Accepted Manuscript

Biological and psychological correlates of self-reported and objective sleep measures

Marta Jackowska, Amy Ronaldson, Jennie Brown, Andrew Steptoe

PII: S0022-3999(16)30069-1
DOI: doi: 10.1016/j.jpsychores.2016.03.017
Reference: PSR 9142

To appear in: *Journal of Psychosomatic Research*

Received date: 12 February 2016
Revised date: 17 March 2016
Accepted date: 20 March 2016

Please cite this article as: Jackowska Marta, Ronaldson Amy, Brown Jennie, Steptoe Andrew, Biological and psychological correlates of self-reported and objective sleep measures, *Journal of Psychosomatic Research* (2016), doi: 10.1016/j.jpsychores.2016.03.017

Biological and psychological correlates of self-reported and objective sleep measures

Marta Jackowska, PhD[1,2]; Amy Ronaldson, MSc[1], Jennie Brown, PhD[1,3], Andrew Steptoe, DPhil[1].

[1]Research Department of Epidemiology and Public Health, University College London, UK.

[2]Department of Psychology, University of Roehampton, London, UK.

[3]School of Psychology, University of East London, London, UK.

*Corresponding author and reprints requests: Marta Jackowska, Department of Psychology, Whitelands College, University of Roehampton, Holybourne Avenue, SW15 4JD, London, United Kingdom. Fax 44 (0) 020 7916 8542; Telephone: +44(0)20 8392 3642, E-mail: marta.jackowska@roehampton.ac.uk

Running head: Correlates of self-reported and objective sleep measures

Abstract

Objective: Objective and self-reported sleep are only moderately correlated and it is uncertain if these two types of sleep measures are associated with distinct biological and psychological outcomes.

Methods: Participants were 119 healthy women aged 26 years on average. Cortisol and blood pressure assessed over one day were the measures of biological function. Psychological variables included optimism, life satisfaction, positive and negative affect as well as emotional distress. Sleep was assessed with the Pittsburgh Quality Index (PSQI), wrist actigraphy and sleep diaries.

Results: Global sleep ratings on the PSQI were unrelated to objective sleep efficiency, duration or latency. Sleep duration derived from sleep diaries was highly correlated with objective duration but was unrelated to the PSQI measure. More disturbed sleep on the PSQI was associated with lower psychological wellbeing, as indicated by reduced levels of optimism, life satisfaction and positive affect as well as greater negative affect and emotional distress. Objective sleep efficiency was reduced among participants with lower positive and higher negative affect but there were no other associations between objective sleep indicators and psychological variables tested in our study. Participants with poorer self-reported sleep had lower cortisol awakening response while those with longer objective sleep latency had higher diastolic blood pressure, independently of covariates.

Conclusion: Our study reveals that self-reported and objective sleep measures, in particular those regarding sleep quality, are weakly associated but have different psychological and biological correlates. This suggests that findings relating self-reported sleep may not necessarily be corroborated by objective sleep indicators.

Keywords sleep, measurement, cortisol, blood pressure, psychological wellbeing

Introduction

The majority of studies relating sleep with disease risk has relied on self-report. This is partly due to ease of measuring and reduced participant burden. Moreover, in large prospective studies the use of objective sleep indices, such as Polysomnography or actigraphy, is often impractical or not feasible financially.

However, when compared with objective sleep indicators, such as actigraphy, self-reported ratings can be imprecise. For example, in the CARDIA study sleep duration was on average overestimated by 48 minutes [1]. Estimations of sleep quality are imprecise as well and may include over- and underestimations [2,3].

Factors that may influence people's perception of sleep have not been systematically explored but fewer years of education, age, lower self-rated health, social support as well as work stress have been implicated [1,2].

Although objective and self-reported sleep are only moderately correlated it remains uncertain if these two sleep measures are associated with distinct psychological and biological outcomes. For example, in Cleveland Family Study long self-reported sleep duration was associated with elevated levels of C-reactive protein and interleukin-6 while short objective sleep duration was linked to higher tumour necrosis factor alpha [4]. Jackowska et al. [2] reported that lower self-reported sleep quality was correlated with depressive symptoms, poorer perceived health, lower levels of social support and work stress but no such associations were found for objective sleep measure.

Using psychological factors and objective markers of biological function collected over one day the aim of this study was, therefore, to test if associations with self-reported sleep measures would be corroborated by objective sleep data. Blood pressure and cortisol were the measures of biological function selected based on their associations with sleep [5,6].

Method

Participants

Participants were 119 women recruited from University College London and neighbouring institutions. This article is based on baseline data derived from a positive wellbeing study described in detail previously [7]. Briefly, women older than 45 years old were not invited to take part since sleep patterns change with age (Ohayon et al., 2004). Women suffering from or diagnosed with a medical or psychiatric condition within the last two years, or those undergoing an early menopause, were also excluded from participation in the study. All participants provided informed consent and the study was approved by UCL Research Ethics Committee.

Measures

Demographic information (e.g. education, age) was assessed by questionnaire. Body mass index (BMI) was measured based on participants' weight and height. Psychological variables described here include optimism, life satisfaction, positive and negative affect as well as emotional distress. The Revised Life Orientation Test [8] was used to measure optimism, life satisfaction was indexed with the Satisfaction with Life Scale [9]. Positive and negative affect and emotional distress were assessed with the Scale of Positive and Negative Experience [10] and the Hospital Anxiety and Depression Scale [11], respectively. Global subjective sleep was indexed with the Pittsburgh Quality Index (PSQI) [12]. Objective sleep was measured with the ActiGraph GT3X (ActiGraph, Pensacola, Florida, US) over 7 nights, and for the purpose of this article sleep efficiency (calculated as the total proportion of the time the person spent sleeping), latency and duration were computed excluding first and last night. Using sleep diaries participants also provided daily sleep duration which was averaged over 5 days, again excluding nights 1 and 7.

Biological data described here included cortisol and blood pressure (BP) measures. Briefly, cortisol was obtained by taking 7 saliva samples over the day and evening using Salivette plastic tubes (Sarstedt, Leicester, UK). Cortisol output was analysed by computing the cortisol awakening response (CAR) [13], and total cortisol output across the day as the area under the curve (AUC) [14]. The cortisol AUC was log transformed prior to analysis. Blood pressure was measured with the SpaceLabs 90217 ambulatory blood pressure monitor (Redmond, WA). The monitor was fitted on a participant's arm; the device was programmed to take readings every 30 minutes and was worn for at least 10 hours over a single day. Systolic and diastolic BP values were averaged across the recording period.

Statistical approach

Associations between self-reported sleep and psychological variables were tested with partial correlations adjusting for age since this is related to both sleep and psychological wellbeing [15,16]. The analyses of biological variables included BMI as an additional covariate as it is related to BP and cortisol [17,18]. Analyses relating objective sleep were conducted in the same fashion. Data were analysed using SPSS v.21 and results are presented as Pearson correlation coefficients (*r*) and p-values.

Results

Participants were on average 26 years old, over one third was married or cohabiting and over 70% of the sample was white. The majority of participants were in full-time postgraduate education while the reminder of the sample was in full-time work. The average BMI was 22.4.

Table 1

Participants characteristics

Variable	Mean (SD)/Frequency (%)
Age	26 (4.9)
Relationship status	
Married/cohabiting	40 (33.6)
Single	75 (63)
Divorced/separated/widowed	2 (1.6)
Ethnicity	
White British/Irish/Other	86 (72.3)

Other	33 (27.7)
Employment status	
Full-time postgraduate student	103 (86.6)
Full-time employment	16 (13.4)
BMI	22.4 (3.2)
PSQI	6.5 (2.8)
Daily sleep duration	7.5 (1.0)
Sleep efficiency (%)	88.1 (6.8)
Duration	7.0 (0.9)
Sleep latency (minutes)	5.7 (6.0)
Optimism (range:1-24)	14.7 (5.1)
Life satisfaction (range:5-35)	22.6 (6.5)
Positive affect (range:1.8-4.8)	3.3 (0.7)
Negative affect (range:1.0-4.2)	2.4 (0.7)
Depressive symptoms (range:3-26)	13.3 (5.7)
Cortisol awakening response (nmol/l) (range:-18.7-36.7)	7.6 (10.0)
Cortisol AUC (log, nmol/l) (range: 6511.2-36730.1)[1]	14682.3 (5182.6)[1]
Systolic BP (mmHg) (range:90.0-132.0)	113.4 (7.8)
Diastolic BP (mmHg) (range:58.9-90.7)	73.9 (6.2)

[1] untransformed data.

Characteristics of sleep measures

The PSQI was on average 6.5 and daily sleep duration (derived from sleep diaries) was 7.5 hours. Objective sleep duration was 7.0 hours, and sleep efficiency was high (88.1%). Objective sleep latency was on average 5.7 min (SD=6.0) indicating large variations within the sample with regards to how long participants took to fall asleep (see Table 1).

Global sleep ratings on the PSQI were unrelated to objective sleep efficiency (r=-0.07 p=0.49), duration (r=0.08 p=0.42) or latency (r=0.002, p=0.99). Daily sleep duration was highly correlated with objective duration (r=0.71, p<0.001) but was unrelated to the PSQI measure (r=-0.07 p=0.46). Daily sleep duration (obtained from sleep diaries) was associated with duration derived from the PSQI (r=0.43, p<0.001), but the size of this association was smaller than between daily and objective sleep duration (see also supplementary table).

Sleep measures and psychological characteristics

Table 2

Partial correlations between subjective and objective sleep and psychological characteristics

	Optimism[1]	Life satisfaction[1]	Positive affect[1]	Negative affect[1]	Depressive symptoms[1]
PSQI	**-0.33****	**-0.28***	**-0.36****	**0.44****	**0.44****
Daily sleep duration	0.08	0.04	0.11	-0.03	-0.10
Sleep efficiency	-0.05	-0.04	**-0.19***	**0.19***	0.16
Duration	0.04	0.06	0.03	0.11	-0.03
Sleep latency	0.09	-0.003	0.12	-0.10	-0.07

[1] adjusted for age; * p<0.05;** p<0.001.

As depicted in Table 2 global ratings of sleep disturbance were associated with lower levels of optimism, life satisfaction and positive affect and greater mood disturbance, independently of age. Associations with objective sleep measures corroborated these findings only with regards to sleep efficiency which was correlated with lower positive and higher negative affect. Self-reported and objective sleep duration as well as sleep latency were unrelated to psychological variables in these data.

Sleep measures and biological characteristics

Table 3

Partial correlations between subjective and objective sleep and biological characteristics

	Cortisol awakening response (nmol/l)[1]	Cortisol AUC (log, nmol/l)[1]	Systolic BP (mmHg)[1]	Diastolic BP (mmHg)[1]
PSQI	**-0.20***	-0.02	-0.001	0.03
Daily sleep duration	0.06	0.10	0.10	0.12
Sleep efficiency	0.01	-0.02	0.03	0.09
Duration	0.06	0.05	0.10	0.12
Sleep latency	-0.03	-0.04	0.10	**0.21***

[1] adjusted for age and BMI; * $p<0.05$.

Analysis of biological variables revealed that greater sleep disturbance on the PSQI was associated with lower CAR, independently of age and BMI but there was no relationship with BP. Both objective and subjective sleep duration as well as sleep efficiency were unrelated to biological variables in our data, but longer sleep latency was more prevalent among those with higher diastolic BP (see Table 3).

Discussion

Our study builds on previous research indicating that self-reported and objective sleep indices are correlated with different psychological and biological data. Greater sleep disturbance on the PSQI was linked to lower psychological wellbeing, as indicated by reduced levels of optimism, life satisfaction and positive affect. Unsurprisingly, higher sleep disturbance was also correlated with more emotional distress and negative affect. These data are in line with previous studies [19,20]. In contrast, objective sleep measures were weakly associated with psychological variables described here since only sleep efficiency was associated with ratings of positive and negative affect but not with life satisfaction, optimism or emotional distress. In line with past studies [e.g. 4] that used the PSQI, global sleep ratings were unrelated to objective sleep indicators.

Subjective and objective sleep are associated with different markers of inflammation [4] and this study tentatively extends this evidence to cortisol and diastolic BP. Namely, while global sleep ratings on the PSQI were associated with lower CAR, objective sleep latency was longer in participants with higher diastolic BP.

In contrast to self-reported sleep, objective sleep was weakly associated with psychological well-being in these data. The mean score on the PSQI was 6.5, which is above the cut-off point of 5> used to distinguish between good and disturbed sleep, while actigraphy data suggested that participants had good sleep efficiency (mean=88.1%) and their sleep duration was within the recommended healthy range [21]. It is plausible that sleep perception rather than the actual sleep may be more closely related to individuals' psychological characteristics, as reported previously in clinical [22,23] and population-based populations [2].

Sleep perception may be negatively affected by menstrual cycle, in particular by the luteal phase [24] so this could in part explain why sleep ratings on the PSQI were not associated with objective sleep data. However, in this study there was no difference in the PSQI scores between women in follicular and luteal menstrual phase (data not shown), so this explanation seems unlikely for our data.

It is well established that evaluations of health [25] and sleep [2] are affected by negative affectivity, and our study shows that sleep assessed with the PSQI is linked to a broader range of psychological characteristic and dispositions such as life satisfaction or optimism. In contrast, self-reported sleep duration obtained from sleep diaries was unrelated to psychological factors described here. One possible explanation for this pattern of findings may be that measures of sleep quality rather than sleep quantity are more closely associated with psychological well-being [26].

Our study has a number of limitations. Participants were mostly white, young and university educated women. The is substantive literature suggesting that sleep is more disturbed among women [27], older people [28], individuals with fewer years of education and among those from deprived socio-economic backgrounds [27,29] as well as in ethnic minority groups [29]. Similarly, psychological wellbeing also varies by people's age and socio-economic factors [16,30]. We cannot thus be certain that the same findings would have emerged if our study was based on a more heterogeneous sample, so our results may not generalise to less educated, older, male or more ethnically diverse populations. Given the variability in biological variables described here, in particular cortisol, the sample was relatively small. Relatedly, the correlations between objective and subjective sleep measures with cortisol and blood pressure were modest and need to be replicated by further research to rule out the possibility our statistically significant results are a reflection of the number of analyses carried out. However, the analysis of ambulatory blood pressure data involved aggregating large numbers of readings over the day, potentially providing more robust estimates than measures obtained under standard clinical conditions. To enable better comparison with past studies it would have been useful also to include other biological measures such inflammation.

Collectively, our findings suggest that subjective and objective sleep indicators may be measuring distinct phenomena. This is important, since to date the majority of studies relating sleep with health conditions have been predominantly based on self-report and found, for example, that sleep duration of ≤5-6 hours is associated with increased risk of cardiovascular outcomes and mortality [31]. In contrast, a study in which sleep was measured with actigraphy found that duration between 5 and 6.5 hours was associated with lowest risk of all-cause mortality [32]. It has been suggested that sleep indexed with self-report may be tapping into chronic sleep exposure while objective sleep indicators could be collecting data on acute sleep patterns [4]. In our study, however, the PSQI was completed with reference to the past week as to make it comparable with actigraphy data.

In conclusion, self-reported and objective sleep measures, in particular those relating sleep quality, are weakly associated but have different psychological and biological correlates. This suggests that findings relating self-reported sleep may not necessarily be corroborated by objective sleep indicators.

Acknowledgments

This work was supported by the Biotechnology and Biological Sciences Research Council, Unilever Discover and the Economic and Social Research Council. The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript. The authors wish to thank all participants who contributed towards this study.

References

[1] Lauderdale DS, Knutson KL, Yan LL, Liu K, Rathouz PJ. Self-reported and measured sleep duration: how similar are they? Epidemiology 2008;19:838-845. http://dx.doi.org/10.1097/EDE.0b013e318187a7b0

[2] Jackowska M, Dockray S, Hendrickx H, Steptoe A. Psychosocial factors and sleep efficiency: discrepancies between subjective and objective evaluations of sleep. Psychosom Med 2011;73:810-816. http://dx.doi.org/10.1097/PSY.0b013e3182359e77

[3] Unruh ML, Redline S, An MW, Buysse DJ, Nieto FJ, Yeh JL, et al. Subjective and objective sleep quality and aging in the sleep heart health study. J Am Geriatr Soc 2008; 56:1218-1227. http://dx.doi.org/10.1111/j.1532-5415.2008.01755.x

[4] Patel SR, Zhu X, Storfer-Isser A, Mehra R, Jenny NS, Tracy R, et al. Sleep duration and biomarkers of inflammation. Sleep 2009;32:200-204.

[5] Pepin JL, Borel AL, Tamisier R, Baguet JP, Levy P, Dauvilliers Y. Hypertension and sleep: overview of a tight relationship. Sleep Med Rev 2014;18,509-519. http://dx.doi.org/10.1016/j.smrv.2014.03.003

[6] Hirotsu C, Tufik, S, Andersen ML. Interactions between sleep, stress, and metabolism: From physiological to pathological conditions. Sleep Sci 2015;8:143-152. http://dx.doi.org/10.1016/j.slsci.2015.09.002

[7] Jackowska M, Brown J, Ronaldson A, Steptoe A. The impact of a brief gratitude intervention on subjective well-being, biology and sleep. J Health Psychol 2015 1359105315572455. http://dx.doi.org/10.1177/1359105315572455

[8] Scheier MF, Carver, CS, Bridges MW. Distinguishing optimism from neuroticism (and trait anxiety, self-mastery, and self-esteem): a reevaluation of the Life Orientation Test. J Pers Soc Psychol 1994;67:1063-1078. http://dx.doi.org/10.1037/0022-3514.67.6.1063

[9] Diener ED, Emmons RA, Larsen RJ, Griffin S. The satisfaction with life scale. J Pers Assess 1985;49:71-75. http://dx.doi.org/10.1207/s15327752jpa4901_13

[10] Diener E, Wirtz D, Tov W, Kim-Prieto C, Choi D W, Oishi S, et al. New well-being measures: Short scales to assess flourishing and positive and negative feelings. Soc Indic Res 2010;97:143-156. http://dx.doi.org/10.1007/s11205-009-9493-y

[11] Zigmond AS, Snaith RP. The hospital anxiety and depression scale. Acta psychiatr scand 1983;67:361-370. http://dx.doi.org/10.1111/j.1600-0447.1983.tb09716.x

[12] Buysse DJ, Reynolds CF, Monk TH, Berman SR, Kupfer DJ. The Pittsburgh Sleep Quality Index: a new instrument for psychiatric practice and research. Psychiatry Res 1989; 28:193-213. http://dx.doi.org/10.1016/0165-1781(89)90047-4

[13] Chida Y, Steptoe A. Cortisol awakening response and psychosocial factors: a systematic review and meta-analysis. Biol Psychol 2009;80:265-278. http://dx.doi.org/10.1016/j.biopsycho.2008.10.004

[14] Pruessner JC, Kirschbaum C, Meinlschmid G, Hellhammer DH. (2003) Two formulas for computation of the area under the curve represent measures of total hormone concentration versus time-dependent change. Psychoneuroendocrinology 2003;28:916-931. http://dx.doi.org/10.1016/S0306-4530(02)00108-7

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

[16] Stone AA, Schwartz JE, Broderick JE, Deaton A. A snapshot of the age distribution of psychological well-being in the United States. Proc Natl Acad Sci USA 2010;107:9985-9990. http://dx.doi.org/10.1073/pnas.1003744107

[17] Carroll D, Ring C, Hunt K, Ford G, Macintyre S. Blood pressure reactions to stress and the prediction of future blood pressure: effects of sex, age, and socioeconomic position. Psychosom Med 2003;65:1058-1064. http://dx.doi.org/10.1097/01.PSY.0000097330.58739.26

[18] Steptoe A, Kunz-Ebrecht SR, Brydon L, Wardle J. Central adiposity and cortisol responses to wakening in middle-aged men and women. Int J Obes 2004;28:1168-1173. http://dx.doi.org/10.1038/sj.ijo.0802715

[19] Steptoe A, O'Donnell K, Marmot M, Wardle J. Positive affect, psychological well-being, and good sleep. J Psychosom Res 2008;64:409-415. http://dx.doi.org/10.1016/j.jpsychores.2007.11.008

[20] Hamilton NA, Gallagher MW, Preacher KJ, Stevens N, Nelson CA, Karlson C, et al. Insomnia and well-being. J Consult Clin Psychol 2007;75:939-946. http://dx.doi.org/10.1037/0022-006X.75.6.939

[21] Watson NF, Badr MS, Belenky G, Bliwise DL, Buxton OM, Buysse D, et al. Recommended Amount of Sleep for a Healthy Adult: A Joint Consensus Statement of the American Academy of Sleep Medicine and Sleep Research Society. Sleep 2014;38:843-844. http://dx.doi.org/10.5665/sleep.4716

[22] Fernandez-Mendoza J, Calhoun SL, Bixler EO, Karataraki M, Liao D, Vela-Bueno A, et al. Sleep misperception and chronic insomnia in the general population: the role of objective sleep duration and psychological profiles. Psychosom Med 2011;73:88-97. http://dx.doi.org/10.1097/PSY.0b013e3181fe365a

[23] Karlson CW, Stevens NR, Olson CA, Hamilton NA. Depression, fatigue, and pre-sleep arousal: a mediation model. J College Stud Psychother 2010;24:307-327. http://dx.doi.org/10.1080/87568225.2010.509259

[24] Baker FC, Driver HS. Self-reported sleep across the menstrual cycle in young, healthy women. J Psychosom Res 2004;56:239-243.http://dx.doi.org/10.1016/S0022-3999(03)00067-9

[25] Watson D, Pennebaker JW. Health complaints, stress, and distress- exploring the central role of negative affectivity. Psychol Rev 1989;96:234-254. http://dx.doi.org/10.1037/0033-295X.96.2.234

[26] Pilcher JJ, Ginter DR, Sadowsky B. Sleep quality versus sleep quantity: relationships between sleep and measures of health, well-being and sleepiness in college students. J Psychosom Res 1997;42:583-96. http://dx.doi.org/10.1016/S0022-3999(97)00004-4

[27] Arber S, Bote M, Meadows R. Gender and socio-economic patterning of self-reported sleep problems in Britain. Soc Sci Med 2009;68: 281-289. http://dx.doi.org/10.1016/j.socscimed.2008.10.016

[28] Ancoli-Israel S. Sleep and its disorders in aging populations. Sleep Med 2009;10: S7-S11. http://dx.doi.org/10.1016/j.sleep.2009.07.004

[29] Grandner MA, Patel NP, Gehrman PR, Xie D, Sha D, Weaver T, et al. (2010). Who gets the best sleep? Ethnic and socioeconomic factors related to sleep complaints. Sleep Med 2010;11:470-478. http://dx.doi.org/10.1016/j.sleep.2009.10.006

[30] Deaton A. Stone AA. Two happiness puzzles. Am Econ Rev 2013;103:591-597. http://dx.doi.org/10.1257/aer.103.3.591

[31] Cappuccio FP, Cooper D, D'Elia L, Strazzullo P, Miller MA. Sleep duration predicts cardiovascular outcomes: a systematic review and meta-analysis of prospective studies. Eur Heart J 2011;32:1484-1492. http://doi.org/10.1093/eurheartj/ehr007

[32] Kripke DF, Langer RD, Elliott JA, Klauber MR, Rex KM. Mortality related to actigraphic long and short sleep. Sleep Med 2011;12:28-33. http://dx.doi.org/10.1016/j.sleep.2010.04.016

HIGHLIGHTS

Self-reported and objective sleep were only moderately correlated.

Sleep disturbance measured with the PSQI was correlated with a range of psychological characteristics.

Sleep duration derived from sleep diaries and objective duration were unrelated to psychological characteristics.

Self-reported and objective sleep measures had different biological correlates.

Findings based on self-reported sleep may not be corroborated by objective sleep indicators.