Chronobiology International, 28(10): 930–941, (2011)

ISSN 0742-0528 print/1525-6073 online
DOI: 10.3109/07420528.2011.624436

informa
healthcare

Ring the Bell for Matins: Circadian Adaptation to Split Sleep by Cloistered Monks and Nuns

Isabelle Arnulf,[1,2] Agnès Brion,[1] Michel Pottier,[1] and Jean-Louis Golmard[3]

[1]*Sleep Disorders Unit, Pitié-Salpêtrière Hospital, APHP, Paris, France,* [2]*CRICM–Pierre and Marie Curie University, Inserm UMR_S 975, CNRS UMR 722, Paris, France,* [3]*Department of Biostatistics, Pitié-Salpêtrière Hospital, ER4, Pierre and Marie Curie University, Paris, France*

Cloistered monks and nuns adhere to a 10-century-old strict schedule with a common zeitgeber of a night split by a 2- to 3-h-long Office (Matins). The authors evaluated how the circadian core body temperature rhythm and sleep adapt in cloistered monks and nuns in two monasteries. Five monks and five nuns following the split-sleep night schedule for 5 to 46 yrs without interruption and 10 controls underwent interviews, sleep scales, and physical examination and produced a week-long sleep diary and actigraphy, plus 48-h recordings of core body temperature. The circadian rhythm of temperature was described by partial Fourier time-series analysis (with 12- and 24-h harmonics). The temperature peak and trough values and clock times did not differ between groups. However, the temperature rhythm was biphasic in monks and nuns, with an early decrease at 19:39 ± 4:30 h (median ± 95% interval), plateau or rise of temperature at 22:35 ± 00:23 h (while asleep) lasting 296 ± 39 min, followed by a second decrease after the Matins Office, and a classical morning rise. Although they required alarm clocks to wake-up for Matins at midnight, the body temperature rise anticipated the nocturnal awakening by 85 ± 15 min. Compared to the controls, the monks and nuns had an earlier sleep onset (20:05 ± 00:59 h vs. 00:00 ± 00:54 h, median ± 95% confidence interval, $p = .0001$) and offset (06:27 ± 0:22 h, vs. 07:37 ± 0:33 h, $p = .0001$), as well as a shorter sleep time (6.5 ± 0.6 vs. 7.6 ± 0.7 h, $p = .05$). They reported difficulties with sleep latency, sleep duration, and daytime function, and more frequent hypnagogic hallucinations. In contrast to their daytime silence, they experienced conversations (and occasionally prayers) in dreams. The biphasic temperature profile in monks and nuns suggests the human clock adapts to and even anticipates nocturnal awakenings. It resembles the biphasic sleep and rhythm of healthy volunteers transferred to a short (10-h) photoperiod and provides a living glance into the sleep pattern of medieval time. (Author correspondence: isabelle.arnulf@psl.aphp.fr)

Keywords: Biphasic, Circadian, Clock, Core body temperature, Monastery, Monk, Sleep, Split sleep

INTRODUCTION

Catholic religious life has organized a circadian rhythm since medieval times that is still maintained today within monasteries of cloistered persons (referred to here as "monks"). Throughout days and nights, the monks pray, work, eat, and rest at the same time, with a common zeitgeber (the tower clock bell). This rhythm predictably changes on certain days (e.g., Friday, Sunday) and periods of the year (e.g., winter fast, Christmas, Easter). Little is known about the habits and quality of sleep in the residents of these communities. The sleep of 10 nuns who had a modest habitual sleep restriction was monitored in a single study by Hoch et al. (1987). They slept better, with shorter sleep latency, higher sleep efficiency, and more rapid eye movement (REM) sleep time, than controls. However, they had a single sleep period without any interruption. In some strict orders, nighttime sleep is interrupted by long prayer Offices (called Matins or Vigils) that have existed since the origin of monastic life. Contrary to shiftworkers and solitary sailors (e.g., Åkerstedt et al., 2010; Ferguson et al., 2008; Ohayon et al., 2010), monks freely volunteer to follow this unusual rhythm during their entire life without interruption during weekends or vacations. Hence, they constitute an exceptional model to observe how the biological clock and the human adapt to split and curtailed sleep. We investigated sleep and body temperature circadian rhythm in a sample of 10 monks.

METHODS

The historical notes in the appendix of this article were obtained from a nonexhaustive study of books related to sleep at circadian times in Catholic monasteries, with

Submitted February 20, 2011, Returned for revision March 18, 2011, Accepted September 7, 2011

Address correspondence to Dr. Isabelle Arnulf, Unité des Pathologies du Sommeil, Hôpital Pitié-Salpêtrière, 47–83 boulevard de l'Hôpital, 75651 Paris Cedex 13, France. Tel.: 00 33 1 42 16 77 01; Fax: 00 33 1 42 16 77 00; E-mail: isabelle.arnulf@psl.aphp.fr

the help of university faculties and librarians of various orders. We were able to speak with 17 monks from the studied Order. A more complete prospective study of sleep, circadian rhythms, and food intake was performed in a subset of 10 monks and 10 controls.

Subjects

After having obtained agreement for the study from the ethical committee (Ile de France 03), we submitted the protocol to the Superior of the Order, who approved it. He recommended that the Order and the locations of the study remain anonymous, that the study include monks (as he had indications that nuns had more difficulties than monks adapting to split nights), and that the study be performed outside the fasting (as members would be less tired) and feast (such as Easter) times. He specified that the community was interested in any expert advice that could improve the adjustment of the monks to their nighttime split-sleep schedule. The Prior and Prioress asked for five volunteers of two monasteries (of 30 members in the monks' monastery and of 12 members in the nuns' monastery). The criteria for inclusion were to be fully French speaking (as these monasteries contained members from 15 different countries) and nonusers of medication that could interfere with the measure of circadian time or sleep. The controls were men and women from the outside world, recruited among friends and family of the investigators, who agreed to take part as controls by altruism. They were matched for age (± 4 yr) and sex, and were studied during the same month and at the same altitude as were the monks. The protocol and analysis conformed to the ethics and methods required by the journal (Portaluppi et al., 2010).

Study Setting

Life in the Monastery

The monks followed a strictly identical rule in both monasteries (Table 1). The organization of sleep time has been unchanged since 1423. At the time of the study (July), the monks ate two meals/d alone in their cell, including a complete lunch, a light meal before Compline, but no breakfast. The daily diet contained no meat (a remnant of medieval time when meat was expensive), but fish or eggs, two vegetables (one starchy), soup, four fruits, butter (20 g), cheese, yoghurt, or jam, two cookies or little cakes, bread, milk, fruit juice, or wine; obviously most monks did not eat all of this, but only what they needed.

Circadian Time

Electrical clocks, set up on the country local time, were used in the two monasteries. All monks woke-up using an alarm clock. In addition, monks wore a wristwatch on special occasions (like our study), which they frequently checked during the medical interviews (discussed later). The rest of the time, they easily regulated their time by the tower clock bell. The Father in charge of the young candidates to the monastic life indicated that candidates usually needed 6 mo to adjust to the monastic schedule. They would occasionally depend on herbal tea or hot wine with herbs, but not hypnotics, for sleeping. The books of the Order recommended monks promptly go to bed after Compline. If sleep was difficult to initiate, they were advised to turn their thoughts toward the Christ in the main church, represented by a permanent small vigil lamp.

Life in Silence

Both monasteries were built in a remote, elevated area, with forests and silence surrounding them. The monks lived together as a community of hermits, with a vow of silence and reduced contact with the outside world and other members of the community. Greetings were limited to a silent head nodding when they crossed in the cloister. They would write messages on small pieces of paper to make known their need(s). They lived alone in their own cell (a four-room house with a small garden surrounded by high walls). Their food was delivered once daily in their cell by a brother via a hatch. They left the hermitage cell daily to attend three prayer services in the monastery church. Additionally, once a week, the community members took a long walk together for an afternoon in the countryside, during which they were encouraged to speak. The monks frequently reported that living in loneliness and silence could make them over-sensitive to noise and the attitudes of other members, which could impact their sleep at night.

Matins

A first bell rang a single beat at 23:45 h (for waking-up, getting dressed, and briefly praying in the cell), followed by a single beat at midnight (for coming to the church), and several beats at 00:15 h (the beginning of the Matins), with a monk designated to ring the bell by pulling on a long cord. The members came together in silence and joined the others in the dark. The monks prayed in silence for 3 min and then the Prior knocked on the wooden stall, which indicated the beginning of Matins. If a monk was absent, the Sacristan went to seek him in his cell and determine if he might be ill. The temperature of the church was 21°C in July, but it could decline to –7°C during the night in winter. During Matins, two choirs in the church faced each other, in stalls, with a 30-lux discrete light mounted from above lighting the large books of chants. This small light was regularly switched off for 5–10 min for silent prayers in the dark. The reason for having such reduced light was to spare the use of candles and wax, and to create an atmosphere conducive to prayer. The Office was composed of Psalms accompanied by songs and lectures called lessons, either from the Scripture or the Church Fathers and Saints. Each sentence of the Psalms was sung *a capella* alternatively by the two facing choirs, with an extremely complex and precise timing, so that attention was required each minute. A monk also loudly read lectures from the Holy Bible and various other sources using a small

TABLE 1. Rules and schedules in the studied monasteries (ordinary day)

Time	Name	Occupation
00:15 h	Matins, followed by Lauds	Office together (prayer of the Psalms with readings) followed by Dawn Prayer in cell
02:30 h, 5 nights/wk		Second sleeping period
03:30 h, 2 nights/wk		
06:45 h	Prime	Early Morning Office
07:00 h	Individual mass	Mass in chapel, 45 min long
08:00 h	Conventual mass	Joint mass, 1 h long
09:00 h	Scripture meditation	Meditation, Contemplative prayer, Lectio Divina
10:00 h	Terce	Mid-Morning Office
10:15 h		Studies or manual work, duties
12:00 h	Sext	Midday Office
12:15 h		Lunch, relaxation (no nap)
14:00 h	None	Mid-Afternoon Office
14:15 h		Manual work or studies
16:15 h	Vespers	Evening Office together in church, 30 min long
18:15 h	Compline	Meditation, contemplative prayer
18:30 h		Light meal Evening Office
19:30 h		First resting period

flashlight. The position of the monks or nuns changed every ~5 min during this 2- to 3-h-long prayer, with kneeling, standing-up, sitting normally or on a mercy seat, and occasionally lying prostrate on the wood floor. As visitors, we had the feeling that the community developed sustained attention following a complex protocol in semi-darkness. Nobody slept or nodded. A dispense of Matins was given by the Prior to infirm monks, whereas the nuns were authorized to skip Matins once a week, if they were exhausted and especially at the time of menstruation.

Sleeping Rooms

The monks' clothes were made of cotton or wool, including a sort of tunic or robe and regular clothes underneath. The wool clothes of the monks in the mountains during the study weighted 7 kg. In the cells, the same variations of temperature as in the church (from –4°C in winter to 24°C in summer) were noted, despite the fact that the walls were 1 m thick. The monks had an individual, small wood-burning stove that could burn for no longer than 4 h; thus, that they had to fill it three times at night, before the first bedding, before Matins, and then before the second sleep period, to keep the cell constantly warm. Sawing and chopping wood into a convenient size for the stove was part of the healthy exercise that every monk performed in the morning and sometimes after Matins to rewarm themselves. The monks' beds had the shape of a medieval "closet" or enclosed beds, organized in a recess of three wooden walls. The nuns had an electric heating system and normal beds. The temperature in the cells varied from 19°C to 21°C in the men's monastery and from 23°C to 24.5°C in the women's monastery during the study weeks.

Occupations

The monks followed a regular regimen of prayers for a total of 6 h/d (ordinary days) to 7 h/d (twice a week) as outlined in Table 1. In addition, they did meditation or contemplative prayer and read and studied religious books for another 2 to 3 h/d. Each member also had a duty for the community (budget, liturgy, formation of new candidates, library, alcoholic beverage manufacture, distribution of food, and secretarial work). However, the most specific occupations of these monks were meditation and contemplation. As an example of meditation, a monk chose the sentence "the name of God gladdens the heart of all men," and mentally worked on this sentence, asking himself several questions, such as "What is the name of God in all languages," imagining the answers, and then looking how men in various countries gladden when pronouncing the name of God and thinking about Him. This mental activity was perceived as energy consuming, and the monk would be tired and even sleepy after it. Contemplation is harder to explain, as this state of consciousness with full contact with God is difficult to achieve, even after years of practice, and specifically researched in this order. One monk explained contemplation as: "I sit, look in front of me, and let me be flowed by the love of God." He reported that, in contrast to meditation, contemplation brought about feelings of quietness, serenity, internal peace, and was energy-filling and followed by full alertness.

Interviews and Data Collection

The monks spoke freely with the investigators, three times alone (during a total of 2 to 3 h each) and once as a group. Appointments were set up via papers placed in the hatch or via the monk in charge of the link with the outside world. Interviews were performed in person, using a semistandardized questionnaire that the subjects had received beforehand. The questionnaire included the Epworth Sleepiness Scale with clarification about entries pertaining to television watching and being in a car since these activities almost never happen in monastic life (Johns, 1991), the Morning-Evening Questionnaire (Horne & Östberg, 1976), and

the Pittsburgh Sleep Quality Index (Buysse et al., 1989). Subjects with a morning-evening score <53 were considered evening types, those with a score >64 morning types, and those between 53 and 64 neutral types (Taillard et al., 2004). In addition, there were free questions about medical, drug, and tobacco history, time spent in monastic life, sleep difficulties, sleepiness during the three times of prayer in church, snoring, sleepwalking, nocturnal micturition, temperature (fever), morning headache, fatigue upon awakening, hypnagogic hallucinations, sleep paralysis, and dream contents (did they have conversations, did they pray in dreams). The controls answered the same questionnaire, with the exception of specific questions relative to monastic life.

Participants underwent a physical examination, with assessment of blood pressure; pulse; height, neck, hip, and waist perimeters; body weight; and body impedance (Tanita, Tokyo, France). They completed a sleep log and wore a wrist actigraph (Actiwatch-Mini; Cambridge Neurotechnology, Cambridge, UK), which measured the intensity of movements at 1-min intervals for 7 d. Core body temperature was measured using an ingested pill containing a thermal sensor and transmitter, which transmitted data every minute for ~48 h (depending on its transit time through the gastrointestinal track) to an external receptor (Vitalsense, xx, UK).

Data Handling and Statistical Analysis

The measures (except body temperature) are reported as medians and 95% confidence intervals. Numeric differences between controls and monks were compared using the two-sample Wilcoxon test. Categorical differences were compared using the chi-square test. The temperature curves were fit using Chronos-Fit 1.06 (Zuther et al., 2009) as partial Fourier series with two (24- and 12-h) harmonics, with nighttime extending from 23:00 to 06:30 h in July. Statistical analyses were performed using SAS 9.2 software (SAS Institute, Cary, NC, USA) on the values obtained via the rhythm analysis, using the two-sample Wilcoxon test for differences between groups. All tests were two-sided, and the threshold for significance was $p < .05$. The mean temperature was calculated by linear analysis.

RESULTS

Demographical and Clinical Characteristics of the Groups

The 10 monks studied (5 men/5 women) were between 38 to 67 yr of age (Table 2). Some additional (n = 7) monks did not take part in the full study, but spoke with us. The monks belonged to the same community and had followed the same rhythm of life for a median 26 ± 9.3 yr (range: 5–46 yr). They were in good health at the time of the study, although some had had breast and prostate cancer (n = 2), neurinoma (n = 1), and hyperthyroidism (n = 1), or were being treated for hypertension (n = 1) and neurosis (n = 1). One control had had lung cancer (n = 1) and two others were being treated for type II diabetes (n = 1) and hypertension (n = 1). The findings of the physical examination were within normal ranges and did not differ between the two groups, as were the norms for body mass index, fat and water body composition, percentage of obesity, waist/hip circumference ratio, neck circumference, systolic and diastolic blood pressures, heart rate, and basal metabolism (Table 2).

The Sleep of the Monks

The monks went to bed much earlier than control subjects, but they tended to take longer to fall asleep (Table 3). The final moment of awakening occurred earlier in monks than in controls. Sleep duration was 1 h shorter in monks than in controls. Monks more frequently complained of sleep problems (including longer

TABLE 2. Demographical and clinical characteristics of monks and controls

	Monks	Controls	*p*
Age, yr	53.0 ± 6.7	53.5 ± 6.3	.88
Blood pressure, systolic, mm Hg	110 ± 10	117 ± 15	.55
Blood pressure, diastolic, mm Hg	60 ± 9	72 ± 7	.26
Heart rate, beats/min	70 ± 4	67 ± 5	.95
Neck circumference, cm	33.5 ± 2.6	33.2 ± 1.9	.75
Waist/hip circumference ratio, %	87 ± 4	79 ± 5	.27
Body mass index, kg/m^2	23.4 ± 3.3	23.4 ± 1.7	.76
Body fat, %	22.6 ± 3.4	24.9 ± 4.2	.43
Body water, %	53.5 ± 2.5	51.5 ± 2.8	.46
Degree of obesity	2.2 ± 9.4	11.2 ± 4.8	.64
Basal metabolism, kcal	1460 ± 207	1676 ± 152	.88
Core body temperature			
Mean, °C	37.1 ± 0.09	37.2 ± 0.12	.66
Peak, °C	37.5 ± 0.18	37.3 ± 0.18	.11
Peak time, h:min	16:50 ± 2:42	17:10 ± 2:00	1.00
Trough, °C	36.5 ± 0.19	36.5 ± 0.18	.66
Trough time, h:min	04:52 ± 2:00	04:61± 1:58	.86
24-h amplitude, °C	0.48 ± 0.15	0.38 ± 0.15	.11

TABLE 3. Sleep and sleep symptoms in monks vs. controls

	Monks	Controls	*p*
Bedtime, h:min	20:05 ± 00:59*	00:00 ± 00:53	<.0001
Sleep offset, h:min	06:27 ± 0:22*	07:37 ± 0:33	.0001
Sleep onset latency, min	17.5 ± 28.1	7.5 ± 2.5	.08
Usual sleep duration, h	6.5 ± .6*	7.6 ± .7	.05
Morning-evening score, 0–86	59.0 ± 9.3	48.5 ± 4.8	.33
Evening chronotype	50%	60%	1.00
Epworth sleepiness score, 0–24	8.0 ± 2.3	5.0 ± 2.6	.18
Sleep paralysis	30%	30%	1.00
Hypnagogic hallucination	60%	10%	.06
Occasional nightmares	80%*	20%	.02
Restless legs syndrome	30%	10%	.58
Pittsburgh Sleep Quality Index			
Global score	6.0 ± 2.1*	2.5 ± .9	.003
Subjective sleep quality	1.0 ± .8	.0 ± .4	.10
Sleep latency	1.0 ± .8*	.0 ± .2	.03
Sleep duration	1.0 ± .0*	.9 ± .0	.05
Habitual sleep efficiency	.0 ± .3	.0 ± .3	1.00
Sleep disturbances	1.0 ± .3	1.0 ± .3	.09
Use of sleeping medication	0 ± 0	.0 ± .2	.34
Daytime dysfunction	1.5 ± .5*	.0 ± .3	.001
Morning tiredness	1.5 ± .7*	1.0 ± .3	.01
Morning headache	.0 ± .3	1.0 ± .3	.08
Memory complaint	2.0 ± .7*	.0 ± .3	.02

*$p < .05$.

sleep onset latency, lower sleep efficiency, more tiredness in the morning, and memory deficiency) than controls, although none took hypnotic sleeping pills. The typical nature of the rest-activity rhythm of the monks, as assessed by wrist actigraphy, is shown in Figure 1.

Waking-up for Matins

Six monks never woke before Matins and four monks were occasionally awake before Matins, but none were almost often or often awake before Matins. They all used several (two to six) alarm clocks. They reported that as young monks they would wake-up suddenly with rapid heart rate before the alarm sounded, believing that they had heard the signal. The Superior recommended them to appease, and this feeling ceased with time (years). Three monks, who had been hospitalized for illness, remembered that they woke-up spontaneously at midnight in the hospital, as if their body still followed the monastic schedule for Matins. They reported that it took them between 6 mo and 5 yr to adapt to the rhythm when they entered the community. Four of them, however, still had difficulties with the rhythm, even after having spent 20 to 46 yr of their life in the monastery. All of them were evening types. After Matins, the monks went to bed between 02:30 and 03:15 h, taking them 17.5 ± 22.8 min (0–120 min) to resume sleep. This second sleep latency was not significantly shorter than the first sleep latency ($p = .67$).

Circadian Rhythm

The morning-evening score of the monks tended to be higher than that of the control subjects (Table 3). Bedtime of the monks varied between 19:00 and 22:00 h, which meant that the first night sleep varied in duration from 2 to 5 h. By clinical interview of the 17 monks, rather than by using the morning-evening score (which was difficult to interpret in the context of monastery life), it appeared that the monks with a morning chronotype had a longer sleep time before Matins. The mean, peak, trough, and amplitude values and the clock-times of the peak and trough core temperatures during the 24 h did not differ between the two groups (Table 2 and Figure 2), although there was a trend for higher peak and amplitude core temperatures in monks vs. controls. Monks showed a biphasic temperature profile, with a first decrease of temperature at 19:39 h (± 270 min) and a plateau or rise at 22:35 h (± 23 min) while asleep, lasting 296 ± 39 min (202–360 min), followed by a second decrease after the night Office (temperature trough at 05:38 h ± 53 min) and morning classical rise (Figures 3 and 4). Although all monks required alarm clocks to awaken for Matins, the rise of core body temperature occurred during sleep and anticipated this nocturnal awakening by 85 ± 15 min (42–110 min).

Dreams and Hallucinations

Six monks had experienced mild (n = 4, ringing of the cell door at sleep offset or of the alarm clock, feeling that someone hit them briefly in the back, waking-up during the second sleep while mentally singing psalms) and moderate (n = 2, nightmarish, prolonged feeling of a demoniac presence at sleep onset after Matins) sleep-related hallucinations vs. one control ($p = .06$). Occasional nightmares were more frequent in monks

than in controls. All monks reported dreaming more often after than before the Matins, and to have conversations in their dreams. These conversations were rare (n = 3), hard to understand (n = 2), or frequent (n = 5). As for prayers, six monks were able to pray while dreaming, although it was rare, whereas two others dreamt of acts of piety, or imagined a disrupted liturgy, and finally two of them dreamt they were never monks.

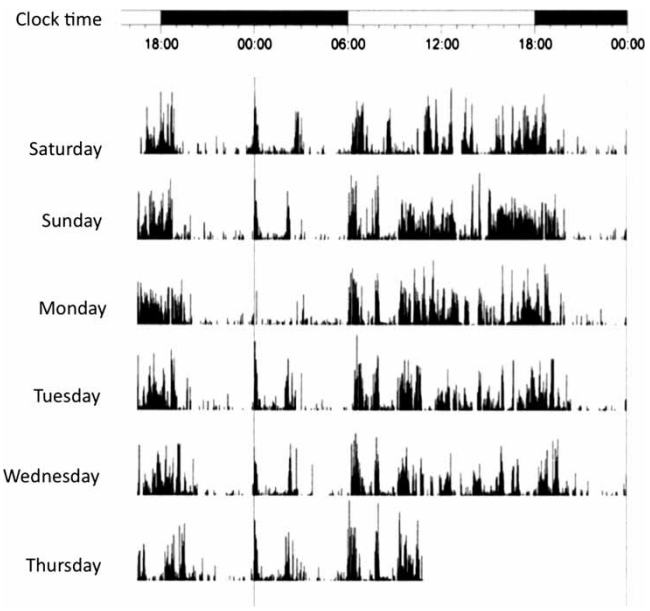

FIGURE 1. Rest-activity rhythm of a nun during 7 consecutive days of wrist actigraphy. The level of activity is illustrated in black, whereas complete rest (assimilated to sleep) appears in white. Each day is a different line, with clock time indicated on the *x*-axis. The first sleep period starts between 19:00 and 20:00 h, with a very low level of activity. It ends at midnight, when a high level of activity signals the nun getting dressed and walking to the church, followed by a lower level of activity (attending the Office), and then a high activity (walking back to the cell) at 02:30 h on normal days and 03:30 h on Sunday and Thursday (special days in Christian liturgy, with a longer Matins Office). Then, the second sleep period (very low level of activity) starts between 02:30 and 03:30 h and ends between 06:00 and 06:30 h. This night schedule has been unchanged in this monastic order since 1423.

DISCUSSION

These contemplative monks following a rule of a split-sleep night have longer sleep latency, shorter sleep time, higher morning fatigue, and more complaints of memory lapses than controls. Furthermore, their core body temperature shows a biphasic profile, with a plateau or rise in temperature while asleep (preceding the nocturnal awakening by a mean of 85 min). Despite this anticipation, they have difficulty awakening spontaneously before midnight. Mild hypnagogic hallucinations and occasional nightmares are more frequent in monks than in controls.

Circadian Pattern in Monks

The main markers of the core body temperature curve (mean, amplitude, peak, and trough values and times) do not differ between monks and controls, but the major finding here is the biphasic temperature profile in the monks, despite they are asleep. The circadian profile of temperature (peak in the afternoon and trough in the early morning) is a strong marker of the circadian brain clock (Czeisler et al., 1999). Healthy subjects sleeping with a single sleep period display the classical decrease in core body temperature during the end of the evening, preceding sleep onset. The time of the downward slope varies with chronotype (Baehr et al., 2000). It starts earlier (~20:00 h) in morning types and later (around midnight) in evening types. The descending temperature in the evening promotes sleep onset, whereas the rise of temperature in the early morning contributes to the termination of sleep (Czeisler et al., 1980).

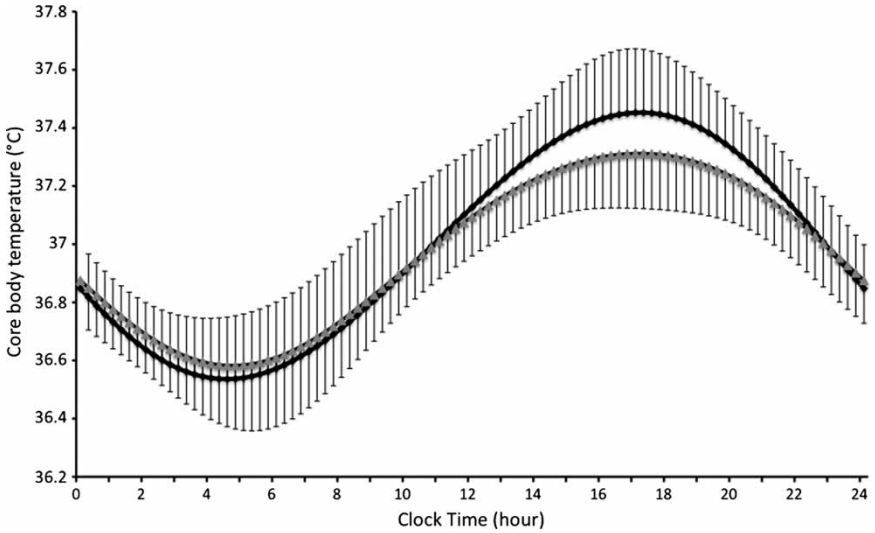

FIGURE 2. 24-h rhythm of core body temperature in monks (black line) vs. controls (gray line), as obtained after fast Fourier transformation into 24 + 12 harmonics. Data are presented as the mean ± SE per 15-min interval.

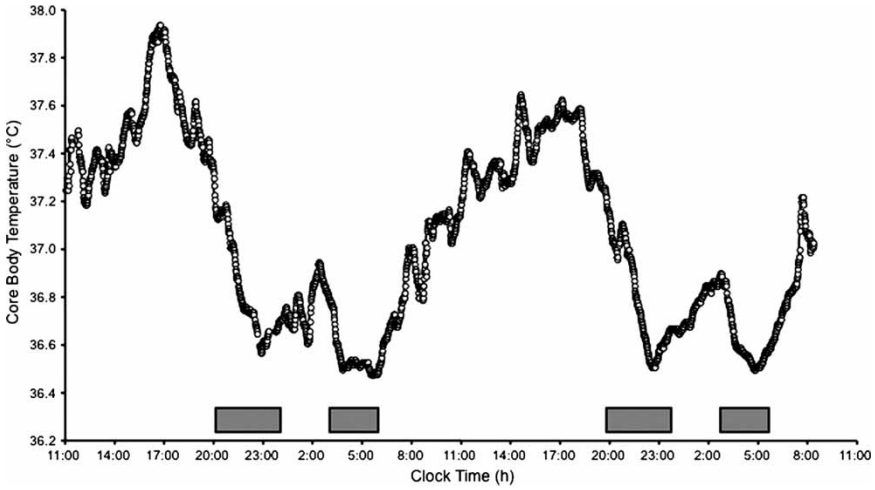

FIGURE 3. 24-h rhythm of core body temperature in a nun studied for 48 h (raw measures). The two periods of sleep, as estimated by actigraphy, are indicated in gray squares. Note the biphasic aspect of the temperature slope at night, with a first decrease ~17:00 h, and an interruption in the descending slope at 22:30 h, while the nun is asleep, followed by a re-increase during sleep, further marked during wakefulness (Matins), with a second decrease at the end of Matins.

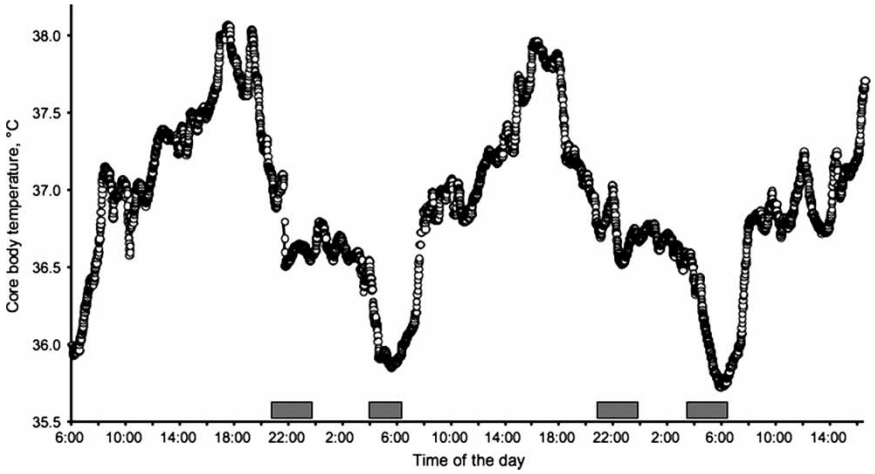

FIGURE 4. 24-h rhythm of core body temperature in a monk studied for 48 h (raw measures). The two periods of sleep, as estimated by actigraphy, are indicated in gray squares. Note the biphasic profile of the temperature slope at night, with a first decrease ~17:00 h, and an interruption in the descending slope at 21:30 h, while he is asleep, followed by a plateau during sleep and later during activity (Matins), with a second decrease at the end of Matins.

In monks, the peak temperature, downward slope, and trough occur at the same time as in controls, but there is a plateau or a re-increase of body temperature soon after the downward slope. As this plateau or re-increase is observed in sleeping monks, it is not caused by physical activity. It is observed daily, which suggests that it is predetermined. The plateau or re-increase precedes nocturnal awakening by 1.5 h. This body temperature pattern resembles the rise in temperature that precedes the final awakening in the morning, but to a lesser extent. The regulation of sleep termination has been thought to be embedded in a daily circadian rhythm controlling in parallel the release of pituitary and adrenal hormones (Czeisler et al., 1980). A routine, predicted time of sleep offset is preceded by a gradual increase of adrenocorticotrophin 90 to 180 min before final awakening (Born et al., 1999). It is tempting to imagine that the circadian clock in monks has adapted to the nighttime split rhythm to the point of becoming biphasic. One may note that normal subjects can advance or delay their temperature rhythm after 1 to 3 wk in a given circadian time. Our monks had been following this unique split-night rhythm for 5 to 46 yr, without interruption during weekends or holidays, which should durably consolidate their circadian clock. As they note that it took them 6 mo to 5 yr to adapt to this specific schedule, it would be interesting to examine how the circadian rhythm changes during the first 6 mo of following the monastic rules. The midnight awakening is fixed, whereas the end of the Matins office varies by 1 h. This biphasic rhythm could facilitate the nocturnal awakening, and could drive the secretion of several hormones so that cortisol would be increased

(and glucose would be available) during the nocturnal physical and mental activities. The profiles of adrenocorticotrophin, cortisol, glucose, leptin, and ghrelin have to be measured to support this hypothesis.

Despite this fascinating change in the core body temperature profile, and following a very regular routine, the monks frequently report difficulties in awakening spontaneously (i.e., without alarm clock) for Matins. The difficulty of waking-up at midnight compels some of them to use several loud alarm clocks, suggesting they have a high threshold for awakening when the clock rings, possibly because they are either in deep slow-wave sleep or in REM sleep, and because the auditory arousal threshold is higher in the first part of the night (Rechtschaffen et al., 1966). If some subjects, who have adapted for decades to a certain rhythm with major changes in their circadian clock and high motivation, still have difficulties awakening at midnight, it suggests that the human brain sleep and circadian systems reach their limits here and cannot fully adjust to a split night. In contrast, three monks reported awakening spontaneously at midnight when they had to be hospitalized outside of the monastery. They possibly mix the higher arousal threshold caused by sleeping in a new environment with their inner clock.

Sleep

The monastic split-night routine impacts the sleep of the studied monks. Compared to the nuns who have a single, short sleep period with high sleep efficiency (Hoch et al., 1987), the monks here have a low sleep efficiency. Those with an evening chronotype have difficulty falling asleep early in the evening, even after decades of this rhythm. As a consequence, despite the fact that the schedule allows 8.5 to 9 h of time in bed, only a median 6.5 h is spent asleep, i.e., 1 h less than the controls. Contrary to the frequent sleep restriction recommended in the early years of monastic history, there is no desire here of asceticism, as the time in bed should be sufficient to allow for a normal sleep duration. However, the schedule is too early for some evening-type monks, and the potential consequence during the daytime is more morning tiredness and memory complaint (lapses) than controls. Despite the reduced sleep time, they are in good shape (most without hypertension), and are not particularly obese, as are, in general, subjects who voluntarily reduce their sleep hours. As reduced sleep time may cause daytime tiredness, one may suggest that monks take a siesta between Sext and None (see Table 1) to compensate for their lack of sleep. Although it is uncommon in the Order we studied, some monastic orders do include a siesta at some times of the year, mostly during summer, when nights (and consequently sleep) are shorter. Another solution for evening-type monks, who experience difficulty falling asleep before 22:00 h, is to prescribe them melatonin in the early afternoon to advance their circadian rhythm. We suggested this solution to some of them with success. One may also suggest they decrease their core body temperature before sleeping, using fresh beverages, drugs, and tea with medicinal plants (as they are famous herbalists) that decrease body temperature.

The split night of the monks evokes a habit of the middle ages, that is, to sleep in two segments, with a wakeful break in between (Ekrich, 2006). Lay people used this time to pray, do security checks of their home, or just reflect. This habit was common during medieval time and was not associated with any deleterious consequences. Similarly, when healthy volunteers are transferred from a conventional 16-h to a 10-h photoperiod, their sleep becomes biphasic, with two symmetrical bouts several hours in duration, and an 1- to 3-h waking interval between them (Wehr, 1992). The duration of melatonin secretion expands during these protocols. Similarly, when the sleep-wake regimen is changed from 8-h asleep/16-h awake to 10/20 or even 12/24 (i.e., increasing the periods allotted to sleep and to wake), sleep efficiency decreases and wakefulness after sleep onset time increases, especially in the last hours of sleep, leading to a sleep termination effect (Webb & Agnew, 1975). From a clinical point of view, the split-night schedule of the monastery also shares some similarities with the maintenance of sleep insomnia. Of course, the long wakefulness after sleep onset is deliberate, in contrast with insomniacs who unsuccessfully try to resume sleep between midnight and 04:00 h. One may, however, measure the body temperature in patients with sleep maintenance insomnia to examine if, after a regular occurrence of this type of insomnia, they also develop a bicircadian temperature rhythm anticipating the nocturnal awakening and thus preventing them from resuming sleep for some hours thereafter during the night. The split sleep of monks (and of medieval time) can also be given to these insomniacs as examples of normal variations in human sleep with little daytime consequences, and particularly without any consequence on life duration. It could help them minimize their anxiety relative to being awake in the middle of the night, and, therefore, resume sleep more easily.

The more frequent hypnagogic hallucinations in the monks clearly occur during the second part of the night, between 03:00 and 06:30 h. We think that falling asleep at this time of the night, especially when sleep-deprived, exposes one to more frequent REM sleep onset periods and associated hallucinations. The themes of the auditory hallucinations (bells, alarms, knocking at the door, singing psalms—all of them being usual sounds in the monastery), which occur mainly at sleep offset, are not surprising in the context of a life in silence and loneliness. The meaning of demoniac visual hallucinations (mainly at sleep onset of the second sleep) is anchored in a life turned towards religion. Demoniac perceptions at sleep onset are also commonly observed in the general population and are often associated with a concomitant sleep paralysis, and even more in patients with narcolepsy when directly entering into

REM sleep (Leu-Semenescu et al., 2011). We think that the second sleep period may be rich in REM sleep, with a short REM sleep latency, as it occurs during extended sleep, after a spontaneous interruption (Barbato et al., 2002), exposing monks to more dreaming and nightmares. However, a complete polysomnography study would be necessary to substantiate this hypothesis, as well as compare the hallucination and nightmare frequency between Orders with and without a split-night sleep schedule. Praying is only occasionally found in some, but not all, monks, despite it being one of their main occupations during the day. Praying requires highly focused cognitive processes, involving a frontal parietal circuit composed of the dorsolateral prefrontal, dorsomedial frontal, and medial parietal cortex (Azari et al., 2001). The perception of God's love activates the right middle frontal gyrus in believers (Kapogiannisa et al., 2009). All these regions are hypoperfused during REM sleep (Braun et al., 1998; Maquet et al., 1996). Meditation also activates a large network of attention-related brain regions, including frontal parietal regions, lateral occipital, insula, multiple thalamic nuclei, basal ganglia, and cerebellar regions (Brefczynski-Lewis et al., 2006), some of them (e.g., frontal parietal regions) being hypoperfused during REM sleep.

Limitations

This preliminary study has several limitations. First, the studied sample is small, limiting statistical power to show differences between monks and controls. We use medians rather than means, and nonparametric tests to reduce the bias of small samples. Plus, the sample (including not only the five monks and five nuns who took part in the entire study, but the 17 interviewed monks) represents only 41% of the total population of both monasteries. Despite this limitation, several differences in sleep duration, efficiency, and quality plus body temperature circadian profile are obvious between monks and controls. The peak and 24-h amplitude of the core body temperature profile tend to be higher in monks, trends that may reach significance in the future if the sample size is increased. The second limitation pertains to the absence of polysomnography and hormone measures. One may understand that performing this study is disturbing to the life of the monks; hence, we deliberately chose to restrict the study to interviews, subjective scales, diaries, and simple measures of motor activity and core body temperature.

In conclusion, this study shows that the human clock can partially adapt to regular split nights, with an anticipatory biphasic temperature profile. It also provides a fascinating, living glance into the history of circadian time and sleep in medieval Europe.

ACKNOWLEDGMENTS

We warmly thank the monks for having taken part in our research and for their kindness, their enthusiasm for the study, and their discretion. They have desired to stay anonymous. We thank the American monk who corrected the manuscript, and the librarian monk. The study was financed by ADOREPS (Association pour le Developpement et l'Organisation de la Recherche en Pneumologie et Sommeil).

Declaration of Interest: The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

APPENDIX

Circadian Rhythm in Monks Since the 4th Century

Since the Roman period, time was calculated from sunrise (Prime, meaning the first hour of the day), then every 3 h, as indicated by the Latin-origin word Terce (standing for the 3rd h), Sext (6th h), and None (9th h). Daytime and nighttime were divided into 12 h each. As a consequence, the Roman "hours" were not 60-min long, but were longer than 60 min during the daytime of summer (lasting a maximum of 90 min at summer solstice), shorter than 60 min during the daytime of winter (lasting 45 min at the winter solstice, when the "day" lasted only 9 of our actual hours), and equal to 60 min at the equinox (Biarne, 1981). The rule of Saint Benedict (6th century), which was the most used in medieval European monasteries, was based on this Roman time, as reported later in the complex universal monastic clock (Van Haeften, 1643). The idea of dividing day and night into 24 equal hours, from midnight to midnight, came later, as in the 12th century in the first Carthusian calendar, which indicated at the beginning of each month the number of night and day hours, such as: "January, the night has 16 hours, the day has 8 hours" (Laporte, 1965). The nighttime, from 18:00 h to 06:00 h, was divided into four watches of 3 h each. The Liturgy of the Hours (also named Divine Office) was the official set of daily prayers prescribed by the Roman Catholic Church to be recited at the canonical hours by the clergy, religious orders, and laity. These prayers included Matins, Lauds, Prime, Terce, Sext, None, Vespers, and Compline. The general principle was to devote to God these various times of the day by an Office made up of songs and recitation of the Psalms, readings, and prayers, following the Jewish practice of offering prayers every 3 h. Another aim mentioned by Saint Benedict was to structure the day of the monk as to avoid idleness. Monasteries were, indeed, an example of the evolution of hermitic life, with the idea that hermits living and praying alone for decades may lose time markers. This explains the importance given to a common schedule. In contemplative Catholic monks, social contacts were restricted to the minimum (to live like hermits, with a rule of silence and loneliness, each monk living alone in a separate cell), but the common information about time (the zeitgeber) was given by the tower or church bell. The importance of keeping time was illustrated by the central place

of bells and clock towers in monasteries, and by the office of timekeeper, given to the Father Vicar in the Order we studied. In addition to ringing the bells, this monk was also in charge of awaking the other monks, mostly by knocking at their cell door at night. His name was *excitatio dominus* (awaking Father). The sleeping monk had to confirm that he was awake, and he did so by knocking back on the wall. Some monasteries used a more complex system of small individual bells driven by the Vicar, ringing within each cell before Matins, with a similar bell feedback from the cells to inform the vicar they were awake. The time was given by the cock chanting; the sundial in the Roman time; the water clock (calibrated with a sundial); marked candles and a hourglass at the time of King Charlemagne (used in monasteries when the weather was not sunny); mechanical clocks with falling weights around the year 1000 and with a spiral coil in the 15th century; and with a pendulum in the 17th century (Dohm-Van Rossum, 1996). In the 11th century in the Carthusian order, the time for waking-up the whole monastery in the mountains was determined by the first ray of sun on a visible summit, a time changing by definition every day (Laporte, 1965). Saint Peter Damian asked the bell-ringer to observe not only the sun, but also the moon and stars to fix time, and to remediate the problem of cloudy weather by singing a given number of psalms (Bède le vénérable [saint], 1844). Psalms are indeed sung with a precise rhythm by monastic choirs, so that their duration can be an indication of time ("Psalms clock"). Yet, there were more Psalms sung during winter than during summer Matins among the Black monks (Ardo seu Smaragdus, 1844), among the Clunisian monks (Uldaric, 1844a), and in the Canterbury monastery (Lanfranc, 1844). The first hour of the day (Prime) was frequently determined as the first hour during which one could read, and the last hour (Compline) when reading was no longer possible. The books of hours appeared in the 12th century as a way to adapt monks' time to the secular Clergy. Some authors even consider that the concept of modern time has arisen from the monastic system of time keeping (Duchet-Suchaux & Duchet-Suchaux, 2006). The bell was heard in the villages around the monastery, and it signaled time of day to the peasants.

Sleep in Monastic Life Since the 4th Century

Bedtime

The last prayer of the day (Compline, which stands for the completion of the day) was said before going to bed in monasteries. It has been translated for secular people as a pre-sleeping prayer. Compline was (and is still) set up ~18:45 h. One must keep in mind that the main human activity in the 4th century was mostly agriculture, so that going to bed ~19:00 h in monasteries was not considered as being different from the bedtime of the farmers in Campania (Italy), where the West European monastic life first appeared. A rule indicated: "After the bell has been rung for the Angelus, they do not put off saying Compline beyond one hour. After reciting it they go to bed without delay. During the time allowed for rest, they must take care to get sufficient sleep so that they may participate with eagerness at the night Office" (Laporte, 1965).

Sleep Duration

Many hermits in the 3rd century (and later some Orders with strict rules) considered sleep as something negative, for it was a waste of time, a time not spent with God, and could be invaded by demonic nightmares. Abba Daniel said of Abba Arsenius (354–450 AD) that he used to spend the whole night without sleeping, and in the early morning when nature compelled him to go to sleep, he would say to sleep: "Come here, wicked servant!" Then, seated, he snatched a little sleep and soon awoke again. He used to say that 1 h of sleep was enough for a monk if he was a good fighter (Dom Regnault, 1981). Ascetic monks (who partly inherited asceticism from Greek philosophers, stating that the mind should overcome bodily needs) tried to reduce not only food and human contacts but also sleep, as did Saint Anthony (3rd century). The ascetic ways of sleeping included sleeping on a column (Saint Simeon Stylites, in Syria, 3rd century), on a trunk covered by pins (Dendrit hermits, 3rd century), sitting (Saint Pacomius, 4th century), leaning back against a wall (Guillaumont, 1979), on the cobblestone floor of the church (Saint Dominic, 12th century), on a bed made of vine shoots (Saint Clare of Assisi, founder of the "Poor Clares" Order), or on a wood board with a stone as a pillow in the Feuillant Order, 16th century (Gain, 1989). The rule of Saint Benedict (8th century) was softer about sleep and contained many details on this topic, including the organization of dormitories, sleeping clothes, and sleeping times: "*It seems reasonable to arise at the 8th hour of the night. By sleeping until a little past the middle of the night, the brothers can arise with their food fully digested*" (Chapter 8, 1–2). "*On arising for the Work of God, they will quietly encourage each other, for the sleepy like to make excuses*" (Chapter 22, 8). In some rules, which included awakening very early, sleeping after the Matins was forbidden except for old or disabled monks who could sleep on a bench. The young monks were prevented from resuming sleep in the early morning during the wintertime by being assigned to shucking beans in the pod, waxing shoes, sewing clothes, and peeling turnips (Laporte, 1965). In the congregations of Cluny, a monk was in charge of checking, with a lantern, that no monk would in secret sleep between Lauds and Prime (Uldaric, 1844b).

Almost all rules limited sleep duration, but it was longer in winter than in summer (Biarne, 1981; Gain, 1989). Saint Columba, who founded monasteries in Ireland and France in the 6th century (e.g., Jumiège or Saint Wandrille in Normandy), recommended monks sleep no more than 5 h/d (Gerhards, 1998). If some

monastic legislators suggested punishing monks who yawned or fell asleep during the Offices, others, such as John Cassian (4th century), underlined that the duration of sleep had to be sufficient to avoid daytime sleepiness (Jean-Cassien [saint], 1965). They recommended a sleep of 7 to 8 h, or to compensate for the shortened sleep in summer (4 h and 15 min) by a siesta after Sext (see Table 1), which was named as the "meridian" (standing for mid-day), and could last up to 3 h (Jean-Cassien [saint], 1965). Even Saint Peter Damian (11th century), who was in favor of restricting sleep in his chapter named "*De somni ratione*," recognized that the use of the meridian siesta in summer allowed the Offices to be more correctly celebrated (Pierre Damien [saint], 1844). In the Carthusian rule, sleep duration varied across the year from 5.5 h in April to 9 h in October (Laporte, 1965).

Early Awakening, Vigils, and Matins

The tradition among the Fathers of the Desert (the first hermits) was to devote half of the night to sleep, and the other half to prayers (Festugière, 1964). Sleep time was either a single period (with a late bedtime or a very early awakening), or was divided in two (and even more) periods, depending on the rules of the Order. In the Benedictine Order, sleep was a single period, with an awakening ~03:30 h for a prayer named Vigils (or Matins, which stands in Latin for "coming with the morning"). The word Vigils refers in Latin to "night watch." The nightly Vigils ended with dawn and the prayer of Lauds, which symbolized the resurrection and ended with sunrise (Niaussat & Thomas, 2000). Notably, the Cistercian churches were oriented East-West so that the altar received the first sunlight of dawn through the church window. Awakening at 05:00 h, however, was difficult for some of the Benedictine monks we met. One reported that he was placed by his superior in a cell located just against the major bell so that he could be awakened by this enormous noise, but he stayed asleep anyway.

In other orders, sleep time was split by the nighttime Office, also called Matins, and followed by the Lauds. The Psalms contained indications of time, such as: "At midnight I will rise and thank You." Here the idea was again to obtain a more continual prayer, the monks being awake, so that the rest of the world could peacefully sleep. Other reasons for being awake in the middle of the night included the research of full silence to read the holy texts (a monk, personal communication), the concept that most divine messages had been delivered at night, and, hence, one should be awake to receive them (another monk, personal communication), asceticism, and the avoidance of sleep-associated nightmares and unwanted dreams (with the idea that they are uncontrolled and possibly sent by the devil). In the Irish abbey of Bangor (6th century), the daytime and nighttime organization included seven different teams of monks, who relayed each other to continuously pray and sing all night long (Arnoux, 2000), as would nurses/physicians or sailors do to ensure the 24/24 h of permanence on duty. The Coptic monks in Egypt still follow a 4- to 5-h-long night Office with one monk singing the Psalms and another one reading holy texts, while the other monks come and leave the church at any time during the night.

REFERENCES

Åkerstedt T, Nordin M, Alfredson L, Westerholm P, Kecklund G. (2010). Sleep and sleepiness: impact of entering or leaving shiftwork—a prospective study. *Chronobiol. Int.* 27:987–996.

Ardo seu Smaragdus. (1844). Vita sancti Benedicti Anianensis. *Patrologiae latinae cursus completus* PL 103:52.

Arnoux P. (2000). *Abbayes et monastères: principaux ordres monastiques et religieux des origines au XX° siècle.* Le Cannet: TSH.

Azari N, Nickel J, Wunderlich G, Niedeggen M, Hefter H, Tellmann L, Herzog H, Stoerig P, Birnbacher D, Seitz RJ. (2001). Neural correlates of religious experience. *Eur. J. Neurosci.* 13:1649–1652.

Baehr E, Revelle W, Eastman C. (2000). Individual differences in the phase and amplitude of the human circadian temperature rhythm: with an emphasis on morningness-eveningness. *J. Sleep Res.* 9:117–127.

Barbato G, Barker C, Bender C, Wehr TA. (2002). Spontaneous sleep interruptions during extended nights. Relationships with NREM and REM sleep phases and effects on REM sleep regulation. *Clin. Neurophysiol.* 113:892–900.

Bède le vénérable (saint). (1844). Libellus de mensura horologii. *Patrologiae latinae cursus completus* PL 90:953.

Biarne J. (1984). [The time of the monk, from the first monastic rules in Occident, IV–VI° centuries]. In Centre National de la Recherche Scientifique (ed.). [*Christian time from antiquity to middle-age. III–XIII° centuries*]. Les editions du CNRS, Paris, pp. 99–128.

Born J, Hansen K, Marshall L, Molle M, Fehm H. (1999). Timing the end of nocturnal sleep. *Nature* 397:29–30.

Braun AR, Balkin TJ, Wesensten NJ, Gwadry F, Carson RE, Varga M, Baldwin P, Belenky G, Herscovitch P. (1998). Dissociated pattern of activity in visual cortices and their projections during human rapid eye movement sleep. *Science* 279:91–95.

Brefczynski-Lewis J, Lutz A, Schaefer H, Levinson D, Davidson R. (2006). Neural correlates of attentional expertise in long-term meditation practitioners. *Proc. Natl. Acad. Sci. U. S. A.* 104:11483–11488.

Buysse D, Reynolds CI, Monk T, Berman S, Kupfer D. (1989). The Pittsburgh Sleep Quality Index: a new instrument for psychiatric practice and research. *Psychiatry Res.* 28:193–213.

Czeisler C, Weitzman E, Moore-Ede M, Zimmerman J, Knauer RS. (1980). Human sleep: its duration and organization depend on its circadian phase. *Science* 210:1264–1267.

Czeisler C, Duffy J, Shanahan T, Brown E, Mitchell J, Rimmer D, Ronda JM, Silva EJ, Allan JS, Emens JS, Dijk DJ, Kronauer RE. (1999). Stability, precision, and near-24-hour period of the human circadian pacemaker. *Science* 284:2177–2181.

Dohm-Van Rossum G. (1996). *History of the hour: clock and modern temporal orders*. Chicago: University of Chicago Press, 440 pp.

Dom Regnault L. (1981). Les sentences des Pères du désert. *Solesmes*: 25.

Duchet-Suchaux G, Duchet-Suchaux M. (2006). *Les ordres religieux*. 318 pp, Paris, France: Flammarion.

Ekrich A. (2006). *At day's close: night in times past*. New York: WW Norton, 415 pp.

Festugière A. (1964). *Les moines d'Orient*. Paris: Cerf, xx pp.

Ferguson SA, Lamond N, Kandelaars K, Jay SM, Dawson D. (2008). The impact of short, irregular sleep opportunities at sea on the alertness of marine pilots working extended hours. *Chronobiol. Int.* 25:399–411.

Gain B. (1989). Sommeil et vie spirituelle. *Dictionnaire de la spiritualité*. Paris: Beauchesnes, 1034–1041.

Gerhards A. (1998). *Dictionnaire historique des ordres religieux*. Poitiers: Fayard, xx pp.

Guillaumont A. (1979). *Aux origines du monachisme chrétien. Pour une phénoménologie du monachisme.* Bégrolles-en-Mauges: Abbaye de Bellefontaine, xx pp.

Hoch CC, Reynolds CF3rd, Kupfer DJ, Houck PR, Berman SR, Stack JA. (1987). The superior sleep of healthy elderly nuns. *Int. J. Aging Hum. Dev.* 25:1–9.

Horne J, Östberg O. (1976). A self-assesment questionnaire to determine morningness-eveningness in human circadian rhythms. *Int. J. Chronobiol.* 4:97–110.

Jean-Cassien (saint). (1965). Institutions cénobitiques; texte latin revu par Jean-Claude Guy, SJ. *Sources chrétiennes* 109:111–113.

Johns MH. (1991). A new method for measuring daytime sleepiness: the Epworth Sleepiness Scale. *Sleep* 14:540–545.

Kapogiannisa D, Barbeya A, Sua M, Zambonia G, Kruegera F, Grafmana J. (2009). Cognitive and neural foundations of religious belief. *Proc. Natl. Acad. Sci. U. S. A.* 106:4876–4881.

Lanfranc. (1844). Decreta pro Ordine Sancti Benedicti, caput primum. Section1. *Patrologiae latinae cursus completus* PL 150:447.

Laporte MC. (1965). *Aux Sources de la vie cartusienne*. France: Grande Chartreuse. Saint Pierre de Chartreuse, xx pp.

Leu-Semenescu S, De Cock VC, Le Masson VD, Debs R, Lavault S, Roze E, Vidailhet M, Arnulf I. (2011). Hallucinations in narcolepsy with and without cataplexy: contrasts with Parkinson's disease. *Sleep Med.* 12:497–504.

Maquet P, Peters J, Aerts J, Delfiore G, Degueldre C, Luxen A, Franck G. (1996). Functional neuroanatomy of human rapid-eye-movement sleep and dreaming. *Nature* 383:163–166.

Niaussat M, Thomas F. (2000). *Sur les chemins de Cîteaux. Moines cisterciens en terre de France.* Paris: Ouest-France, xx pp.

Ohayon M, Smolensky MH, Roth T. (2010). Consequence of shiftworking on sleep duration, sleepiness, and sleep attacks. *Chronobiol. Int.* 27:575–589.

Pierre Damien (saint). (1844). Opuscule XV de suae congregationis institutis, ad Stephanum monachum, caput 17 *Patrologiae latinae cursus completus* PL 145:349.

Portaluppi F, Smolensky MH, Touitou Y. (2010). Ethics and methods for biological rhythm research on animals and human beings. *Chronobiol. Int.* 27:1911–1929.

Rechtschaffen A, Hauri P, Zeitlin M. (1966). Auditory awakening thresholds in REM and NREM sleep stages. *Percept. Mot. Skills* 22:927–942.

Taillard J, Philip P, Chastang JF, Bioulac B. (2004). Validation of Horne and Ostberg morningness-eveningness questionnaire in a middle-aged population of French workers. *J. Biol. Rhythms* 19:76–86.

Uldaric. (1844a). Antiquiores consuetudines Cluniacensis monasterii, Liber primus, caput 3 et 4. *Patrologiae latinae cursus completus* PL 149:646–647.

Uldaric. (1844b). Antiquiores consuetudines Cluniacensis monasterii, liber primus, caput 41. *Patrologiae latinae cursus completus* PL 149:687.

Van Haeften B. (1643). Seven Litanies to St. Benedict. *Disquisitionum monasticarum*. Anvers. p. 783.

Webb WB, Agnew HW Jr. (1975). Sleep efficiency for sleep-wake cycles of varied length. *Psychophysiology* 12:637–641.

Wehr TA. (1992). In short photoperiods, human sleep is biphasic. *J. Sleep Res.* 1:103–107.

Zuther P, Gorbey S, Lemmer B. 2009. Chronos-Fit 1.06. Available at: http://www.ma.uni-heidelberg.de/inst/phar/lehre/chrono.html. Accessed August 10, 2011.