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Age and work environment characteristics in relation to sleep: additive, interactive and curvilinear effects

Katharine R Parkes

University of Oxford

University of Western Australia

Corresponding author

Department of Experimental Psychology

University of Oxford

South Parks Road,

Oxford, OX1 3UD, UK

Tel. +44 1865 271401

e-mail: kathy.parkes@psy.ox.ac.uk

Abstract

Although additive combinations of age and work environment characteristics have been found to predict sleep impairment, possible *age x work environment* interactions have been largely disregarded. The present study examined linear and curvilinear interactions of age with work environment measures in relation to sleep quality and duration. Survey data were collected from offshore day-shift personnel (N=901). Main effects and interactions of the age terms with work environment measures (job demand, control, and social support, physical environment and strenuous work) were evaluated. Sleep duration was predicted by a curvilinear interaction, *age^2 x job demand* (p<.005), and by the *age x social support* interaction (p<.002); sleep quality was predicted by *age x job demand* (p<.002). Job control and physical environment showed significant additive effects. At a time when older employees are encouraged to remain in the workforce, the findings serve to increase understanding of how ageing and work demands jointly contribute to sleep impairment.

Keywords: Sleep**;** age**;** psychosocial/physical work characteristics**;** offshore workers; interactions

1. Introduction

Global, economic and technological changes in recent years have led to 'work intensification', characterized by increased workloads, time pressures, long work hours, lean production methods, and deteriorating employment conditions (Chandola, 2010). At the same time, the age profile of the workforce is increasing (Office of Science and Technology, 2011), and current employment policies encourage older workers to continue working longer than was expected in previous generations. Together, these factors highlight the importance of understanding how work environment characteristics and age combine to predict organizational and individual outcomes. Sleep impairment, the outcome examined in the present study, is particularly relevant as there is evidence that insufficient or poor quality sleep is a causal factor in short-term performance decrements (Williamson & Feyer, 2000), and longer-term outcomes, including work absences (Lallukka et al., 2014), reduced productivity (Rosekind et al., 2010), occupational injuries (Hägg et al., 2015; Salminen et al., 2010), and chronic ill-health (Grandner et al., 2012). The present study builds on published research, as summarized below, into the roles of age and the work environment in relation to sleep impairment.

1.1 Age and sleep

Higher age is typically associated with greater risk of sleep impairments in the general population (e.g. Ansiau et al., 2005; Moraes et al., 2014). However, relations between age and sleep are complex; they are not necessarily linear (Grandner et al., 2012), and they may be at least partially attributable to lifestyle factors rather than physiological changes (Ohayon et al., 2001). Also, patterns of change over time vary with the nature of the sleep impairment examined. Thus, Salo et al. (2012) found that the prevalence of insomnia symptoms was higher at older ages, relative to the age range 34-45 y, while 'sleep lost over worry' showed a high prevalence at age 34-60 y followed by a decline at older ages.

More directly relevant to the present work, age-related changes in sleep have also been found in occupational samples (Marquié et al., 2012; Ribet & Derriennic, 1999). Among shift workers, there is evidence of non-linear relationships between age and sleep; thus, some studies report an upturn in sleep quality at higher ages, most likely due to the tendency of older workers to give up shift work if they experience sleep difficulties (Marquié et al., 2012; Tucker et al., 2011). A similar upturn in sleep quality at older ages was found by Parkes (2015a), but it applied only to night-shift work. Curvilinear age effects have also been found in relation to measures of occupational well-being (Hochwarter et al., 2001; Zacher et al., 2014).

1.2 Work environment and sleep

1.2.1 Psychosocial work characteristics

Findings relating psychosocial work characteristics to sleep quality were reviewed by Van Laethem et al. (2013). A total of 16 longitudinal studies, including three judged to be of high standard, met the inclusion criteria. Evaluating these studies, the authors concluded that *"higher job demands are associated with lower future sleep quality"* (p.544); they also found moderate evidence of a positive link between job control and sleep quality. However, they noted that the proportion of variance attributable to these job characteristics was relatively small and, for other measures, including social support, the evidence was insufficient to draw firm conclusions. More specific findings are summarised below.

Job demand. Measures of job demands or job strain (Karasek & Theorell, 1990) are typically found to be strong predictors of adverse sleep outcomes; prospective studies have demonstrated that, among participants free of insomnia at baseline, high demands and/or high strain increases the risk of insomnia at follow-up (Jansson & Linton, 2006; Jansson-Fröjmark et al., 2007; Linton, 2004; Ota et al., 2009). Changes from low to high job demand (Åkerstedt et al., 2012), or job strain (de Lange et al., 2009) are also associated with onset of, or increases in, sleep impairments. Structural modeling analyses have provided further evidence of the causal role of job demand in sleep disturbance (Magnusson Hanson et al., 2014).

Job control. Studies of job control in relation to sleep have tended to produce inconsistent findings. Prospectively, de Lange et al. (2009) found that higher control predicted a reduction in sleep complaints; other studies reported that low influence over decisions predicted maintenance of insomnia over a one-year period (Jansson & Linton, 2006; Jansson-Fröjmark et al., 2007). However, some authors have reported non-significant findings (Åkerstedt et al., 2012; Nakata et al., 2004). Evidence also indicates that '*low control over work time*' predicts impaired sleep (e.g. Kubo et al., 2013; Takahashi et al., 2011). Other studies have produced more complex results, suggesting that additional factors may also be implicated. Thus, among physicians, work-time control was associated with fewer short sleeps (<6 h), but only among those who never worked long shifts (>12 h) (Tucker et al., 2015). Also, increased risk of sleep problems was linked to low work-time control among employees who worked low or average hours, but also to high work-time control among those working very long hours (Salo et al., 2014).

Social support. The nature, magnitude and direction of the relationships between social support and sleep remain unclear. In cross-sectional analyses, Hämmig and Bauer (2014) found that low social support was related to sleep disturbances among industrial employees; other researchers reported similar findings (Åkerstedt, Knutsson, et al., 2002; Sinokki et al., 2010). Prospectively, two studies have shown that low social support predicts the maintenance of insomnia over a one-year period (Jansson & Linton, 2006; Ota et al., 2009), but Magnusson Hanson et al. (2011) identified a significant reverse causal path, sleep disturbance leading to low social support. Saijo et al. (2014) reported 'more-than-additive' effects of job control and social support; low control combined with low support predicted high risk of insomnia.

1.2.2 Physical work conditions

Physical environment stressors and strenuous physical work are also associated with sleep impairments. Among industrial employees, an adverse physical environment, including exposure to noise /vibration and awkward postures (Hämmig & Bauer, 2014; Ribet & Derriennic, 1999) and poor lighting, temperature and ventilation (Nakata et al., 2004), and have been found to increase the risk of insomnia. Strenuous work is also a significant risk factor for sleep disturbance (Åkerstedt, Fredlund, et al., 2002; Åkerstedt, Knutsson, et al., 2002). More generally, Zhang et al. (2015) found that a composite measure of favorable physical/psychosocial work characteristics (including low levels of physical work demands and violence at work, and high physical safety) was inversely and linearly related to the proportion of the sample reporting short sleep duration (defined as $\leq$ 6 h per day).

1.3 Research questions

The findings reviewed above demonstrate that both age and the work environment are significantly associated with sleep impairments. However, a limitation of much research in these areas is that only additive combinations of age and work environment measures are considered (e.g. Åkerstedt, Fredlund, et al., 2002; Ribet & Derriennic, 1999); often, age is treated solely as a control variable (e.g. Ota et al., 2009; Lallukka et al., 2010; Swanson et al., 2011). These approaches may over-simplify the nature of the joint contribution of age and work environment characteristics to sleep impairment. Theoretical models (Israel et al., 1996; Siegrist, 2008) suggest that more complex mechanisms, particularly mediator and moderator effects, may be implicated in pathways that link age and the work environment to health-related outcomes. These mechanisms have rarely been considered in relation to sleep, although Virtanen et al. (2009) noted that high job demands could partially explain links between long work hours and sleep disturbances.

The role of age as a potential moderator of relations between work environment characteristics and sleep remains largely unexplored. Marquie et al. (1999) noted that few studies addressed the extent to which job characteristics interact with age to predict sleep quality. This observation still applies, although in one recent exception, age was found to moderate the association between control over work hours and sleep disturbance (Loudoun et al., 2014). Failure to consider possible moderator effects limits understanding of relations between work characteristics, age and sleep, and may lead to important issues being overlooked. For instance, if older age combines synergistically with adverse work characteristics to predict sleep disturbance, this mechanism could contribute to negative outcomes associated with work intensification (e.g. Worrall & Cooper, 2014).

1.4 Present study

The present study sought to examine how age and measures of the psychosocial/physical work environment combine to predict the duration and quality of sleep. The participants were day-work personnel employed in the North Sea oil/gas industry. Demanding work conditions and long hours are inherent in offshore employment; day-shift personnel work 14 x 12-h shifts (and possible overtime) during offshore work weeks, alternating with 2-3 weeks of shore leave. In the present study, psychosocial work characteristics were assessed with measures of job demand, control, and social support; the physical environment measures assessed adverse ambient conditions (e.g. noise, poor air quality) and strenuous work, respectively. In view of evidence of curvilinear effects of age on sleep, both linear and curvilinear age terms and their interactions with work environment variables were evaluated, using multiple regression methods. It was predicted *a priori* that interactions between age and work characteristics would contribute significantly to variance in sleep outcomes; however, no predictions were made about specific individual interactions. In addition, to address particular concerns about the adverse health and safety consequences of short sleep hours (≤ 6 h per day) (Grandner et al., 2010), further analyses were carried out to identify the extent to which age and work environment characteristics acted as risk factors for short sleep.

2. Method

2.1 Participants and data collection procedure

Personnel working on North Sea oil/gas installations took part in the study. Researchers visited the sites involved to explain the nature of the research (emphasizing that participation was voluntary and that individual data would be treated as confidential) and respond to questions about the work. Two visits were made to each site to enable crew members on leave during the initial visit to take part. Survey materials, identified by ID numbers, were distributed to all personnel on board. Completed questionnaires were returned to the researchers in individual sealed envelopes. Further details of the data collection are given by Parkes (2015a). Completed questionnaires were returned by 971 day-shift personnel (>80% response rate). After exclusion of personnel with less than two months' employment on the installation, females (< 3% of personnel), and those with missing data, 901 personnel remained in the sample.

2.2 Measures

Age. The mean age of participants was 40.8 (SD 8.9) y, range 20 – 61 y.

Psychosocial work environment. Job demand was assessed by five items concerned with quantitative work demands, time pressures, and work overload (Karasek & Theorell, 1990). *Job* *control* was measured with six items referring to control over work tasks, involvement in decision-making, and influence at work. Participants responded on a 5-point, 0 (do not agree at all) - 4 (agree strongly) scale. The measure of *social support* (House, 1981) consisted of eight items (0-3 response scales) assessing support from supervisors and co-workers.

Physical work environment. Six items taken from Hellesøy (1985) assessed the extent to which personnel were exposed to an *adverse physical environment* (e.g., noise, poor air quality, and confined workspace) during work weeks. Exposure to *strenuous manual work* was assessed on a 5-point scale (0 = 'not at all' to 4 = 'to a high extent').

Sleep measures. Sleep duration and sleep quality were assessed separately in relation to offshore day-shift weeks (DS) and leave weeks (LS). The questions: '*When you are working day shifts, how many hours do you usually sleep during the off-shift period?*', and '*How well do you usually sleep during this period?*' (0 – 6 scale), were used to assess DS sleep. LS sleep was assessed with the questions, '*When you are on leave, how many hours do you usually sleep at night?'*, and *'How well do you usually sleep when on leave?'* using the same 0 – 6 response scale.

Control variables. The control variables included in the multivariate analyses were: *installation type*, fixed platforms (n=527 personnel), mobile installations (n=374 personnel); *job categories* (managers /administration, n = 275; maintenance/production/technical, n=451; drilling/deck/ construction work, n=175); *job tenure* (years in present job); and *overtime* (overtime, n=493; standard12-h shifts only, n=408). Two health-related measures associated with sleep impairment, *body mass index* (BMI) and *smoking* were also used as control variables. To take into account individual differences in habitual sleep patterns, *LS sleep duration* and *LS sleep quality* were included in the analyses of DS sleep duration and DS sleep quality, respectively.

2.3 Statistical analysis

Hierarchical regression analysis was used to assess the extent to which DS sleep duration and DS sleep quality were predicted by the main and interactive effects of age and work environment characteristics. In addition, logistic regression was used to identify the extent to which these variables acted as significant risk factors for short sleep duration (≤ 6 h per day).

The hierarchical regression analysis followed the recommendations of Cohen et al. (2003). Continuous variables were standardized prior to analysis. The control variables were entered in two steps: first, the LS sleep measure corresponding to the DS sleep outcome, then the remaining control variables (Model 0). Next, the main additive effects of age and the set of five work environment variables were entered into the model (Model 1).

The following stage (Model 2) had three steps: *Model 2a*. The set of five linear interaction terms, *age x work environment variables*, was evaluated to determine if it accounted for significant incremental variance relative to the additive model. *Model 2b*. The *age*^{2} curvilinear term was entered. *Model 2c*. The higher-order interaction set, *age*^{2} *x work environment variables*, was evaluated to determine if it accounted for significant incremental variance relative to Model 2b. Individual interactions within a set were only interpreted if the set as a whole contributed significantly to the explained variance on entry to the analysis. This approach was consistent with the *a priori* prediction, and reduced the likelihood of Type 1 errors arising from chance findings when multiple interactions are tested individually on an exploratory basis.

Following the method described by Aiken and West (1991), the form of the significant individual interactions was determined from the unstandardized B coefficients in the final reduced model (Model 3), which included control variables, age and work environment variables, and only the interactions (and lower-order component terms) that contributed to a significant interaction set. Interactions were evaluated at high (+1.5 SD) and low (−1.5 SD) levels of the work characteristics. Age, plotted along the x-axis, ran from 27 y (–1.5 SD) to 55 y (+1.5 SD).

3. Results

3.1 Means, standard deviations and inter-correlations of study variables

Descriptive statistics for the study variables are shown in Table 1. Overall mean DS sleep duration (6.74 ± .88 h/night) was shorter ($p<.001$), and DS sleep quality (3.87 ± 1.31) poorer ($p<.001$), than the corresponding LS values. Correlations of age with DS and LS sleep duration were significant and negative, but age was unrelated to sleep quality. Age was also significant in

Table 1
Means, standard deviations and inter-correlations of the study variables

		Mean	s.d.	2	3	4	5	6	7	8	9	10
1.	DS sleep duration (h)	6.74	.88	.22**	.29**	.10**	-.13**	-.18**	-.04	.10**	.02	.10**
2.	DS sleep quality	3.87	1.31		-.04	.35**	.03	-.06	.18**	.23**	-.10**	.00
3.	LS sleep duration (h)	7.73	1.03			.25**	-.19**	.05	-.08*	-.05	.06	.01
4.	LS sleep quality	4.85	1.08				.04	.04	.07*	.05	.01	.07*
5.	Age (y)	40.79	8.94					.14**	.22**	.15**	-.08*	-.10**
6.	Job demands	2.31	.91					[.85]	.17**	-.10**	-.05	-.08*
7.	Job control	2.68	.70						[.73]	.37**	-.23**	-.18**
8.	Social support	3.58	1.15							[.82]	-12**	-.03
9.	Adverse physical environment	1.87	0.87								[.81]	.54**
10.	Strenuous work	1.70	1.22									----

DS = day-shift weeks; LS = leave weeks
N = 901
** p < .01 * p < .05
Coefficient alpha values are shown in the square brackets

relation to the other study variables; older personnel reported more favorable work characteristics. Overall, the inter-correlations among the psychosocial/physical work environment measures and sleep were small to moderate, although several reached significance in the relatively large sample. Among the control variables, LS sleep measures were the strongest predictors of the corresponding DS measures. Smoking, BMI and overtime were significantly and negatively related to DS (but not LS) sleep duration; job tenure was not related to either DS or LS sleep. Type of installation was unrelated to all the sleep measures, but DS sleep duration varied significantly across job types.

3.2 Multivariate analyses: Sleep duration

3.2.1 Multiple regression models

The hierarchical regression method outlined in Section 2.3 was used to evaluate the extent to which the independent variables jointly predicted DS sleep duration. The significance of each model, and the successive change statistics, are shown in Table 2. Each of the models was highly significant overall. The control variables were entered in two steps; first, LS sleep duration, then the other control variables (Model 0). Age and the set of work environment measures, entered at the next stage (Model 1), significantly increased the explained variance relative to the control variables. Next, entry of the linear interaction set, *age x work environment variables*, resulted in a significant R^2 increment (Model 2a). The curvilinear term, *age*^{2}, was non-significant (Model 2b), but entry of the *age*^{2} *x work environment* interaction set gave rise to a further significant increase in R^2 (Model 2c).

The final model retained only the control variables, age and the work environment variables, and the significant linear and curvilinear interactions from Model 2c, together with their lower-order components. The adjusted R^2 value for this reduced model (0.183) did not differ significantly from that for the full interactive model, Model 2c (0.185). Table 3 shows the unstandardized B regression coefficients for the initial additive analysis and for the final interactive model. In the additive model, age was non-significant in relation to DS sleep duration; strenuous

Table 2
Summary statistics for regression analysis predicting sleep duration during work weeks

		Sleep duration								
		Model statistics					Change statistics			
		R^2	Adjusted R^2	F	df	p	R^2 change	F change	df	p
Model 0	LS sleep duration	.083	.082	81.283	1,899	<.001	.083	81.283	1,899	<.001
	+ Control variables	.147	.139	19.189	8,892	<.001	.064	9.546	7.892	<.001
Model 1	Main effects: age and work environment measures	.179	.166	13.805	14,886	<.001	.032	5.799	6,886	<.001
Model 2a	Work environment x age	.194	.177	11.189	19,881	<.001	.015	3.353	5,881	<.005
Model 2b	+ Age^2	.195	.177	10.684	20,880	<.001	.001	1.074	1,880	*ns*
Model 2c	+ Work environment x age^2	.206	.185	9.492	25,875	<.001	.011	3.037	5,875	<.02
Model 3	Final reduced model (main effects and significant interactions only)	.199	.183	12.191	18,882	<.001	.020	5.551	4,882	<.001

Model 0. Control variables*:* LS sleep duration, +Job type, installation type, smoking, BMI, overtime, job tenure. *Model 1.* As Model 0, + age, job demand, job control, social support, strenuous work, adverse physical environment. *Model 2a*. As Model 1, + linear interactions of age with job demand, job control, social support, strenuous work, adverse physical environment. *Model 2b*. As Model 2a, + age^2. *Model 2c*. As Model 2b, + curvilinear interactions of age with work environment variables. Model 3, Reduced model including only main effects and significant interactions from Model 2c.

work was a positive predictor (p<.05), while adverse physical environment showed a negative trend (p<.06). Social support and job demand were also significant in the additive model, but these variables interacted with age. The linear interaction *age x social support*, and the curvilinear interaction, *age^2 x job demand* were both significant; the effect sizes (partial eta squared) for these interaction terms were .011 and .010, respectively.

Table 3

Sleep duration: Regression coefficients from additive and interactive analyses

	Additive model				Final interactive model			
	Unstandardized coefficients		t	p	Unstandardized coefficients		t	p
	B	s.e.			B	s.e.		
Age	−0.035	.030	−1.136	ns	-.056	.031	-1.810	ns
Job demand	−.101	.030	−3.416	<. 001	-.162	.036	-4.541	<.001
Job control	.018	.032	<1	ns	.012	.032	<1	ns
Social support	.086	.030	2.881	<.005	.105	.030	3.524	<.001
Strenuous work	.075	.034	2.214	<.05	.061	.034	1.812	[<.10]
Adverse physical environment	-.063	.033	-1.928	[<.10]	-.060	.033	-1.857	[<.10]
‡Age^2					.003	.024	<1	ns
‡Age x job demand					-.043	.029	-1.504	ns
Age^2 x job demand					.067	.022	3.013	<.005
Age x social support					-.088	.028	-3.140	<.002

N=901. Control variables were included in both models. Continuous predictor variables were standardized prior to entry. Both analyses are adjusted for all other variables in the model.

‡These terms were included as components of the *age^2 x job demand* interaction.

Age x social support. The form of this interaction is shown in Figure 1. At the low level of social support (−1.5 SD), age was non-significant (t<1); DS sleep duration was approximately 6.6 h/day irrespective of age. However, among personnel with high social support, age was significantly and negatively related to sleep duration (B= −.135, t= −2.755, p<.01). The combination of low age (27 y) and high support (+1.5 SD) was associated with mean sleep duration of 7.24 h/day, relative to 6.65 h/day for high age (55 y) combined with high support.

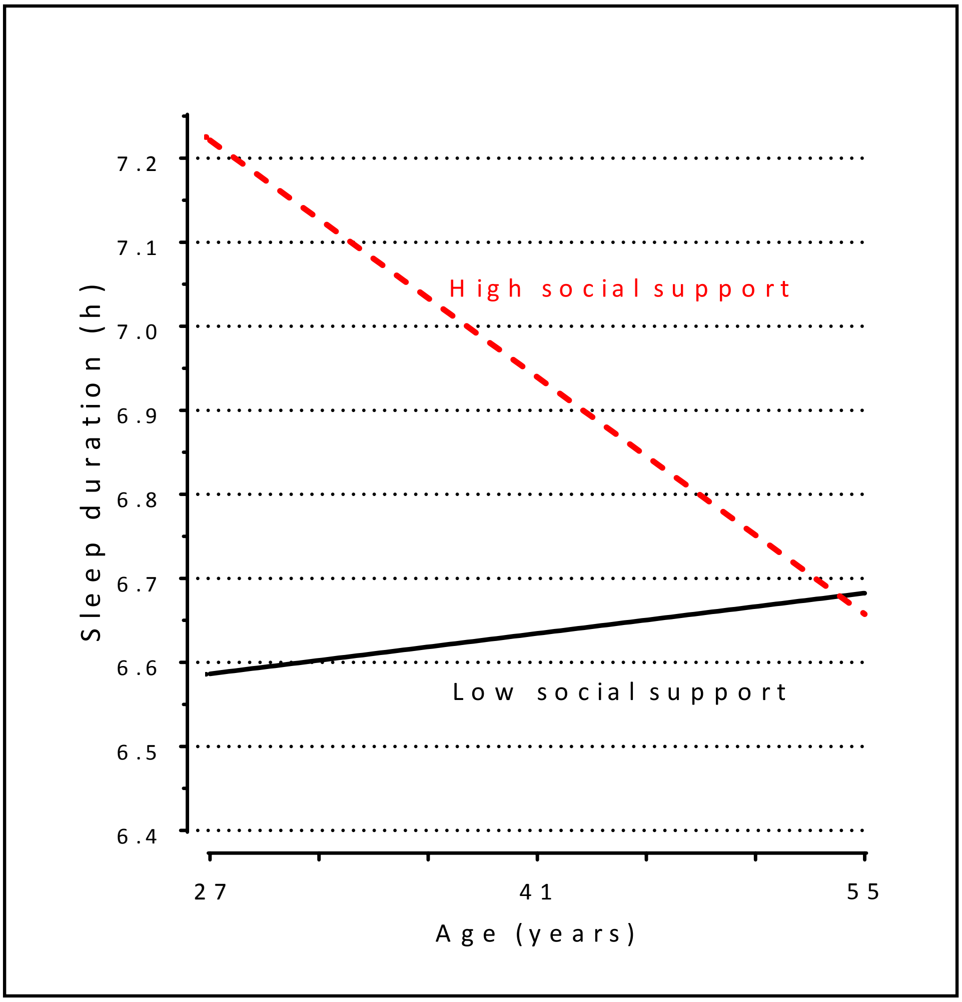

Fig. 1. Sleep duration in relation to age for high (+1.5 SD) and low (−1.5 SD) levels of social support.

Age^2 x job demand. Figure 2 shows the curvilinear interaction between age and job demand. For high job demand (+1.5 SD) the association between age and sleep duration was U-shaped. Sleep duration was 6.88 h/night at age 27 y, but it fell to a minimum of 6.45 h/night in the age range 45-47 y, and then turned upward with increasing age. In contrast, for low demand (-1.5 SD), the relationship took an inverted U form, sleep duration increasing up to the mean age (40.8 y), and subsequently showing a downward slope. These opposing curvilinear trends were significant at the low demand level (B_{age} = .009, *ns*, B_{age^2} = −.097, p<.005), and at the high demand level (B_{age} = −.121, $p<.05$, B_{age^2} = .104, p<.025). The largest difference in sleep duration associated with job demand (~30 minutes per night) occurred in the age range 41- 47 y. At the low end of the age scale, level of demand had no significant impact on sleep, while at ages >47 y the difference in sleep duration decreased progressively relative to the central age range.

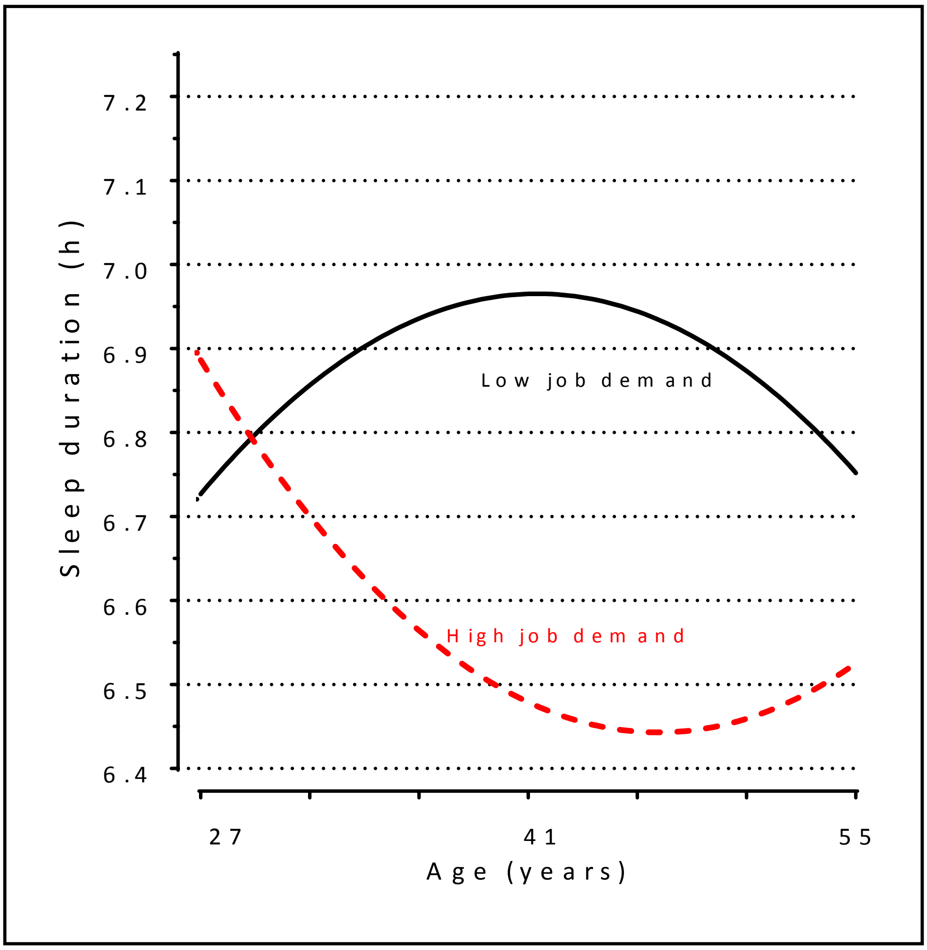

Fig. 2. Sleep duration in relation to age for high (+1.5 SD) and low (−1.5 SD) levels of job demand.

3.2.2 Logistic regression analysis

Further analyses were carried out to identify a sub-group of personnel who reported short sleep hours (i.e. ≤ 6 h per day). In the sample as a whole, 34.4% (n=310 personnel) fell into this 'short sleep' category, while the range >6 to <7 h per day accounted for a further 8% (n=72). Sleep hours in the recommended range of 7 – 9 h per day were reported by the remaining 57.6% of the sample (n=519); however, the great majority of these personnel reported sleep hours of ≤8 h per day (only 2% of the sample, n=18, reported sleep durations >8 h per day). There were no reports of unduly long sleep durations (> 9 h per day). The subsequent analyses focused on identifying age and work environment measures associated with short sleep hours. As shown in Table 4, personnel who reported sleep hours of ≤ 6 h per day were significantly older, higher in job demand, lower in social support, but less exposed to strenuous physical work, than personnel sleeping >6 h per day.

Table 4

Age and work environment variables in relation to short sleep duration

	Sleep duration					
	≤ 6 h N=310		> 6 h N=591		t^1	p
	Mean	SD	Mean	SD		
Age (y)	42.3	8.40	40.0	9.12	3.68	<.001
Job demand	2.51	0.91	2.20	0.90	4.84	<.001
Job control	2.38	0.74	2.33	0.73	1.03	ns
Social support	3.43	1.22	3.66	1.09	−2.88	<.005
Strenuous work	1.59	1.26	1.76	1.20	−2.10	<.05
Adverse physical environment	1.85	0.86	1.88	0.87	<1	ns

[1]df = 899

A logistic regression analysis was carried out to identify the significant risk factors for short sleep. The analysis evaluated additive and interactive models as in Section 3.2.1. The additive logistic regression analysis showed that high age (B = .20, $p<.05$; OR = 1.22, CI 1.02 – 1.45), high workload (B = .30, $p<.001$; OR = 1.35, CI 1.14 – 1.60), and low social support (B = −.26, $p<.005$; OR = .77, CI .65 – .91) were significant risk factors for short sleep duration, over and above the control variables and other terms in the model. In the interactive model, two interactions were highly significant. The *social support x age* interaction ($p<.002$) indicated that low support combined with low age was associated with the highest risk of short sleep. The form of the significant *job demand x age*^{2} quadratic interaction ($p<.005$) was such that, across the age range, different curvilinear patterns of risk applied to high and low demand conditions. Thus, the logistic regression findings broadly reflected those of the multiple regression analysis.

3.3 *Multivariate analysis: Sleep quality*

The regression analysis for sleep quality is shown in Table 5. Entered as the initial control variable, LS sleep quality accounted for a large proportion (R^2 = .122) of the variance explained by Model 0 (R^2 =.134). At the next stage, entering the additive effects of age and the work environment variables gave rise to a significant R^2 increment (Model 1). Entry of the linear *age x work environment* interaction set gave rise to a further significant increase in R^2 (Model 2a). However, neither the quadratic term, *age*^{2}, nor the set of *age*^{2} *x work environment* interactions further increased R^2; these terms were therefore not retained in the model. Table 6 shows the B regression coefficients for the additive model and for the final interactive model (which included the significant interaction from Model 2a). The effect sizes (partial eta squared) for the main effect of social support, and for the *age x job demand* interaction, were .025 and .011 respectively.

Sleep quality was predicted by positively by the main effects of job control and social support, and negatively by adverse physical environment. The significant *age x job demand* interaction ($p<.002$) had a cross-over form (Figure 3). Sleep quality was negatively related to age for high demand (B= −231, t=−2.795, $p<.005$), but the relationship was positive for low demand (B= .162, t=2.292, $p<.05$). Among older personnel, high demand conditions were associated with significantly poorer sleep quality than low demand (at 55 y, B = −.243, t = −3.204, $p<.001$); at younger ages, the difference was reversed, but only marginally significant (at 27 y, $p<.10$).

Table 5

Summary statistics for hierarchical regression analysis predicting sleep quality during work weeks

		Sleep quality								
		Model statistics					Change statistics			
		R^2	Adjusted R^2	F	df	p	R^2 change	F change	df	p
Model 0	LS sleep quality	.122	.121	124.337	1,899	<.001	.122	124.337	1,899	<.001
	+ Control variables	.134	.126	17.185	8,892	<.001	.012	1.771	7.892	[<.10]
Model 1	Main effects: age and work environment measures	.196	.183	15.420	14,886	<.001	.062	11.456	6,886	<.001
Model 2	Work environment x age interactions	.206	.189	12.024	19,881	<.001	.010	2.219	5,881	<.05
**Model 3*	Final reduced model (main effects and significant interaction only)	.205	.191	15.174	15,885	<.001	.009	9.629	1,885	<.002

Model 0. Control variables*:* LS sleep duration, + Job type, installation type, smoking, BMI, overtime, job tenure. *Model 1.* As Model 0, + age, job demand, job control, social support, strenuous work, adverse physical environment. *Model 2*. As Model 1, + linear interactions of age with job demand, job control, social support, strenuous work, adverse physical environment. Model 3, Reduced model including only main effects and significant interaction from Model 2.

Table 6

DS Sleep quality: Regression coefficients from additive and interactive analyses

	Additive model				Final interactive model			
	Unstandardized coefficients		t	p	Unstandardized coefficients		t	p
	B	s.e.			B	s.e.		
Age	−0.011	.044	<1	ns	−.038	.045	<1	ns
Job demand	−.050	.044	−1.145	ns	−.056	.043	−1.287	ns
Job control	.169	.047	3.579	<.001	.159	.047	3.389	<.001
Social support	.193	.044	4.389	<.001	.207	.044	4.698	<.001
Strenuous work	.009	.050	<1	ns	.005	.050	<1	ns
Adverse physical environment	−.116	.049	−2.384	<.025	−.115	.048	−2.382	<.025
Age x job demand					-.125	.040	-3.103	<.002

N=901. Control variables were included in both models. Continuous predictor variables were standardized prior to entry. Both analyses are adjusted for all other variables in the model.

3.4 Further analyses

Exploratory analyses were carried out to test whether higher-order interactions of age with the psychosocial measures contributed significantly to the explained variance in sleep over and above the regression models in Table 2 and Table 5. The two-way interactions among job demand, control and support were entered, followed by the higher-order interactions (e.g. *job demand x job control x age*). Neither set of interactions contributed significantly to explaining variance in the sleep outcomes. Interactions between the two physical environment measures, and between the sets of physical and psychosocial variables, were also non-significant.

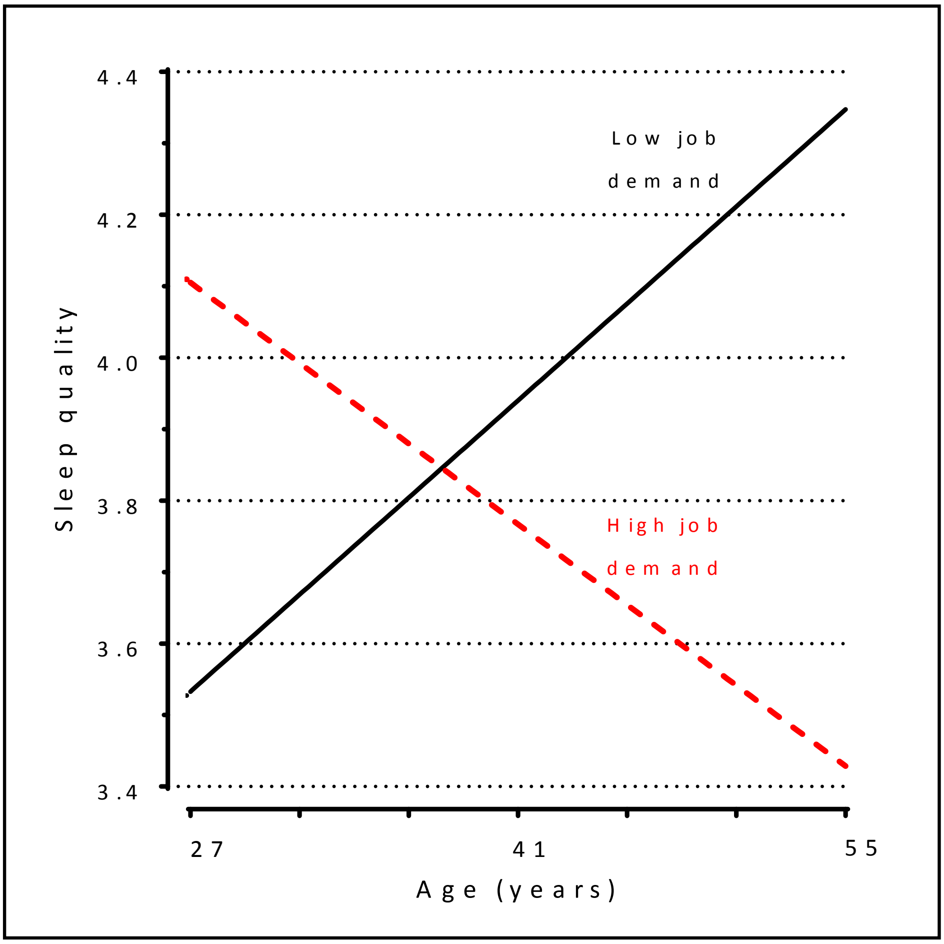

Fig. 3. Sleep quality in relation to age for high (+1.5 SD) and low (− 1.5 SD) levels of job demand

4 Discussion and conclusions

As reviewed in the Introduction, age and work environment measures have been widely studied as predictors of sleep impairment. In the present study, consistent with published findings (e.g. Hämmig & Bauer, 2014; Jansson-Fröjmark et al., 2007; Lallukka et al., 2010), low social support, low job control, and adverse physical environment predicted shorter sleep duration and/or impaired sleep quality, although strenuous work was associated with longer sleep duration. The non-significant main effects of age in relation to sleep found in the present study have also been reported previously (e.g. Takahashi et al., 2014; Waage et al., 2010), as have non-linear age effects (Tucker et al., 2011). Thus, in these respects, the present results are in line with published findings.

The new contribution of the present study was in demonstrating significant curvilinear and linear interactions of age with psychosocial work measures. The general prediction that *work environment x age* interactions would contribute significantly to the explained variance in sleep was supported for both sleep measures. For sleep duration, linear and curvilinear age terms showed significant interactions with the psychosocial environment variables, but only the linear interaction set was significant for sleep quality. In contrast, measures of the physical environment and strenuous work showed no significant interactions with age; only main effects were significant.

4.1 Age and psychosocial variables as predictors of sleep duration

High support at work has been linked to more favorable sleep in previous research (e.g. Ota et al., 2009), while higher age has been linked to sleep disturbances (e.g. Moraes et al., 2014). However, the *age x social support* interaction showed that sleep duration was negatively related to age only when support was high. Thus, younger personnel (27 y) reported significantly longer sleep duration (7.2 h/night) than those who were older (6.7 h/night, 55y) under high support conditions. When support was low, sleep duration (~6.6 h/night) was unrelated to age. These findings suggest that level of support is particularly important for the sleep of younger personnel, possibly because they have more limited experience of offshore work and hence greater need of support from supervisors and co-workers. While the present study does not identify intervening variables these relationships, high support plays a role in reducing anxiety and depression (Clark et al., 2012; Dour et al., 2014), and promoting mastery at work (Ljoså et al., 2013); conversely, inadequate support acting through these pathways may increase anxiety and hence impair the sleep of younger workers.

The form of the curvilinear *age^2 x job demand* interaction showed that the relationship between age and sleep duration was U-shaped when job demand was high but had an inverted U-shape when job demand was low. For high job demand, the curvilinear relationship was such that sleep duration initially decreased with increasing age, reaching a minimum of 6.44 h per day in the age range 44-49 years, followed by an upturn at higher ages. Evidence of a non-linear relationship of sleep duration with age is consistent with other published findings (e.g. Sekine et al., 2006; Tucker et al., 2011). In particular, Tucker et al. found that the adverse effects of shift work on sleep were most apparent among middle-aged participants, and suggested that the curvilinear effect could be explained by personnel choosing to give up shift work at an age when they found sleep adaptation increasingly difficult, leaving a more adaptable 'survivor' group.

Similarly, in a study of naval personnel, Bridger et al. (2010) noted that older and younger personnel did not differ in need for recovery from work, and noted that this result could be due to a survivor effect. The present findings suggest that survivor effects may also apply to offshore personnel in high demand jobs; thus, at age 45-50 y, if personnel find that workload and time pressures significantly impair their sleep, they may leave offshore work either voluntarily, or involuntarily (e.g. from loss of medical certificate). It is also possible that some personnel choose to continue working offshore but move to less demanding roles. In a study of older (>50 y) workers, Volkoff et al. (2010) noted that some employees used this strategy as a way of 'sheltering from the job'. In the present study, in contrast to the findings for high demand, under low demand conditions the relationship between age and sleep duration took an inverted U-shape. Sleep duration increased up to mean age (41 y) and then showed a decrease comparable to that found in the general population (e.g. Moraes et al., 2014). Thus, overall, the difference in sleep duration between high and low demand conditions was most apparent at ages 41–46 y, with lesser differences on either side of this range.

Sleep durations of ≤ 6 h per day are associated with impaired health and performance (van Dongen et al. 2003; Grandner et al. 2010); they are therefore a particular cause for concern among personnel, such as the present participants, with responsibility for safety-critical tasks in hazardous environments. The prevalence of self-reported short sleep duration varies across industries and occupations, but the prevalence level found in the present study (34.4%) was closely similar to that found for manufacturing employees (34.8%) in a large-scale epidemiological study (Luckhaupt et al., 2010). Logistic regression analysis identified high age, high job demand, and low social support as significant risk factors for short sleep duration in the present sample, but there was also evidence of significant linear and curvilinear interactions similar to those already considered.

An expert review panel recently recommended sleep durations in the range 7 – 9 h per day for healthy adults (Hirshkowitz et al., 2015); the majority (57.6%) of the present sample reported sleep durations in this range. Unduly long sleep durations (i.e. >9 h per day) are associated with poor health outcomes (e.g. Lallukka et al., 2014). However, the offshore work pattern largely precludes extended sleep hours; in the present sample, there were no reports of sleep durations > 9 h per day; moreover, only 2% of personnel reported sleep hours in excess of 8 h per day.

4.2 Age and psychosocial variables as predictors of sleep quality

Sleep quality was predicted by a linear *age x job demand* interaction; the association between age and sleep quality was negative for high job demand but positive for low job demand. The cross-over form of this interaction is consistent with a ‘person-environment’ fit model (Caplan, 1987). Thus, impaired sleep quality among younger personnel may be attributable to boredom and frustration at routine monotonous tasks, as reflected in perceived low job demand while, among older workers poor sleep quality may reflect difficulty coping with work overload, time pressures, and operational demands. However, there was no evidence of an upturn in sleep quality at higher ages among older personnel exposed to high job demands which suggests that poor sleep quality was not implicated in the apparent ‘survivor’ effects found for sleep duration.

The finding that older age and high job demand combined synergistically in predicting sleep impairments merits particular comment as offshore employees in the 45-55 y age range typically include a high proportion of senior personnel with day-to-day responsibility for the safe operation of the installation, and the well-being of all on board. Thus, their ability to manage potentially hazardous production processes, to make effective decisions, and to respond to emergencies is of critical importance. Sluiter (2006) identifies ways in which highly demanding jobs may overtax the capacities of older workers with adverse repercussions for performance and health; impaired sleep may be a contributing factor.

For instance, Volkoff et al. (2010) found high rates of sleep disorders and fatigue among older workers (>50 y) who reported difficulty managing work pressures. Similarly, Devereux and Rydstedt (2009) noted that, relative to their younger co-workers, older workers had a significantly greater need for recovery at the end of a day of high work demands. Overall, the present findings suggest that high job demands may be particularly detrimental to the sleep of older personnel, and a potential cause of senior personnel choosing to retire or move to another job at an earlier age than they might otherwise do, thus depriving the offshore industry of skilled and experienced personnel.

4.3 Conclusions

At a time of increasing life expectancy, older employees are encouraged to remain in the workforce longer than has traditionally been customary. Difficulty recruiting skilled personal has further increased the need for older people to remain at work, while global economic pressures have exposed many employees to longer work hours and greater work demands. Thus, it has become increasingly important to understand how age and work conditions are jointly implicated in individual and organizational well-being. If, as the present study suggests, synergistic combinations of older age and high job demands give rise to 'more-than-additive' adverse effects on sleep, then individual and organizational consequences may be particularly severe.

However, the findings of the present study derive from an unusually challenging work environment; thus, caution is needed in considering the relevance of the findings to more typical work settings. In particular, work on North Sea installations imposes demanding psychosocial and physical work conditions, an isolated environment, extended work periods and long work hours, conditions rarely encountered in onshore industry. Also, offshore personnel are required to meet rigorous medical standards (Oil & Gas, UK, 2008); they therefore represent an exceptionally 'healthy worker' group, more likely to be able to cope with adverse work conditions than comparable onshore employees. In both these respects, the present sample cannot be regarded as representative of the onshore workforce.

It is also important to emphasize that cross-sectional datasets, such as that analyzed in the present study, do not permit causal interpretation. Moreover, the effect sizes for the significant main and interactive effects were small, raising questions as to the practical significance of the findings. Small effect sizes were also noted by Van Laethem et al. (2013) in a systematic review of psychosocial work characteristics in relation to sleep. These authors consider several possible explanations, including the limited work characteristics examined relative to the total profile of psychosocial factors that may influence sleep. In the present study, small effect sizes may also be partially attributable to the homogeneous nature of the sample (all personnel were exposed to the same work and living conditions while offshore), and the constraints of offshore work schedules which largely preclude sleep hours in excess of 8 h per day, thus reducing the variability in sleep that would be expected in more heterogeneous samples.

In spite of these limitations, the present findings are consistent with the few studies of onshore work settings that address similar issues (Bridger et al., 2010; Devereux & Rydstedt, 2009; Volkoff et al., 2010). It is also relevant that the work conditions of onshore industry employees have become more stringent in recent years (Chandola, 2010), and some evidence suggests that among oil/gas industry personnel the intensity of job demands and pressures experienced at onshore sites is greater than that offshore (Bjerkan, 2011). Moreover, in the present study, the mean sleep durations reported (6.74 h/night, DS sleep; 7.73 h/night, LS sleep) were similar to those found in a national sample of U.S. employees (workdays, 6.8 h; non-work days, 7.5 h) (Swanson et al., 2011), and the proportion of the sample reporting sleep of ≤ 6 h per day (34.4%) agreed closely with epidemiological data for manufacturing employees (Luckhaupt et al., 2010).

Overall, the available evidence does not allow definite conclusions about the extent to which the present findings would be applicable to industry employees in general; more rigorous prospective research is needed to clarify the nature, magnitude, and consequences of the combined effects (including indirect pathways) of age and work environment characteristics on individual and organizational outcomes. Such research would not only contribute to further development of theoretical models but it would also have important practical implications for job design.

5. Methodological issues

Interpretation of the present findings is limited by the cross-sectional self-report methodology, which precludes causal interpretation and is potentially subject to problems of common method variance. In addition, sleep was assessed by single items, rather than established scales, and no objective sleep assessments were employed; use of actigraphic methods would have allowed additional information about sleep patterns (e.g. time in bed, sleep latency, and number of awakenings) to be recorded, thereby providing a more comprehensive account of offshore sleep patterns. Similarly, use of subjective measures of daytime sleepiness would have extended the relatively limited outcome measures used in the present study.

However, some aspects of the present study design were more favorable. In particular, separate measures of sleep during offshore weeks (DS measures) and leave weeks (LS measures) were obtained, allowing the LS measures to be treated as control variables for the corresponding DS measures. Thus, the study examined the extent to which, relative to sleep during leave weeks, sleep during work weeks was associated with offshore work characteristics. In this way, the analyses controlled for individual differences in habitual sleep patterns, and ‘third factor’ effects which may confound cross-sectional associations between self-reported work conditions and sleep. However, inclusion of other individual difference measures relevant to sleep, such as chronotype (Horne & Ostberg, 1976), personality, e.g. neuroticism, extraversion, and locus of control (Saksvik et al., 2011), and anxiety (Strine & Chapman, 2005) would be a valuable addition to future research in this area.

These and other methodological aspects of offshore survey research are considered in more detail by Parkes (2015b). In summary, from a methodological viewpoint, the present study highlights the need to adopt more sophisticated, prospective designs in future research into offshore sleep patterns, to combine objective (actigraphic) and subjective (established validated scales) sleep assessments, and to include measures of chronotype, personality, and other individual differences.

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