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Psychosocial work characteristics, sleep disturbances and risk of subsequent depressive symptoms: a study of time-varying effect modification

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SUMMARY

Job strain and low social support at work are recognized risk factors for depression. However, people with poor sleep may represent a high-risk group more likely to benefit from interventions against work stress. The present study examined whether the associations between these work stressors and depressive symptoms differed by strata of sleep disturbances (effect modification/effect moderation) considering repeat measures of work characteristics and sleep. The study was based on five biennial measurements of the Swedish Longitudinal Occupational Survey of Health, including 1537 respondents recurrently in paid work, from an originally representative sample of the Swedish working population. High work demands, low decision authority and low social support were measured waves 2 and 4, sleep disturbances (putative moderator/modifier) waves 1 and 3, and depressive symptoms (outcome) wave 5. Causal effect modification, whether the effect of working conditions differed by strata of sleep disturbances, was analysed by structural nested mean modelling estimated using a regression-with-residuals with inverse-probability-of-treatment weighting approach. High demands and low social support, but not low decision authority, influenced subsequent depressive symptoms. The relationship between social support and depressive symptoms was not apparently modified by sleep disturbances. However, disturbed sleep wave 3 modified the effect of high demands wave 4 (coefficient 1.77, $P < 0.05$) on depressive symptoms wave 5. The results indicate that high job demands is a stronger risk factor for depressive symptoms in people with pre-existing sleep disturbances, suggesting that targeted workplace interventions may be more effective when it comes to preventing negative effects of job demands.

INTRODUCTION

Both sleep problems and depressive symptoms are highly prevalent in many parts of the world. They have been found to be associated with short- and long-term negative consequences for health and wellbeing, including increased risk of cardiovascular disease and mortality (Ferrie *et al.*, 2011; Whiteford *et al.*, 2013). However, more knowledge translated into practice is needed to decrease the public health burden of sleep and depressive symptoms.

A recent review based on high-quality studies on the relationship between work and sleep found indications that psychological demands and lack of control at work may be related to poorer subsequent sleep quality (Van Laethem *et al.*, 2013). Linton *et al.* also report some evidence of a prospective association between other working conditions representing possible work stressors, such as job strain (high demands and low control), low social support at work, insufficient rewards, an imbalance between effort and rewards, injustice at the workplace, bullying/social exclusion and shift work on the one hand, and sleep disturbances on the other hand (Linton *et al.*, 2014).

Similarly, studies on psychosocial work characteristics, such as work demands, job strain, decision latitude/control,

social support, effort–reward imbalance and justice tend to show prospective associations with depression (Theorell *et al.*, 2015). According to a recent review, there is substantial evidence that job strain and low decision latitude may increase depressive symptoms (Theorell *et al.*, 2015), but little is known about the interplay between these kinds of work stressors and other work and non-work factors. Some workplace intervention studies have also been carried out aiming at preventing development of depression, but results are typically mixed and insufficient (Montano *et al.*, 2014; Tan *et al.*, 2014). A better understanding of how and when poor psychosocial working conditions are unfavourable to mental health could, however, facilitate design of more effective interventions (MacKinnon and Luecken, 2008). Identification of moderators of associations between work stressors and depression can determine high-risk groups who are most likely to benefit from an intervention.

According to the diathesis-stress model, people may be more or less vulnerable or predisposed to develop depression when exposed to stressful environments (Hammen, 2016). Factors contributing to this kind of vulnerability may be genetic, personality related and physiological. It is, for example, assumed that recovery plays an important role for long-term health consequences of poor psychosocial work environment (Geurts and Sonnentag, 2006). By exacerbating allostatic load/overload (accumulated physiological wear and tear associated with chronic stress), health-related behaviours including sleep may contribute to increase the risk of disease (McEwen *et al.*, 2015). Sleep problems, particularly insomnia, have been associated with increased risk for depression (Baglioni and Riemann, 2012). A meta-analysis based on 21 studies demonstrated that people with insomnia were twice as likely to develop depression as people without sleep problems (Baglioni *et al.*, 2011). However, according to our knowledge, no previous studies have examined whether sleep problems can act as an effect modifier/moderator (i.e. whether the effect of a work stressor differs by strata of sleep quality; Vanderweele, 2009).

Both working conditions and sleep disturbances can, however, change over time, which represents a major challenge for analysis. When the interest is on effect modification and when a putative exposure and a putative moderator are time-varying, it may be necessary to establish that it is the moderator that moderates the effect of the exposure on the outcome, and not the exposure that moderates the relationship between the moderator and the outcome. This necessitates longitudinal data and that the moderator precedes the exposure (Kraemer *et al.*, 2008). Previous research has also shown that a poor work environment may lead to sleep disturbances, and that sleep disturbances can predict certain working conditions (Akerstedt *et al.*, 2015; Hanson *et al.*, 2011). Similarly, there may be bidirectional associations between working conditions and depressive symptoms, and between sleep problems and depressive symptoms (Jansson-Frojmark and Lindblom, 2008; Tang, 2014). This implicates that there is a need to consider temporality. Some more sophisticated techniques to analyse effect modification have been suggested also for repeated-measures data incorporating the appropriate temporal order between the variables of interest. We here applied an approach developed to investigate effect modification of time-varying treatment in intervention studies in an observational study. Our objective was to investigate if sleep disturbances modify the relationships between psychosocial work characteristics (high work demands, low decision authority and low support at work) and depressive symptoms in a time-varying setting.

MATERIALS AND METHODS

Study population

The study population consisted of participants of the Swedish Longitudinal Occupational Survey of Health (SLOSH) study, a nationally representative longitudinal cohort survey focusing on work life participation, social situation and health/wellbeing. SLOSH started in 2006 with a first follow-up of participants in the Swedish Work Environment Survey (SWES) 2003 ($n = 9214$), including gainfully employed individuals from the entire country, 16–64 years of age, and stratified by county and citizenship (Magnusson Hanson *et al.*, 2008). All eligible SWES participants were followed-up by means of postal self-completion questionnaires, one addressed to people in paid work, i.e. those in gainful employment for at least 30% full time, and one to people working less or who had left the labour force temporarily or permanently (Magnusson Hanson *et al.*, 2008). The same group of people, still alive, with known address in Sweden and who had not actively opted out were again asked to fill in a questionnaire in 2008 (wave 2), in 2010 (wave 3), in 2012 (wave 4) and in 2014 (wave 5). The design was largely balanced with a mean time lag of 1.9–2.1 years. In each wave, responders to SLOSH differed from the SWES populations on a number of characteristics, the general pattern being that more women, older, married or registered partners, born in Sweden, with university education and from the governmental sector respond to SLOSH and that these differences tend to be larger in later follow-ups. A flow chart of the sub-cohort originating from SWES 2003 is presented in Fig. 1. The study has been approved by the Regional Research Ethics Board in Stockholm, and informed consent was obtained from all respondents.

Psychosocial work characteristics

Psychosocial work characteristics represented by the dimensions demands, control and support were measured by the Swedish version of the Demand-Control Questionnaire (DCQ), a widely used questionnaire for these dimensions of the demand-control-support model (Fransson *et al.*, 2012), with satisfactory psychometric properties (Sanne *et al.*, 2005). Current demands at work were measured with five questions (working fast, working intensively, too much effort,

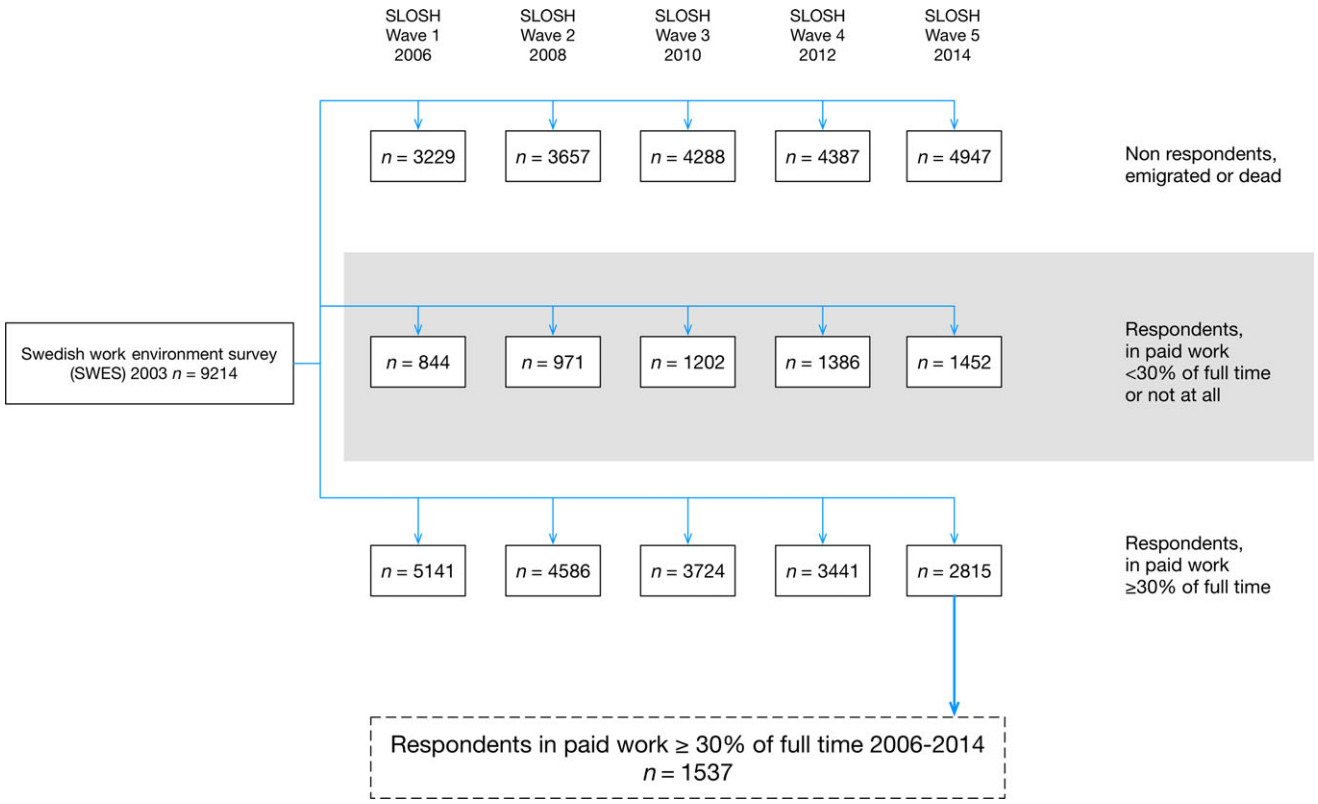

Figure 1. Flow chart illustrating the number of participants and non-participants in Swedish Longitudinal Occupational Survey of Health (SLOSH) at each wave of data collection between 2006 and 2014 for the SLOSH sub-cohort originating from the Swedish Work Environment Survey (SWES) 2003.

enough time, and conflicting demands; Cronbach's alpha 0.66). The item working intensively from the original demand scale was excluded from the demand component in order to improve the factor structure and measurement invariance over time (Chungkham *et al.*, 2013). Decision authority was considered to represent job control, and was assessed by two items from the DCQ (choice in deciding how to do work and what to do at work; Cronbach's alpha 0.76). Social support at work was measured with five of the six DCQ questions included in all five waves of SLOSH (calm and pleasant atmosphere, good spirit of unity, colleagues are there for me, people understand a bad day, get on well with my superiors; Cronbach's alpha 0.81). The occurrence and frequency of demands, and decision authority, were quantified on a scale from 1 = Yes, often to 4 = No, hardly ever/never, while support was quantified on a scale from 1 = Strongly agree to 4 = Strongly disagree. The composite scales were dichotomized according to the median of the distributions. Individuals with scores above or below the median were regarded to have high demands, low control and poor support at work, respectively (Fransson *et al.*, 2012).

Sleep disturbances

Disturbed sleep during the past 3 months was assessed with four questions from the Karolinska Sleep Questionnaire (difficulty falling asleep, repeated awakenings, early awakening, and disturbed sleep). The items covering symptoms of difficulties with initiating or maintaining sleep have been validated and found to have good psychometric properties (Hanson *et al.*, 2011; Kecklund and Akerstedt, 1992; Nordin *et al.*, 2013). The occurrence and frequency of problems were quantified on a scale from 1 = Never to 6 = Always, five times a week or more. Sleep was regarded as disturbed when at least one of the symptoms was experienced three-four times a week or more in line with some of the diagnostic criteria for insomnia (DSM-IV-R, 2000; Mallon *et al.*, 2014).

Depressive symptoms

Depressive symptoms were measured with a brief subscale from the Hopkins Symptom Checklist (SCL-90), the SCL-CD_6 (Magnusson Hanson *et al.*, 2014b), which assesses intensity of being troubled by: feeling blue; feeling no interest in things; feeling lethargy or low in energy; worrying too much about things; blaming yourself for things; and feeling everything is an effort over the past week; Cronbach's alpha 0.90. The intensity was quantified on a five-category scale from 0 = Not at all to 4 = Extremely. The six items represent core symptoms, identified as most important by experienced psychiatrists. The scale has been validated and was found to have good psychometric properties, and results have shown that the items are suitable to add into a composite

score (0–24) indicative of depression severity (Magnusson Hanson *et al.*, 2014b). A score of 17 or higher may be indicative of major depression (Magnusson Hanson *et al.*, 2014b).

Analytic strategy

We assess causal effect moderation/modification using an approach based on structural nested mean modelling (SNMM) estimated by means of a regression-with-residuals (RWR) approach with an inverse-probability-of-treatment weighting (IPTW) strategy (Almirall *et al.*, 2014). This method can be used in observational studies with both time-varying exposure and moderator variables, and is based on the counterfactual (potential outcome) framework (Almirall *et al.*, 2010, 2013). The method provides unbiased estimates of effect modification when time-varying confounders and putative moderator is affected by past exposure. These analyses were based on observations from all five waves of SLOSH. All in all, 1537 men and women had responded all five times and were in paid work (30% or more) at all time points. Some characteristics of these participants are presented in Table 1. The exposure variables, high demands, low decision authority and low social support were measured at wave 2 (distal exposure) and wave 4 (proximal exposure), while disturbed sleep from waves 1 and 3 were treated as the putative time-varying moderator. Furthermore, depressive symptoms measured wave 5 was used as the dependent variable to ensure an appropriate temporal order between moderator, exposure and outcome. The selected measures and hypothesized causal relationships between the measures are illustrated in Fig. 2.

An exploratory data analysis (EDA) was initially performed by means of box and whisker plots, which is a quick way of examining one or more sets of data graphically and is particularly useful for comparing distributions between several groups or sets of data. They display variation in samples of a statistical population without making any assumptions of the underlying statistical distribution (Rousseeuw *et al.*, 1999; Tukey, 1977). Separate models for high work demand, low support at work and low decision authority were then fitted using the IPTW-RWR approach in a two-stage procedure. In the first stage, we estimated IPTW weights via logistic regression models for the conditional probability of work characteristics at each time point given prior exposure to work characteristics, sleep disturbances and confounders. Different time-varying covariates were treated as putative effect modifiers to adjust for confounding. These included education (Compulsory, 2-year upper secondary/vocational training, 3- or 4-year upper secondary, University or equivalent <3 years, University or equivalent ≥ 3 years) and civil status (Married/co-habiting, Single) assessed in the questionnaires in waves 1 and 3, as well as income derived from register data for 2006 and 2010, respectively. Time-invariant covariates derived from register data such as sex and age were also included in these analyses. Weighting by the ratio of these conditional probabilities at each time point balances prior time-varying confounders but not moderators (Wodtke and Almirall, 2015). Then, sleep disturbances was residualized conditional on prior work characteristics and prior sleep disturbances using an IPT-weighted regression, before fitting the SNMM. The IPTW is that way used to balance observed confounders across different levels of exposure variables, while a linear weighted regression model is used for examining effect moderation (Almirall *et al.*, 2014; Wodtke and Almirall, 2015). Individuals with missing values at any time point were excluded from the analysis. Bootstrap standard errors were calculated for the IPTW-RR estimates. In supplementary analyses, prior depressive symptoms were additionally included to take into account potential influence of prior depressive symptoms on exposure and potential mediator. All analyses were conducted using STATA 13.

Table 1 Descriptive statistics according to demographic variables, working time, work schedule and health

Variables	*Mean/%*	*Minimum*	*Maximum*	*SD*
Age(years)*	46.1	20	67	8.2
Sex				
Male	44.2	–	–	–
Female	55.8	–	–	–
Education				
Compulsory or 2-year upper secondary	7.0	–	–	–
3–4-year upper secondary	44.7	–	–	–
University or equivalent	48.3	–	–	–
Income from work (1000SEK)*	299.1	0	12 494	346.3
Civil status*				
Married/co-habiting	78.4	–	–	–
Single	21.6	–	–	–
Living with children at home*				
Yes	39.2	–	–	–
No	60.8	–	–	–
Full- or part-time work				
Full-time	83	–	–	–
Part-time	16	–	–	–
Work schedule				
Daytime work	77	–	–	–
Evening work, shift work two-shift and other	18	–	–	–
Night work, shift work three-shift	4	–	–	–
Self-reported health				
Good	82	–	–	–
Neither good nor bad	14	–	–	–
Poor	4	–	–	–
Heart disease or diabetes	3.6	–	–	–

*Data from Wave 1. If missing in Wave 1, information was drawn from later time points. Age was then recalculated as age at Wave 1.

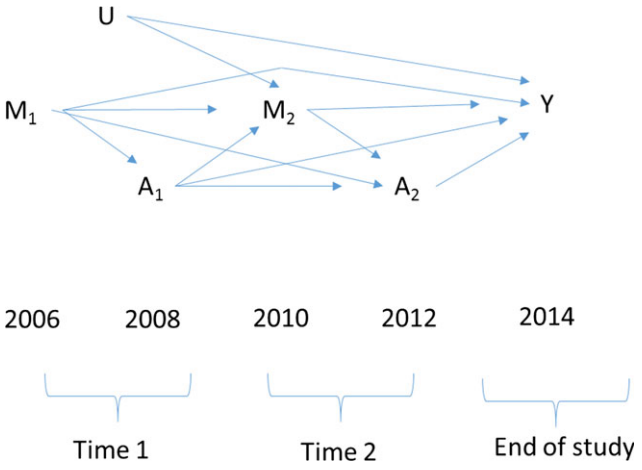

Figure 2. A directed acyclic graph representing the assumed dynamic process in which nodes represent variables, arrows represent assumed direct causal effects, and the absence of an arrow indicates no causal effect. Sleep disturbances (M_t) are allowed to affect work characteristics (high job demand, low control, low support; A_t) and work characteristics to affect future levels of sleep disturbances. Work characteristics at each time point are also allowed to have a direct effect on depressive symptoms in 2014 (Y), and work characteristics in 2008 an indirect effect through future sleep disturbances in 2010. Unobserved factors (U) are also permitted to directly affect sleep disturbances and the outcome but not exposure to work stressors.

RESULTS

Of the individuals that responded and were in paid work at all five waves, included in the analyses on effect modification, 16% were regarded to have disturbed sleep at wave 1 while this proportion increased to 22% at wave 3. About 3% experienced high symptoms of depression (17 or higher on the scale from 0 to 24) in wave 5. The number of individuals included in the analyses on work demands was 1301, while 1302 individuals were included in analyses on decision authority, and 1296 individuals in the analyses on low support at work.

The results of the EDA are shown in Figs 3–6. The box-whisker plots show the level of depressive symptoms in wave 5 according to work characteristics only conditional on the moderator from the earlier wave (Fig. 3) or additionally conditional on prior levels of exposure and moderator (Figs 4–6). The median and interquartile range (IQR) are used to construct the box. The box has a height equal to the IQR, starting at the lower quartile value and stopping at the upper quartile value. A horizontal bar is drawn at the height of the median. In Fig. 3, the box for high demands was higher than the box for low demands, indicating that high work demand (versus low work demand) in wave 2 was related to higher depressive symptom scores in wave 5, especially among participants with disturbed sleep in wave 1. The analyses in Fig. 4 also suggested higher depressive symptom scores for persons with high work demands in wave 4, especially if experiencing earlier disturbed sleep (in wave 3) and prior high demands or not (wave 2). No clear differences in depressive symptoms were observed for low decision authority versus high decision authority (Fig. 5). Low support in wave 2 (versus high support) was, however, also related to higher depressive symptoms especially among participants with prior disturbed sleep (wave 1; Fig. 3). Similar results were obtained from the EDA of low social support in wave 4 (Fig. 6), except when participants reported disturbed sleep in wave 3, low social support also wave 2 and disturbed sleep wave 1.

In Table 2, we present average causal effects (contrasts between potential outcomes in the counterfactual framework) of work characteristics and standard errors for the SNMM causal parameters at the two different time points: wave 2 (2008) and wave 4 (2012). The first set of estimates show the main effects of the work characteristics (a), while the second set of estimates give the moderated effects (b). The estimates of moderated effect in wave 2 are estimates of effect modification of the association between work characteristics wave 2 and depressive symptoms wave 5 by prior sleep disturbances in wave 1. The second set of moderated effects instead estimate effect modification of the association between work characteristics wave 4 and depressive symptoms wave 5 by prior sleep disturbances in wave 3. Sex, age, education, income and civil status were also considered in the models. Based on separate models for each work characteristic, we found that high demands and low social support at wave 2 and wave 4 were associated with depressive symptoms wave 5 ($\beta = 0.93$, $P < 0.05$ for demands wave 4; and $\beta = 1.29$, $P < 0.05$ for social support wave 4). This suggests a 0.93 increase in depressive symptom scores associated with job demands and 1.29 increase on the scale associated with low social support at that point to wave 4. Disturbed sleep wave 3 also appeared to modify the effect of high demands wave 4 ($\beta = 1.77$, $P < 0.05$). This suggested a 2.7 increase in depressive symptoms among people with sleep disturbances and subsequent experience of high job demands. There was also a tendency towards effect modification of the support-depressive symptom relationship ($\beta = 1.08$, $P = 0.15$).

An extension of the models considering also prior depressive symptoms also showed a slightly higher estimate of effect modification for demands wave 4, but the estimates were not statistically significantly increased in these analyses (*P*-value 0.15).

DISCUSSION

The results of this study indicate that disturbed sleep is an effect modifier of the relationship between high job demands and depressive symptoms. People with disturbed sleep and subsequent high demands at work were found to have higher end-of study depressive symptoms, whereas the effect of high demands at work was less pronounced among individuals with no prior disturbed sleep.

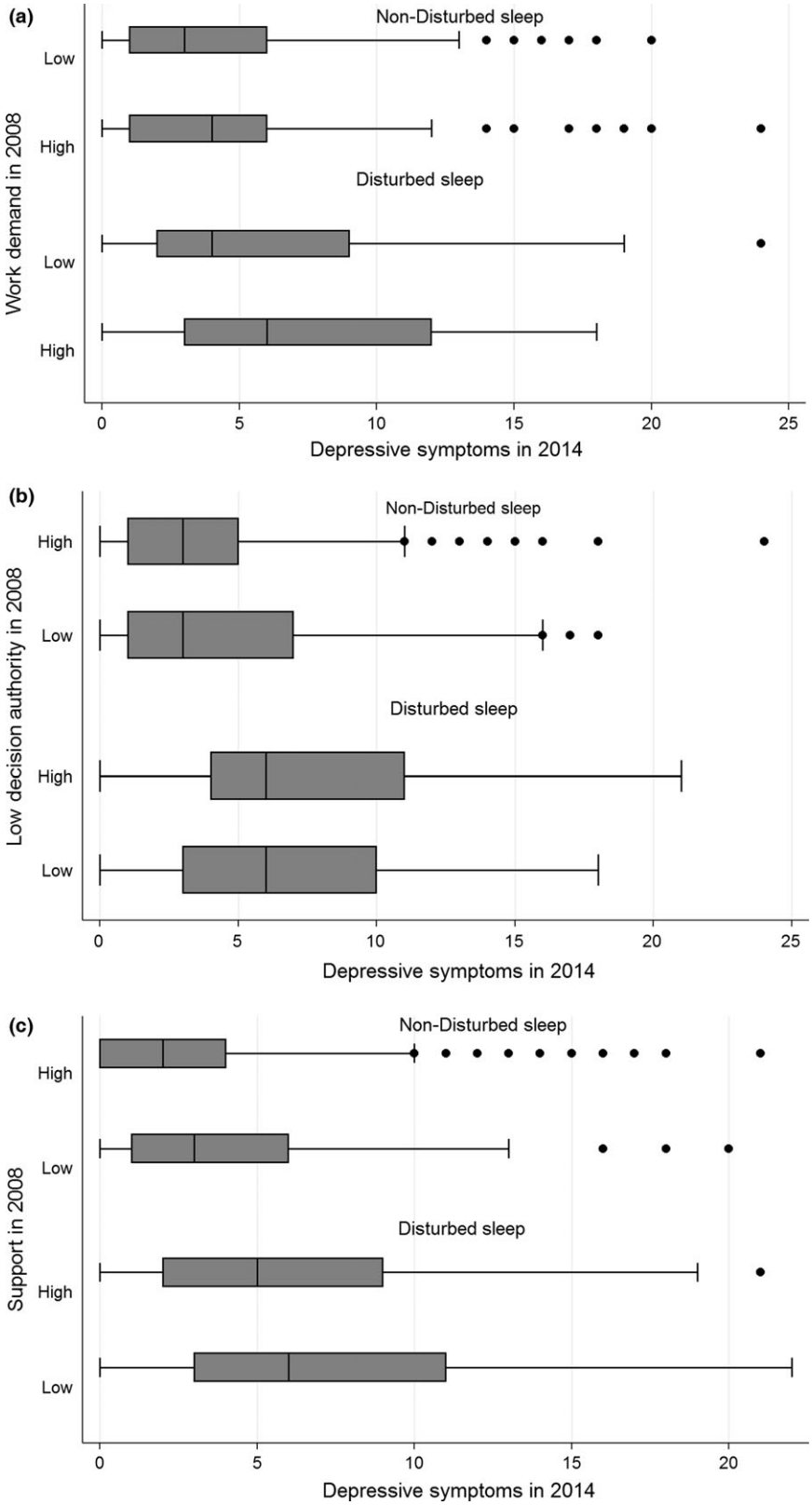

Figure 3. Box and whisker plots of depressive symptoms wave 5 (2014) by high work demands, low decision authority and low social support, respectively, wave 2 (2008) conditional on disturbed sleep wave 1 (2006). Blue vertical lines denote the median. A depressive symptoms level below 17 may be considered no to minor symptoms, while higher symptom levels may be considered major depressive symptoms.

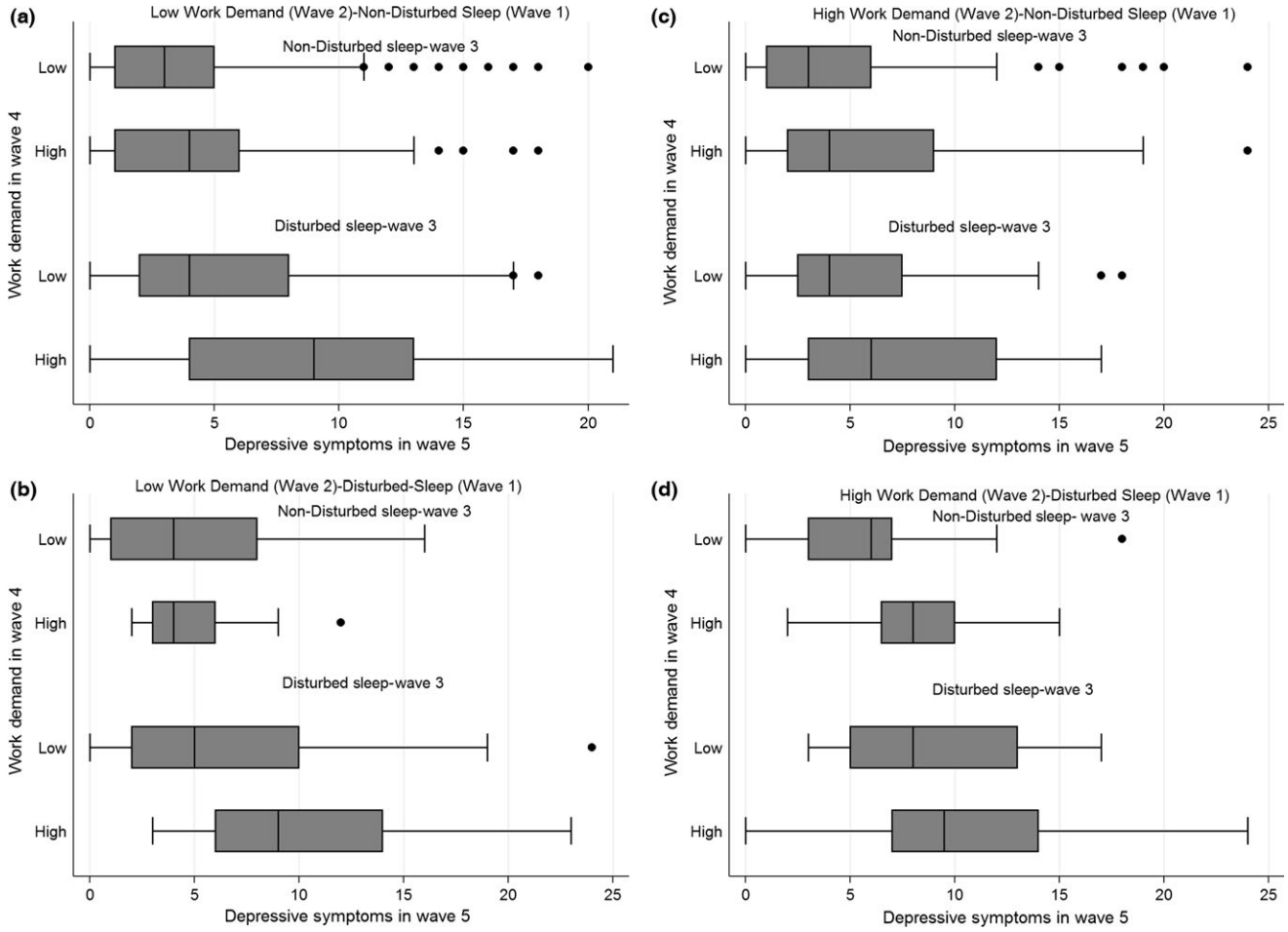

Figure 4. Box and whisker plots of depressive symptoms wave 5 (2014) by high work demands wave 4 (2012) conditional on disturbed sleep wave 1 (2006), high work demands wave 2 and disturbed sleep wave 3 (2010). Blue vertical lines denote the median. A depressive symptoms level below 17 may be considered no to minor symptoms, while higher symptom levels may be considered major depressive symptoms.

According to our knowledge, this is the first study to specifically investigate if sleep disturbances modify the effect of psychosocial working conditions on depression. One earlier paper has investigated job strain and sleep quality in relation to cortisol reactivity, and found indications of flattened diurnal cortisol reactivity as a result of high job strain in combination with lack of sleep (Rydstedt and Devereux, 2013), and such a dysregulated cortisol response may be related to depression (Burke *et al.*, 2005). To disentangle whether a third variable acts as moderator or mediator (intermediate in a causal pathway) is, however, useful in understanding causality and causal pathways. In an earlier paper, we found that sleep disturbances partly mediated the relationship between higher work demands and depressive symptoms (Magnusson Hanson *et al.*, 2014a). An interaction between work demands and sleep disturbances may have partly accounted for those findings. In this paper, we show that demands indeed appear to interact with sleep disturbances, but we specifically examine if sleep disturbances is an effect modifier. We can rule out that the findings are explained by a role as intermediate in the pathway from demands to depressive symptoms as we studied sleep disturbances prior to exposure to demands. Sleep disturbances may, however, act both as an intermediate variable in the relationship between work demands and depressive symptoms and as effect modifier. The latter suggest that an improvement of workplace demands in groups with sleep disturbances may have a more pronounced positive influence on depressive symptoms. However, intervening on sleep disturbances is also likely to have a positive effect.

The present study thus extends the previous literature with regard to the understanding of the interrelationship between sleep problems and work stress. The novel approach applied in this study, however, is likely to provide more well-founded conclusions than traditional interaction analyses for several reasons. The SNMM approach allows subgroup analysis when both predictors and putative moderators are time varying and when the candidate moderator may be impacted by prior exposure. In our analysis we also considered exposure variables in wave 2 and wave 4, and putative moderators in wave 1 and wave 3, respectively, as well as a

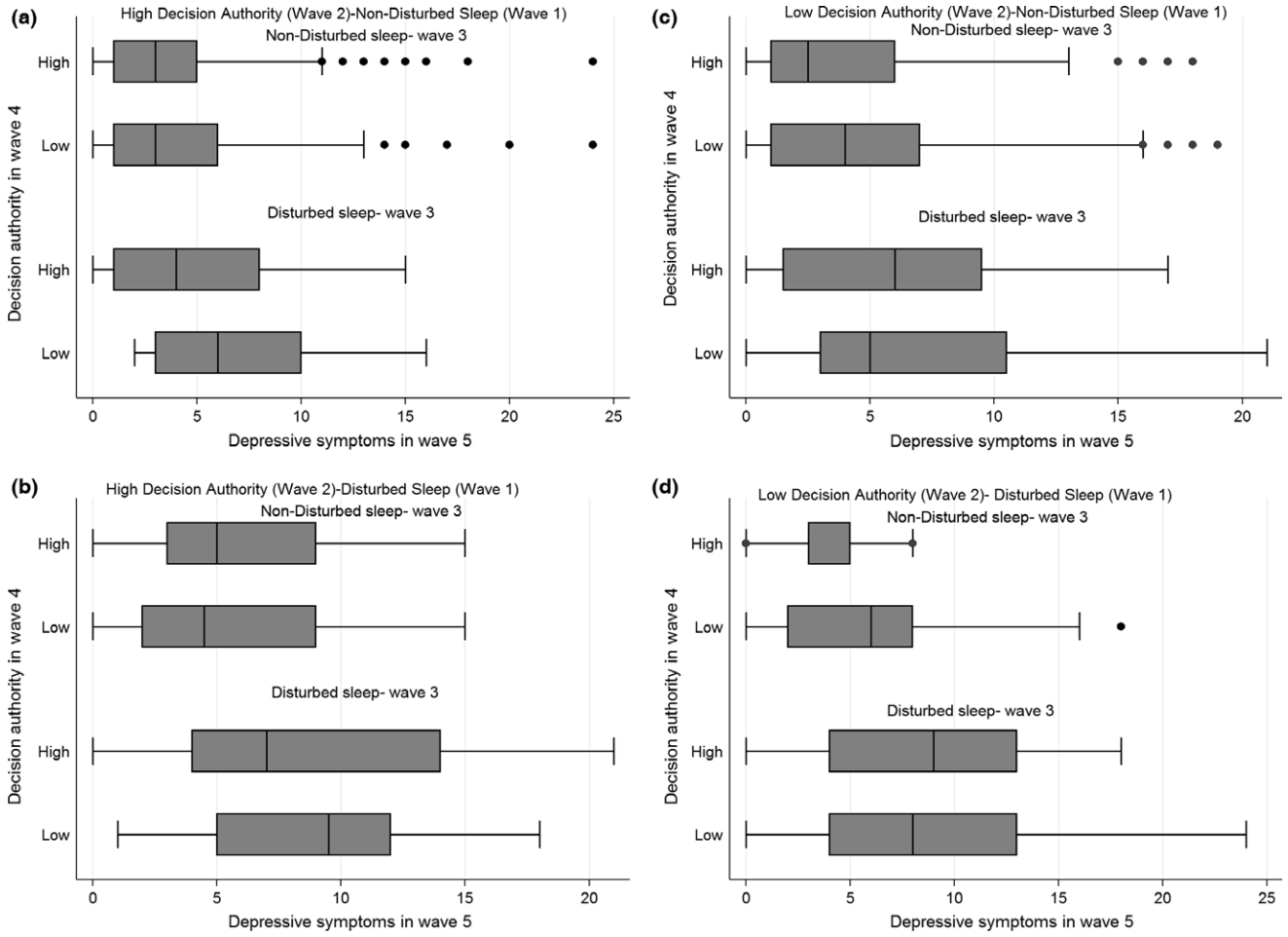

Figure 5. Box and whisker plots of depressive symptoms wave 5 (2014) by low decision authority wave 4 (2012) conditional on disturbed sleep wave 1 (2006), low decision authority wave 2 and disturbed sleep wave 3 (2010). Blue vertical lines denote the median. A depressive symptoms level below 17 may be considered no to minor symptoms, while higher symptom levels may be considered major depressive symptoms.

continuous outcome variable in wave 5, thus ensuring that the moderator precedes exposure variables, which in turn precede the outcome. Given that it has been shown that there is a bidirectional relationship between social support and sleep disturbances (Hanson *et al*., 2011) and possibly between demands and sleep disturbances (Akerstedt *et al*., 2015), this temporal order is key for casual inference about sleep disturbances as a moderator of the relationship between work characteristics and depressive symptoms rather than work characteristics as moderator of the relationship between sleep disturbances and depressive symptoms (Kraemer *et al*., 2008). This does, however, not rule out that demands may act as a mediator in the relationship between disturbed sleep and depressive symptoms.

Furthermore, we have been able to account for several covariates in our analyses, which is valuable in observational studies like this one. Controlling for the potential moderator or time-varying confounders in traditional regression analyses may result in underestimation of the moderated effect. This IPTW-RWR approach, however, overcomes several potential limitations of the conventional regression analysis as well as limitations of the SNMM-RR approach (Almirall *et al*., 2010), making it appropriate for analyses of data where the number of putative covariates used to control for time-varying confounding is much larger than that of the putative moderators (Almirall *et al*., 2014). The applications of SNMM are also still rare despite the many advantages with these types of models (Vansteelandt and Joffe, 2014). However, we cannot rule out that residual confounding from common causes of work stressors, sleep disturbances, and depressive symptoms may influence our results. We only found that sleep disturbances modified the effect of proximal high demands at work (when work characteristics were measured wave 4). However, these analyses are arguably of most interest as assessing more proximal effects and as accounting for both prior exposure and putative moderator. In some earlier studies, social support and demands were predictive of later sleep disturbances (Akerstedt *et al*., 2015; Hanson *et al*., 2011).

The study suggested a 2.7 increase in depressive symptoms among those with prior sleep disturbances and subsequent experience of high job demands. Whether such an

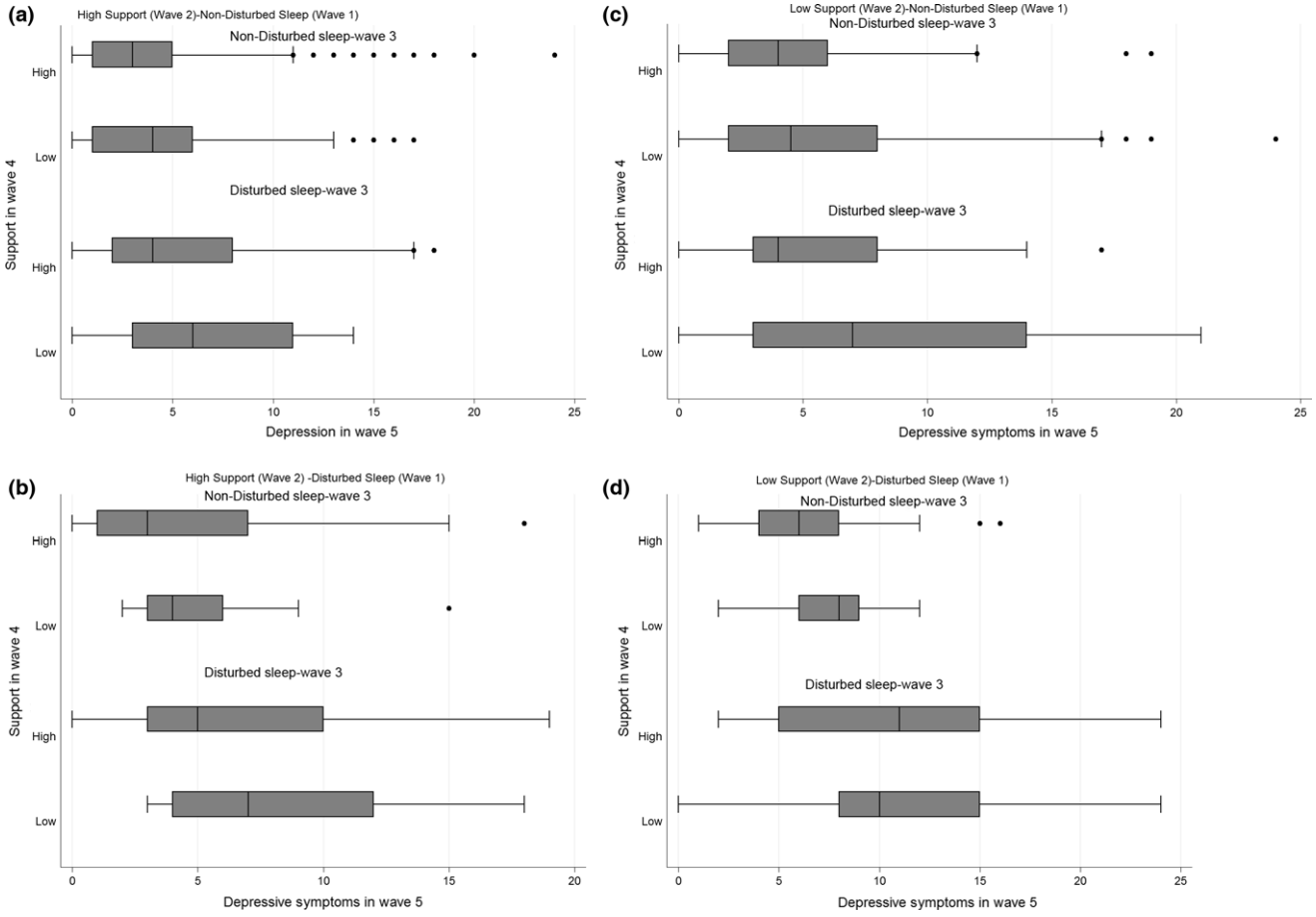

Figure 6. Box and whisker plots of depressive symptoms wave 5 (2014) by low social support wave 4 (2012) conditional on disturbed sleep wave 1 (2006), low social support wave 2 and disturbed sleep wave 3 (2010). Blue vertical lines denote the median. A depressive symptoms level below 17 may be considered no to minor symptoms, while higher symptom levels may be considered major depressive symptoms.

increase in symptoms has any negative impact depends on the baseline level of symptoms. While some people will remain on a low level with no or doubtful symptoms, some may even go from no or doubtful depression to moderate depression, or from moderate to major symptoms. If moderate or severe symptoms are developed, that may negatively affect functioning and the long-term course of symptoms. Even subthreshold symptoms may increase the risk of major depressive symptoms later in life (Fergusson *et al*., 2005).

However, our analyses also have some limitations. When assessing effect modification we explicitly measured putative moderators at waves preceding exposure variables to ensure an appropriate temporal ordering. However, a time lag of 2 years may be too long or short for appropriate assessment of the associations of interest and thus may reduce the strength of moderated effects. Further, in our analysis we focus solely on a single outcome at the end of the study, although it is possible that depressive symptoms may influence later experience of the work environment and be associated with sleep disturbance. Previous research has shown that wellbeing such as depressive symptoms may influence perception of job demands (Tang, 2014) as well as sleep patterns (Jansson-Frojmark and Lindblom, 2008). It has, however, been shown that sleep disturbances are much more likely to lead to depressive symptoms than the other way around (Magnusson Hanson *et al*., 2014a). Supplemental analyses taking into account earlier depressive symptoms also indicated effect modification, although those estimates were attenuated and not statistically significant. Furthermore, sleep disturbances may serve as a proxy for other associated third variables. Finally, the estimation method for effect modification we have used is a complete case estimator. Therefore, individuals with missing values at any time point are excluded from the analysis, limiting the generalizability of the results. Dropout over the course of the four waves may also limit generalizability to relatively resilient individuals with a strong attachment to the labour market. It is possible that sleep disturbances have a stronger influence in non-selected individuals.

Nonetheless, the present study suggests that sleep disturbances modify the relationship between high demands at work and depressive symptoms, i.e. that people with high demands are at higher risk of depressive symptoms when suffering from pre-existing sleep disturbances. People with sleep

Table 2 Estimates of causal effects from separate linear models for each of the work characteristics

	Distal effects wave 2 (2008)		*Proximal effects wave 4 (2012)*	
High demands	*Coefficient*	*SE*	*Coefficient*	*SE*
Intercept	4.03	0.96*		
High demands†	1.09	0.36*	0.93	0.36*
High demands × prior disturbed sleep‡	0.58	0.44	1.77	0.83*
Low decision authority				
Intercept	4.48	0.93*		
Low decision authority†	0.63	0.35	0.48	0.29
Low decision authority × prior disturbed sleep‡	−1.01	0.89	0.15	0.12
Low social support				
Intercept	2.93	0.93*		
Low social support†	1.09	0.26*	1.29	0.29*
Low social support × prior disturbed sleep‡	0.40	0.77	1.08	0.75

The table shows the main effects of the work characteristics from two time points wave 2 (distal effects) and wave 4 (proximal effects) on depressive symptoms wave 5 and the corresponding moderated effects by prior sleep disturbances (wave 1 or wave 3, respectively) represented by × between the exposure and putative moderator.
*$P < 0.05$.
†Main effects of work characteristics while taking into account civil status, education and income.
‡Moderated effects by prior sleep disturbances while taking into account civil status, education and income.

disturbances may thus be particularly sensitive to high demands at work and may be a target group for interventions. The results are in line with several theoretical models, such as the diathesis-stress model and allostatic load theory. However, further research is needed to clarify if sustained sleep problems increase stress reactivity (Meerlo *et al*., 2008).

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AUTHOR CONTRIBUTIONS

LMH conceived the study and drafted the manuscript; PP performed the analyses. All authors contributed to the design and interpretation of data, critical revision of the work, gave final approval of the version to be published, and agreed to be accountable for all aspects of the work.

CONFLICTS OF INTEREST

No author has reported a conflict of interest.

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