

## **CIRCADIAN SLEEP-WAKE CYCLES, WELL-BEING, AND LIGHT THERAPY IN BORDERLINE PERSONALITY DISORDER**

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Individuals with borderline personality disorder (BPD) frequently suffer from sleep disturbances. The authors investigated circadian rhythms, sleep, and well-being in women with BPD in their habitual life conditions during 3 weeks with morning light therapy (LT) and 3 weeks without LT (oLT). Sleep-wake cycles were measured using wrist actimetry, proximal skin temperature as an indirect index of relaxation, as well as weekly salivary melatonin to document the internal circadian rhythm phase. Questionnaires assessed clinical state throughout the 6-week protocol. Ten matched healthy women followed the same 6-week protocol without light treatment. Women with BPD had significantly worse subjective sleep quality and reduced daytime alertness compared to controls. Sleep-wake cycles in BPD ranged from highly disturbed to extremely regular patterns. Melatonin and proximal skin temperature profiles revealed appropriate synchronization of the circadian system with the sleep-wake cycle in most BPD women and in all controls. Morning LT significantly phase-advanced activity in BPD compared to oLT, shortened sleep duration, decreased movement time, and increased skin temperature during sleep (a marker of relaxation). Although general depression scores and borderline symptoms did not change, daytime alertness improved with morning LT, and atypical depression scores were attenuated. Morning LT is a potential adjunct treatment for BPD.

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Borderline personality disorder (BPD) is characterized by a disturbance of affect regulation, often accompanied by a depressive syndrome (Lieb, Zanarini, Schmahl, Linehan, & Bohus, 2004). Patients with BPD frequently report sleep disturbances (Dagan, Stein, Steinbock, Yovel, & Hallis, 1998; Plante, Zanarini, Frankenburg, & Fitzmaurice, 2009) independent of comorbidity such as depression and substance abuse (Harty, Duckworth, Thompson, Stuewig, & Tangney, 2010). Conversely, BPD patients with sleep disturbances often manifest depression and dysthymia as well as anxiety, tension, and psychic distress (Papadimitriou & Linkowski, 2005; Soldatos & Paparrigopoulos, 2005).

Sleep is primarily regulated by interactions between a homeostatic process, where sleep pressure rises during wakefulness and declines during sleep, and a circadian pacemaker, which times the occurrence and architecture of sleep (Borbély, 1982). Circadian rhythms are driven by the master clock located in the suprachiasmatic nuclei (SCN) and by “slave” oscillators found in every cell in the body (Schibler, Ripperger, & Brown, 2003). Their endogenous genetic period is somewhat different from 24 hours (usually longer) and needs to be adequately synchronized every day for optimal functioning. The primary synchronizing agent is light. Under conditions without synchronizing time cues, human circadian rhythms show their natural non-24-hour periodicity, and some people may show internal desynchronization between their sleep-wake cycle and the biological clock. Interestingly, such individuals had significantly higher neuroticism scores compared to subjects without desynchronization (Lund, 1974), providing a possible link between circadian misalignment and personality traits. Under real-life conditions, misalignment of sleep-wake cycles with respect to the biological clock is associated with increased susceptibility to mood swings (Wirz-Justice, 2006).

Light has been developed as a therapy for seasonal affective disorder (SAD), and increasingly also for nonseasonal major depressive disorder (e.g., ante- and postpartum depression, geriatric depression), bipolar illness, and attention-deficit disorder (Even, Schröder, Friedman, & Rouillon, 2008; Lieverse et al., 2011; Terman & Terman, 2005; Wirz-Justice et al., 2011).

There is good evidence that circadian rhythm disturbances play a role in many psychiatric illnesses such as depression, posttraumatic stress disorder, and eating disorders, which are often comorbidities of BPD. These disturbances are characterized by a blunted amplitude and altered circadian phase (Boivin, 2000; Wirz-Justice, Bromundt, & Cajochen, 2009). Information concerning circadian sleep-wake cycles in individuals with BPD is scarce. A high prevalence of personality disorders, including BPD, has been found in a cohort of 50 patients with circadian rhythm sleep disorders such as delayed sleep phase syndrome and non-24-hour sleep-wake syndrome (Dagan, Sela, Omer, Hallis, & Dar, 1996; Okawa & Uchiyama, 2007). In a cohort of 59 patients with a history of recurrent suicide attempts, an association between non-24-hour periodicities of rest-activ-

ity cycles and BPD, suicidal ideation, and depression was found (Verkes, Kerkhof, Beld, Hengeveld, & van Kempen, 1996).

We hypothesized that patients with BPD suffer from irregularities in circadian sleep-wake cycles, and that light treatment helps to consolidate these patterns with benefits for mood, daytime alertness, and sleep quality.

## **METHODS**

### **PARTICIPANTS AND STUDY DESIGN**

Fourteen women diagnosed with BPD according to *DSM-IV* criteria and with a cutoff value  $> 8$  in the Borderline Personality Inventory (BPI) and 10 healthy control women were recruited at the Psychiatric Hospitals of the University of Basel.

The BPD cohort comprised outpatients aged 23–41 years (mean age:  $30.1 \pm 6.0$  *SD*) with weekly commitments of 0–16 hours (mean  $6.1 \pm 6.3$  *SD*) and therefore to a large extent free in choosing their sleep times. All patients underwent psychotherapeutic treatment. Four patients were unmedicated, whereas 10 patients were on stable medication for at least 2 weeks prior to the study.

We investigated the BPD patients during 6 weeks in the winter half-year (September to March 2007–2010) in their habitual life conditions and self-chosen sleep-wake times. Light treatment (Daylight<sup>®</sup>, Uplift Technologies, Canada; 8000 lux, 30–40 min daily) was administered at home during 3 weeks in a crossover design: five women with BPD received light treatment during weeks 1–3, whereas nine women with BPD were treated with light during weeks 4–6. Bright light therapy was scheduled in the morning after getting up within a time window until 9:00 a.m. Compliance was checked by the light sensor on the Actiwatch<sup>®</sup> (Cambridge Neurotechnology Ltd., UK). All BPD patients had an ophthalmological checkup prior to light treatment.

Ten healthy unmedicated controls, without psychiatric disorders in their lifetime or in near relatives, were matched by age (22–36 years, mean age:  $25.7 \pm 4.8$  *SD*) and weekly commitments (0–14 hours, mean  $8.6 \pm 5.2$  *SD*). Furthermore, the control group did not differ from the patient group in body mass index and education level ( $p > 0.1$ ), and 50% of each group was in a relationship. The controls were investigated over 6 weeks following the same protocol as the BPD women, but without light treatment. The study procedure was approved by the local Ethics Committee of Basel, Switzerland (EKBB), and all procedures conformed to the Declaration of Helsinki.

### **CLINICAL STATUS, INTERVIEWS, AND QUESTIONNAIRES**

Sociodemographic data were collected, and a range of questionnaires and interviews were used to assess clinical state of the patients. For selection

of participants, the SCID-II-questionnaire and parts of the SCID interview were conducted to check for BPD and comorbidities (Wittchen, Wunderlich, Gruschwitz, & Zaudig, 1996). Throughout the study, we used the BPI, the Borderline Symptom List (BSL-95), State-Trait-Anxiety Inventory (STAI), State-Trait-Anger Inventory (STAXI), and State-Trait-Anger Expression Inventory (STAXI-II) (Bohus et al., 2007; Laux, Glanzmann, Schaffner, & Spielberger, 1981; Leichsenring, 1999; Schwenkmezger, Hodapp, & Spielberger, 1992).

Subjective sleep quality was assessed by the Pittsburgh Sleep Quality Index (PSQI; Buysse, Reynolds, Monk, Berman, & Kupfer, 1989), the subjects' chronotype by the modified Morningness-Eveningness-Questionnaire (MEQ; [www.cet.org](http://www.cet.org); Horne & Ostberg, 1976), and the Seasonal Pattern Assessment Questionnaire (SPAQ; Rosenthal, Genhart, Sack, Skwerer, & Wehr, 1987) was used to check for SAD. None of the participants suffered from sleep apnea syndrome, as assessed by a sleep apnea risk questionnaire (Douglass et al., 1994).

#### MEASURING REST-ACTIVITY CYCLES AND PROXIMAL SKIN TEMPERATURE

Rest-activity cycles were measured by wrist actimetry using the Actiwatch system for approximately 42 days. Activity recordings were edited for completeness as previously described (Bromundt et al., 2011) and analyzed by the Sleep and Activity Analysis Software 7.23V (Cambridge Neurotechnology Ltd., U.K.) for estimates of sleep parameters such as sleep onset or nocturnal movement time. Nonparametric circadian rhythm analysis (NPCRA; Van Someren et al., 1999) is a method for extracting circadian characteristics from the rest-activity cycle. Of major interest is the relative amplitude (RA), since it shows how activity is distributed throughout the day compared with night: the higher the RA, the better the consolidation of daytime activity and nighttime sleep. The RA is calculated from the ratio of the most active 10-hour period (M10) to the least active 5-hour period (L5) across the averaged 24-hour profile. A second characteristic is the interdaily stability (IS), which quantifies the invariability day by day, that is, how well the sleep-wake cycle is synchronized to supposedly stable environmental cues. Thirdly, intradaily variability (IV) gives an indication of the fragmentation of the rhythm. Timing information comes from determining the onset of the 5 hours with least activity (L5 onset) and onset of the 10 hours with most activity (M10 onset).

Parallel to activity recordings, we measured proximal skin temperature using wireless temperature sensors (BS 1922L Thermochron iButton®, accuracy 0.0625°C, Maxim, U.S.). Many studies have shown that skin temperature is an important correlate of sleepiness, and that higher skin temperatures indicate relaxation (vasodilatation) prior to falling asleep and follow a circadian pattern (Kräuchi & Deboer, 2010). iButtons were fixed to the infraclavicular skin region and skin temperature was recorded and

stored in 10-min intervals. Temperatures outside the physiological range—due to showering or iButton removal—were replaced by the individual's highest (~36.6°C) and lowest skin temperature (~32.4°C). If temperature values were out of range for more than 3 hours during the day or for more than 1 hour during the night, then data from that 24-hour period were discarded.

#### SALIVA COLLECTION FOR MELATONIN DETERMINATION

Six sampling days at 1-week intervals were conducted on a weekday. Saliva collection using Salivettes® (Sarstedt AG, Switzerland) started right after getting up (morning), followed by four samples (midmorning, midday, midafternoon, evening), and five samples at 1-hour intervals until bedtime. Three further samples were collected in 1-hour intervals next morning after getting up. The study volunteers were instructed to stay at home on the sampling day and avoid exercise and bright light that evening.

Melatonin was determined by a direct double-antibody radioimmunoassay (analytical sensitivity 0.2 pg/mL; functional least detectable dose 0.65 pg/mL; Bühlmann Laboratories AG, Allschwil/Switzerland) (Weber, Schwander, Unger, & Meier, 1997). The threshold for melatonin onset was set at 30% of the highest value before lights off, and onset was calculated assuming a linear increase between measurements before and after the melatonin threshold (Bromundt et al., 2011).

#### WEEKLY WELL-BEING STATE ASSESSMENT

On the weekly sampling days, study volunteers answered three questionnaires on getting up, at midday, in the evening, and at bedtime: the Multidimensional Mood State Questionnaire (MDBF; Steyer, Schwenkmezger, Notz, & Eid, 1997), assessing good–bad mood (GS), daytime alertness–tiredness (WM), and ease–unease (RU); STAI to assess anxiety; and STAXI to assess anger (Laux et al., 1981; Schwenkmezger et al., 1992). Self-ratings were made with the BSL-95, the Beck Depression Inventory (BDI; Beck, Ward, Mendelson, Mock, & Erbaugh, 1961), and the Hamilton Depression Scale with Atypical Depression Supplement (SIGH-ADS-SR, [www.cet.org](http://www.cet.org)).

#### STATISTICAL ANALYSIS

For analysis, weeks 2 and 3 of both conditions, oLT and LT, were used. The first week was omitted to avoid a novelty effect and to reduce the influence of the prior light condition. In controls, values of weeks 2 and 3 were used for comparison with the BPD group. In controls,  $14.1 \pm 0.7$  days and  $13.8 \pm 1.1$  nights, and in BPD women,  $13.6 \pm 1.3$  days and  $13.5 \pm$

1.2 nights during oLT, and  $13.4 \pm 1.8$  days and  $13.3 \pm 1.8$  nights during LT entered the analysis.

Comparisons of BPD women and controls were conducted using Student's *t* test or the Mann-Whitney *U* Test, if data were not normally distributed. For the comparison of differences in variance, the *F* test for equality of two standard deviations was applied. The effect of light treatment in the BPD cohort was analyzed by analysis of variance for repeated measures with Huynh-Feldt's statistics and Duncan's alpha-corrected *t* test for post-hoc tests. Original degrees of freedom are reported.

Since we aimed at understanding the influence of good or poor circadian sleep-wake cycles, we split the BPD cohort by the median of the relative amplitude (RA) of day:night activity using the same method as in our recent study of men with schizophrenia in a comparable setting (Bromundt et al., 2011).

Analysis was conducted using SPSS 15.0 (SPSS Inc., Chicago, IL, U.S.) and STATISTICA 9.1 (StatSoft Inc., Tulsa, OK, U.S.) for Windows. The alpha criterion was set at a significance level of  $p \leq .05$  and tendencies on a level between  $.05$  and  $\leq .1$ .

## RESULTS

### CLINICAL STATE

Individuals with BPD differed significantly from control women in borderline symptoms (BPI and BSL), in symptoms of depression (BDI), and in anxiety (STAI trait) (Table 1). They showed significantly more feelings of anger (STAXI trait) than controls, even though the groups showed no difference in "anger under control" scores (STAXI AC).

Significantly more women from the BPD cohort (seven patients) showed symptoms of SAD as assessed by the SPAQ, and two patients had subsyndromal-SAD, compared to the control group with only two women with subsyndromal-SAD (Fisher's exact test, two-tailed:  $p = .019$ ; Table 2).

### CIRCADIAN REST-ACTIVITY CYCLES AND SALIVARY MELATONIN

Visual inspection of actigrams revealed irregular to highly regular patterns in both the BPD and the control group (Figure 1, A-D). The circadian characteristics of rest-activity cycles in the BPD group were not significantly different from those in the control group, as indicated by the IS, RA, IV, onset of M10, or L5 ( $p > .14$ ), but showed a wider range in actimetric measures of the RA (F-test:  $F(13, 9) = 5.5$ ,  $p = .007$ ; Figure 2).

Light treatment significantly phase advanced the L5 onset in BPD patients compared to oLT ( $t(13) = 2.69$ ,  $p = .019$ ), and the M10 onset and the melatonin onset tended to phase advance (M10 onset:  $t(13) = 1.8$ ,  $p = .096$ ; melatonin onset:  $t(10) = 1.86$ ,  $p = .092$ ). Moreover, the spread (standard deviation) of getting up times significantly decreased during LT compared

**TABLE 1. Clinical State at Baseline in Control (n = 10) and BPD Women (n = 14)**

	Controls (n = 10)	BPD women (n = 14)	z-values, p
BPI total	4.4 ± 5.1	30.1 ± 8.4	-4.13, <0.001
BPI identity diffusion	1.5 ± 1.8	7.2 ± 2.5	-3.86, <0.001
BPI fear of closeness	0.6 ± 1.1	5.6 ± 1.5	-4.13, <0.001
BPI primitive defense mechanisms	0.3 ± 0.9	4.5 ± 2.1	-3.98, <0.001
BPI inadequate reality check	0.1 ± 0.3	1.3 ± 1.6	-2.37, 0.040
BPI cutoff	1.8 ± 2.3	13.4 ± 3.2	-4.12, <0.001
BSL total score	20.5 ± 6.3	158.1 ± 63.1	-4.10, <0.001
BSL self-perception	1.4 ± 1.3	24.7 ± 14.2	-4.11, <0.001
BSL affect regulation	2.5 ± 2.0	26.7 ± 10.3	-4.08, <0.001
BSL auto-aggression	0.5 ± 0.7	20.9 ± 13.1	-4.14, <0.001
BSL dysphoria	12.9 ± 4.0	29.4 ± 7.2	-3.88, <0.001
BSL social isolation	0.9 ± 1.4	17.1 ± 12.1	-3.93, <0.001
BSL hostility	0.8 ± 1.1	7.1 ± 4.6	-3.39, <0.001
BSL intrusions	0.1 ± 0.3	9.6 ± 5.7	-3.92, <0.001
BSL destructive behavior	0.1 ± 0.2	4.4 ± 3.0	-4.12, <0.001
BDI depression	1.2 ± 2.3	22.4 ± 7.5	-4.14, <0.001
STAI anxiety trait	29.8 ± 5.0	57.3 ± 6.5	-4.10, <0.001
STAXI anger trait	13.7 ± 2.3	22.9 ± 6.0	-3.38, <0.001
STAXI AI anger inwards	12.5 ± 4.1	21.4 ± 5.9	-3.08, 0.002
STAXI AO anger outwards	9.5 ± 1.4	14.8 ± 5.6	-2.84, 0.004
STAXI AC anger under control	22.3 ± 5.3	22.9 ± 5.8	-0.12, 0.907

Note: Group differences by Mann-Whitney *U* Test. BPI = Borderline Personality Inventory; BSL = Borderline Symptom List; BDI = Beck Depression Inventory; STAI = State-Trait-Anxiety Inventory; STAXI = State-Trait-Anger Inventory.

**TABLE 2. Additional Symptoms, Addictive Drug Use, and Medication in the BPD Cohort, Median Split into a Low and a High Relative Amplitude (RA) Group**

BPD Subjects	Current or Lifetime Symptoms			Substance Use			Medication				Chronotype MEQ	RA Group	
	Disordered Eating	ADS	Traumatic Experience	SAD	N	A	D	AD	AP	MS			A
D01	+	-	+	-	-	-	-	+	+	+	-	intermediate	low
D02	+	+	+	+	+	+	+	-	+	+	-	intermediate	low
D07	-	-	-	-	+	+	+	-	-	-	-	mod. evening	low
D08	+	-	-	+	+	+	+	-	-	-	-	extr. evening	low
D10	+	+	+	-	+	+	-	+	+	-	+	mod. morning	low
D13	-	-	-	(+)	+	+	+	-	-	-	-	intermediate	low
D14	+	-	-	+	+	+	+	-	-	-	-	intermediate	low
D03	+	-	-	+	+	-	-	+	+	-	-	mod. morning	high
D04	+	-	-	+	-	-	-	+	-	+	-	intermediate	high
D05	+	+	-	+	-	-	-	+	-	-	-	mod. morning	high
D09	-	+	-	-	-	-	-	+	-	-	-	mod. evening	high
D11	+	-	+	-	-	-	-	+	-	-	-	mod. morning	high
D15	+	-	+	+	-	-	-	+	+	-	+	intermediate	high
D16	-	+	-	(+)	+	+	-	+	-	-	-	intermediate	high

Note: ADS = attention deficit syndrome; SAD = seasonal affective disorder; SAD (+) = subsyndromal-SAD; N = nicotine; A = alcohol; D = cannabis and/or stimulants; AD = antidepressants; AP = antipsychotics; MS = mood stabilizers; A = anxiolytics; MEQ = Morningness-Eveningness Questionnaire; mod. = moderate; extr. = extreme.

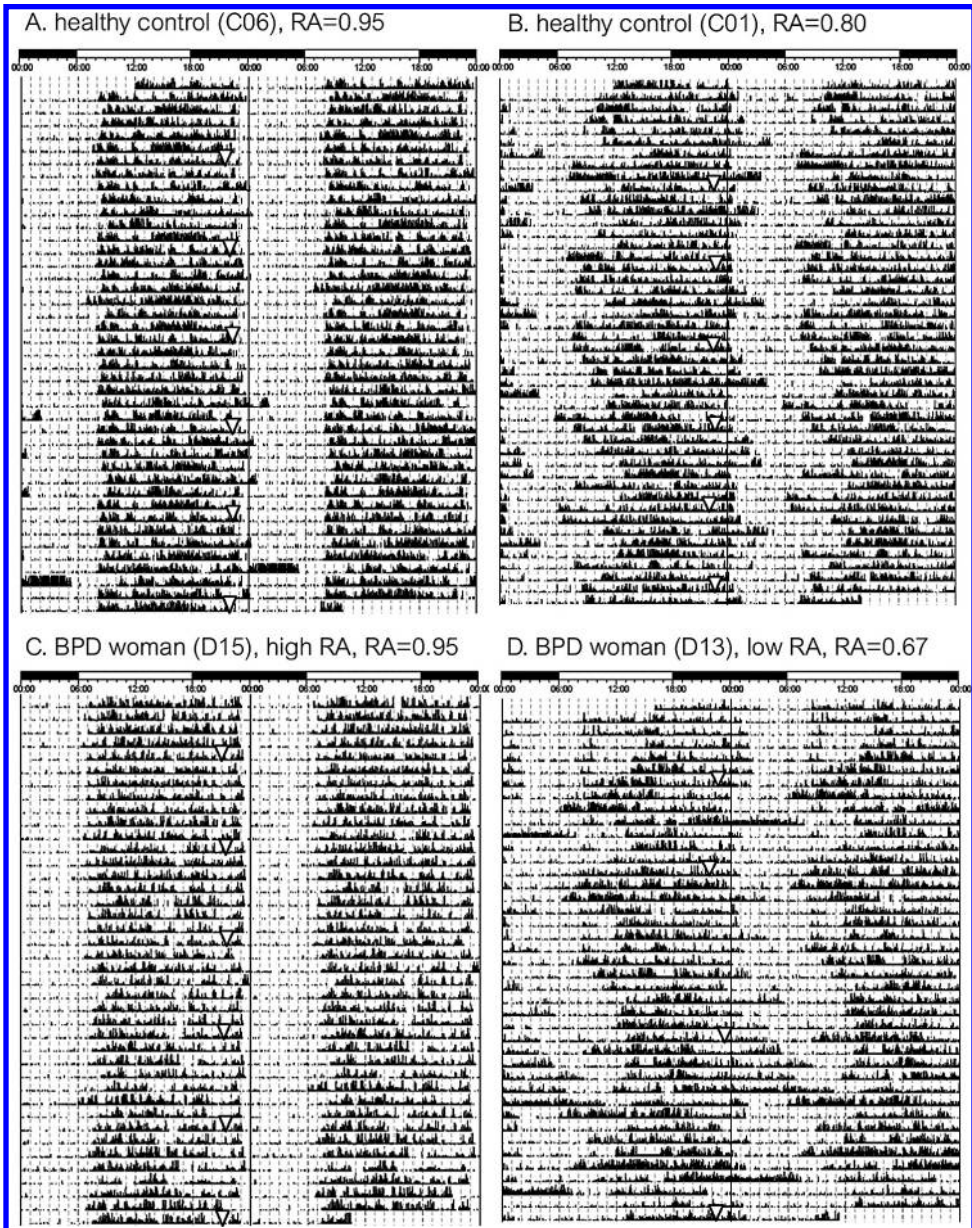


FIGURE 1. Actigrams of two controls (A, B), one high-RA BPD (C), and one low-RA BPD woman (D). The black bars represent the amount of activity: the higher the bar, the more active. Data are double-plotted over 48 hours, that is, day 1 and day 2 next to one another on the x-axis, and day 1 and day 2 below one another on the y-axis, to allow better visualization of abnormal rhythms during the sleep period (clearly seen as a white period with small movements).  $\nabla$  = timing of melatonin onset.



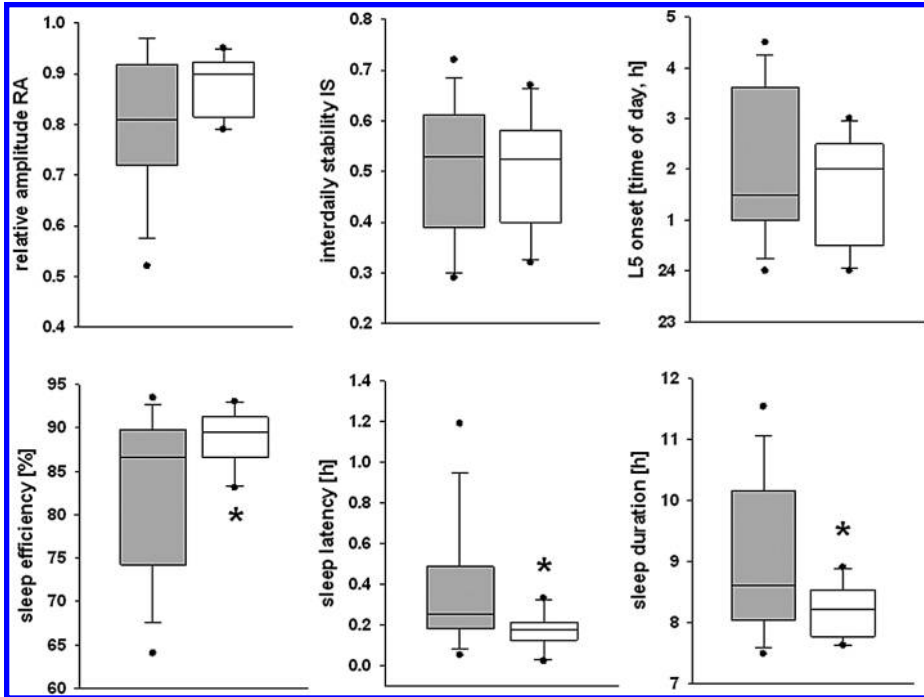


FIGURE 2. Actimetric measured circadian and sleep parameters in women with BPD ( $n = 14$ , gray box) and healthy controls ( $n = 10$ , white box); boxplots depict 25–75 percentile of scores in the box and median as black line, highest and lowest values are indicated by whiskers and outliers by black dots; asterisks indicate significant differences. Relative amplitude RA = relative amplitude of day:night activity; interdaily stability IS = interdaily stability of activity patterns; L5 onset = onset of the 5 hours with least activity.

to oLT ( $t(13) = 5.9$ ,  $p < .001$ ), whereas such a decrease was not observed for bedtimes ( $p = .26$ ). Other circadian parameters such as RA, IS, and IV did not significantly differ between the oLT and LT conditions ( $p > .4$ ).

The circadian profiles of melatonin levels were normal in 11 BPD women as well as in all 10 controls. In BPD, melatonin onset was at  $21:13 \pm 0:57$  h:m (mean  $\pm$  SD), and the time interval between melatonin onset and lights off at bedtime (the so-called phase angle as an indicator for the relationship between the circadian system and the sleep–wake rhythm) was  $2:24 \pm 0:58$  h:m during oLT. In healthy women, melatonin onset was at  $21:44 \pm 0:40$  h:m with a phase angle of  $2:18 \pm 0:56$  h:m. Three BPD women showed abnormalities in their melatonin profiles so that melatonin onset could not be calculated.

## SLEEP

Subjective sleep quality at baseline revealed significantly worse sleep in the BPD group compared to sleep in controls (PSQI total score:  $z = -3.71$ ,  $p < .001$ ). Actimetric-derived sleep parameters showed that BPD women

slept significantly longer than controls ( $t(22) = -2.18, p = .043$ ), had lower sleep efficiency ( $t(22) = 2.40, p < .028$ ), longer sleep latency ( $t(22) = -2.28, p = .037$ ) and increased mean wake bout time ( $z = -2.68, p = .016$ ), whereas other parameters did not significantly differ.

During morning LT, the BPD women got up significantly earlier ( $t(13) = 5.86, p < .001$ ) and slept less ( $t(13) = 2.68, p = .019$ ) compared to oLT. No other sleep parameter changed significantly. When sleep of BPD women during LT was compared with sleep of controls, sleep duration was no longer significantly different ( $p = .852$ ), but the BPD women still retained significantly lower sleep efficiency, longer sleep latency, and more mean wake bout time ( $p < .04$ ).

The time course of the hourly mean values of activity counts, log-transformed to emphasize values during the sleep episode, was not significantly different in the BPD cohort compared to controls during sleep either during oLT or during LT (group:  $F(1, 22) = 0.12, p = .730$ ). However, activity during the first 7 hours after sleep onset was significantly decreased in BPD women during LT compared to oLT (Figure 3A, treatment:  $F(1, 13) = 7.21, p = .019$ ). Proximal skin temperature during the first 7 hours after sleep onset was significantly increased in BPD women during LT compared to oLT (Figure 3B, treatment:  $F(1, 13) = 6.02, p = .029$ ).

## DEPRESSION AND WELL-BEING

Weekly assessed depression state revealed significantly higher depression scores in BPD women during both LT and oLT compared to the healthy control women (BDI oLT:  $t(22) = -7.00, p < .001$ ; LT:  $t(22) = -8.55, p < .001$ ). Depression scores in BPD did not improve with light treatment (BDI:  $t(13) = 0.57, p = .576$ ; SIGH-ADS-SR: H21:  $t(13) = 1.30, p = .216$ ). However, the atypical depression scores assessed by the SIGH-ADS-SR A8 significantly improved in women with BPD during LT compared to oLT ( $t(13) = 2.55, p = .024$ ) (Figure 4).

Well-being scores, self-assessed four times during the day, showed that healthy controls had overall significantly better mood (GS: group:  $F(1, 22) = 22.16, p < .001$ ), higher alertness (WM: group:  $F(1, 22) = 12.92, p = .002$ ), more ease (RU: group:  $F(1, 22) = 14.41, p = .001$ ), less anxiety (STAI: group:  $F(1, 22) = 15.79, p = .001$ ), and fewer feelings of anger (STAXI: group:  $F(1, 22) = 8.52, p = .008$ ) than the BPD group during oLT. LT in BPD women improved alertness (treatment:  $F(1, 12) = 9.33, p = .010$ ), without any change in mood (treatment:  $F(1, 13) = 0.26, p = .620$ ), feelings of ease (treatment:  $F(1, 12) = 0.23, p = .641$ ), anxiety (treatment:  $F(1, 12) = 1.42, p = .256$ ), or anger (treatment:  $F(1, 13) = 0.84, p = .377$ ) (Figure 4).

## COMPARISON OF REGULAR AND IRREGULAR RHYTHMS (HIGH-RA VS. LOW-RA GROUP)

We median split the BPD cohort by the RA according to Bromundt et al. (2011), resulting in a high-RA group with regular sleep-wake cycles ( $n = 7$ ;

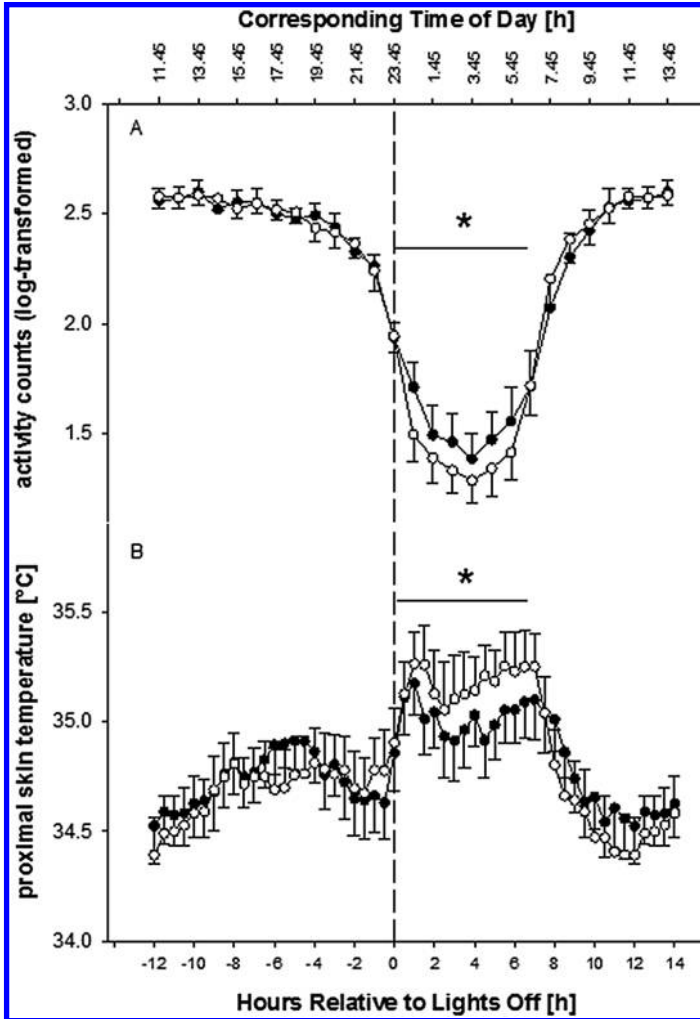


FIGURE 3A. Wrist motor activity (log transformed to emphasize values during the sleep episode) and B. Proximal (intraclavicular) skin temperature in BPD women during oLT (black) and LT (white). Mean values ( $\pm$ SEM) are plotted relative to bedtime (=0), with the corresponding time of day during oLT = 23:49  $\pm$  0:30 (m  $\pm$  SEM) and during LT = 23:38  $\pm$  0:27.

RA range: 0.81–0.97, median = 0.91) and a low-RA group with irregular rhythms ( $n = 7$ ; RA range: 0.52–0.81, median = 0.74). For comparison, the RA of the control group ranged from 0.79 to 0.95, with a median of 0.9.

Clinical assessment at baseline revealed that the high-RA cohort had fewer borderline symptoms than the low-RA group (BSL total:  $t(12) = 2.57$ ,  $p = .025$ , BSL affect regulation:  $t(12) = 3.96$ ,  $p = .002$ , BSL dysphoria:  $t(12) = 3.11$ ,  $p = .009$ , BSL intrusions:  $t(12) = 2.44$ ,  $p = .031$ ), whereas lifetime and/or current comorbidities and other symptoms such as lifetime borderline symptoms, depression, anxiety, and feelings of anger did not significantly differ (Table 2). However, the low-RA group comprised signifi-

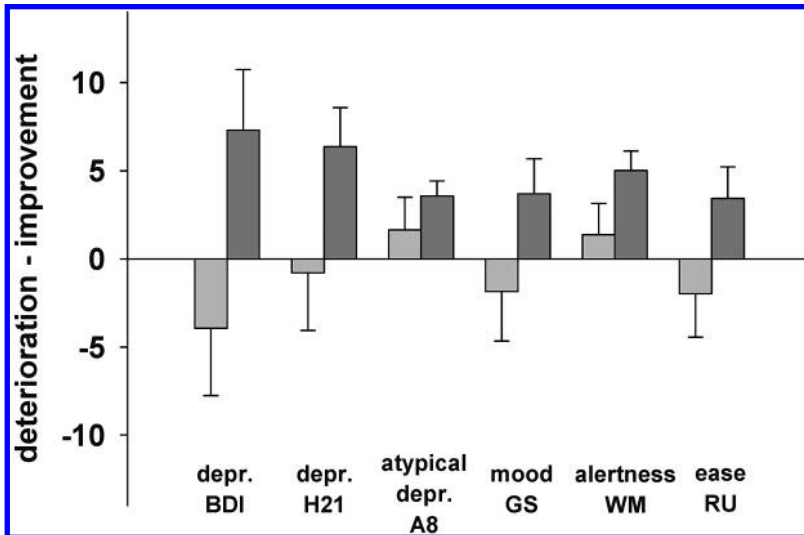


FIGURE 4. Clinical effect of light treatment ( $\Delta$ -values) on depression and well-being in BPD patients with low RA ( $n = 7$ , light gray), and high RA ( $n = 7$ , dark gray); mean  $\pm$  SEM, for statistics see text.

cantly more women with alcohol and drug consumption (Fisher's exact, two-tailed: alcohol:  $p = .029$ , drug:  $p = .025$ ) and a tendency to more smokers (Fisher's exact, one-tailed:  $p = .051$ ). The high-RA group included significantly more women treated with antidepressants (Fisher's exact two-tailed:  $p = .021$ ).

The groups differed not only in the RA day:night activity *per definitionem* ( $t(12) = -4.51$ ,  $p < .001$ ), but also in IS ( $t(12) = -3.69$ ,  $p = .003$ ), but not in IV. The high-RA group comprised earlier chronotypes with a significantly earlier L5 and M10 onset (L5:  $t(12) = 3.67$ ,  $p = .003$ ; M10:  $t(12) = 2.20$ ,  $p = .05$ ) and earlier getting up times ( $t(12) = 3.42$ ,  $p = .005$ ). Moreover, the low-RA group showed more irregular rhythms indicated by a larger spread of getting up times ( $t(12) = 3.42$ ,  $p = .005$ ) and bedtimes ( $t(12) = 2.76$ ,  $p = .017$ ).

PSQI-assessed subjective sleep quality revealed that the high-RA cohort rated their sleep quality significantly better than the low-RA group (PSQI total:  $t(12) = 2.49$ ,  $p = .029$ ). There was a tendency to lower total activity during sleep in the high-RA group ( $t(12) = 2.12$ ,  $p = .056$ ). No other sleep parameters differed significantly between groups.

During 3 weeks of light treatment, women in the high-RA group averaged  $18.1 \pm 3.2$  days (mean  $\pm$  SD) using the therapy lamp for a duration of  $34.9 \pm 5.7$  min starting at  $7:38 \pm 0:33$  h:m, and the low-RA group received light treatment on  $17.0 \pm 4.0$  days for  $30.3 \pm 8.3$  min, however starting significantly later than the high-RA group, at  $8:47 \pm 0:57$  h:m ( $t(12) = 2.7$ ,  $p = .019$ ). Weekly assessed BSL scores did not improve with light treatment (treatment:  $F(1, 12) > 1.84$ ,  $p > .200$ ). However, the BSL dysphoria

subscore tended to improve during LT in the high-RA group, but not in the low-RA group ( $F(1, 12) = 4.53, p = .055$ , post-hoc  $p = .072$ ). We also found a tendency of RA group  $\times$  treatment interaction, in that only the high-RA group had a significant decline in depression scores during LT (BDI:  $F(1, 12) = 4.72, p = .05$ , post-hoc  $p = .081$ ; H21:  $F(1, 12) = 3.27, p = .096$ , post-hoc  $p = .042$ ), whereas the low-RA group did not ( $p > .326$ ) (Figure 4).

## DISCUSSION

Sleep is an important component of our daily well-being. Given that sleep disorders are intrinsic to or accompany many psychiatric disorders, it is surprising how little sleep research on BPD is available. The major characteristic of sleep-wake cycles in BPD women was higher variance, ranging from highly disturbed to extremely regular sleep-wake cycles. The melatonin and proximal skin temperature profiles were normal in most BPD women and in all controls, which suggests that the internal clock was synchronized with the sleep-wake cycle and to the day-night cycle. Thus, even though sleep-wake cycle disruptions occurred more often in BPD women than in healthy controls, they do not seem to be specific for this patient group, a phenomenon also described for other psychiatric illnesses with or without depressive syndromes (Wirz-Justice et al., 2009; Wulff, Gatti, Wettstein, & Foster, 2010). However, BPD women suffered significantly more from reduced daytime alertness and from subjective and objective sleep disturbances, which confirms the few previous observations (Akiskal, Yerevanian, Davis, King, & Lemmi, 1985; Benson, King, Gordon, Silva, & Zarcone, 1990; Harty et al., 2010; Plante et al., 2009).

Bright light in the morning is an established synchronizing agent capable of phase advancing circadian rhythms in healthy volunteers (Khalsa, Jewett, Cajochen, & Czeisler, 2003). Thus, it is not surprising that a phase advance of the circadian rest-activity cycle and a tendency for a phase advance of melatonin onset were found during light treatment. The phase-advancing effect of light with its stabilization of getting up times may have helped to consolidate sleep, a correlate of which is better daytime alertness. The acute alerting effect of light has been well documented (Cajochen, 2007; Cajochen et al., 2005) and may also be valid for longer term treatment as here. Moreover, light therapy caused more relaxed sleep and improved atypical depressive symptoms in individuals with BPD, which may be related to the increased alertness levels, since atypical depression includes symptoms about sleepiness and lack of energy.

SAD is characterized by atypical depression scores, and light therapy is the treatment of first choice for these patients. Therefore, it might have been the treatment of SAD as a comorbidity to BPD in some of the patients that resulted in the improvement of atypical depression scores by light treatment. Seasonal variation of affect is not specific for SAD, but it is found in other psychopathologies (Simonsen, Shand, Scott, & Eagles,

2011). As far as we know, there are no studies investigating the occurrence of seasonality in BPD. In fact, the finding that 50% of our sample fulfilled the questionnaire criteria for SAD and another 14% for the sub-syndromal form (and only 20% of controls) indicates an important comorbidity that supports the use of light as an adjunct treatment.

Splitting the patient cohort by the amplitude of day:night activity revealed interesting differences. The low-RA group had highly irregular sleep-wake timing, were significantly later chronotypes than the high-RA group, and had more disturbed affect regulation, but did not differ in depression, anxiety, and feelings of anger. The low-RA group comprised fewer women treated with antidepressants. They did take more occasional activating and sedating drugs and alcohol, which may have additionally caused irregular circadian sleep cycles, since these substances can modify neuronal regulation of circadian rhythms and sleep (Roehrs & Roth, 2001; Wulff et al., 2010). Smoking and alcohol consumption are higher the later the chronotype in healthy subjects, and are also related to diminished well-being (Wittmann, Paulus, & Roenneberg, 2010). Depression symptoms tended to improve during light treatment only in the high-RA group, in which all patients were treated with antidepressants (SSRI and SNRI). Light may have potentiated the efficacy of the antidepressant drug, which already has been shown in several studies of nonseasonal major depression (e.g., Benedetti et al., 2003; Even et al., 2008; Kripke, 1998; Martiny, 2004) and in depressed patients with comorbid BPD (Prasko, Brunovsky, Latalova, Grambal, & Raszka, 2010).

Although light elicited beneficial effects on sleep and rhythm stability after only 1 week of exposure, improvement of mood in BPD patients did not reach a clear euthymic state. This may be due to the relatively short treatment time of only 3 weeks. It is important to emphasize that the antidepressant efficacy of light in nonseasonal depression may require longer treatment of at least 5 weeks, for example, as found in antepartum depression (Wirz-Justice et al., 2011).

We studied a relatively small sample size of 14 women with BPD, but obtained highly valuable longitudinal data over 6 weeks. In addition, the women were heterogeneous concerning prevailing symptoms, comorbidity, and medication, despite their diagnosis of a common underlying personality disorder. We aimed to investigate the sleep-wake cycles of women with BPD in their habitual life conditions, taking care to recruit a behaviorally comparable control group. Our findings suggest that clinicians should be aware that if irregular patterns and long sleep duration are observed in individuals with BPD, these sleep problems should be explicitly addressed in the treatment plan (e.g., by using light therapy).

Morning light therapy has beneficial effects on sleep disturbances, daytime sleepiness, and atypical depression in women suffering from BPD and is well liked by them as a treatment. Light may be a useful adjuvant in BPD to support other psychopharmacological and psychotherapeutic treatments, particularly if administered for longer periods of time.

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