doi: 10.1111/j.1365-2869.2009.00735.x

A hard day's night: a longitudinal study on the relationships among job demands and job control, sleep quality and fatigue

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Accepted in revised form 2 December 2008; received 30 May 2008

SUMMARY This prospective four-wave study examined (i) the causal direction of the longitudinal relations among job demands, job control, sleep quality and fatigue; and (ii) the effects of stability and change in demand–control history on the development of sleep quality and fatigue. Based on results of a four-wave complete panel study among 1163 Dutch employees, we found significant effects of job demands and job control on sleep quality and fatigue across a 1-year time lag, supporting the strain hypothesis (Demand–Control model; Karasek and Theorell, Basic Books, New York, 1990). No reversed or reciprocal causal patterns were detected. Furthermore, our results revealed that cumulative exposure to a high-strain work environment (characterized by high job demands and low job control) was associated with elevated levels of sleep-related complaints. Cumulative exposure to a low-strain work environment (i.e. low job demands and high job control) was associated with the highest sleep quality and lowest level of fatigue. Our results revealed further that changes in exposure history were related to changes in reported sleep quality and fatigue across time. As expected, a transition from a non-high-strain towards a high-strain job was associated with a significant increase in sleep-related complaints; conversely, a transition towards a non-high-strain job was not related to an improvement in sleep-related problems.

KEYWORDS demand–control history, fatigue, longitudinal research, psychosocial work characteristics, sleep quality

INTRODUCTION

Over the last decades it has been well established that high work demands and low job control constitute risk factors for ill health (e.g. Belkiç *et al*., 2004; De Lange *et al*., 2003; Karasek and Theorell, 1990). However, additional studies are needed into the mechanisms that may explain how combinations of such stressful work characteristics in the long term may cause ill health (Härmä *et al*., 2006). This article concentrates on one such mechanism, i.e. the psychophysiological effort–recovery mechanism based on effort–recovery theory (Geurts and Sonnentag, 2006; Meijman and Mulder, 1998) and allostatic load theory (Clow, 2001; McEwen, 1998; Sterling and Eyer, 1990). The core assumption of effort–recovery theory is that normal load reactions that are associated unavoidably with effort expenditure at work (such as accelerated heart rate and fatigue) can develop into more chronic load reactions in case of continued exposure to workload and incomplete recovery. Recovery is a process of psychophysiological unwinding that is the opposite of the activation of the sympathetic–adrenal–medullary system and the hypothalamic–pituitary–adrenal system during effort expenditure, particularly under stressful conditions (Geurts and Sonnentag, 2006). The central tenet of allostatic load

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theory is that disturbances in the homeostatic balance between sympathetic and parasympathetic activity can occur in situations of repeated or prolonged exposure to stressors. The psychophysiological effort–recovery mechanism thus holds that, in the case of prolonged or repeated (daily) exposure to stressful work characteristics and of insufficient recovery, a cumulative process may develop in which initial potentially reversible psychophysiological reactions in the long term transfer into subsequent ill-health, such as depression and burnout (Stansfeld and Candy, 2006), cardiovascular diseases (Belkiç *et al*., 2004; Kivimaki *et al*., 2006) and musculoskeletal diseases (Bongers *et al*., 1993).

The present study builds on this effort–recovery hypothesis. Specifically, we focus upon the role of sleep quality and fatigue as key factors in recovery from high work demands and low work control. Sleep is the recovery activity par excellence. Poor sleep quality is mainly a matter of sleep (dis)continuity. According to a recent report of an American Academy of Sleep Medicine Work Group (Edinger *et al*., 2004, p. 1580), research diagnostic criteria (RDC) for insomnia disorder include one or more of the following sleep-related complaints: (i) difficulty initiating sleep; (ii) difficulty maintaining sleep; (iii) waking up too early; and (iv) sleep that is chronically non-restorative or poor in quality. Poor sleep is associated with accidents, long-term ill-health and mortality (Åkerstedt, 2006).

There have been few studies on the effects of everyday work stress on sleep quality and related fatigue (Åkerstedt, 2006; Åkerstedt *et al*., 2002; Kalimo *et al*., 2000). Accordingly and contrary to the commonsense conviction that occupational stress disturbs sleep, our knowledge about work stress, sleep and fatigue is surprisingly limited. Moreover, the available evidence for such a relationship is built almost exclusively upon cross-sectional designs (Åkerstedt, 2006; Åkerstedt *et al*., 2007b), but some prospective studies have been performed. A recent study by Åkerstedt *et al*. (2007a) indicated that self-reported disturbed sleep and fatigue are predictors of long-term sickness absence. In another prospective study, Sivertsen *et al*. (2006) demonstrated that insomnia was a strong predictor of subsequent permanent work disability. Much of the necessary knowledge on the important role of sleep in relation to psychosocial stress and its long-term effects is still missing. Clearly, there is a need for longitudinal studies that focus on the effects of real-life stress on sleep (Åkerstedt, 2006; Åkerstedt *et al*., 2007b).

Against this background, the aim of the current prospective 3-year, four-wave study is twofold. Our first aim is to longitudinally examine the causal relationships between job demands and job control (i.e. two central work characteristics), on one hand, and sleep quality and fatigue on the other hand. We assume normal causality (hypothesis 1: work characteristics affect sleep quality and fatigue across time). As it is also plausible that sleep quality and fatigue influence the assessment of work characteristics across time (De Lange *et al*., 2005; Finkelman, 1994; Kalimo *et al*., 2000), we also hypothesize reverse causation (hypothesis 2: sleep quality and fatigue affect work characteristics across time). Hypotheses 1 and 2 are non-competing, as these two types of causality may co-occur. If the latter is the case, there are reciprocal influences (A $\rightarrow$ B and B $\rightarrow$ A), and we will examine which direction is causally predominant.

The second study aim was to conduct a fine-grained analysis of the temporal dynamics between these two work characteristics and sleep quality and fatigue. We will examine the effects of stable versus changing demand–control histories (DCHs) on both recovery indicators. To the best of our knowledge, to date no study has examined the development of sleep quality and fatigue in response to such repeated (chronic) combinations of high demands and low control ('exposure histories'). Similarly, few researchers have addressed the sleep quality or fatigue effects of across-time changes in job demands and job control (cf. the strain hypothesis of Karasek and Theorell, 1990; that holds that in particular the combination of high job demands and low job control causes ill health). In this study we will compare six theoretically derived prototypical job demands–job control subgroups (De Lange *et al*., 2002) with respect to the across-time development of their subjective sleep quality and fatigue (measured at times 1 and 4). These six DCH groups consist of four groups with stable DCHs: group 1 with high job demands and low job control at all four waves (stable high-strain group); group 2 with low demands and high control at all four waves (stable low-strain group); group 3 with high demands and high control at all four waves (stable active group); and group 4 with low demands and low control at all four waves (stable passive group). In addition to these four stable groups we also focus on two changing groups, one (group 5) that changes for the worse, and one (group 6) that changes for the better. Group 5 consists of those employees who initially (time 1) were in the low-strain, active or passive quadrant and who moved into the high-strain quadrant at a later time-point (group 5: into high-strain group). Group 6 consists of employees who moved from the initial high-strain quadrant into another quadrant (group 6: into non-high-strain group).

Based on the theoretical propositions (effort–recovery theory, allostatic load theory, demand–control model) as discussed above, we developed six specific hypotheses regarding the six DCHs (hypotheses 3–8).

- (3a) Employees in high-strain jobs will report the lowest sleep quality and highest level of fatigue on both time-points;
- (3b) they will report a significant increase in sleep complaints (reduced sleep quality) and fatigue across time (from time 1 to time 4);
- (4a) employees in low-strain jobs will report the highest sleep quality and lowest level of fatigue on both time-points;
- (4b) they will report a stable level of sleep complaints and fatigue across time;
- (5a, 6a) employees in active and in passive jobs will report an average level of sleep quality and fatigue on both time-points;
- (5b, 6b) they will report a stable level of sleep complaints and fatigue across time;

(7) employees who changed from the non-high-strain group into the high-strain group will report an increase of sleep complaints and fatigue across time; and
(8) employees who changed from the high-strain group into the non-high-strain group will report a decrease of sleep complaints and fatigue across time.

METHOD

Sample

The current study was conducted within the framework of the prospective Dutch cohort Study on Musculoskeletal disorders, Absenteeism, Stress and Health (Ariëns *et al.*, 2001; Hoogendoorn *et al.*, 2000). At baseline (i.e. 1994), 1789 employees working in 34 different companies located throughout the Netherlands participated in this study. Each year (i.e. 1994, 1995, 1996, 1997) the respondents received a self-administered questionnaire that collected information on general working conditions, changes in the workplace, psychosocial work characteristics, physical workload, health status and background factors.

To be included, companies were required not to be involved in major reorganizations during the 3 years of examination and to have a prestudy annual turnover rate of their workforce of less than 15%. Further, only respondents who had been working for at least 1 year in their current job for at least 20 h per week were selected. Both blue-collar and white-collar jobs were included. Employees with a temporary contract and employees receiving a (partial) disability benefit were excluded (47 of 1789 respondents). Response rates were relatively high and varied between 84% (n = 1742) at baseline and 85% (n = 1473) at the third follow-up measurement. Analysis of attrition revealed that dropouts reported significantly less job control [M = 2.67 versus M = 2.83 of response group, standard deviation $(SD)_{dropout/response}$ = 0.58/0.48], significantly more sleep complaints (M = 0.65 versus M = 0.48 of response group, $SD_{dropout/response}$ = 0.99/0.83) as well as significantly more feelings of fatigue [M = 0.81 versus M = 0.57 of response group, $SD_{dropout/response}$ = 1.00/0.91] on baseline compared with the response group. No significant differences were found for job demands.

After listwise deletion of missing values, the sample included 1136 employees (71% male and 29% female; average age at baseline was 35.6 years, SD = 8.8; average number of years of employment was 9.6 years, SD = 7.7; 10.4% completed primary education or lower; 44.8% lower vocational education, 29.8% secondary education or middle vocational education, 7.8% had higher vocational education and 7.2% completed college/university education).

Measures

Job demands

Job demands were measured using a five-item Dutch version of Karasek's (1985) Job Content Questionnaire (e.g. 'My job requires working very fast', four response alternatives from 1 = 'strongly disagree' to 4 = 'strongly agree'). The reliability (Cronbach's alpha) of this scale varied from 0.65 to 0.72 across occasions (median alpha = 0.71).

Job control

Consistent with Karasek's (1985) conceptualization, job control was measured using eight items reflecting skill discretion and decision authority (e.g. 'My job requires that I learn new things', 'My job allows me to take many decisions on my own'; 1 = 'strongly disagree' to 4 = 'strongly agree). The reliabilities of this scale ranged from 0.81 to 0.83 (median alpha = 0.82).

Sleep quality

Sleep quality was measured at times 1 and 4 with a three-item sleep scale based on Appels and Schouten (1991). The items measured whether respondents experienced trouble falling asleep, trouble staying asleep and waking up early in the morning (0 = 'no', 1 = 'yes'). Appels and Mulder (1988) and Appels and Schouten (1991) found that these items were a significant predictor of myocardial infarction. The reliabilities of the scale were 0.65 at time 1 and 0.67 at time 4. The range of this scale was 0–3, with higher scores indicating more sleep complaints.

Fatigue

Fatigue was measured at times 1 and 4 with three items of the validated health questionnaire, Vragenlijst Onderzoek Ervaren Gezondheid (Standard Health Questionnaire) (Dirken, 1969; Martens *et al.*, 1999). The items measured whether respondents often experienced a feeling of being fatigued, whether they experienced fatigue more than they would regard as normal and whether they (in general) woke up feeling fatigued and not rested (0 = 'no', 1 = 'yes). The reliabilities of the scale were 0.69 at time 1 and 0.77 at time 4. This scale range was 0–3, with higher scores indicating higher levels of fatigue. An exploratory factor analysis that combined the three sleep-quality items and the three fatigue items revealed that the two measured two separate aspects of recovery (results available upon request from the first author).

Covariates

Age, level of education (1 = primary education or lower, 5 = college or university education), gender (male = 1; female = 2) and years of work experience were included as covariates in the analysis, because these variables may be related to demands and control and to the outcome variables employed in this study. Failing to control for these variables may distort the effects of other variables (Schnall *et al.*, 1994).

Creation of demand–control histories

Six groups were created on the basis of their exposure to different combinations of job demands and control. First, all

Table 1 Description of demand–control histories (DCHs)

Group number	*Group label*	n
1	Stable high-strain group (no across-time change)	61
2	Stable low-strain group (no across-time change)	108
3	Stable active group (no across-time change)	97
4	Stable passive group (no across-time change)	93
5	Change from no high-strain job to high-strain job	84
6	Change from high-strain job to no high-strain job	135
	Total	578
7	Other (e.g. ambiguous DCHs with > 1 change in job characteristics; omitted from further analysis)	558
	Total	1136

variables measuring job demands and job control at each of the four waves included in this study were dichotomized using a median split procedure. For each measurement point, four job demands/job control combinations were formed (Karasek and Theorell, 1990). As this study included four waves, theoretically 4 (four demands/control combinations) to the fourth power (four waves) equalling 256 different DCHs could be distinguished. Four of these consisted of stable DCHs, i.e. in which no transition from one type of job to another was observed during the four occasions (*n*s varying from 61 for the stable high-strain group to 108 for the stable low-strain group, cf. Table 1).

Groups 5 and 6 consisted of employees whose DCHs included *one* transition across time. The timing of that transition was deemed irrelevant. Group 5 included DCHs in which the employees were initially in the low-strain, active or passive quadrant and at a later time-point moved to the high-strain quadrant ($n = 84$). Group 6 consisted of employees who moved from the high-strain to the low-strain, active or passive quadrant ($n = 135$). A seventh group consisted of 558 subjects (49%) whose DCHs included more than a single transition. These relatively complex and ambiguous histories could not be classified theoretically and were therefore omitted from the analysis.

Statistical analysis

Correlational analyses were conducted to obtain basic insight into the data. Structural equation modelling (SEM; Jöreskog and Sörbom, 1993) was used to test hypotheses 1 and 2 and to test and compare various competing models for the relationships among job demands, job control and sleep quality and fatigue. SEM has the advantage of providing global measures of fit for latent variable models (Brannick, 1995). We performed a comparative analysis in which the fit of several competing models was assessed to determine which model fitted the data most effectively (Kelloway, 1998). All model tests were based on the covariance matrix and maximum likelihood estimation. Model fit was assessed using the chi-squared test, the goodness-of-fit index (GFI), the non-normed fit index (NNFI) and the root-mean square error of approximation (RMSEA). Levels of 0.90 or better for GFI and NNFI and levels of 0.05 or lower for RMSEA indicate that models fit the data acceptably (Byrne, 2002).

Considering potential problems caused by estimating the relationships among observed items and latent variables (insufficient power and underidentification; Bentler and Chou, 1987; Schumacker and Lomax, 1996), we assumed scale and latent variables to be identical. However, following the two-step approach proposed by James *et al.* (1982), we first tested the measurement models for each of the variables before fitting the structural models. These analyses showed that the factor structures of the research variables were consistent across time. Finally, all results presented below were based on the standardized results from the covariance matrices of the variables.

Competing structural models

To examine the causal relationships between the two work characteristics, sleep quality and fatigue (hypotheses 1 and 2), we tested a baseline model versus several competing nested models. These models were:

(1) *Baseline model* (M_0): includes temporal stabilities and synchronous (i.e. within-wave) effects of variables over time and controls for the influence of covariates (age, gender, level of education and years of experience). This model is used as the reference model.
(2) *Normal causation model* (M_1): this model resembles M_0 but includes additional cross-lagged structural paths from the times 1, 2 and 3 work characteristics to time 4 sleep quality and fatigue.
(3) *Reversed causation model* (M_2): this models resembles M_0 but is extended with cross-lagged structural paths from time 1 sleep quality and fatigue to times 2, 3 and 4 job demands and job control.
(4) *Reciprocal causation model* (M_3): this model is similar to M_0 but includes additional reciprocal cross-lagged structural paths from the work characteristics on sleep quality, fatigue and vice versa (i.e. the normal paths included in model M_1 as well as the reversed paths included in model M_2).

Stability and change

To investigate hypotheses 3–8, the data were analyzed using a 6 (group; the four stable and two changing DCHs) × 2 (time: two occasions) ANOVA with time as a within-participants factor and group as a between-participants factor.

RESULTS

Correlational analysis

Table 2 presents the means, standard deviations and correlations among the measures. The cross-sectional correlations

Table 2 Means, standard deviations and correlations between research variables (n = 1136 after listwise deletion)

Variables	*M*	*SD*	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*	*(10)*	*(11)*	*(12)*	*(13)*	*(14)*	*(15)*
Time 1																	
(1) Age	35.82	8.50	–														
(2) Gender*	1.29	0.45	−0.17	–													
(3) Education	2.74	1.12	−0.08	0.15	–												
(4) Experience	9.66	7.56	0.59	−0.21	−0.19	–											
(5) Job demands	2.59	0.46	0.03	0.03	−0.02	0.03	–										
(6) Job control	2.86	0.47	0.11	−0.17	0.22	0.09	−0.02	–									
(7) Sleep quality	0.45	0.81	0.14	0.07	−0.08	0.09	0.12	−0.12	–								
(8) Fatigue	0.53	0.90	0.00	0.14	0.03	−0.00	0.14	−0.07	0.31	–							
Time 2																	
(9) Job demands	2.54	0.49	0.03	0.01	−0.02	−0.01	0.55	−0.02	0.11	0.11	–						
(10) Job control	2.89	0.48	0.11	−0.14	0.21	0.07	−0.01	0.64	−0.11	−0.07	−0.06	–					
Time 3																	
(11) Job demands	2.65	0.47	0.06	−0.01	−0.02	0.03	0.51	−0.04	0.09	0.11	0.58	−0.06	–				
(12) Job control	2.89	0.46	0.07	−0.13	0.22	0.04	−0.06	0.61	−0.12	−0.08	−0.07	0.64	−0.09	–			
Time 4																	
(13) Job demands	2.59	0.47	0.04	−0.01	0.04	0.01	0.47	0.03	0.09	0.11	0.54	0.02	0.60	0.00	–		
(14) Job control	2.88	0.48	0.04	−0.17	0.23	0.04	−.03	0.59	−0.15	−0.06	−0.07	0.62	−0.07	0.69	−0.00	–	
(15) Sleep quality	0.58	0.92	0.12	0.07	−0.03	0.05	0.12	−0.06	0.54	0.25	0.15	−0.07	0.15	−0.11	0.18	−0.14	–
(16) Fatigue	0.64	1.00	−0.02	0.12	0.07	−0.01	0.14	−0.03	0.19	0.52	0.16	−0.05	0.19	−0.13	0.21	−0.13	0.41

Correlations of 0.06 and higher are significant at $P < 0.05$.
*1 = male, 2 = female.

among the measures were in the expected direction. For instance, no or weak correlations were found for job demands and job control across time, whereas significant positive correlations were found for sleep quality and fatigue (time 1: $r = 0.31$; time 4: $r = 0.41$). With regard to the across-time stability of these variables, the one-lag (times 1–2) test–retest correlations ranged from 0.55 (for job demands) to 0.64 (for job control; all Ps < 0.001); whereas the three-lag (times 1–4) test–retest correlations ranged from 0.54 (for sleep quality) to 0.47 (for job demands; all P's < 0.001).

Hypotheses 1 and 2

The fit indices for the four competing structural models (M_0–M_3) are presented in Table 3. The fit of all models was satisfactory (NNFI, GFI ≥0.90 and RMSEA ≤0.05). Further, we examined the chi-squared difference test for the nested structural models versus the baseline model.

Table 3 shows that models 1–3 fitted the data significantly more accurately than the baseline model. Thus, there was a relationship between job demands, job control and sleep quality and fatigue. These results support hypothesis 1: the normal causation model (M_1) accounted for the data more accurately than the baseline model [M_0 versus M_1: $\Delta\chi^2$ (12, n = 1136) = 63.43, $P < 0.01$]. Furthermore, the results did not support hypothesis 2, as the reversed causation model did not fit the data more accurately than the baseline model [M_0 versus M_2: $\Delta\chi^2$ (12, n = 1136) = 15.9, $P > 0.05$]. The reciprocal model (with normal as well as reversed effects included) fitted the data more accurately than the baseline model, but not more accurately than the normal causation model [M_1 versus M_3: $\Delta\chi^2$ (12, n = 1136) = 15.9, $P > 0.05$]. As simple models should be preferred to more complex models with the same fit (Kelloway, 1998), and as no significant reversed cross-lagged effects were found from time 1 sleep quality or fatigue on later reported work characteristics, we conclude that the normal causation model (M_1) fitted the data most accurately.

Fig. 1 shows that only significant effects were found after a time-lag of 1 year. More specifically, time 3 job demands

Table 3 Fit indices structural equation analyses (n = 1136)

Model	χ^2 *(df)*	*NNFI*	*GFI*	*RMSEA*	χ^2 *Δ(df) versus* M_0	χs^2 *Δ(df)* M_1 *versus* M_3
0	137.14 (41)	0.95	0.98	0.046		
1	73.71 (29)	0.97	0.99	0.036	63.43* (12)	15.94 (12)
2	121.24 (29)	0.94	0.99	0.053	15.9 (12)	
3	57.77 (17)	0.95	0.99	0.045	79.37* (24)	

NNFI: non-normed fit index; GFI: goodness-of-fit index; RMSEA: root-mean square error of approximation. *$P < 0.01$.
In the analyses we controlled for age, gender, education and years of experience.

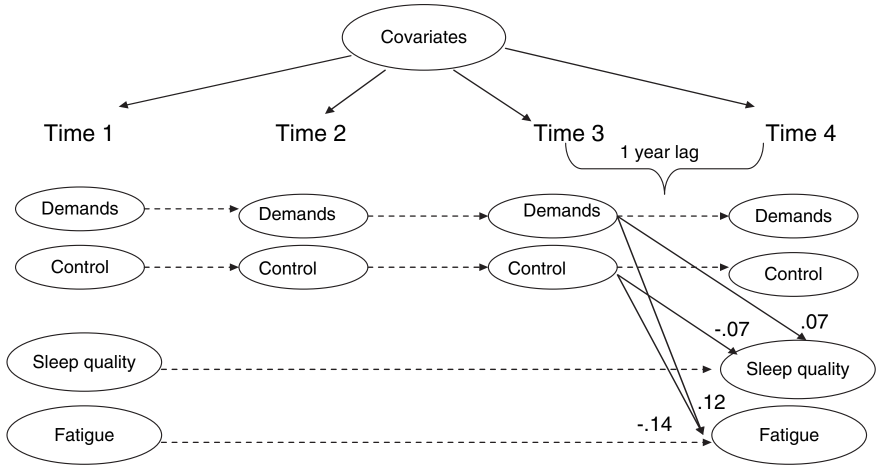

Figure 1. Results of the best-fitting normal causal effects model (M_1). Total explained variance (R^2) for time 3 sleep quality was 0.29 and for time 3 fatigue 0.28.

affected time 4 sleep quality ($\beta = 0.07$, $P < 0.05$) and fatigue ($\beta = 0.12$, $P < 0.05$) significantly. These effects suggest that higher levels of job demands are related to more sleep complaints and fatigue 1 year later. In addition, time 3 job control influenced time 4 sleep quality ($\beta = -0.07$, $P < 0.05$) and fatigue ($\beta = -0.14$, $P < 0.05$). Higher levels of job control were thus related to fewer sleep complaints and fatigue across time.

Hypotheses 3–8

Table 4 presents the means and standard errors of the outcome variables as a function of time and group. As Table 4 reveals, there were significant main effects of time for sleep quality, $F_{(1,\ 458)} = 18.55$, $P < 0.01$ and for fatigue, $F_{(1,\ 458)} = 10.55$, $P < 0.01$. The scores for both variables tended to become less favourable across time (i.e. more sleep complaints and fatigue).

Main effects of group were found for sleep quality, $F_{(5,\ 458)} = 6.72$, $P < 0.01$ as well as fatigue, $F_{(5,\ 455)} = 7.20$, $P < 0.01$. The pattern of effects was similar across groups, with groups 1 (stable high-strain), 3 (stable active) and 5 (non-high-strain to high-strain) reporting relatively the most negative outcomes in terms of sleep quality and fatigue, and group 2 (stable low-strain) the most favourable sleep-related outcomes. *Post hoc* pairwise between-group comparisons (Bonferroni test) revealed that the low-strain workers reported the most significant differences at times 1 and 4, relative to the other exposure groups (Table 4).

Significant interaction effects between time and group were again found for sleep quality, $F_{(5,\ 458)} = 2.36$, $P < 0.05$ as well as fatigue, $F_{(5,\ 455)} = 3.21$, $P < 0.01$. These interaction effects are elaborated below in relation to hypotheses 3–8.

Differences among stable DCH groups (hypotheses 3–6)

Fig. 2 presents the means for the stable exposure groups for sleep quality and fatigue. For sleep quality, a group (DCH 1–4) × time (two occasions) ANOVA with planned contrasts on time revealed main effects of time, $F_{(1,\ 315)} = 14.10$, $P < 0.01$ and group, $F_{(3,\ 315)} = 11.95$, $P < 0.01$. These main effects were further qualified by a group × time interaction effect, $F_{(3,\ 315)} = 3.54$, $P < 0.05$. Similar results were obtained for fatigue: main effects of time, $F_{(1,\ 312)} = 7.50$, $P < 0.01$; group, $F_{(3,\ 312)} = 12.22$, $P < 0.01$, and a group × time interaction effect, $F_{(3,\ 312)} = 2.92$, $P < 0.05$. Tukey's least significant difference test revealed that compared with the stable passive and low-strain group, respondents in the stable high-strain group reported the worst sleep quality and highest level of fatigue compared with the other stable groups (hypothesis 3a supported). However, the differences compared with the stable active group of workers were neither significant for the times 1 and 4 sleep quality scores nor for the time 1 fatigue score (hypothesis 5a not supported). As expected for the high-strain group levels, sleep complaints and fatigue increased significantly, respectively, $F_{(1,\ 59)} = 8.96$, $P < 0.01$ and $F_{(1,\ 59)} = 6.27$, $P < 0.05$ (hypothesis 3b supported). Furthermore, the respondents in the low-strain group reported the best sleep quality and lowest level of fatigue, and reported no significant across-time changes (hypotheses 4a and 4b supported). The passive workers presented average results, and both the active and passive workers reported no significant across-time changes (hypotheses 5b, 6a–6b supported).

Changing DCH groups (hypotheses 7–8)

Fig. 3 presents the means for the changing exposure groups for sleep quality and fatigue. For sleep quality, a group (DCH 5–6) × time (two occasions) ANOVA with planned contrasts on time revealed only main effects of time, $F_{(1,\ 143)} = 4.70$, $P < 0.05$. For fatigue only a significant group × time interaction effect was found, $F_{(1,\ 143)} = 6.60$, $P < 0.05$. As for the changing exposure groups, the change into high-strain group (group 5) revealed significant increases in sleep complaints, $F_{(1,\ 72)} = 4.73$, $P < 0.05$, and fatigue, $F_{(1,\ 72)} = 9.70$, $P < 0.01$, across time (hypothesis 7 supported). Group 6, involving a transition towards a non-high-strain group, showed no significant across-time decreases in sleep quality or fatigue (hypothesis 8 not supported).

Table 4 Means and standard errors of sleep quality and fatigue as a function of time (T1 and T4) and group (standard errors in brackets)

Variables		*DCH* Mean full sample	DCH 1: stable high-strain group	DCH 2: stable low-strain group	DCH 3: stable active group	DCH 4: stable passive group	DCH 5: change non-high-strain to high-strain	DCH 6: change high-strain to non-high-strain	MANOVA F values: Time (η^2)	Group (η^2)	Time × group (η^2)
Sleep quality	Time 1	0.49 (0.87)	0.72 $(0.11)_{2}$	0.25 $(0.08)_{1}$	0.58 (0.11)	0.45 (0.09)	0.48 (0.11)	0.65 (0.11)	$F_{(1, 458)} = 1855^{**}$	$F_{(5, 458)} = 6.72^{**}$	$F_{(5, 458)} = 2.36^{*}$
	Time 4	0.64 (0.97)	$1.13^{\dagger}$ $(0.11)_{2,4}$	0.25 $(0.09)_{1,3,5,6}$	0.79 $(0.11)_{2}$	0.54 $(0.09)_{1}$	$0.73^{\dagger}$ $(0.12)_{2}$	0.72 $(0.12)_{2}$	($\eta^2 = 0.04$)	($\eta^2 = 0.03$)	($\eta^2 = 0.07$)
Fatigue	Time 1	0.60 (0.94)	0.90 $(0.11)_{2}$	0.35 $(0.09)_{1,6}$	0.66 (0.12)	0.49 $(0.09)_{6}$	0.55 (0.12)	0.83 $(0.12)_{2,4}$	$F_{(1, 455)} = 10.55^{**}$	$F_{(5, 455)} = 0.20^{**}$	$F_{(5, 455)} = 3.21^{**}$
	Time 4	0.72 (1.07)	$1.27^{\dagger}$ $(0.13)_{2,4}$	0.36 $(0.09)_{1,3,5}$	0.90 $(0.13)_{2}$	0.47 $(0.10)_{1,5}$	$0.93^{\dagger}$ $(0.14)_{2,4}$	0.76 (0.14)	($\eta^2 = 0.02$)	($\eta^2 = 0.03$)	($\eta^2 = 0.07$)

DCH, demand–control histories.
$^{*}P < 0.05$, $^{**}P < 0.01$; †significant across-time difference effect for demand–control history (DCH) group ($P < 0.05$); within each row, means with different subscripts (1–6) differ at $P < 0.05$ minimally (based on Bonferroni *post hoc* tests). For example, the time 4 sleep quality scores of the low-strain group (DCH 2) differ significantly from the high-strain group (DCH 1; indicated with '1') the active group (DCH 3; indicated with '3'), change non-high-strain to high-strain group (DCH 5; indicated with '5'), and change high-strain to non-high-strain group (DCH 6; indicated with '6').

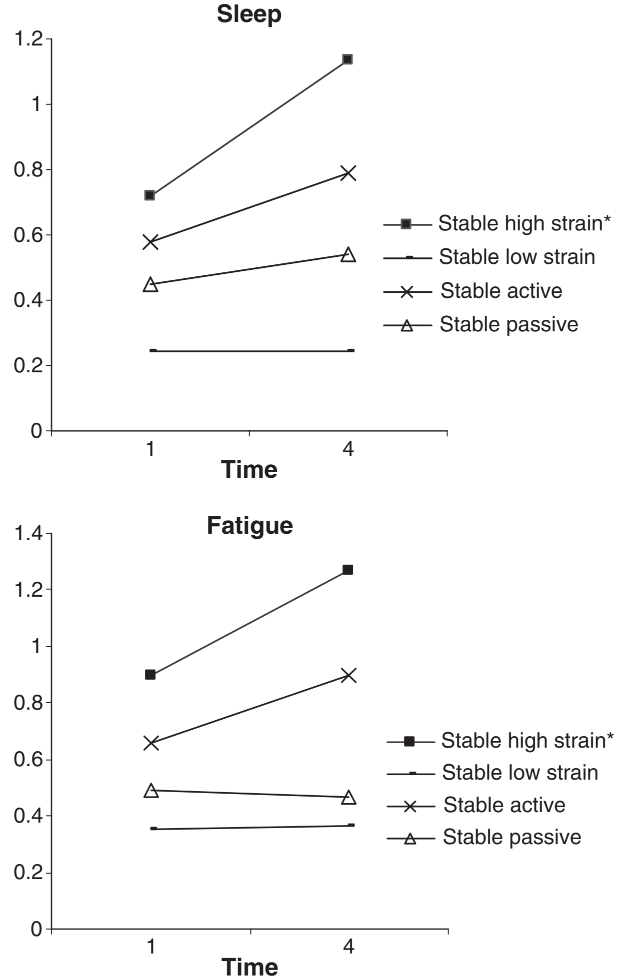

Figure 2. Results of sleep quality and fatigue scores for four stable demand–control histories (groups 1–4). *Significant across-time change (two time-points: times 1 and 4).

DISCUSSION

Sleep is essential for physiological balance and long-term health and mental functioning (Åkerstedt, 2006). Our aim was to examine the longitudinal relationships between job demands and job control, on one hand, and sleep quality and fatigue on the other hand, and to consider the effects of stability and change in DCH on the development of these two crucial recovery indicators. We examined eight hypotheses.

Our results revealed significant normal cross-lagged relations only between job demands, job control and sleep and fatigue across a time-lag of 1 year (supporting hypothesis 1 and not supporting reversed causation hypothesis 2). High job demands and low job control were related to an increase in sleep-related problems across time, which is in line with cross-sectional associations reported in earlier studies (cf. Åkerstedt, 2006; Åkerstedt *et al.*, 2007b).

To investigate further these longitudinal relations between psychosocial work characteristics and sleep and fatigue, we examined the role of DCHs (exposure history, cf. Frese and

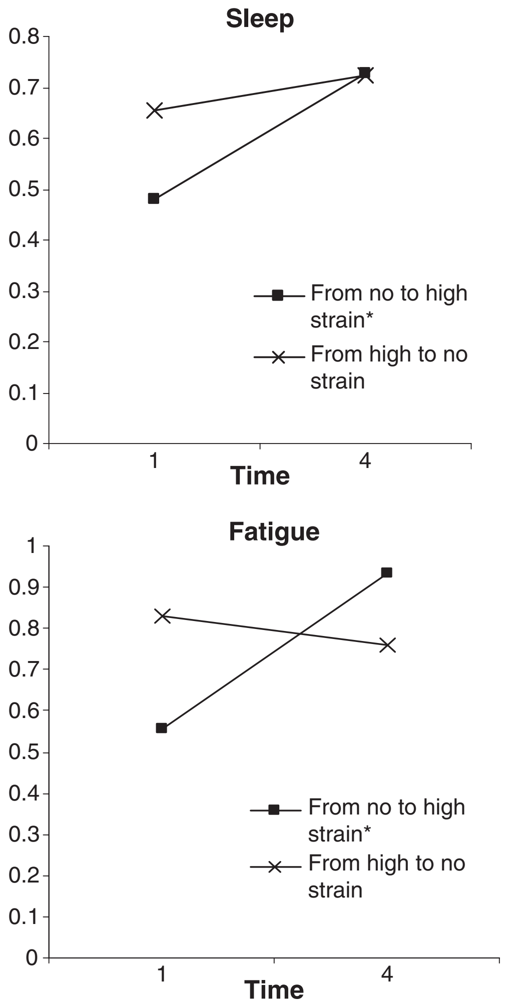

Figure 3. Results of sleep quality and fatigue for two changing demand–control histories (groups 5 and 6). *Significant across-time change (two time-points: times 1 and 4).

Zapf, 1988). Demand–control theory, effort–recovery theory and allostatic load theory postulate that the long-term or repeated exposure to the negative combination of high work demands and low job control impacts recovery and well-being negatively. We thus compared employees with a stable high-strain DCH to workers with other stable DCHs: low-strain, active or passive jobs. Workers who were exposed to a high-strain work environment across all four study waves indeed reported the worst sleep quality. Their sleep complaints also increased across time (supporting hypotheses 3a–3b). Employees in passive or low-strain work environments reported lower scores (with low-strain employees revealing the best sleep quality) than the high-strain workers, and showed no significant increases in their recovery indicators across time (supporting hypotheses 4a–4b, 6a–6b). Notably, this study revealed that workers in stable active jobs also experienced high levels of fatigue and reduced sleep quality. They appeared to experience similar problems to the high-strain workers in recovering from work. Our results indicate that high job control may not always reduce the 'tiring' impact of high job demands. It may be that high job demands elicit long work hours, which in turn limit the time for recovery and sleep. In support of this, Van der Hulst (2003), in her review of the relation between long work hours and sleep hours, found evidence for such a relationship. It may also be that high job demands cause a cognitive preoccupation with work ('perseverative cognition'; Brosschot *et al.*, 2005), manifesting itself as rumination (about past stressors) and anticipation (about potential future stressors). Psychologically, both rumination and the anticipation of stress seem to be key factors in insomnia, supporting the assumption that cognitive stress-related processes are important with respect to recovery from stress (Geurts and Sonnentag, 2006).

If one assumes a causal relation between job demands and job control (A), on one hand, and sleep quality and fatigue (B) on the other hand, a change in A should result in a change in B (Taris and Kompier, 2003). Such further causal evidence for the relationship between work characteristics and sleep quality and fatigue follows from our study of two groups with changing DCHs. We expected that positive (negative) changes in terms of job demands and job control would be related temporally to better (worse) sleep quality and less (higher) fatigue. Indeed, this study revealed that the transition from a non-high-strain towards a high-strain job was associated across time with increased sleep-related problems (supporting hypothesis 7), but we did not find evidence for a significant positive effect of a change from a high-strain towards a non-high-strain job (hypothesis 8 not supported). This pattern of results suggests that a change into a high-strain condition resulted in elevated levels of self-reported fatigue and reduced sleep quality. However, the corresponding positive change away from the high-strain condition seemed to have weaker effects on recovery. This suggests that the adverse effects of having a high-strain job are such that they are not resolved easily when positive changes occur; this is what Frese and Zapf (1988) have defined as 'accumulation effect'.

In our analyses we have corrected for possible gender differences. From Table 2 we learn that being female is related significantly to job control (less job control, all time-points), and also to both recovery indicators (both times 1 and 4, women reporting less recovery). Future studies might further concentrate on potential gender differences.

Future studies may also take into account more 'objective' indicators of strain, such as company registered sickness absence (duration, frequency) when investigating the across-time associations between exposure to psychosocial work characteristics and recovery indicators. Recent studies indicate that DCHs are related to sickness absence (De Lange *et al.*, 2002), and that sleep complaints (Åkerstedt *et al.*, 2007a) and fatigue (Bültmann *et al.*, 2005) are related to subsequent sickness absence. Trying to disentangle the causal relationships between work exposures, recovery indicators and sickness absence is one of the main challenges in this research area.

Limitations

One limitation of the present research refers to the sample under study. In order to reduce possible loss to follow-up, it was decided to select companies with a relatively low turnover rate and workers who had been employed in their current job for at least 1 year. This selection might have contributed to a healthy worker effect. Furthermore, dropout analyses revealed less control and more sleep problems and fatigue among the dropout group. This implies that this sample consists of relatively healthy employees and that this study's outcomes may present an underestimation of the 'true' effect sizes. It may also be noted that, although the initial sample was of good size, the six subgroups were smaller, with *n*s ranging from 61 to 135. Secondly, the cross-lagged effects of job demands and job control were small. Hence, relatively little variance in the recovery indicators is accounted for by these work characteristics. Small standardized effects are to be expected in longitudinal research, as there is an upper limit of 15–20% variance in outcomes that can be explained by job stressors (Semmer *et al*., 1996). Further, it is important to note that the cross-lagged effects of, for instance, job demands on sleep quality refer to predicting changes in sleep quality from times 1–4 (i.e. partialling out for the relatively high times 1–4 stability effects of 0.52 and 0.54). We thus corrected for the previous (time 1) sleep quality and fatigue scores. A third limitation relates to the study design, whereas the two work characteristics were measured at all four waves, sleep quality and fatigue were measured only at the first and fourth waves, resulting in a suboptimal data collection when compared to a design that would include measures of all variables at all four waves. Because time 3 recovery indicators were not collected, it was not possible to control for time 3 sleep quality and fatigue when studying the relationship between demands and control at time 3 and sleep quality and fatigue at time 4. Instead we controlled for time 1 sleep quality and fatigue, and we cannot exclude the possibility that these scores may differ from the true time 3 scores. This may result in a possible under- or overestimation of the true effect sizes. Furthermore, we cannot exclude the possibility that reversed effects of times 2 and 3 sleep quality scores do exist across time (De Lange *et al*., 2003). Also, it is possible that the 3-year time lag between the two measurements of sleep quality and fatigue may have been too long to reveal reversed effects of sleep-related complaints on job demands or job control. Fourth, these findings were based entirely upon self-reports, and future studies might try to capture other more detailed and 'more objective' indicators of sleep quality. For example, the present study is not informative with respect to the severity or time-frame of sleep disturbances. The content validity of our sleep quality measure, on the other hand, seems to be of good quality. Its three items correspond closely with three of the four operational RDC for insomnia (Edinger *et al*., 2004), whereas the fourth RDC ('non-restorative sleep') corresponds with one of our fatigue items. Although it might have been possible to construct one insomnia measure that would correspond to all four RDC, we preferred to study both recovery indicators separately. It is a challenge for future researchers in this intriguing field to tackle these limitations.

Implications

We believe that our results have important theoretical and practical implications. From a theoretical point of view we note that, in accordance with central assumptions of Karasek and Theorell (1990) Demand–Control model, effort–recovery theory and allostatic load theory, job demands and job control do contribute to the development of sleep quality across time. Our results suggest that working in a high-strain job over a prolonged period of time can have adverse effects for sleep quality and fatigue. It is tempting to speculate that there '...is an important sequence of putative causality from occupational stress via disturbed sleep and its consequences for metabolic and mental functioning to their possible endpoints in stress-related disorders and accident risk' (Åkerstedt *et al*., 2007b, p. 255). This study concentrated upon one part of this putative chain: the longitudinal relation between two central psychosocial work characteristics and sleep and fatigue. Most interestingly, this study made it clear that not only employees in stable high-strain jobs but also employees in stable active jobs report impaired sleep. This seems to indicate that high job demands may hinder recovery, even when combined with high job control.

From a more practical stance we argue that companies should strive for well-designed jobs, i.e. jobs that balance work-related effort and recovery. Job demands may certainly be high and for many employees such high demands are challenging. However, job demands should not be too high. This means that employees must have the possibility to recover from work-induced effort, either internally (i.e. during the working day, for example through rest breaks and job variety) or externally, i.e. between (series of) working days (e.g. weekends, vacations). High job control and especially high work time control (Härmä, 2006) are thus important prerequisites for well-designed jobs. The fact that, in addition to employees in stable high-strain jobs, employees in stable active jobs also report impaired sleep implies that high job control does not necessarily 'buffer' the negative impact of high job demands on recovery, and that especially too-high job demands should be prevented.

ACKNOWLEDGEMENTS

This study was financially partially supported by the Dutch Ministry of Social Affairs and Employment; The Dutch Ministry of Public Health, Welfare, and Sports; and the Dutch National Institute for Social Security.

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