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Changes in effort-reward imbalance at work and risk of onset of sleep disturbances in a population-based cohort of workers in Denmark

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A B S T R A C T

Objective/background: Associations between exposure to effort-reward imbalance at work (eg, high time pressure/low appreciation) and risk of sleep disturbances have been reported, but the direction of the effect is unclear. The present study investigated changes in effort-reward imbalance and risk of concomitant and subsequent onset of sleep disturbances.
Methods: Participants with sleep disturbances at baseline were excluded. We included participants from a population-based cohort in Denmark (n = 8,464, 53.6% women, mean age = 46.6 years), with three repeated measurements (2012 (T_0); 2014 (T_1); 2016 (T_2)). Changes in effort-reward imbalance (T_0-T_1) were categorized into ‘increase’, ‘decrease’ and ‘no change’. Self-reported sleep disturbances (difficulties initiating or maintaining sleep, non-restorative sleep, daytime tiredness) were dichotomized (presence versus absence). We regressed concomitant (T_1) and subsequent (T_2) sleep disturbances on changes in effort-reward imbalance (T_0-T_1) and calculated odds ratios (OR) and 95% confidence intervals, adjusted for sex, age, education and cohabitation.
Results: At follow-up, 8.4% (T_1) and 12.5% (T_2) reported onset of sleep disturbances. Increased effort-reward imbalance was associated with concomitant sleep disturbances (T_1) (OR = 3.16, 2.56–3.81), whereas decreased effort-reward imbalance was not (OR = 1.22, 0.91–1.63). There was no association between increased effort-reward imbalance and subsequent sleep disturbances (T_2) (OR = 1.00, 0.74–1.37). Results were similar for men and women.
Conclusions: Increased effort-reward imbalance was associated with a three-fold higher risk of concomitant onset of sleep disturbances at two-year follow-up, but not subsequent onset of sleep disturbances at four-year follow-up, indicating that changes in effort-reward imbalance have immediate rather than delayed effects on sleep impairment. It is possible that the results from the two-year follow-up were to some extent affected by reverse causality.

1. Introduction

Sleep is vital for humans [1]. Good sleep (eg, sleep of sufficient duration or adequate quality) is associated with self-reported life satisfaction and well-being [2]. Poor sleep is associated with impaired cognitive function and low performance associated with

Abbreviations: DPQ, The Danish Psychosocial Work Environment Questionnaire; ERI, effort-reward imbalance; ICC, intraclass correlation coefficient; OR, odds ratio; RC, reliable change; RCI, reliable change index; SD, standard deviation; WEHD, Work Environment and Health in Denmark 2012–2020; 95% CI, 95% confidence interval.

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human errors, accidents, poor decision-making and adverse health-behavior, as well as adverse health outcomes, including cardiovascular, mental, immunologic and metabolic disorders, and mortality [1,3–5]. The population prevalence of sleep disturbances is high [6,7] with estimates for self-reported sleep disturbances ranging between 13 and 18% for men and 17–25% for women in the US adult population [8].

Adverse working conditions, such as exposure to psychosocial work stressors and shift work, are increasingly recognized as possible risk factors for sleep disturbances, and workers who suffer from sleep disturbances often attribute their sleep disturbances to factors in their work environment [1,6,9–11]. Thus, the workplace may potentially be considered a contributing arena for preventive interventions against sleep disturbances and the workplace may therefore be relevant from a public health perspective [12,13].

The model of effort-reward imbalance (ERI) is a widely utilized approach to measure adverse psychosocial working conditions in epidemiologic research [14]. The ERI-model posits that a mismatch between the perception of high efforts at work, eg, having time pressure and high work pace, and perception of low rewards (eg, lack of esteem and job promotion prospects) induces emotional distress that is potentially hazardous to health. Previously, it has been shown that ERI is associated with depressive disorders [15], cardiovascular disease [16–20] and diabetes [21–23] all of which have also received attention as possible sequelae and endpoints of sleep disturbances [1,24].

Several previous studies have investigated the prospective relation between ERI and self-reported sleep disturbances in Danish [25], French [26], and Norwegian [27] working populations, all linking ERI to a higher risk of sleep disturbances with rather consistent findings of a doubling of risk among men, but no association among women. However, the previous studies have been limited by the use of only two measurements, one measuring baseline exposure to ERI and one assessing onset of sleep disturbances at follow-up. This is a limitation because such an association does not allow to infer whether changing the exposure is associated with altered risk of sleep disturbances. Of the previous studies, only Johannessen and Sterud [27] investigated changes in ERI and risk of sleep disturbances. However, the study was limited to examining changes (increased and decreased) between baseline and four-year follow-up and concomitant onset of sleep disturbances, while adjusting for baseline occurrence of sleep disturbances. This approach complicates distinguishing cause and effect due to their simultaneous assessment, hence limiting conclusions about temporal relationships. Potential bias may further arise from not excluding participants with prevalent sleep disturbances at baseline from the analyses.

In the present study, we used two and three repeated measurements to investigate (i) the association between changes in ERI (T_0-T_1) and concomitant onset of sleep disturbances at two-year follow-up (T_1) in a population based sample of workers free of sleep disturbances at baseline (two-wave design), and (ii) whether changes in ERI between two years (T_0-T_1) is associated with subsequent onset of sleep disturbances two years after (T_2, three-wave design). We also investigated the separate dimensions of ERI (ie, efforts and rewards) on risk of sleep disturbances, because information about these dimensions may be relevant for designing interventions. As previous studies have found associations among men only [25–27], we also present analyses stratified by sex.

2. Methods

2.1. Study design and population

The study population was derived from the 'Work Environment and Health in Denmark 2012–2020' study (WEHD). Initiated in 2012, WEHD consists of a series of biennial surveys targeting the national work force in Denmark with the purpose of national surveillance of working conditions and health. Sampling criteria in 2012 were (i) 18–64 years of age with records of an address in Denmark and (ii) monthly working hours ≥35 and a monthly income of ≥3000 Danish kroner ($530/€400) subject to taxation. The response rate in WEHD was approximately 50% across waves 2012–2016. Compared to respondents with two or three measurements, non-respondents and respondents who only contributed with one measurement were more often men, younger, had lower educational level, had migration background, and lived alone as previously described [28].

We conducted analyses on data from the cohort of WEHD that consists of all respondents in 2012 (T_0) who were re-invited and contributed with repeated measurements to wave 2014 (T_1, n = 10,320) and 2016 (T_2, n = 6878). Fig. 1 shows a flowchart of the final analytical samples and an overview of the study designs. In the two-wave design, we excluded participants with missing data on relevant questions regarding sleep disturbances (n = 117), with prevalent sleep disturbances at T_0 (n = 1125) and with missing data on ERI (n = 558) and covariates (n = 56). Thus, the final analytical sample in the two-wave design consisted of participants without sleep disturbances at T_0 and who had complete data (n = 8464). For the three-wave design, we repeated the exclusion process from the two-wave design while also excluding participants with prevalent sleep disturbances at T_1, yielding a sample of participants without sleep disturbances at T_0 and T_1 who had complete data (n = 5,056, Fig. 1).

Participants who were excluded due to prevalent sleep disturbances had higher ERI, and they were more often women, of lower education and not cohabiting (Table A.1, Appendix A). There were no large differences between participants who provided data for the two-wave design and three-wave design (Table A.1, Appendix A). Among respondents at T_0 who were invited again at T_1, sleep disturbances at T_0 were associated with a slightly lower likelihood of responding at follow-up at T_1 (odds ratio (OR): 0.89, 95% confidence interval (CI): 0.80–0.99, adjusted for baseline values of sex, age, educational level and cohabitation).

The study was approved by The Danish Data Protection Agency through the joint notification of the National Research Centre for the Working Environment, Copenhagen, Denmark (no. 2015-57-0074). According to Danish legislation, research projects involving surveys with questionnaire and register-based data only, do not need approval from The National Committee on Health Research Ethics. We obtained register-based information from Statistics Denmark (no. 706706) and Sundhedsdatastyrelsen ('The Danish Health Authority', no. FSEID-00003251 and no. FSEID-00003281).

2.2. Operationalization of effort-reward imbalance and reliable change index

We measured self-reported efforts and rewards with proxy measures covering ERI [29] as previously described in detail [23]. Briefly, the efforts scale (6 items) assessed time pressure, work pace and work time. The rewards scale (5 items) assessed esteem, financial and career-related rewards and job security. We computed sum scale scores of perceived efforts (range = 6–30) and rewards (range = 5–25), respectively, for participants with answers to more than half of the questions to each dimension and imputed missing items with the scale mean, so that higher values denote higher exposures, ie. higher efforts (mean = 18.6, SD = 3.85, Cronbach's alpha = 0.78) and higher rewards (mean = 18.1, SD = 3.32, Cronbach's alpha = 0.66). In accordance with the theoretical concept of ERI [14], we divided efforts by rewards

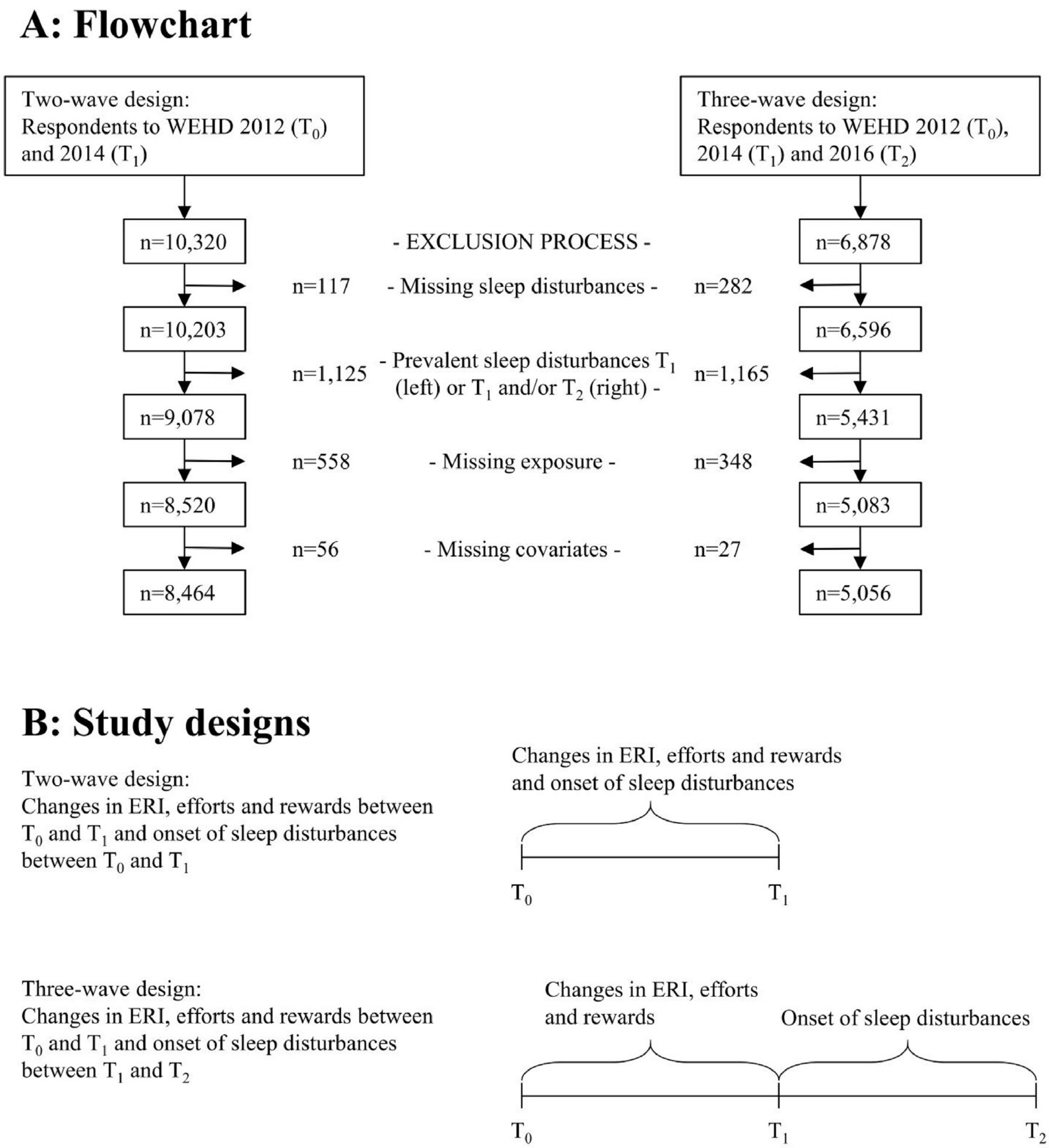

Fig. 1. Flowchart (A) and study designs (B). ERI = effort-reward imbalance; WEHD=Work Environment and Health in Denmark.

multiplied by a correction factor of 0.83 so that an ERI-ratio of 1.0 denotes balance between efforts and rewards at work (mean ERI-ratio = 0.89, SD = 0.29).

We followed the recommendations for defining statistically reliable change proposed by Jacobson & Truax [30,31]. We calculated reliable change (RC) in the exposures between T_0 and T_1 by taking into account day-to-day fluctuations (defined as test-retest reliability) and observed variance (defined as standard deviation) of the exposures. Reliable changes in ERI, efforts, and rewards were calculated as changes exceeding the 95% confidence interval under the assumption of no change, which has the interpretation, that 95% of the time, participants would experience a real change in the exposures.

Calculation of reliable change requires data on the reliability of the measure. As short-term test-retest data were unavailable in WEHD, we obtained data from the short-term test-retest of The Danish Psychosocial Work Environment Questionnaire (DPQ), a newly developed and validated questionnaire for assessing psychosocial work factors [32]. DPQ contains data from short-term test-retest (mean follow-up = 18.3 days) of similar worded items on efforts and rewards as those in WEHD, from a stratified sample representing the Danish labor market in terms of educational level and job tasks (n = 514 participants). Based on items from DPQ we constructed ERI, efforts and rewards as described in the present study. The reliability of each measure was high, with intraclass correlation coefficients (ICCs) of 0.83, 0.83 and 0.84, for ERI, efforts, and rewards, respectively.

Using the ICCs from the DPQ, we calculated a reliable change index (RCI) and categorized change into ‘increased’ exposure ($RC \geq 1.96$), ‘decreased’ exposure ($RC \leq -1.96$) and ‘no change’ in exposure ($-1.96 < RC < 1.96$), denoting the interpretation that the changes are greater than the minimal detectable change. Examples of calculations of RCI for a hypothetical participant is presented in Table B.1, Appendix B.

2.3. Sleep disturbances

Sleep disturbances were self-reported and consisted of a scale measuring difficulties initiating or maintaining sleep, non-restorative sleep, and daytime tiredness. Sleep disturbances were measured with a scale consisting of three items: "How often … (i) have you woken up several times and have had difficulties falling asleep again within the last 4 weeks? (ii) have you felt not well-rested upon awakening within the last 4 weeks? iii) have you felt tired during the day within the last 4 weeks?" All items were scored 1−5 ('Always; Often; Sometimes; Seldom; Never'). We included participants with answers to at least two of the three items and imputed missing items with the scale mean. We reversed the scale so that higher scores denote more sleep disturbances (range = 3−15). We dichotomized the sleep scale by an a priori defined cut-off of ≥12 (yes/no), that is, before analyses commenced. The decision to use a cut-off of 12 was chosen after a discussion about the interpretation of the items. Scoring ≥12 on the sleep disturbance scale reflects that at least two of the three sleep disturbances have been present often or always, in the last four weeks. Cases of sleep disturbances may for instance have answered (i) 'Always' to all three questions, (ii) the combination of 'Always', 'Often' and 'Sometimes' to the three questions, or (iii) the combination of 'Always' to two items and 'Seldom' to a third. Because this cut-off has not been validated previously, we assessed its performance in terms of predicting self-rated health. In a sample of participants with repeated measurements to T_0 and T_1, who at T_0 had self-rated good health only (n = 5196), sleep disturbances at baseline (yes versus no) predicted poor health at 2-year follow-up with an OR of 2.00 (95% CI: 1.55−2.58), adjusted for sex, age, education and cohabitation. Thus, the measure of sleep disturbances showed good predictive validity. The internal consistency reliability of the sleep disturbance scale was satisfactory (Cronbach's alpha = 0.76).

2.4. Covariates

As covariates we included sex, age (continuous in analyses, categorical in Table 1), educational level and cohabitation obtained from linking the participants to national administrative data by their unique personal identification number [33]. As a measure of socioeconomic status we included educational level with three categories (High, ≥13 years; Intermediate, 10−12 years; Low, ≤9 years). Cohabitation was defined as either living alone or not. All covariates have previously been associated with both ERI and sleep disturbances and were therefore considered potential confounders [25−27].

2.5. Statistical analyses

We performed logistic regression and calculated ORs and 95% CIs for estimating the association between changes (increase or decrease versus no change) in ERI and its components (efforts and rewards) between T_0 and T_1, and (i) risk of concomitant onset of sleep disturbances between T_0 and T_1 (two-wave design), and (ii) risk of subsequent onset of sleep disturbances between T_1 and T_2 (three-wave design) (Fig. 1). The analyses were adjusted for time of follow-up between measurements to take into account that participants were not under observation for the same amount of time (model 1), sex and age (model 2) and further adjusted for educational level and cohabitation (model 3). We stratified the analyses of both the two- and three-wave design by sex to investigate potential differential effects, because previous studies have reported an association between ERI and sleep disturbances among men only [25−27].

All analyses were carried out in the statistical software R version 3.6.1.

3. Results

3.1. Characteristics of the study population

Table 1 shows characteristics of the study population. Mean age was 46.6 years and 53.6% were women. Men had higher ERI-scores (mean = 0.91) than women (mean = 0.88). Mean ERI-scores were also higher among higher educational levels and among those living alone. More participants below 40 years of age had a change in ERI (both increase and decrease) between T_0 and T_1 compared to older age groups. Experiencing changes in ERI between T_0 and T_1 were more common with lower educational level and among those living alone. There were no obvious sex differences regarding changes in ERI between T_0 and T_1.

3.2. Changes in ERI, and efforts and rewards, and risk of concomitant onset of sleep disturbances (two-wave design)

Between baseline and follow-up, 8.4% of participants developed sleep disturbances. Increase in ERI between baseline and follow-up was associated with a higher risk of concomitant onset of sleep disturbances between baseline and follow-up with a fully-adjusted OR of 3.12 (95% CI: 2.56−3.81, Table 2). The separate effect of an increase in efforts and a decrease in rewards were OR = 1.97 (95% CI: 1.56−2.49) and OR = 2.03 (95% CI: 1.67−2.47), respectively. The OR for decrease in ERI and risk of sleep disturbances was 1.22 (95% CI: 0.91−1.63). No statistically significant effects were observed for a decrease in efforts or an increase in rewards (Table 2). We found no clear signs of effect modification by sex in stratified analyses (Table C1, Appendix C).

3.3. Changes in ERI, and efforts and rewards, and risk of subsequent onset of sleep disturbances (three-wave design)

At follow-up, 631 participants (12.5%) reported onset of sleep disturbances. Table 3 shows the associations between changes in ERI over a two-year period and risk of onset of sleep disturbances two years later. The fully-adjusted association between increase in ERI and risk of onset of sleep disturbances yielded an OR of 1.00 (95% CI: 0.74−1.37). The OR for decreased ERI and subsequent risk of onset of sleep disturbances was 1.03 (95% CI: 0.76−1.40). Correspondingly, no subsequent risk of onset of sleep disturbances was observed when we evaluated increased or decreased efforts and rewards, separately (Table 3). Associations were similar for men and women in stratified analyses (Table D.1, Appendix D).

4. Discussion

In this population-based cohort of workers in Denmark, we investigated changes in ERI over a two-year period on risk of both concomitant and subsequent onset sleep disturbances. Increased ERI was associated with a three-fold higher risk of concomitant onset of sleep disturbances. Similarly, increased efforts and decreased rewards were relatively strong predictors of sleep disturbances.

When applying a design using three repeated measurements, we found no evidence for an effect of changes in effort-reward imbalance over a two-year period and risk of subsequent onset of sleep disturbances two years later.

Table 1
Characteristics of the study population.

	n or (mean)	% or (SD)	ERI-ratio at T_0		Changes in ERI between T_0 and T_1 n (%) or (mean (SD))		
			Mean	(SD)	No change	Increase	Decrease
Total	8464	100	0.89	(0.29)	7018 (82.9)	789 (9.3)	657 (7.8)
Sex							
Women	4535	53.6	0.88	(0.28)	3756 (82.8)	435 (9.6)	344 (7.6)
Men	3929	46.4	0.91	(0.29)	3262 (83.0)	354 (9.0)	313 (8.0)
Age (years)	(46.6)	(10.3)					
18-39	2159	25.5	0.90	(0.27)	1733 (80.3)	234 (10.8)	192 (8.9)
40-49	2701	31.9	0.90	(0.29)	2239 (82.9)	253 (9.4)	209 (7.7)
≥50	3604	42.6	0.88	(0.29)	3046 (84.5)	302 (8.4)	256 (7.1)
Educational level							
High	3874	45.8	0.90	(0.27)	3271 (84.4)	327 (8.4)	276 (7.1)
Intermediate	3626	42.8	0.88	(0.29)	2981 (82.2)	350 (9.7)	295 (8.1)
Low	924	11.4	0.87	(0.32)	766 (82.9)	112 (12.1)	86 (9.3)
Cohabitation							
Yes	6754	79.8	0.89	(0.28)	5657 (83.8)	602 (8.9)	495 (7.3)
No	1710	20.2	0.91	(0.31)	1361 (79.6)	187 (10.9)	162 (9.5)
ERI-ratio at T_0					(0.85 (0.24))	(0.85 (0.26))	(1.30 (0.36))
ERI-ratio at T_1					(0.86 (0.24))	(1.40 (0.42))	(0.81 (0.27))

Table 2
Association between changes in effort-reward imbalance (ERI), and efforts and rewards between T_0 and T_1 and risk of concomitant onset of sleep disturbances between T_0 and T_1 (two-wave design).

Changes between T_0 and T_1	Exposed, n	Cases, n (%)	Onset of sleep disturbances between T_0 and T_1					
			Model 1		Model 2		Model 3	
			OR	(95% CI)	OR	(95% CI)	OR	(95% CI)
ERI								
No change	7018	501 (7.1)	1	(ref)	1	(ref)	1	(ref)
Increase	789	156 (19.8)	3.20	(2.63–3.90)	3.15	(2.59–3.85)	3.12	(2.56–3.81)
Decrease	657	57 (8.7)	1.24	(0.93–1.65)	1.24	(0.93–1.65)	1.22	(0.91–1.63)
Efforts								
No change	7251	578 (8.0)	1	(ref)	1	(ref)	1	(ref)
Increase	640	96 (15.0)	2.05	(1.62–2.58)	1.99	(1.57–2.51)	1.97	(1.56–2.49)
Decrease	573	40 (7.0)	0.87	(0.62–1.21)	0.86	(0.61–1.19)	0.84	(0.60–1.17)
Rewards								
No change	6493	489 (7.5)	1	(ref)	1	(ref)	1	(ref)
Increase	923	71 (7.7)	1.03	(0.79–1.33)	1.01	(0.78–1.31)	1.00	(0.77–1.29)
Decrease	1048	154 (14.7)	2.12	(1.74–2.57)	2.06	(1.69–2.50)	2.03	(1.67–2.47)

Model 1: Adjusted for time of follow-up.
Model 2: Adjusted for time of follow-up + sex + age.
Model 3: Adjusted for time of follow-up + sex + age + educational level + cohabitation.

Table 3
Association between changes in effort-reward imbalance (ERI), and efforts and rewards between T_0 and T_1 and risk of subsequent onset of sleep disturbances between T_1 and T_2 (three-wave design).

Changes between T_0 and T_1	Exposed, n	Cases, n (%)	Onset of sleep disturbances between T_1 and T_2					
			Model 1		Model 2		Model 3	
			OR	(95% CI)	OR	(95% CI)	OR	(95% CI)
ERI								
No change	4229	529 (12.5)	1	(ref)	1	(ref)	1	(ref)
Increase	414	51 (12.3)	0.98	(0.72–1.34)	1.00	(0.74–1.36)	1.00	(0.74–1.37)
Decrease	413	51 (12.3)	1.00	(0.74–1.36)	1.03	(0.76–1.41)	1.03	(0.76–1.40)
Efforts								
No change	4384	558 (12.7)	1	(ref)	1	(ref)	1	(ref)
Increase	332	39 (11.7)	0.91	(0.64–1.29)	0.94	(0.66–1.33)	0.94	(0.66–1.33)
Decrease	340	34 (10.0)	0.78	(0.54–1.12)	0.80	(0.55–1.16)	0.80	(0.55–1.15)
Rewards								
No change	3938	496 (12.6)	1	(ref)	1	(ref)	1	(ref)
Increase	563	70 (12.4)	0.99	(0.76–1.29)	0.94	(0.66–1.33)	1.00	(0.76–1.31)
Decrease	555	65 (11.7)	0.93	(0.70–1.22)	0.80	(0.55–1.16)	0.92	(0.70–1.22)

Model 1: Adjusted for time of follow-up.
Model 2: Adjusted for time of follow-up + sex + age.
Model 3: Adjusted for time of follow-up + sex + age + educational level + cohabitation.

4.1. Comparison with previous research

Our assessment of changes in ERI was novel, as we are not aware of any previous study investigating changes in ERI that took into account the day-to-day variability in measurement for assessing reliable changes. This is important to limit the potential for bias from non-differential misclassification of changes that may otherwise occur when studying changes in exposures over time.

Recently, Johannessen & Sterud [27], examined changes in ERI over the course of four years and concomitant risk of sleep disturbances, while adjusting for baseline presence of sleep disturbances. Increased and decreased ERI were associated with higher and lower risk of sleep disturbances, respectively, in men only [27]. However, not excluding participants with sleep disturbances at baseline may be problematic, in that sleep disturbances are known to reduce performance and cognition and may affect the experience of efforts and rewards at work. This explanation may be plausible since a reciprocal relationship between ERI and sleep disturbances was reported in the study by Johannessen and Sterud [27], where sleep disturbances at baseline predicted ERI at follow-up. Further, by not taking into account the reliability of the measure of change, it complicates translating the findings into intervention initiatives as participants may accidently have been categorized as having changes, when no changes may in fact have taken place [31].

In the present study, increased ERI predicted risk of sleep disturbances in both men and women, who were free of sleep disturbances at baseline. In contrast to Johannessen and Sterud [27], we did not find that decreased ERI was associated with sleep disturbances at follow-up. One explanation may be that decreased ERI is perceived differently than increased ERI in populations with and without sleep disturbances when changes are taking place.

4.2. Interpretation

The present study corroborates previous findings of a prospective association between ERI and sleep disturbances, but unlike previous studies [25–27], we found this association in both men and women.

The analyses on changes in ERI between baseline and follow-up and concomitant onset of sleep disturbances were limited with regards to separating cause and effect because both changes in ERI and onset of sleep disturbances were measured simultaneously. Therefore, in order to separate cause and effect, we also used three repeated measurements for examining changes in ERI over a two year period on risk of subsequent onset of sleep disturbances two years later in a population sample initially free of sleep disturbances. Changes in ERI were associated with a three-fold higher risk of concomitant onset of sleep disturbances in the two-wave design but were not associated with onset of sleep disturbances two years later in the three-wave design. At least two explanations for this result are conceivable. First, increase in ERI may have an immediate but not a delayed effect on sleep disturbances [34]. Thus, after experiencing an increase in ERI, individuals are at heightened risk of developing sleep disturbances (two wave design), but if they manage to remain free of sleep disturbances, then they have no further increased risk of developing sleep disturbances in the long-term (ie, two years later, three wave design). Second, there may have been, at least partly, reverse causality in the two-wave design (ie, not changes in ERI had caused onset of sleep disturbances, but onset of sleep disturbances had caused changes in ERI).

The population under study was for analytical reasons restricted to participants without sleep disturbances at T_0 (two-wave design) and both T_0 and T_1 (three-wave design), respectively. On the one hand side we consider this a strength of the study, as excluding prevalent cases is crucial in incidence studies. On the other hand these selection processes may be problematic in terms of generalizability of our results to a general working population, where sleep disturbances are common [6,7]. Furthermore, by excluding prevalent cases, we could not analyze whether ERI may contribute to the prolongation of sleep disturbances. We acknowledge that this is an important issue that should be investigated in future studies.

4.3. Strengths and limitations

The main strength of our study is the use of a population-based cohort with up to three repeated measurements and the operationalization of changes in the exposures in a population without sleep disturbances when the change took place. To distinguish meaningful change from random change we took into account the day-to-day variability in our measures of changes in ERI and its components, and limited potential bias from non-differential misclassification of changes that may otherwise have biased the results towards null.

It may be considered a limitation that we used self-reported measures of sleep disturbances in the present study. Self-reported sleep disturbances have shown poor correlation with actigraphy-measures of sleep disturbances in some studies [35]. However, correlations between self-reported sleep disturbances with polysomnography measures of physiological sleep, which is considered as the gold standard for measuring sleep objectively, were satisfying in other studies [36]. Although our measure of sleep disturbances showed good predictive validity, it nevertheless remains a challenge in large-scale epidemiologic studies to cost-effectively assess sleep disturbances.

It was a limitation that data were collected in two-year intervals, because this precludes information on processes that have taken place between measurements. This may be of greatest threat to the two-wave design, because it hinders conclusions about causal relationships, as it is unknown whether changes in ERI occurred before or after onset of sleep disturbances. Attempts were performed to separate cause and effect in the three-wave design, but this design was based on the debatable assumption that there were no immediate effects of ERI on sleep. A further limitation is, that when studying changes in terms of increased or decreased exposure versus no change, the reference group with no change may include participants who, for example, score repeatedly low, high or somewhere in-between, between the two measurements, which limits inferences about the severity of exposure in the reference group.

We do not know the reason for changes in ERI, which may be considered a limitation. It may be speculated, that if participants experience adverse working conditions it is possible that they may be more likely to change job, which may result in misclassification of changes in ERI and potential dilution of the results.

Furthermore, the findings may be prone to residual confounding by unmeasured factors that may affect both ERI and risk of sleep disturbances (eg, organizational changes, life crises and chronic diseases) information which was unavailable in the present study. Lastly, bias arising from selection processes may be a concern. At baseline, participants with sleep disturbances had approximately a 10% lower likelihood of responding at first follow-up, but whether this has affected the association estimates is unknown.

5. Conclusion

In conclusion, increased effort-reward imbalance was associated with a three-fold higher risk of concomitant onset of sleep disturbances at two-year follow-up, but not subsequent onset of sleep disturbances at four-year follow-up, indicating that changes in effort-reward imbalance have immediate rather than delayed effects on sleep impairment. Our findings suggest that preventive actions of changing adverse working conditions in which efforts exceeds rewards may be beneficial for altering risk of sleep disturbances. It is possible, though, that the results from the two-year follow-up were to some extent affected by reverse causality. Future research is encouraged to further examine the temporal order between effort-reward imbalance and sleep disturbances by the use of several repeated measurements with shorter intervals than in the present study.

CRediT authorship contribution statement

Mads Nordentoft: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Data curation, Writing - original draft, Writing - review & editing, Visualization, Project administration. **Naja H. Rod:** Conceptualization, Methodology, Investigation, Writing - review & editing, Supervision, Project administration, Funding acquisition. **Jens Peter Bonde:** Conceptualization, Methodology, Investigation, Writing - review & editing, Supervision, Project administration, Funding acquisition. **Jakob B. Bjorner:** Conceptualization, Methodology, Investigation, Writing - review & editing, Funding acquisition. **Bryan Cleal:** Conceptualization, Methodology, Investigation, Writing - review & editing. **Ida E.H. Madsen:** Conceptualization, Methodology, Investigation, Writing - review & editing. **Linda L. Magnusson Hanson:** Conceptualization, Methodology, Investigation, Writing - review & editing. **Mette A. Nexo:** Conceptualization, Methodology, Investigation, Writing - review & editing. **Tom Sterud:** Conceptualization, Methodology, Investigation, Writing - review & editing. **Reiner Rugulies:** Conceptualization, Methodology, Investigation, Resources, Data curation, Writing - review & editing, Supervision, Project administration, Funding acquisition.

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Conflict of interest

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The ICMJE Uniform Disclosure 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.sleepx.2020.100021.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.sleepx.2020.100021.

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