	858	194	
Age, median (IQR)	28 (23, 32)	65 (26, 71)	20 (19, 20)	27 (22, 35)	20 (19, 21)	<0.001
Sex (% male)	38.5%	40.0%	15.5%	48.8%	–	<0.001
Self-Rated Health, median (IQR)	8 (7, 9)	8 (7, 9)	8 (7, 8)	8 (7, 9)	7 (7, 8)	<0.001
Sleep Duration in hours, median (IQR)	7 (7, 8)	7 (6, 8)	7 (7, 8)	8 (7, 9)	7 (7, 8)	<0.001
Sleep Quality, median (IQR)	4 (3, 4)	4 (3, 4)	4 (3, 4)	4 (3, 4)	3 (3, 4)	0.260
Sleep Duration Categories, n (%)						0.009
Short (<7 h)	12 (18.5%)	29 (32.6%)	23 (23.7%)	205 (23.9%)	40 (20.5%)	
Normal (7–9 h)	42 (64.6%)	57 (64.0%)	62 (63.9%)	489 (57.0%)	113 (58.5%)	
Long (≥9 h)	11 (16.9%)	3 (3.4%)	12 (12.4%)	164 (19.1%)	41 (21.0%)	
Sleep Quality Categories, n (%)						0.029
Poor (1–2)	7 (10.8%)	13 (14.4%)	9 (9.3%)	152 (17.7%)	40 (20.6%)	
Intermediate (3)	16 (24.6%)	27 (30.0%)	31 (32.0%)	199 (23.2%)	60 (30.9%)	
Good (4–5)	42 (64.6%)	50 (55.6%)	57 (58.8%)	507 (59.1%)	94 (48.5%)	
Fatigue, median (IQR)	–	–	2 (2, 3)	2 (1, 4)	2 (1, 3)	0.720
Medical condition (at least one disorder), n (%)		12 (13.3%)	6 (6.2%)	84 (9.8%)	33 (16.9%)	0.008
Cardiovascular	–	10 (11.1%)	1 (1.0%)	15 (1.7%)	0 (0%)	
Psychiatric	–	1 (1.1%)	3 (3.1%)	35 (4.1%)	24 (12.4%)	
Musculoskeletal	–	2 (2.2%)	0 (0%)	10 (1.2%)	2 (1.0%)	
Immune	–	1 (1.1%)	1 (1.0%)	25 (2.9%)	6 (3.1%)	
Neurological	–	2 (2.2%)	1 (1.0%)	5 (0.6%)	2 (1.0%)	
Other	–	1 (1.1%)	2 (2.1%)	26 (3.0%)	4 (2.1%)	
Undefined/unclear	–	3 (3.1%)	4 (4.1%)	5 (3.2%)	10 (5.2%)	

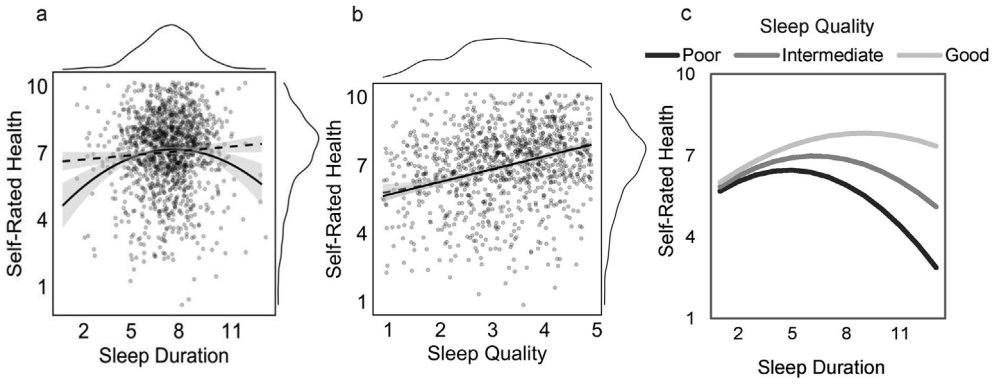

Fig. 1. Scatterplot depicting the relationships of (a) sleep duration (in hours) and (b) sleep quality with self-rated health ratings. Dashed lines represent linear curve fits, solid lines represent quadratic curve fits, and dots represent jittered raw data. Shaded areas indicate 95% confidence intervals. Top and right marginal density plots show distribution of the data. (c) Shows the simple slopes of sleep duration predicting self-rated health at poor (score of 1 or 2), intermediate (score of 3), and good (score of 4 or 5) sleep quality.

by poor sleep quality. When having good sleep quality, individuals with long sleep duration reported better SRH, suggesting that good sleep quality may protect long sleepers from poor SRH. Furthermore, fatigue and poor sleep quality were associated with, and partially mediated, the inverted U-shaped relationship between sleep duration and SRH. Current fatigue and last night's sleep quality are thus factors linking sleep duration to SRH.

A significant point to be taken from the current results is the importance of assessing both sleep duration and sleep quality when investigating sleep–health relationships. Last night's long sleep duration does not seem to be associated with poor subjective health unless it is coupled with poor sleep quality. Poor sleep quality, as well as poor SRH, are potentially factors that make an individual prioritize sleeping longer. The current results suggest that future studies on the potential health risks of long sleep will benefit from including measures of sleep quality.

The current study suggests that the association between last night's sleep duration and SRH is partially driven by current fatigue and the quality of the slept hours. A potential mechanism for this includes present medical problems. However, the participants in the current study were relatively healthy, ie, 88.4% reported no present medical problems. A second possible mechanism by which fatigue and sleep quality could be associated with SRH is their signaling potential of low-grade inflammation. Fatigue, sleep disturbances, and inflammation commonly co-occur and are increasingly recognized as a symptom cluster that is prevalent in patient populations [38–40]. Experimental studies that induce acute inflammation via administration of immune activators such as lipopolysaccharides (LPS), *Salmonella typhi*, or patients receiving immunotherapy, further show that inflammation can induce fatigue and sleep disturbances and reduce SRH [41–44]. Together these findings support the notion that inflammation may be a common underlying factor linking sleep quality and fatigue to SRH. However, low-grade inflammation is a physiological process that does not seem to be readily detectable by an individual if no medical symptoms are present [45]. Although speculative at this point, fatigue and sleep quality may act as a signal for low-grade inflammation, and thereby influence SRH.

Besides shedding new light onto the importance of a multidimensional approach when addressing sleep–health relationships, a further strength is the relatively large pooled dataset of five independent studies. Nevertheless, several limitations apply. First, by solely measuring subjective and self-reported aspects of sleep, information of undiagnosed sleep apnea or insomnia may have been missed. Second, the present study was largely limited to the influence of the last night's sleep. While, one night of low sleep quality or short sleep duration is common, it is unknown whether participants experienced a single night or chronic short or long sleep duration or low sleep quality. Further studies on how more chronic aspects of sleep or physiological characteristics, measured with polysomnography, may reveal additional associations. Third, sleep duration and quality and SRH were self-reported in the present study and there is thus a risk of bias, although this unlikely explains the moderating effect of sleep duration on the association between sleep quality and self-rated health, as such bias on SRH is relatively small [46]. Fourth, the current study was observational in nature and no causal assumptions can be made. For example, short and long sleep duration can be the result of poor SRH, vice versa, and sleep duration and SRH can be bidirectional [47]. Moreover, how the associations between sleep and SRH may change across time (both short- and long-term), and their potential causes, would be of interest to study. Fifth, the relationship between sleep and SRH may be indirect since sleep is related to many aspects that are also linked to SRH besides fatigue (eg, mental health) [48,49]. No single determinant explains all aspects of the relationship between sleep duration and SRH. Multiple processes contribute and all are intertwined. For example, environmental exposures (eg, noise or air pollution) and lifestyle factors (eg, stress, smoking, medication/substance use) have each been shown to be linked to sleep and health [50,51]. Lastly, the sample consisted of mostly young and healthy individuals, and results with respect to sleep duration and SRH may not generalize to other age categories, or those with a medical condition.

In conclusion, the current study suggests that good sleep quality may protect long sleepers from poor health and identified sleep quality and fatigue as potential pathways affecting the link between sleep duration and self-rated health. Further studies, preferably longitudinal in nature, are needed to increase the understanding of how different dimensions of sleep develop and interact across time, and how they together impact health.

Credit author statement

LB: Conceptualization, Methodology, Software, Formal analysis, Investigation, Writing - Original draft preparation, Visualization; **AA**: Conceptualization, Formal analysis, Writing - Reviewing and Editing; **JA**: Writing - Reviewing and Editing; **JB**: Writing - Reviewing and Editing.

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Conflict of interest

None.

The ICMJE Uniform Disclosffigure Form for Potential Conflicts of Interest associated with this article can be viewed by clicking on the following link: https://doi.org/10.1016/j.sleep.2021.10.020.

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