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Sleep Quality and Inflammation in Married Heterosexual Couples: an Actor-Partner Analysis

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Abstract

Background Subjective sleep quality is a predictor of important health outcomes, but little work has examined the social context of sleep that might inform theoretical models and intervention approaches. The present study tested actor-partner models of sleep quality and its links to inflammatory markers.

Method Participants were 84 middle-age to older adult heterosexual married couples who completed the Pittsburgh Sleep Quality Index and had blood drawn for determination of CRP and IL-6 levels.

Results Main results indicated that only actor levels of poor global sleep quality predicted higher CRP levels. No actor × partner or gender × actor/partner interactions were significant. These results were also not moderated by relationship quality. Secondary analyses, focused on the different components of sleep quality, revealed marginally significant evidence for partner's poor sleep (i.e., sleep disturbances, sleep latency) on one's own inflammatory outcomes.

Conclusion These results suggest the promise of modeling sleep quality as a dyadic process that can impact inflammation and potentially related health outcomes.

Keywords Sleep quality · Inflammation · Actor-partner · Dyadic

Introduction

Sleep quality is now a well-established predictor of health outcomes [1]. Several meta-analytic reviews have found that both objective and subjective measures of poor sleep (e.g., duration, quality) are prospective predictors of increased metabolic and cardiovascular diseases, as well as all-cause mortality [2–4]. Importantly, it has been estimated that about 1/3 of individuals have at least one insomnia symptom, hence highlighting the importance of understanding the determinants of poor sleep [5].

There are multiple contributors to poor sleep, including work status/conditions, mental/physical health, and personal/socio-demographic factors such as depression, marital status, and age [6]. Of these factors, relationship processes are increasingly appreciated as major contributors to sleep duration and quality [7–11]. It has been speculated that the importance of relationships for sleep may reflect evolutionary processes in which the presence of others signals safety and offers protection from danger during a vulnerable period [12]. For instance, according to the sentinel hypothesis, [13], others in a group can directly provide safety by natural variations in their wake-sleep cycles. This variation increases the chances that "sentinels" would be vigilant to danger during various points of the sleep cycle. Recent evidence for such a pattern was found in the Hazda hunter-gatherers of Tanzania in which at least one individual was awake in 99.8% of sampled epochs over a 20-day period [14].

Despite the importance of relationships processes for understanding sleep problems and its links to health, very few studies take a dyadic approach to examine how partners may mutually influence each other for better or worse [15]. That is, most studies only examine how an individual's sleep quality influences their own health outcomes such as inflammation [16–19]. For instance, in an early study Mills and colleagues [18] found that objective measures of poor sleep quality were related to indicators of inflammation (e.g., endothelin-1).

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Even studies that explicitly examine social factors and sleep focus on individual reports of relationship status/quality and sleep [11, 20].

The dominant approach in this area that focuses on individuals and its links to health has important statistical and conceptual limitations [21]. Statistically, dyadic approaches directly model important actor and partner sources of variance which can provide a more sensitive test of links between sleep, spousal interactions, and health [22]. Actor influences would represent the extent to which one's own sleep quality predicts one's own outcomes, whereas partner influences represent the extent to which a partner's sleep quality influences one's own outcomes [23]. Separating out these sources of variance can clarify the relative contribution of each dyad member and whether one source of influence (i.e., actor/partner) is more highly related to health than the other.

Dyadic approaches are also of importance conceptually because they explicitly acknowledge the social context of sleep. Marriage, in particular, is one of the most important relationships in adulthood and 82% of couples in the USA sleep in the same bed [24]. Sleep parameters are typically correlated within couples, and women's sleep quality influences their partner's sleep quality [25]. Revenson and colleagues [26] also found that an individual's anxiety and depression prospectively predicted a partner's sleep problems 1 year later. In addition, treatment of sleep apnea is often initiated by a spouse and treatment improves not only the patient, but the partner's quality of life [27]. The importance of relationship processes is also evident in the fact that partners' social control strategies, support, and conflict are tied to cooperation with CPAP [28, 29] and sleep parameters more generally [15, 30].

There have only been a few sleep studies that appear to have examined dyadic processes and linked them to biological health and these studies differ considerably in their approach. In one study, Gunn and colleagues [9] examined if the degree of concordance in couples' sleep-wake cycles predicted inflammation. These researchers found that greater concordance within couples was associated with lower C-reactive protein (CRP) levels [9]. A second study used an experimental protocol and tested if sleep difficulties during the past two nights were related to inflammatory responses to a laboratory marital conflict task [10]. Results showed that individuals who had less recent sleep showed greater stimulated IL-6 and TNF-alpha levels following the conflict discussion. However, no significant links were evident with partners' levels of cytokine production [10].

Given the hypothesized importance of the social context and the lack of work in the area, the present study examined actor-partner models linking subjective sleep quality to inflammatory outcomes (i.e., IL-6 and CRP) in married heterosexual couples. Inflammation is an important outcome as it influences every stage of cardiovascular disease from the initiation of early endothelial injury to later arterial obstruction or plaque rupture [31, 32]. Two important markers of inflammation include interleukin-6 (IL-6) and C-reactive protein (CRP) which have been linked to poor sleep in a recent meta-analysis [33] and also predict future risk for cardiovascular disease and related mortality [34–36]. Based on the larger literature, it was predicted that one's own poor sleep quality (actor influences) would be related to higher levels of both IL-6 and CRP [33]. One's sleep is also influenced by the social context (e.g., partner's tossing and turning might keep one awake) [15]. Thus, it is also predicted that a partner's poor sleep quality will be related to higher levels of inflammation in the spouse [15, 37, 38].

Method

Participants

Eighty-four heterosexual married adult couples (M_{age} = 56.47, SD = 7.34, range 42 to 78 years) were included in this study (average years of marriage = 26.8 years, SD = 11.9 years). The study was part of a larger study that investigated social interactions and cardiovascular health in middle-aged and older adults [39]. Most were White (95.2%) and had a household income over $40,000 per year (88.6%). Many older adults are on some form of medication so only individuals who (a) were on strong immunosuppressive treatment (e.g., corticosteroid therapy) and/or (b) had cancer or HIV were excluded due to potential effects of treatment on inflammation.

Procedure

Eligible participants were screened via phone interviews and scheduled for a laboratory appointment during a 3-hour late morning block (9 am to 12 pm) to control for diurnal influences on inflammation. Following informed consent, participants were first rechecked against the exclusion criteria upon their arrival for their session. Participants then completed background questionnaires (i.e., demographic, medication/health questionnaires) as well as the Pittsburgh Sleep Quality Index (see below). Twenty cubic centimeters of blood was also drawn and treated with EDTA to prevent clotting. Plasma was separated via centrifuge and levels of IL-6 and CRP were determined at the University of Amsterdam (see below). Couples were then debriefed and received $60.00 each for their participation.

Measures

Health Assessment A standardized health questionnaire provided information on height, weight, and medications/medical conditions (0 = no, 1 = yes). This questionnaire has been used

in a large longitudinal study on the chronic stress of caregiving for a relative with Alzheimer's disease and its effects on physiological function [40].

PSQI The Pittsburgh Sleep Quality Index (PSQI) assesses sleep quality disturbances during the previous month [41]. The scale is comprised of 19 items which are used to derive a total of seven component scores: sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, sleep medication, and daytime dysfunction. Component scores are summed to produce a global PSQI score with higher scores indicating poorer sleep quality. This instrument has demonstrated good reliability (alpha = 0.83) and validity [42]. The internal consistency for the subscale that had more than two items (i.e., sleep disturbances) was acceptable (alpha = .63).

Inflammation Assessments High sensitivity CRP was measured by immunonephelometry using a Behring Nephelometer II. The limit of detection for C-reactive protein is 0.015 mg/L (High Sensitivity CRP, Dade Behring). All samples were assayed in the same run, yielding a within-assay CV% of < 4.5% for CRP. IL-6 was determined using a commercially available high sensitivity ELISA (hsIL-6 Quantikine, R&D systems), which has a lower detection limit of 0.15 pg/ml and yielded an intra-assay CV% of < 6%. Consistent with prior work, CRP and IL-6 were natural log transformed to normalize the distribution prior to analyses [43]. The non-normality of the data was confirmed by significant Shapiro-Wilk tests for CRP ($W = .67$, $p < .001$) and IL-6 ($W = .83$, $p < .001$) [44].

Statistical Model

Proc mixed (SAS institute) was utilized for these actor-partner models [22]. All factors were treated as fixed [45] and proc mixed treats the unexplained variation within individuals as a random factor. All variables were grand mean centered prior to analyses [46]. The covariance structure for the repeated measures factors of dyad (i.e., 1 = husband, 2 = wife) was modeled using the compound symmetry structure [22]. The outputs of these models were unstandardized parameter estimates (b) using the Satterthwaite approximation to determine the appropriate degrees of freedom [22]. Consistent with prior work, analyses simultaneously statistically controlled for age, gender, body mass, income, and medication use such as statins and anti-inflammatory agents [47]. Main analyses first focused on global sleep quality scores. Analyses also examined the specific components of sleep duration, disturbances, latency, daytime dysfunction, efficiency, perceived quality, and sleep medication which provided the basis for the global scale. Finally, analyses involving potential statistical interactions (e.g., sleeping arrangements, gender differences) were based on the models above but also entering the cross-product term based on the centered main effects.

Results

Descriptive Analyses

Descriptive data on demographics and medication use by gender as well as correlations among the main study variables are included in Tables 1 and 2. The mean untransformed CRP and IL-6 levels in the sample were .19 ($sd = .25$) and 1.58 pg/ml ($sd = 1.07$), respectively. The average level of global sleep quality in the sample was 4.92 ($sd = 3.0$) which is close to the cut-off indicating poor sleep quality (i.e., 5.0) [48]. As shown in the diagonals, actor-partner sleep quality scores were also positively correlated ($r = .19$, $p < .02$). However, the correlation suggests only a small to moderate association. Most actor-partner correlations were positive and significant, with the exception of CRP and IL-6. Consistent with prior research, IL-6 and CRP were significantly related and body mass was related to higher inflammation for both men and women (*p*s < .01). Of particular note is that the raw correlation between poor sleep quality and CRP was significant for both men and women (*p*s < .05).

Main Analyses

As shown in Table 3, after controlling for basic factors and medication use that might influence inflammation, actor levels of poor global sleep quality predicted higher CRP levels only ($b = .08$, $SE = .03$, $p = .01$). A scatterplot of the raw data is shown in Fig. 1. Examination of this figure revealed no extreme outliers and an overall positive relationship between poor sleep quality and higher CRP levels. Inconsistent with predictions, partner levels of global sleep quality did not predict either CRP ($p = .76$) or IL-6 ($p = .11$). Given the

Table 1 Sample characteristics

Variable	Wives	Husbands
Mean (SD)		
Age	55.16 (6.89)	57.73 (7.58)
Body mass	25.07 (4.38)	27.44 (4.84)
Sleep quality	5.19 (3.29)	4.66 (2.68)
Raw IL-6	1.65 (1.01)	1.51 (1.14)
Raw CRP	0.21 (0.29)	0.17 (0.21)
Frequency		
Ethnicity (% White)	92.7	97.7
Statin use (% yes)	6.1	9.4
Anti-inflammatory use (% yes)	26.8	24.7
Hormone replacement use (% yes)	9.8	0

Table 2 Zero order correlations among main study variables for women (top panel) and men (bottom panel)

Variable	1.	2.	3.	4.	5.	6.	7.	8.	9.
1. PSQI	0.19*	.21	− .03	− .02	.13	.06	.08	− .04	.26*
2. BMI	− .05	0.29**	− .03	.11	.16	− .04	.21	.52**	.52**
3. Age	.12	− .03	0.94**	.21	− .18	.15	.10	.07	− .10
4. Statin	.23*	.00	.24*	0.34**	.08	.09	.01	.08	.04
5. Inflam.	.09	− .01	− .06	.10	0.21**	− .01	− .11	− .08	.18
6. HRT	–	–	–	–	–	–	.08	− .13	.17
7. Income	− .03	− .00	.01	.08	.06	–	–	.08	− .06
8. IL-6	.20	.45**	.11	.09	− .09	–	.06	0.09	.52**
9. CRP	.32**	.36**	− .03	.05	.02	–	.04	.61**	0.04

PSQI Pittsburgh sleep quality index, *BMI* body mass index, *Inflam.* anti-inflammatory, *HRT* hormone replacement therapy, *IL-6* Interleukin-6, *CRP* C-reactive protein. *$p \leq .05$, **$p \leq .01$

unexpected results for partner sleep quality, ancillary analyses explored whether sleeping in close proximity to the partner moderated these results. That is, are partner influences more likely if spouses slept in the same room and hence directly influenced by a partner's sleep quality. Sleeping arrangement was thus coded using the PSQI as partner not in same room (i.e., no bed partner or partner not in same room) or same room (i.e., partner in same room/bed). In these analyses, 92% of participants reported sleeping in the same room. None of the statistical interactions with sleeping arrangement approached significance (*p*s > .55). In addition, simple main effect analyses focused only on individuals who shared a bed revealed no significant partner links to IL-6 or CRP (*p*s > .16).

Exploratory moderation analyses were aimed at further explaining potential sources of variation. Actor × partner interactions were first explored to test if the concordance in sleep quality for actors and partners mattered. However, no actor × partner interactions were significant (CRP: $p > .74$, IL-6: $p > .72$). Analyses also considered the possibility that the quality of the relationship might matter so that a partner's poor sleep might be particularly impactful if relationship quality was low. However, such exploratory analyses revealed that these results were not significantly moderated by the quality of the relationship as indexed by the social relationship index (*p*s > .09) [49]. Finally, no gender × actor/partner interactions were significant for CRP (*p*s > .90) or IL-6 (*p*s > .52).

Analyses next examined specific components of the global sleep quality score that might provide greater sensitivity if specific components were more influential (e.g., actor or partner sleep disturbances). Although most subscales for actor influences were in the predicted direction, only days of dysfunction was marginally related to higher CRP levels ($b = .26$, $SE = .14$, $p = .07$) and sleep medication use was significantly associated with higher CRP levels ($b = .28$, $SE = .09$, $p = .003$). In addition, several marginally significant partner influences emerged on these component scores. Partner sleep disturbances predicted higher CRP levels ($b = .34$, $SE = .18$, $p = .056$), and partner sleep latency predicted higher IL-6 levels ($b = .12$, $SE = .06$, $p = .06$) in the spouse. The same patterns were also found when only examining partners who reported sharing a bed.

Table 3 Main actor-partner sleep quality results on inflammation

Variable	IL-6			CRP		
	b	SE	*p*	*b*	SE	*p*
Body mass	.06	.01	.00**	.11	.08	.00*
Age	.01	.01	.21	− .01	.01	.37
Gender (male-female)	.33	.08	.00**	.16	.19	.40
Statin	.08	.16	.63	.08	.33	.80
Anti-inflammatory	− .17	.10	.07	.15	.20	.44
Hormone replacement	− .30	.20	.12	.75	.42	.07
Income	− .01	.04	.88	− .06	.33	.80
Actor sleep quality	− .00	.01	.76	.08	.03	.01**
Partner sleep quality	.02	.01	.11	− .00	.03	.93

*$p \leq .05$, **$p \leq .01$

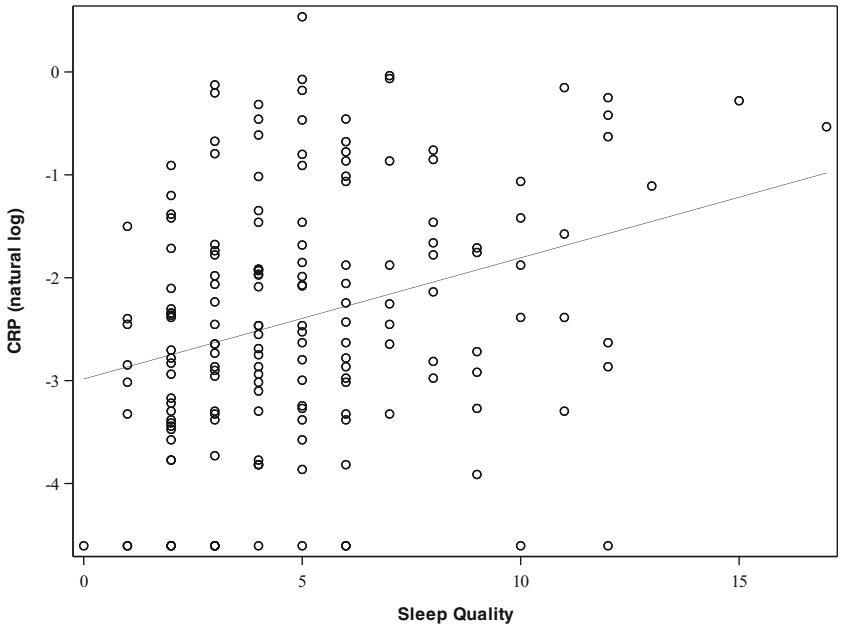

Fig. 1 Raw scatterplot depicting the link between actor sleep quality and CRP levels

Discussion

The main goal of this study was to examine dyadic links between sleep quality and inflammation in order to directly model the social context of sleep. Results indicated that one's own overall sleep quality was related to higher CRP levels, with no link between a partner's overall sleep quality and inflammation. Exploratory analyses did not reveal any actor × partner interactions, or moderation via relationship quality or gender. Secondary analyses did indicate that partner levels of sleep disturbances and sleep latency were marginally predictive of their spouse's inflammation. Pending replication, these results indicate that actor influences were more strongly related to inflammation, but partner influences might be evident on select subscales of sleep quality.

The main contribution of this study is that it explicitly models the social context of sleep using dyadic models. Recent work is highlighting the importance of approaching sleep as a social process given its proposed evolutionary significance and links to health [13–15]. Past evolutionary perspectives have highlighted the positive role of relationships in terms of its protective or sentinel value to the individual and group [13, 14]. However, it is also clear that relationship processes can contribute to poor sleep. Past research indicates that couples' sleep patterns are linked and can be negatively influenced by mental health problems, poor social control strategies, and low social support [15, 25, 26, 50]. Only a few studies have taken a dyadic approach and revealed mixed findings in terms of partner influences on health indices [9, 10]. For instance, Willson and colleagues [10] found no significant links between past sleep and acute inflammatory responses to conflict in the partner. One possibility is that partner influences might have a smaller influence on outcomes compared to actor influences as they are inherently more multiply determined [51]. That is, the link between partner attributes and spouse's own outcomes is likely one of many factors that influence their health. Indeed, in an earlier study, Strawbridge and colleagues (2004) found that one's own sleep quality (actor influences) appeared to have a larger influence on mental and physical health compared to partner influences. Although the current sample of heterosexual couples was relatively large for studies on dyadic processes and biological outcomes, future research should recruit larger samples to address this limitation.

Consistent with prior research, one's own sleep quality significantly predicted CRP levels [52, 53]. Although we did not find links to IL-6, CRP is the most stable and well-established inflammatory marker in terms of predicting future health problems as it has been related to cardiovascular disease risk and all-cause mortality [34, 54]. However, these results are inconsistent with a recent meta-analysis which found links between aspects of sleep and both CRP and IL-6 [33]. It should be noted that this meta-analysis did not examine overall sleep quality and results were stronger for CRP compared to IL-6 for some questionnaire assessments [33]. CRP also is a more downstream marker of inflammation, secreted (mainly) by the liver upon integration of multiple inflammatory signals besides IL-6 [55]. Thus, other inflammatory factors also influence CRP release (e.g., IL-1, interferon-α) and may be stronger contributors to the observed findings [56]. This is consistent with research indicating that IL-6 and CRP are relatively independent predictors of cardiovascular risk [57].

Given the importance of the social context for sleep, it was predicted that a partner's global sleep quality would predict one's inflammation. However, no partner influences were significant. Analyses of sleep components did show marginal partner influences for sleep disturbances and sleep latency on inflammation. Although caution is warranted in these

findings pending replication, these are two components that are most likely to directly influence the partner during sleep. That is, given the behavioral characteristics of sleep disturbances and sleep latency (e.g., tossing, shifting positions), bedfellows are more likely to be negatively influenced by such factors [38]. Future research should continue to examine both global and specific components which could guide the development of models linking social processes to sleep.

Combined with the larger literature on couples and sleep [25–27], these data may have important clinical implications. Although sleep interventions that typically focus on the patient are helpful for both the individual and their partner [27, 58], there may be value in examining couple's based approaches. For instance, simply treating couples who have difficult interaction patterns (e.g., conflict) as an important source of their sleep problems or treating sleep issues that contribute to relationship distress may prove useful [15]. A recent study examined this possibility and found that in the context of marital therapy, changes in men's marital quality predicted better sleep 3 months later [59]. However, no partner influences emerged and results were different for women. The current study did not find evidence for gender differences but was probably underpowered to examine the issue. Although women in marital therapy are less satisfied with their marriage compared to men [60], there does not appear to be gender differences in therapeutic outcomes [61, 62]. However, future research in the area will be important given the lack of data in the context of sleep-related processes.

There are several additional limitations that should be addressed. First, the study did not include any objective measures of sleep such as actigraphy. The PSQI is related to such objective measures [42, 48]; however, future work will be needed to examine similar questions using such assessments. Second, the study included a relatively healthy sample. Poor sleep is relatively more common in chronic disease populations [63] and hence dyadic processes might be more important given the role of family members in helping individuals cope [64]. Finally, the cross-sectional design is a limitation as there are likely reciprocal associations between inflammation and sleep, especially in a social context [15, 65]. Longitudinal designs will be able to model more complex processes linking dyadic sleep processes to inflammation. These limitations notwithstanding, this is one of the first actor-partner analyses of sleep and biological health, with important implications for future work on the social context of sleep.

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Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflicts of interest.

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent Informed consent was obtained from all individual participants included in the study.

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