Associations between seasonal variations in day length (photoperiod), sleep timing, sleep quality and mood: a comparison between Ghana (5°) and Norway (69°)

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SUMMARY

The hypothesis of whether day length (photoperiod) is an important zeitgeber (time-giver) for keeping the circadian rhythm entrained to a 24-hour cycle was examined, as was its association with sleep patterns and mood problems. Data were collected prospectively from a site with very large differences in daylight duration across seasons (Tromsø in Norway, 69°39′N) and a site with very small seasonal differences in daylight duration (Ghana in Accra, 5°32′N). Two hundred subjects were recruited from both sites in January. At the follow-up in August, 180 and 150 subjects in Ghana and Norway participated, respectively. Use of a weekly sleep diary indicated low to moderately strong seasonal changes in rise- and bedtime, sleep efficiency and sleep onset latency only in the northern latitude. No seasonal changes in sleep duration or night awakenings were observed. The self-report measures indicated moderate to strong seasonal differences in insomnia and fatigue, and weaker differences in depressed mood in Norway, but small to non-existing seasonal differences in Ghana. Lack of daylight was related to phase-delayed rise- and bedtimes, increased problems falling asleep, daytime fatigue and depressive mood. However, total sleep duration and sleep quality appeared unaffected.

INTRODUCTION

Sleep is a behaviour regulated by two independent factors: a sleep-dependent homeostatic factor and a sleep-independent circadian factor (Borbely *et al.*, 1989). The homeostatic drive factor is a function of prior wakefulness that declines exponentially during sleep and increases linearly during wakefulness. The circadian factor is governed by the suprachiasmatic nuclei (SCN) in the hypothalamus and has an endogenous rhythm that is somewhat longer than 24 hour. It is entrained by external stimuli (zeitgebers: time-givers) to adhere to a 24-hour rhythm (Duffy and Wright, 2005). Its contribution to wakefulness is at its minimum in the early morning and at its maximum in the evening, when the core body temperature is usually lowest (nadir) and highest, respectively (Dijk and Czeisler, 1995).

Daylight is the most important zeitgeber, but the entrainment effect of light depends upon when the light exposure takes place. Exposure prior to temperature nadir will phase-delay the circadian rhythm, while exposure after nadir will phase-advance the circadian rhythm (Khalsa *et al.*, 2003). In the total absence of light, the circadian rhythm might be free-running and successively delayed each night (Czeisler *et al.*, 1999). Hence, lack of proper entrainment of the endogenous circadian rhythms might cause circadian rhythm sleep disorders (Bjorvatn and Pallesen, 2009). The increased report of winter insomnia in areas north of the Polar Circle (Husby and Lingjærde, 1990), when light is absent for several months, may be caused by a lack of daylight exposure in one's biological morning.

As the amount of daylight varies hugely between seasons in polar areas and zero at the equator, to what extent people living near the poles experience more seasonal variations in sleep compared with people living near the equator may be studied. Systematic studies are few, however. In a study of 10 healthy male subjects in Japan, subjects both went to bed and woke up earliest in the summer and latest in the winter (Honma *et al*., 1992). In a large cross-sectional study in Norway, individuals reported more problems falling asleep during winter than during summer, combined with a higher frequency of daytime impairment (Pallesen *et al*., 2001). Seasonal changes in sleep duration show conflicting results. In a German study, 34 medical students slept 18 min longer in autumn than in spring (Lehnkering and Siegmund, 2007). In New Zealand, the sleep duration was 41 min longer among children during winter than in summer (Nixon *et al*., 2008). However, in Iceland, sleep duration was longer only in winter than in spring among pre-school children (Thorleifsdottir *et al*., 2002), but not among older children or adolescents.

Light may also affect mood. A study comprising 24 subjects in Rochester (44°N) and 30 subjects in San Diego (32°N) found more depression symptoms during winter than summer in Rochester only (Park *et al*., 2007). Low levels of daylight have therefore been suggested as a causal factor in seasonal affective disorder (SAD), supported partly by reports of higher prevalence of SAD at higher latitudes (Mersch *et al*., 1999) and evidence of bright light therapy alleviating winter depression (Golden *et al*., 2005).

In order to increase the power of detecting differences in seasonal influences on sleep and mood, we collected data prospectively from two parts of the world with large seasonal variations in daylight. In Tromsø in Norway (69°39′N) the average duration of visible sunlight is 4.4 h and 16.1 h in January and in August, respectively, while the corresponding numbers for Accra in Ghana (5°32′N) are about 11.9 and 12.2 h, respectively.

Hypothesis

Subjects in Tromsø (69°) were expected to show notable seasonal variations in sleep diary data (i.e. a phase-delay in sleep start and sleep end, longer sleep onset latency, reduced sleep efficiency and longer sleep duration during the winter) and questionnaire data (i.e. more reports of insomnia, fatigue and negative mood during winter), whereas no or minimal seasonal differences were expected among participants from Accra (5°). The prevalence of SAD estimates was expected to be higher in Tromsø than in Accra.

MATERIALS AND METHODS

Participants

Wave 1

Subjects were recruited during lectures at the Universities of Ghana and Tromsø in January 2009. In Ghana, 96 women [25.4 years of age, standard deviation (SD) = 7.5, range 19–49] and 104 men (25.3 years of age, SD = 6.1, range 19–51) participated. In Tromsø, Norway, 145 women (22.7 years of age, SD = 4.8, range 19–50) and 53 men (22.7 years of age, SD = 5.5, range 18–54) participated. The number of female participants was significantly higher in Norway (72.5%) than in Ghana (48.0%) ($\chi^2_1 = 26.9$, $P < 0.001$), reflecting the fact that 60% and 33% of the University students in 2008 in Tromsø and Accra, respectively, were women. Students in Ghana were slightly older (25.4 versus 22.7 years of age) ($t_{396} = 4.49$, $P < 0.001$) and had more years of education (2.9 versus 2.0 years) ($t_{394} = 7.14$, $P < 0.001$) compared with Norwegian students.

Wave 2

In August 2009, 180 participants responded in Ghana (10% loss), while 150 responded in Norway (25% loss). A withdrawal analysis found no differences between participators and non-participators in Ghana. In Norway, only one difference emerged showing that students dropping out of the study had a later rise-time (09 : 29 h) than those who did not (08 : 56 h) ($t_{198} = 2.81$, $P = 0.005$).

Other sample differences

While 25 students in Ghana were married or had a partner, 89 students in Norway had a partner ($\chi^2_1 = 53.4$, $P < 0.001$). No differences emerged in birth month or number of children.

Study design

The design of the study was mixed factorial composed of a between-group factor (latitude : 5° versus 69°) and a within-group factor (season : January versus August).

Procedures

Sleep data were measured by examination of a sleep diary that the students kept for 1 week at home. The questionnaire was completed at home before the sleep diary was completed. Participants in Tromsø were paid 200 NOK (approximately US30) *twice*. In Accra, the payment was US10 due to a lower mean income. All participants received written information about the study and provided informed consent before participating. They were instructed to complete the sleep diary each morning and to return the material 1 week later, at which time they were paid. A unique code was assigned to each sleep diary and the questionnaires in order to de-identify them, according to the requirements of the Norwegian Data Inspectorate. The study was approved by the Regional Committee for Medical and Health Research Ethics in Norway.

Differences in activities

The daytime activities for the university students in January and August were comparable between countries as the data were collected at the beginning of the first and second semester at both sites.

Differences in climate

The most distinct climate variations in Ghana concern the wet and dry seasons. In January the weather is generally dry, with sunny skies and an average temperature of 27 °C. It has two rainy seasons, one peaking in May/June and the other in October, and August normally has scattered showers and a temperature of approximately 24 °C. The humidity is constant at approximately 80%. The most distinct climate changes in Tromsø, Norway, are variations in temperature and precipitation type. In January, the average temperature is −4 °C, with a snow depth of approximately 70 cm. In August, the average temperature is 11 °C. Maximum precipitation occurs in October (129 mm), with about 92 mm and 79 mm in January and August, respectively. The humidity is constant at about 79%.

Instruments

Demographics

Questions about age, sex, month and place of birth, years of education, marital status and number of children were included.

Sleep diary

The sleep diary contained questions of daily time estimates for going to bed (bedtime), sleep onset latency (SOL), number and duration of nightly awakenings (NWAK and WASO), time for getting out of bed (rise-time) and duration of daytime naps (DN). The parameters that were calculated from the sleep diary were total time in bed (TIB), early morning awakening (EMA; time from waking up to getting out of bed), total sleep time or duration (TST) and sleep efficiency (SE% = TST/TIB × 100) (Lichstein and Riedel, 1994).

The Bergen Insomnia Scale (BIS) is a recently developed scale that measures insomnia comprising six items covering both nocturnal and daytime symptoms. Each item is scored along an eight-point scale (range : 0–7 days per week), indicating symptom frequency. Total scores ranges were 0–42. Higher scores indicate more insomnia complaints (Pallesen *et al.*, 2008).

The Fatigue Questionnaire (FQ) consists of 11 items (seven items measuring physical fatigue and four measuring mental fatigue). Each item is scored 0–3 (total range 0–33) and higher scores indicating higher levels of fatigue. The scales are suitable for normal populations and have good psychometric properties (Chalder *et al.*, 1993).

The Hospital Anxiety and Depression (HAD) scale consists of seven items assessing the non-vegetative symptoms of depression and seven items assessing the non-vegetative symptoms of anxiety. Items are scored 0–3 for a total range of 0–42. It is used widely as a screening instrument with a cut-off score ≥8 indicating a potential diagnosis of depression or anxiety, respectively (Øyane *et al.*, 2008b).

The Seasonal Pattern Assessment Questionnaire (SPAQ) is used to assess seasonality and SAD. The global seasonality score (GSS) assesses seasonality in sleep, mood, weight, energy, social activity and appetite (item range : 0–4; total range : 0–24). In addition, the SPAQ contains one item measuring which months of the year the person feel worst, and another item assessing in what degree seasonal variations represent a problem for the respondent. Both SAD and subsyndromal SAD criteria were computed similarly, as in (Mersch *et al.*, 2004): (1) feeling worst in the winter months (December, January or February), (2) a GSS score of ≥11 and (3) experiencing seasonal change as a 'moderate problem' or worse. The criteria for subsyndromal SAD were: a GSS score ≥11 and experiencing seasonal changes as no problem or a GSS score ≥9 and at least experiencing it as a mild problem.

Statistics

Linear mixed regression analyses (restricted maximum likelihood) was conducted in PASW version 18.0.2 to include all available observations at both time-points, hence producing more correct error bands than a repeated analysis of variance (ANOVA). Least significant difference (LSD) *post-hoc* tests were used. Cohen's $d\left(\frac{t}{\sqrt{n}}\right)$ was used to indicate the effect size (0.2 as small, 0.5 as moderate and 0.8 as large). Differences in proportions of SAD cases between latitudes were compared using the log-likelihood ratio (G).

RESULTS

Descriptive data

The internal consistency of the scores was adequate to good (Cronbach's α = 0.66–0.86). Descriptive statistics for the sleep diary and questionnaire data are presented in Tables 1 and 2, respectively.

Seasonal changes in sleep diary data

As shown in Table 1, four of the nine interaction tests (season × latitude) for work days were significant, but none of the tests for weekend days were significant. *Post-hoc* tests of workdays confirmed that the differences between seasons were only significant in the northern latitude, and hence these were analysed further.

Seasonal variation in sleep patterns

Normal sleep patterns, namely, bedtime, rise-time and TST, differed between latitudes. Norwegians went to bed 1.3 and 2.7 h later than Ghanaians during work- and weekend days, respectively ($P < 0.001$, both), and correspondingly rose

Table 1 Descriptive and inferential statistics for the weekly sleep diary data

	Ghana 5º						Norway 69º								
	Workdays (1–5)			Weekend days (6–7)			Workdays (1–5)			Weekend days (6–7)					
	January n = 200 mean (SD)	*August* n = 180 mean (SD)	d_s	*January* n = 200 mean (SD)	*August* n = 180 M (SD)	d_s	*January* n = 200 mean (SD)	*August* n = 150 mean (SD)	d_s	*January* n = 200 mean (SD)	*August* n = 150 mean (SD)	d_s	F_{LxS} 1–5	F_{LxS} 6–7	F_{LxS} 1–7
Bedtime	22 : 38 (0.89 h)	22 : 31 (0.86 h)	NS	22 : 35 (0.97 h)	22 : 29 (1.08 h)	NS	23 : 59 (1.08 h)	23 : 47 (0.94 h)	0.14**	1 : 15 (1.42 h)	1 : 03 (1.42 h)	NS	NS	NS	NS
SOL	0.22 h (0.16 h)	0.19 h (0.13 h)	NS	0.23 h (0.20 h)	0.18 h (0.14 h)	NS	0.52 h (0.55 h)	0.39 h (0.33 h)	0.30***	0.36 h (0.48 h)	0.26 h (0.20 h)	0.25***	8.23**	NS	7.62**
NWAK	0.99 (0.63)	0.95 (0.62)	NS	0.85 (0.78)	0.75 (0.59)	NS	0.95 (0.93)	0.81 (0.79)	0.10*	0.83 (10.10)	0.78 (0.87)	NS	NS	NS	NS
WASO	0.25 h (0.28 h)	0.24 h (0.27 h)	NS	0.22 h (0.31 h)	0.21 h (0.26 h)	NS	0.15 h (0.19 h)	0.13 h (0.16 h)	NS	0.15 h (0.24 h)	0.15 h (0.26 h)	NS	NS	NS	NS
EMA	0.28 h (0.23 h)	0.34 h (0.36 h)	NS	0.29 h (0.29 h)	0.36 h (0.49 h)	0.11*	0.33 h (0.38 h)	0.23 h (0.25 h)	0.18***	0.39 h (0.42 h)	0.44 h (0.65 h)	NS	16.29***	NS	11.69***
Rise-time	6 : 30 (0.89 h)	6 : 26 (0.86 h)	NS	6 : 39 (0.93 h)	6 : 38 (10.17 h)	NS	8 : 36 (10.30 h)	8 : 04 (10.04 h)	0.33***	10 : 06 (1.66 h)	10 : 00 (1.69 h)	NS	15.51***	NS	10.38***
TST	6.82 h (1.02 h)	6.90 h (1.09 h)	NS	6.91 h (1.48 h)	7.03 h (1.64 h)	NS	7.27 h (0.95 h)	7.1 4 h (0.97 h)	NS	7.85 (1.99 h)	7.92 (1.80 h)	NS	NS	NS	NS
SE (%)	86.1 (6.3)	86.4 (7.2)	NS	86.5 (7.9)	86.6 (9.5)	NS	84.8 (9.5)	87.4 (7.3)	0.22***	86.9 (8.9)	88.1 (8.8)	NS	7.47**	NS	6.07*
DN	0.39 h (0.27 h)	0.35 h (0.32 h)	NS	0.48 h (0.42 h)	0.36 h (0.38 h)	0.17**	0.16 h (0.27 h)	0.18 h (0.27 h)	NS	0.22 h (0.46 h)	0.14 h (0.34 h)	NS	NS	NS	NS

All means and standard deviations are adjusted for the covariates gender, age, marital status and education. $^{*}P < 0.05$; $^{**}P < 0.01$; $^{***}P < 0.001$. d_s: Cohen's *d* effect size for the seasonal difference. F_{LxS}: *F*-test for the interaction latitude × season, 1–5 workdays, 6–7 weekend days, 1–7 all days. SOL, sleep onset latency (minutes); NWAK, number of awakenings; WASO, wake time after sleep onset (minutes); EMA, early morning awakening (minutes); rise-time = time leaving bed; TST, total sleep time (hours); SE, sleep efficiency (%); DN, daytime naps (minutes); NS, non-significant.

Table 2 Descriptive and inferential statistics for the questionnaire data

	Ghana 5º			*Norway 69º*				
	January (*n* = 200) mean (SD)	*August* (*n* = 180) mean (SD)	d_s	*January* (*n* = 200) mean (SD)	*August* (*n* = 150) mean (SD)	d_s	F_{LxS}	*G*
GSS	8.17 (4.22)	7.90 (4.47)	NS	7.62 (4.30)	7.35 (3.94)	NS	NS	
SAD		5/179 (2.8%)			13/146 (8.9%)			5.82*
		♀2/86 (2.3%)			♀11/110 (10.0%)			5.14*
		♂3/93 (3.2%)			♂2/36 (5.6%)			NS
Sub SAD		11/179 (6.1%)			26/146 (17.8%)			10.94***
		♀7/86 (8.1%)			♀22/110 (20.0%)			5.69*
		♂4/93 (4.3%)			♂4/36 (11.1%)			NS
SAD+HAD-D		1/179 (0.6%)			5/146 (3.4%)			3.79
		♀0/86 (0.0%)			♀4/110 (3.6%)			4.69*
		♂1/93 (1.1%)			♂1/36 (2.8%)			NS
BIS	13.25 (6.83)	12.02 (6.90)	0.17*	10.79 (7.62)	6.97 (6.00)	0.53***	10.71***	
Physical fatigue	6.51 (4.03)	6.04 (3.49)	NS	9.88 (3.11)	6.83 (3.33)	0.76***	33.93***	
Mental fatigue	2.69 (2.05)	2.65 (1.90)	NS	4.87 (1.53)	4.05 (1.66)	0.42***	13.29***	
HAD-A	6.14 (3.52)	6.64 (4.23)	NS	5.77 (3.28)	5.28 (3.44)	NS	6.05*	
HAD-D	4.80 (3.25)	4.95 (3.53)	NS	3.30 (2.75)	2.45 (2.62)	0.26**	7.73**	

All means and standard deviations are adjusted for the covariates gender, age, marital status, education and rise-time. *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$. d_s = Cohen's *d* effect size for the seasonal difference. F_{LxS}: *F*-test for the interaction latitude × season. *G*: log likelihood-ratio for the between latitude difference. GSS, global seasonality score; SAD, seasonal affective disorder; SAD+HAD-D, Same as SAD, but excluding summer depressants; BIS, Bergen Insomnia Scale; HAD-A, Hospital Anxiety and Depression, anxiety subscale; HAD-D, Hospital Anxiety and Depression, depression subscale; NS, non-significant.

from bed 1.9 and 3.4 h later than Ghanaians ($P < 0.001$, both). The interaction term was not significant, as expected, although the *post-hoc* tests indicated that Norwegians went to bed 12 min earlier on work days during summer compared with winter ($P < 0.01$, Fig. 1a). The interaction term for rise-time was significant, however. The *post-hoc* tests were only significant for Norwegians, indicating that they rose from bed 32 min earlier during summer than winter ($P < 0.001$, Fig. 1b).

TST (or sleep duration) differed between latitudes, Norwegians sleeping about 21 and 55 min ($P < 0.001$, both) longer during work- and weekend days compared with the Ghanaians. The interaction term was not significant, nor were the *post-hoc* tests, thus indicating that the shifted timing in bedtimes and rise-times did not affect total sleep duration.

Seasonal variation in other sleep parameters

The most important variables were SOL, WASO/NWAK, EMA and SE%. The results from three of these indicators favoured our hypothesis. First, the SOL interaction term was significant, and the *post-hoc* tests confirmed a SOL reduction of 8.1 min ($P < 0.001$) from winter to summer only occurring in Norway (Fig. 1c). The SOL variance statistics were notably larger in Norway during winter than during summer (SD = 33 versus 20 minutes; Levene's $F_{329} = 4.34$, $P < 0.05$), but equal in Ghana (SD = 13 versus 11 min).

The interaction term for the SE% was significant, indicating a differential pattern of seasonal change. Sleep efficiency increased 2.6% from winter to summer in Norway ($P < 0.001$), but was similar across seasons in Ghana (Fig. 1e).

Early morning awakening data supported the hypothesis. The interaction term was significant, and the *post-hoc* tests showed a reduction in EMA of 6 min ($P < 0.001$) from winter to summer only in Norway (Fig. 1d). There was a slight inverse relation in Ghana, which disappeared if requiring $P < 0.01$ due to the number of tests. The WASO and the NWAK interaction terms were not significant.

Effects of season on questionnaire data

The questionnaire data revealed a comparable pattern of results (Table 2). Insomnia problems were more prevalent in Ghana than in Norway ($P < 0.001$). Most importantly, the interaction term was significant. The *post-hoc* tests revealed that insomnia problems decreased in both countries from January to August (Fig. 2a), but definitely strongest in Norway ($d = 0.53$ versus 0.17).

The interaction effects for mentally and physically experienced fatigue were both significant, but strongest for the physical fatigue scale ($d = 0.76$ versus 0.42). Again, these seasonal changes were only present in Norway ($P < 0.001$, $P < 0.001$) going markedly down from winter to summer (Fig. 2b,c).

Changes in anxious and depressed mood and SAD

The interaction term for anxiety was significant. However, as none of the *post-hoc* tests were significant, a negative

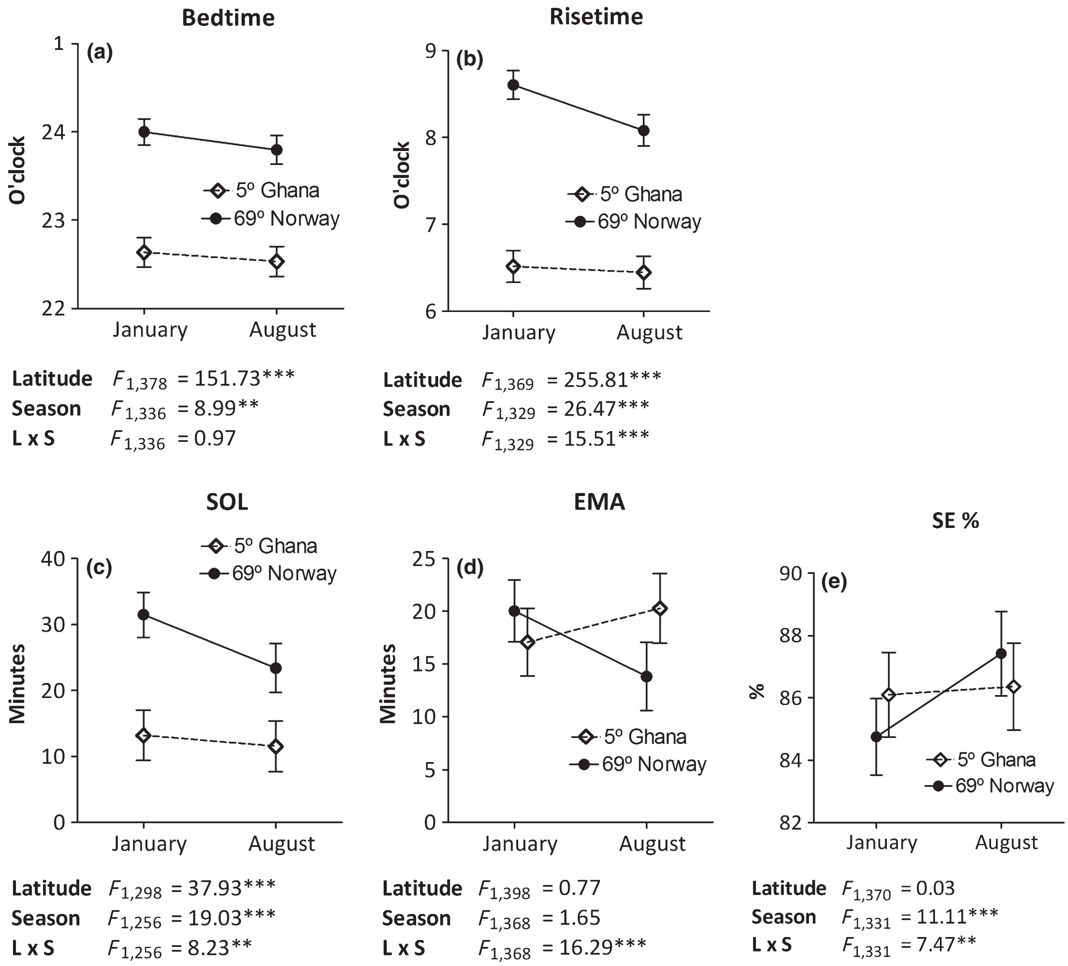

Figure 1. (a) Time for going to bed in decimal hours during workdays, depending on season and latitude. (b) Time for getting out of bed in decimal hours during workdays, depending on season and latitude. (c) Sleep onset latency in minutes during workdays, depending on season and latitude. (d) Degree of early morning awakening in minutes during workdays, depending on season and latitude. (e) Sleep efficiency in percentage during workdays, depending on season and latitude.

change in anxious mood from summer to winter could not be ascertained (Fig. 2d).

The interaction term for depression was significant. *Post-hoc* tests ascertained that a reduction in depressive symptoms from winter to summer was only present in Norway ($P = 0.002$, Fig. 2e). However, the effect size was small. Using a cutoff score ≥8 classified 15 of 198 (7.6%) and 12 of 149 (8.1%) subjects as having a potential depression during winter and summer, which was a non-significant change.

The GSS of the SPAQ was based on average January and August ratings. The mean GSS difference between latitudes was not significant, which was unexpected. The coding of seasonal changes as a ‘problem’ was based on January data to avoid underestimation during the summer (Mersch *et al.*, 2004). The number of subjects with SAD and subsyndromal SAD in Ghana was significantly lower than in Norway ($G_{327} = 5.82$, $P = 0.02$ and $G_{327} = 10.94$, $P < 0.001$) (see Table 2). However, subjects with winter SAD should report a significant relief in depression during the summer (Mersch *et al.*, 2004). Using a reliable change index, according to Jacobson and Truax (1991), cases not improving by four or more HAD depression points were coded as unchanged. This reduced the difference in proportions between Ghana (0.6%) and Norway (3.4%), which were then barely approaching significance ($G = 3.79$, $P = 0.052$). The effect of gender was added by conducting additional tests separately for women and men (Table 2). All tests indicated that SAD, subsyndromal SAD and SAD based on HAD occurred more frequently in Norway among women only. The main effect of gender was non-significant.

DISCUSSION

While the homeostatic factor operates relatively independently of external stimuli, the circadian factor is influenced by light exposure, as well as the timing of exposure (Khalsa *et al.*, 2003). Thus, a lack of exposure to daylight in one's biological morning throughout winter in the northern latitude should correlate with more seasonal changes in sleep and mood in Norway, but not in Ghana.

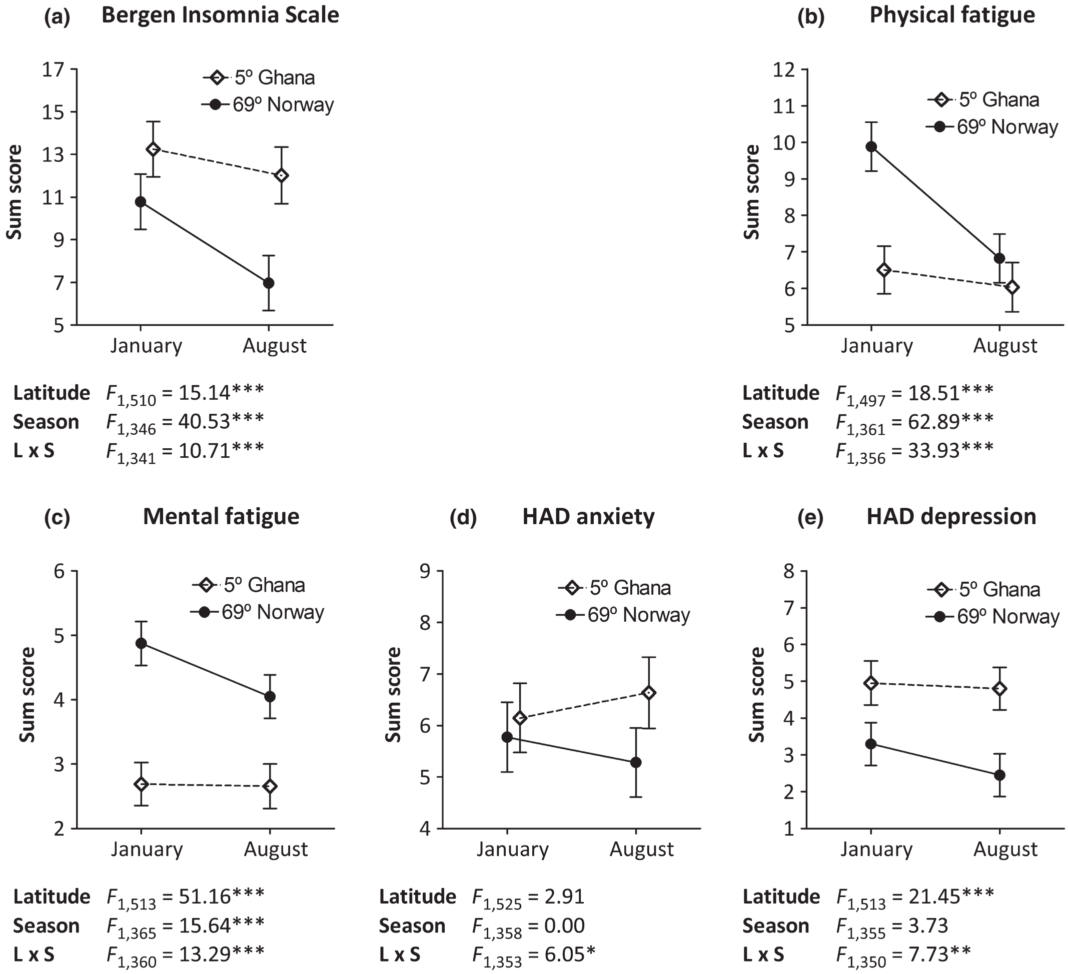

Figure 2. (a) Sum score of insomnia problems depending on season and latitude. (b,c) Sum scores for physical and mental fatigue scores depending on season and latitude. (d,e) Degree of symptoms of anxiety and depression depending on season and latitude.

Seasonal changes in sleep parameters

Subjects living above the Polar Circle experienced seasonal changes in the following sleep indicators mainly during weekdays. During the winter they went to bed 12 min later and rose from bed 32 min later, which mimicked findings by Honma *et al.* (1992) in a controlled experiment. Similar findings were observed in a large survey on Iceland (Thorleifsdottir *et al.*, 2002) among children, but not among adolescents. Moreover, the sleep timing was delayed only during workdays in our study, while a comparable delay was observed only during weekends in Iceland. Norwegians had more problems falling asleep and spent more time in bed after awakening in the morning. Hence, their sleep efficiency was more reduced during the winter than during the summer.

A discrepant result was the finding of no seasonal change in sleep duration, whereas Lehnkering and Siegmund (2007) and Nixon *et al.* (2008) reported longer sleep periods during periods of less daylight. However, Thorleifsdottir *et al.* (2002) also found no seasonal change in sleep duration among adolescents. The reasons for these differences are uncertain, but the Lehnkering and Siegmund (2007) study comprised a small sample of medical students (n = 34). Furthermore, the difference in sleep duration between seasons was small (18 min). Nixon *et al.* (2008) based their findings on 7-year-old children, who may have less stringent early morning routines, whereas adolescents need to attend school early in the morning. Finally, our findings matched those of a Norwegian cross-sectional study (Øyane *et al.*, 2008a), reporting no seasonal differences in sleep duration. In conclusion, minimal entrainment by daylight in the early morning does not necessarily influence sleep duration, but it does influence the timing of bedtimes and rise-times. This seasonality was observed only for workdays, for which we have no apparent explanation. The cross-cultural differences in sleep timing (bedtimes and rise-times) were strikingly high, but they were of no importance for the purpose of the hypotheses. These differences, however, indicate that sleep patterns are affected strongly by unknown factors that were not measured in the present study, such as culture or habits. It should also be mentioned that Norway has Daylight Saving Time (DST) (+1 h during winter), while Ghana does not. An adjustment of the Norwegian data was not performed as a DST change has relatively short-lived effects on wakeup times (Monk and Folklard, 1976), with complete adaptation within a week. The data in the present study was collected about 2 months before and after daylight saving.

Sleep latency was equal between seasons in Ghana, but considerably longer during the winter in Norway, and even passing the 30-min marker used as a diagnostic indicator of insomnia (Pallesen *et al*., 2008). Hence, subjects in Norway have more problems falling asleep during winter than summer. This interpretation was supported by converging data on self-reported insomnia in the current study. In another Tromsø study in northern Norway, insomnia was found more frequently during dark periods than during light periods (Husby and Lingjærde, 1990).

Sleep efficiency increased 2.6% from winter to summer in Norway, while it remained the same across seasons in Ghana. Night-time awakenings were expected to vary across seasons, but seasonal changes in these parameters were observed neither in Norway nor in Ghana. One interpretation may be that lack of daylight exposure in the early morning throughout the winter may primarily affect parameters related to sleep period initiation and ending, but not the quality as long as the timing shift is not extreme.

Seasonal effect on mood

A seasonal change in mood was observed for depressive but not for anxiety symptoms and, as hypothesized, only in the northern latitude. However, the effect was weaker than that in a study from Rochester (44°N) and San Diego (32°N) (Park *et al*., 2007). One reason may be the lack of covariate control of age, gender, marital status and education in the Rochester study, all of which were controlled for in the present study. The clinical relevance of the reduction in depressive symptoms during the summer was marginal, however, as the proportion of subjects classified as having a potential clinical depression according to Øyane *et al.* (2008b), were equal between the seasons. Therefore, the prevalence of clinical depression appears to be unrelated to season. This conclusion may, however, generalize poorly to other populations, such as blue-collar workers, patients suffering from a mood disorder or older patients.

Fatigue was related strongly to seasonal changes in Norway, which may seem counterintuitive compared with the small changes in depression scores. However, as it is quite normal to experience fatigue without being clinically depressed, this finding fits well with the general layman opinion of periods of darkness being associated with more fatigue and tiredness, but not an increase in depression. Several studies have demonstrated acute stimulant effects of light exposure, both on subjective (Campbell *et al.*, 1995) and objective measures of activation such as brain imaging studies (Lockley and Gooley, 2006). As such, winter darkness appears to be associated more strongly with fatigue than with depression.

The term SAD is used as a way to describe a seasonal pattern in major depression. In the present study, the SPAQ was the only method used to diagnose SAD which, strictly speaking, is insufficient (Mersch *et al*., 1999). With this limitation in mind, the proportion of identified SAD cases (8.8%) was similar to those reported in another study in northern Norway (10%) (Lund and Hansen, 2001). Despite similar results, three caveats must be considered. First, the GSS was equally as high in Ghana as in Norway, whereas it was expected to be higher in Norway if light is the prime reason for the seasonality. Thus, other climate factors may play complementary roles. Secondly, the SPAQ identified 2.8% of subjects in Ghana as having SAD, which is counterintuitive to the idea of SAD being caused by seasonal fluctuations in light. Thirdly, the SPAQ-based SAD prevalence of 8.8% is too high compared with the 12-month prevalence rate of depression (Kringlen *et al*., 2001). An additional DSM-IV criterion was therefore used to exclude cases not showing a significant summer relief in depression. The adjusted proportions of SAD approached zero in Ghana and fell to 3.4% in Norway, which is more in line with studies using clinical diagnostic methods reporting lower prevalence of SAD (Mersch *et al*., 1999), and questionnaire-based studies using similar additional DSM-IV criteria (Steinhausen *et al*., 2009). Finally, the prevalence of SAD cases in the present study was consistently higher among women than among men in the northern latitude only. This converged with previous findings, for example, in Dalarna, Sweden (60.5°N), where SPAQ-based SAD estimates were twice as high among women than among men (Rastad *et al*., 2005).

CONCLUSIONS

The quasi-experimental design of the study naturally precludes any causal inferences. In order to minimize sample differences related to socioeconomic, academic/educational, daytime cohort activities and mandatory tasks between Norway and Ghana, university students from both sites were recruited. However, differences in climate were not possible to control for. Because the present results mainly overlapped with the experimental and longitudinal data (Honma *et al*., 1992; Lehnkering and Siegmund, 2007; Nixon *et al*., 2008), lack of sufficient daylight exposure in one's biological morning stands out as an important accessory for the influence of sleep timing, efficiency and onset latency, as well as self-reported insomnia, fatigue and negative mood. Sleep duration and quality were unaffected by season.

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REFERENCES

Bjorvatn, B. and Pallesen, S. A practical approach to circadian rhythm sleep disorders. *Sleep Med. Rev.*, 2009, 13: 47–60.

Borbely, A. A., Achermann, P., Trachsel, L. and Tobler, I. Sleep initiation and initial sleep intensity – interactions of homeostatic and circadian mechanisms. *J. Biol. Rhythms*, 1989, 4: 149–160.

Campbell, S. S., Dijk, D. J., Boilos, Z., Eastman, C. I., Lewy, A. J. and Terman, M. Light treatment for sleep disorder: consensus report. III. Alerting and activating effects. *J. Biol. Rhythms*, 1995, 10: 129–132.

Chalder, T., Berelowitz, G., Pawlikowska, T. *et al.* Development of a fatigue scale. *J. Psychosom. Res.*, 1993, 37: 147–153.

Czeisler, C. A., Duffy, J. F., Shanahan, T. L. *et al.* Stability, precision, and near-24-hour period of the human circadian pacemaker. *Science*, 1999, 284: 2177–2181.

Dijk, D. J. and Czeisler, C. A. Contribution of the circadian pacemaker and the sleep homeostat to sleep propensity, sleep structure, electroencephalographic slow waves, and sleep spindle activity in humans. *J. Neurosci.*, 1995, 15: 3526–3538.

Duffy, J. F. and Wright, K. P. Entrainment of the human circadian system by light. *J. Biol. Rhythms*, 2005, 20: 326–338.

Golden, R. N., Gaynes, B. N., Ekstrom, R. D. *et al.* The efficacy of light therapy in the treatment of mood disorders: a review and meta-analysis of the evidence. *Am. J. Psychiatry*, 2005, 162: 656–662.

Honma, K. I., Honma, S., Kohsaka, M. and Fukuda, N. Seasonal variation in the human circadian rhythm—dissociation between sleep and temperature rhythm. *Am. J. Physiol.*, 1992, 262: 885–891.

Husby, R. and Lingjærde, O. Prevalence of reported sleeplessness in northern Norway, in relation to sex, age and season. *Acta Psychiatr. Scand.*, 1990, 81: 542–547.

Jacobson, N. S. and Truax, P. Clinical significance: a statistical approach to defining meaningful change in psychotherapy research. *J. Consult. Clin. Psychol.*, 1991, 59: 12–19.

Khalsa, S. B. S., Jewett, M. E., Cajochen, C. and Czeisler, C. A. A phase response curve to single bright light pulses in human subjects. *J. Physiol.*, 2003, 549: 945–952.

Kringlen, E., Torgersen, S. and Cramer, V. A Norwegian psychiatric epidemiological study. *Am. J. Psychiatry*, 2001, 158: 1091–1098.

Lehnkering, H. and Siegmund, R. Influence of chronotype, season, and sex of subject on sleep behavior of young adults. *Chronobiol. Int.*, 2007, 24: 875–888.

Lichstein, K. L. and Riedel, B. W. Behavioral assessment and treatment of insomnia. A review with an emphasis on clinical application. *Behav. Ther.*, 1994, 25: 659–688.

Lockley, S. W. and Gooley, J. J. Circadian photoreception. Spotlight on the brain. *Curr. Biol.*, 2006, 16: R795–R797.

Lund, E. and Hansen, V. Responses to the Seasonal Pattern Assessment Questionnaire in different seasons. *Am. J. Psychiatry*, 2001, 158: 316–318.

Mersch, P., Middendorp, H., Bouhuys, A. L., Beersma, D. and Van Den Hoofdakker, R. H. Seasonal affective disorder and latitude: a review of the literature. *J. Affect. Disord.*, 1999, 53: 35–48.

Mersch, P. P. A., Vastenburg, N. C., Meesters, Y. *et al.* The reliability and validity of the Seasonal Pattern Assessment Questionnaire: a comparison between patient groups. *J. Affect. Disord.*, 2004, 80: 209–219.

Monk, T. H. and Folklard, S. Adjusting to the changes to and from Daylight Saving Time. *Nature*, 1976, 261: 688–689.

Nixon, G. M., Thompson, J. M. D., Han, D. Y. *et al.* Short sleep duration in middle childhood: risk factors and consequences. *Sleep*, 2008, 31: 71–78.

Øyane, N. M., Ursin, R., Pallesen, S., Holsten, F. and Bjorvatn, B. Self-reported seasonality is associated with complaints of sleep problems and deficient sleep duration: the Hordaland Health Study. *J. Sleep Res.*, 2008a, 17: 63–72.

Øyane, N. M. F., Bjelland, I., Pallesen, S., Holsten, F. and Bjorvatn, B. Seasonality is associated with anxiety and depression: the Hordaland health study. *J. Affect. Disord.*, 2008b, 105: 147–155.

Pallesen, S., Nordhus, I. H., Nielsen, G. H. *et al.* Prevalence of insomnia in the adult Norwegian population. *Sleep*, 2001, 24: 771–779.

Pallesen, S., Bjorvatn, B., Nordhus, I. H., Sivertsen, B., Hjornevik, M. and Morin, C. M. A new scale for measuring insomnia: the Bergen Insomnia Scale. *Percept. Motor Skills*, 2008, 107: 691–706.

Park, D. H., Kripke, D. F. and Cole, R. J. More prominent reactivity in mood than activity and sleep induced by differential light exposure due to seasonal and local differences. *Chronobiol. Int.*, 2007, 24: 905–920.

Rastad, C., Sjoden, P.-O. and Ulfberg, J. High prevalence of self-reported winter depression in a Swedish county. *Psychiatry Clin. Neurosci.*, 2005, 59: 666–675.

Steinhausen, H.-C., Gundelfinger, R. and Metzke, C. W. Prevalence of self-reported seasonal affective disorders and the validity of the seasonal pattern assessment questionnaire in young adults: findings from a Swiss community study. *J. Affect. Disord.*, 2009, 115: 347–354.

Thorleifsdottir, B., Bjornsson, J. K., Benediktsdottir, B., Gislason, T. and Kristbjarnarson, H. Sleep and sleep habits from childhood to young adulthood over a 10-year period. *J. Psychosom. Res.*, 2002, 53: 529–537.