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Coexisting wrestling lunisolar periods in a selenosensitive circulation rather than circadian free-running?

Abstract

We report the coexistence specifically of a double tidal average period of 24.8 hours, with another shorter near 24.0-hour period in the same variable urine volume of the same periodically depressed individual, JF. Rather than free-running, a 24-hour desynchronized circadian system may be synchronized by the moon.

Background

Out of the recording and interpretation of celestial omens came "diaries" of the movements of the sun, moon and planets and eventually the discovery of cycles in these movements (in Babylon, thousands of years BC). Mathematical models of these movements built around arithmetical sequences spawned the calendar and, more generally, astronomy (1). Are we now experiencing the same transition from (sometimes derogatory) omens like "lunacy" (2, 3) and diaries (through accumulating records) over even forestry (4-6), with 13 contributions by Prof. Miroslav Mikulecky in physiology and pathology (7) to a new body of rigorous science?

A 62-year-old lady, JF, is influenced by the moon -- i.e., she is selenosensitive -- to the point that there is lunar (24.8-hour) synchronization in some analyses of her self-ratings of vigor/well-being, of her blood circulation and of urinary volume and excretion rate during depressed-adynamic episodes. This finding strongly qualifies our earlier concept of free-running. The analogy of an independent oscillator, for the case of circadian desynchronization, concerns what began with free-running after loss of the eyes by surgery or genetics 60 years ago (8). It compared the organism with a self-sustained oscillator, that is usually locked into a 24.0-hour average periodicity of the environment, such as the about (~) 12-hourly alternation of light and darkness (9). The earlier evidence for synchronizers other than light and a diet restricted in calories has reached a tipping point, which is the repeated finding of the 24.8-hour (double tidal) period in human physiology, i.e., the circulation of blood, the excretion of urine, locomotor activity and pathology (depressive loss of vigor), and of a near-tidal (~12.4-hour) period in two salivary hormones, DHEA and melatonin (10-13).

We may be subject to an ever-present lunar attraction, which is normally dominated to the point of extinction (completely masked) by the solar-societal 24-hour schedule, but becomes apparent once we get out of sync during isolation from society, e.g., in a cave. The long-

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claimed lunar pull may become particularly strong the longer the isolation from society; in the longest (267-day) record available for existence without societal communication, we found the signature of the moon in heart rate (14). In shorter records there is a pull toward 24.8-hour length in the form of an intermediate period between 24.0 and 24.8 hours (15-29) and often an average period of about or near 24.8 hours (30, 31).

Both the sun and the moon bulge periodically in tides, presumably because there is gravitational attraction. Do the moon and the sun do the same to us who are continuously exposed to both?

Results

We mimic not only the sun's period, τ, of 24.0 hours in societal schedules. We also find a precise double tidal τ of 24.8 hours in a 61-year-old woman's (JF) around-the-clock self-ratings of vigor during the first month of two consecutive depressive episodes ("downtimes"), i.e., in a first summer (2009) and in the following winter episode (but not in the third downtime in the summer of 2010). These downtimes, lasting 2 or 3 months, had reportedly recurred half-yearly for 20 years, Table 1 (10-13).

While, in the summer of 2010, we could not detect a double tidal τ of 24.8 hours in vigor, we find it in urine volume (or excretion rate) and in the automatically monitored systolic and diastolic blood pressure and heart rate, which had desynchronized with periods longer than 24 hours but shorter than 24.8 hours in earlier episodes, investigated by chronobiologic serial sections in Figures 1-3 (11-13). The dashed vertical lines in these figures each correspond to a full moon. The third rows of acrophases, ϕs, of these figures reveal, in the first 2 months, a horizontal time course indicating 24-hour synchronized spans. After the second such vertical line, a diagonal delaying time course of ϕs follows during ~3 lunar months of desynchronization (note double plotting when the ϕ approaches one of the dashed horizontal lines, each indicating local midnight, one day apart between 0 and 360 degrees). The lower curves in the second rows of Figures 1-3 are the MESORs, M, short for <u>M</u>idline-<u>E</u>stimating <u>S</u>tatistic <u>O</u>f <u>R</u>hythm; the distances between the two curves are the circadian amplitudes, As, which vary. The question "Are we dealing with more than a single circadian frequency?" is answered in the affirmative in the gliding spectral windows of Figure 4 and 5, the latter obtained with a program requiring equidistant data. Both figures show two separate areas of darkness at the same time, perhaps indicating more than one circadian peak, one longer than 24 hours, the other slightly shorter than 24 hours, the former darker (more prominent) than the latter.

It seemed indicated to vary the resolution by changing the interval used for consecutive analyses. This variation of the resolution was done in the range from 1 to 10 months in monthly steps, of which we show results with 1, 2 and 10 months in Figure 6. (The moving windows in this figure allow us to look for and to find more than a single frequency in the circadian region and beyond for all three variables investigated, whether we focus upon either original equidistant data between 2 gaps or upon all available data including those before and after the gaps.) Figure 6 shows analyses of truncated data, without the extrema separated from the more or less continuous data series by gaps, whereas another figure (not shown) includes the analyses of data beyond these gaps after they are filled in by wavelets or by a special program (32). Analyses at 1-month intervals in Figure 6 support the assumption that the results on all data correspond to those on the truncated set. Both analyses show much more than an alternation of 24-hour synchronization and desynchronization from society. The critical question is no longer that of 24-hour synchronization and desynchronization, documented in Figures 1-3, but the appearance of an added near-24-hour component in the desynchronized state. Figure 6 suggests, for both blood pressure and heart rate, coexisting separate circadian components during the desynchronized span, one that is slightly shorter than precisely 24-hours as well as a longer than 24.0-hour circadian period pulled toward 24.8 hours. The coexistence of 2 periods is further visualized by the use of 10-month intervals in the bottom section of Figure

6. This analysis further reveals that, among the 3 variables investigated, the pull toward 24.8 hours in the circulation of JF is strongest for diastolic blood pressure and weakest for heart rate.

The extent to which this impression of 2 circadian components competing with each other holds is best examined by the concomitant fit of a 24.0-hour and a 24.8-hour cosine curve to shorter intervals of 1 month displaced in increments of 1 week so that the coexistence of two components is not due to the 10-month interval used at the bottom of Figure 6. The results in Figure 7 obtained with the shorter intervals indicate, in the top section, that for most intervals the 2 components coexist, insofar as both periods can be validated during most intervals by rejection of the zero-amplitude assumption. The bottom section of Figure 7 displaying amplitudes shows a competition (wrestling) of the 2 periods. In some intervals (during an adynamic depressed downtime), the circadian amplitude of the diamonds corresponding to 24.0-hour trial periods is greater than that of the circles corresponding to the 24.8-hour trial period, and in other intervals the amplitude of the circles is larger. In the bottom amplitude section of Figure 7, the moon wrestles with the sun and society; it may lengthen and sometimes synchronize the circadian period, τ, with the double tidal τ. Torn between the influence of the sun and moon, the organism may assume a shorter-than-24-hour component. The near-24-hour synchronizing component's amplitude can vary even when the frequency does not, as seen in the moving windows carried out with 1-month intervals, Figure 6, or in the chronobiologic serial sections of Figures 1-3.

Discussion

Wavelet cross-spectra with solar wind speed and geomagnetism in the equidistant data of Figures 5 and 6, could complement Figure 7, a task remaining. The about 24-hour periods found in cave studies of social isolation of a group (15) or of individuals (16-30) for 2 or preferably more, up to 8, months, are usually, in our hands, between 24.0 and 24.8 hours. Rütger Wever's studies (30) in two underground isolation chambers (i.e., "the Bunker") in Germany in continuous overhead lighting, stable room temperature, soundproofing and the absence of time cues from the outside environment, reported a mean societally desynchronized (if not "free-running") τ as 25.0 ± 0.5 hours; the median free-running τ was 24.73 hours with a 95% range of 24.85 to 25.01 hours and a 99% range of 24.82 and 25.04 hours. Some societally 24-hour desynchronized periods in some subgroups were precisely 24.8 hours, but most had longer τs. In some cases, τs were shorter than 24 hours and changed during isolation (30, 31). In our current reanalysis of Robert B. Sothern's data, the only data set available to us from Wever's studies, the period found was of precisely 24.8 hours, Table 2 (31). Wever's studies covered weeks; our studies in social isolation covered months. The heart rate during our longest isolation span of 267 days is of precisely 24.8 hours.

A double tidal τ of 24.8 hours was also reported by Miles et al. (33) in a blind subject. Furthermore, throughout the ad-lib phase of this sleep study, there was a remarkable coincidence between his sleep onset and a local tide. Miles et al. (33) deserve further credit for studying the patterns along the 24-hour scale of serum cortisol throughout days 12, 17, 22, 28 and 35 (during the ad-lib phase of their sleep study) and on day 78, the last day of their entrainment study. These strategically placed samplings allowed them to indirectly suggest a circadian desynchronization of cortisol, since the rhythm was apparent to the naked eye in data stacked along a scale of 24.9 hours, but not along the scale of 24.0 hours. Miles et al. (33) align their case with our interpretation of data on late blind subjects by Remler (34), and a meta-analyzed case by Bryson and Martin (35). Adrenocortical desynchronization was also noted by Orth et al. (36) in a blind subject.

It seems pertinent that rats in continuous light of low intensity also show a period of 24.8 hours of their circadian rhythm in core temperature (37), Figure 6. The analogy of partly endogenous rhythms such as a critical adrenal cycle with a free-running oscillator was useful 60 years ago, when a now-documented partly internal timepiece, or rather time structure, was described (9, 38). But calling each non-24-hour but near-24-hour period "free-running" is no longer justified, once a lunar double tidal period or an intermediate period between 24.8 and 24.0 hours is found, even though the problem of periods slightly longer than 24.8 hours, like that of changing periods, must be resolved. They could be transients for a number of unknown reasons, if we remember that the time series obtained in the longest series investigated in isolation from society is of precisely 24.8 hours (39), as are a number of periods from a selenosensitive woman, JF (40).

We conclude again, as in (40) that ~24.8-hour and ~12.4-hour periods are in keeping with a genetically-anchored resonance of living matter with earth, air and sea tides, among other critical periodicities of our solar system and from beyond it. A lunar pull may also act when periods happen to be intermediate between 24.0 and 24.8 hours. Two round (not flat), moving (not fixed) and heterogeneous magnets -- sun and earth with its moon -- interact (41), as seen along an evolutionary scale from an archaeon (40) to a healthy person in isolation from society for 267 days (42) and in a number of dominant 24.8-hour periods in a selenosensitive grandmother and her granddaughter (10-13). The pull of the moon in a magneto-sensitive person may lead to an alteration of period (ecfrequentia) that may become a vascular variability disorder (dysfrequentia) associated with the circulation, cortisol and other endocrines, all getting out of sync with society (42) and, with an accompanying loss of vigor, a half-yearly recurring adynamia lasting 2-3 months. A mechanism is even available for lunar pull or synchronization, Figure 8. The bilateral ablation of the SCN leads to the loss of its synchronization (43).

The alternative of purely endogenous free-running is "simpler", perhaps only in the sense of making things as simple as possible but not "simpler", as phrased by Einstein (44) *"... the supreme goal of all theory is to make the irreducible basic elements as simple and as few as possible without having to surrender the adequate representation of a single datum of experience."* The tidal and double tidal periods in JF in depression, in the longest series of social isolation, and that by Miles in a blind subject and the 24.8-hour period of rats' core temperature in continuous light, each are such data of experience.

Epilogue

Dr. Karl-Heinz Bernhardt (personal communication), to whom this paper is dedicated on his 75^{th} birthday "honor colloquium" (Ehrenkolloquium) at the Leibniz Society for the Sciences, called our attention to a report by Chapman in 1916 (45) of a lunar effect upon the atmospheric pressure, with a follow-up by Bartels in 1932 (46), particularly notable contributions in the pre-computer era that, according to Bernhardt, constituted a scientific sensation. In commenting on Chapman's report in the Quarterly Journal of the Royal Meteorological Society (45):

> The President (Sir Napier Shaw) said that as a rule the Society regarded the question of the influence of the moon on the earth's atmosphere as already sufficiently discussed, but the present paper was an exception. Transposing the result into a unit which was now more familiar to him than the inch or the millimetre which Dr. Chapman used, it worked out at one-thirteenth of a millibar, and a tenth of a millibar was the limit of accuracy of a barometer reading. That a periodic term of such small magnitude should be demonstrated so conclusively by the combination of many readings was very remarkable.

If the lunar effect in the biosphere (usually regarded as small), as one of two or more competing synchronizing periods, is as profound as it appears to be in JF, it seems possible and desirable that it may start a series of investigations in a unified transdisciplinary science.

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Figures and Tables

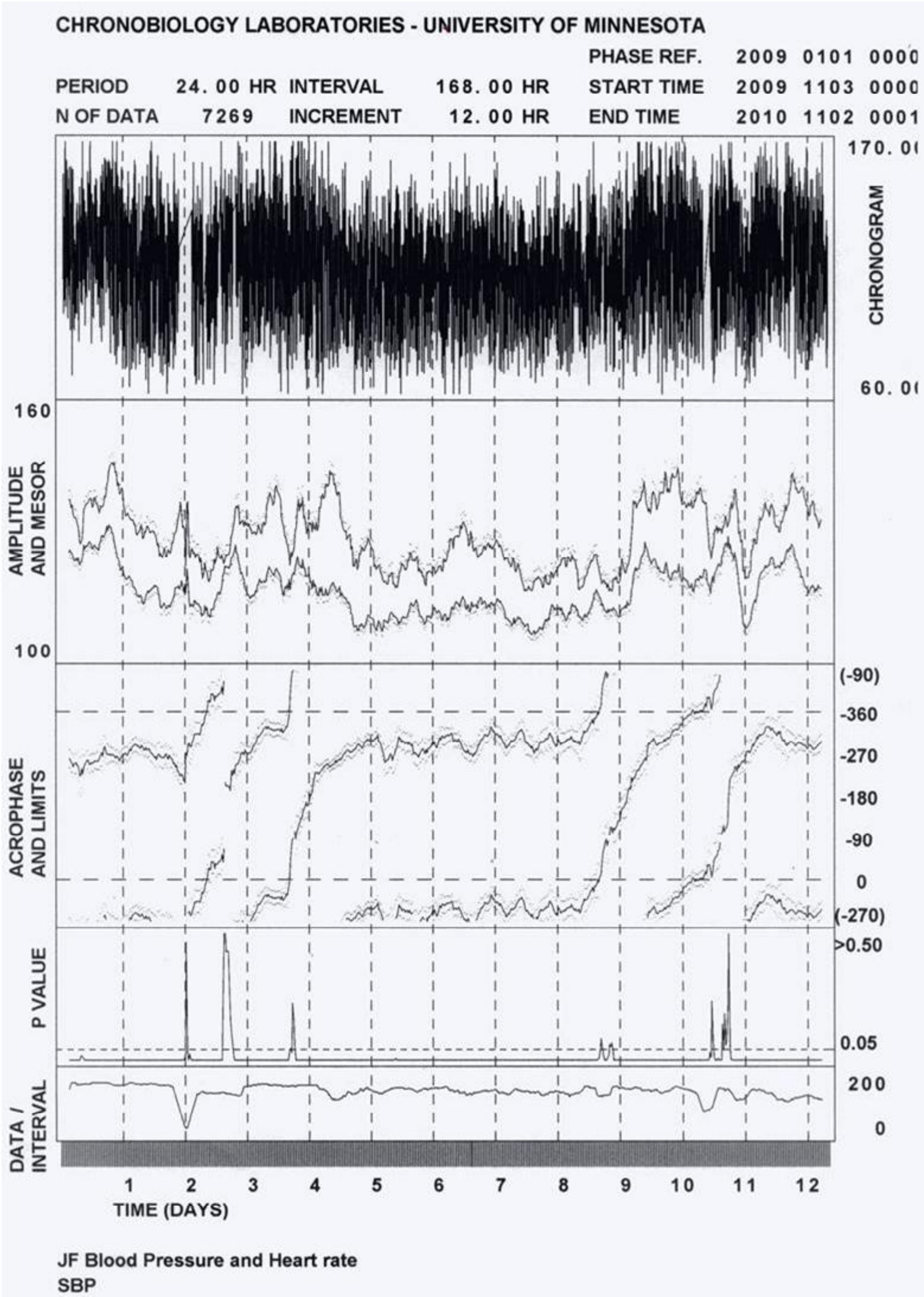

Figure 1. Chronobiologic serial section of systolic blood pressure of JF. Note in row 3 for the first 2 lunar cycles, a horizontal time course of acrophases, ϕ, denoting 24-hour synchronization. The oblique time course of ϕ in cycles 3-5 and again in cycles 8-11 denotes desynchronization. © Halberg.

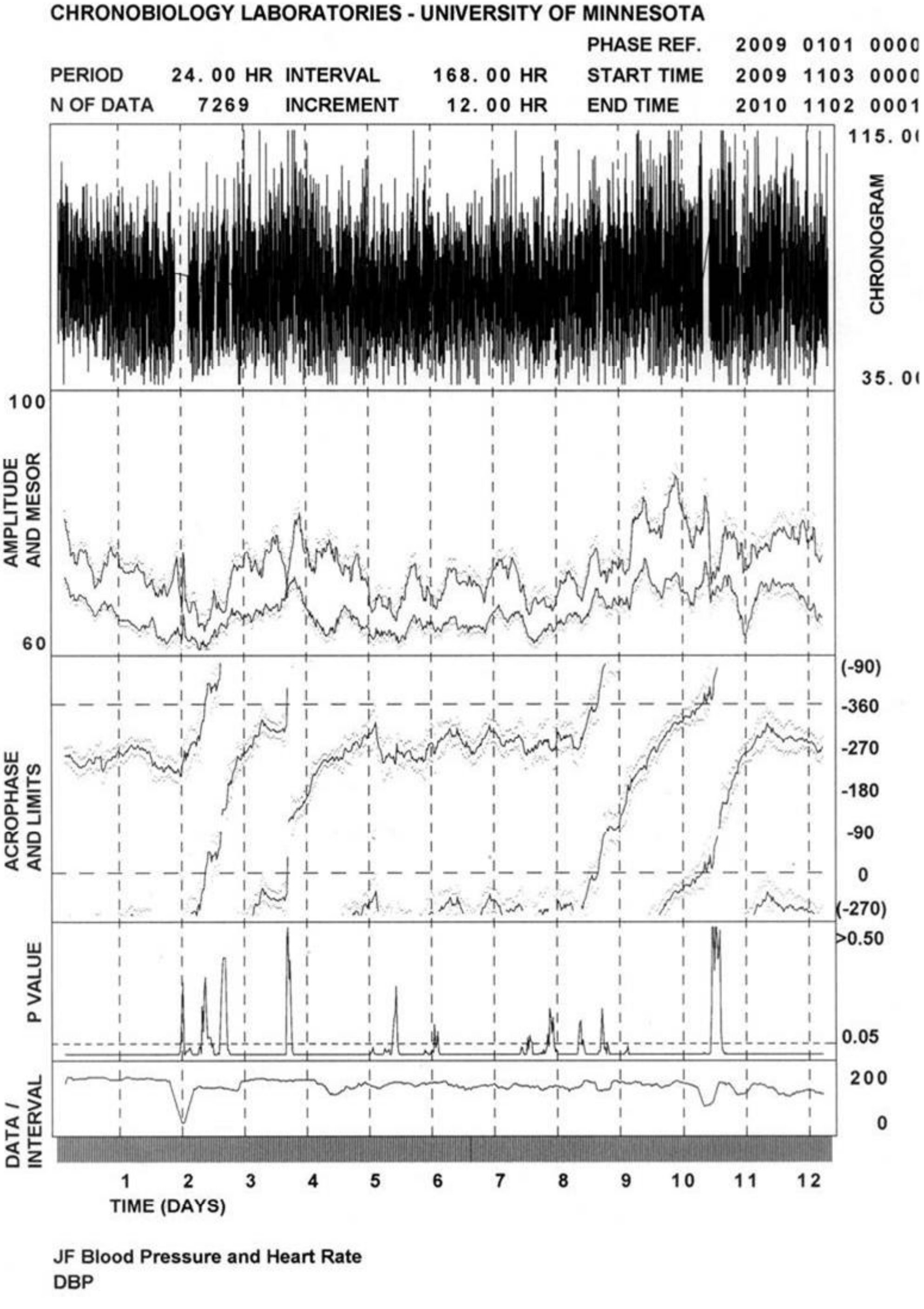

Figure 2. Chronobiologic serial section of diastolic blood pressure of JF. © Halberg.

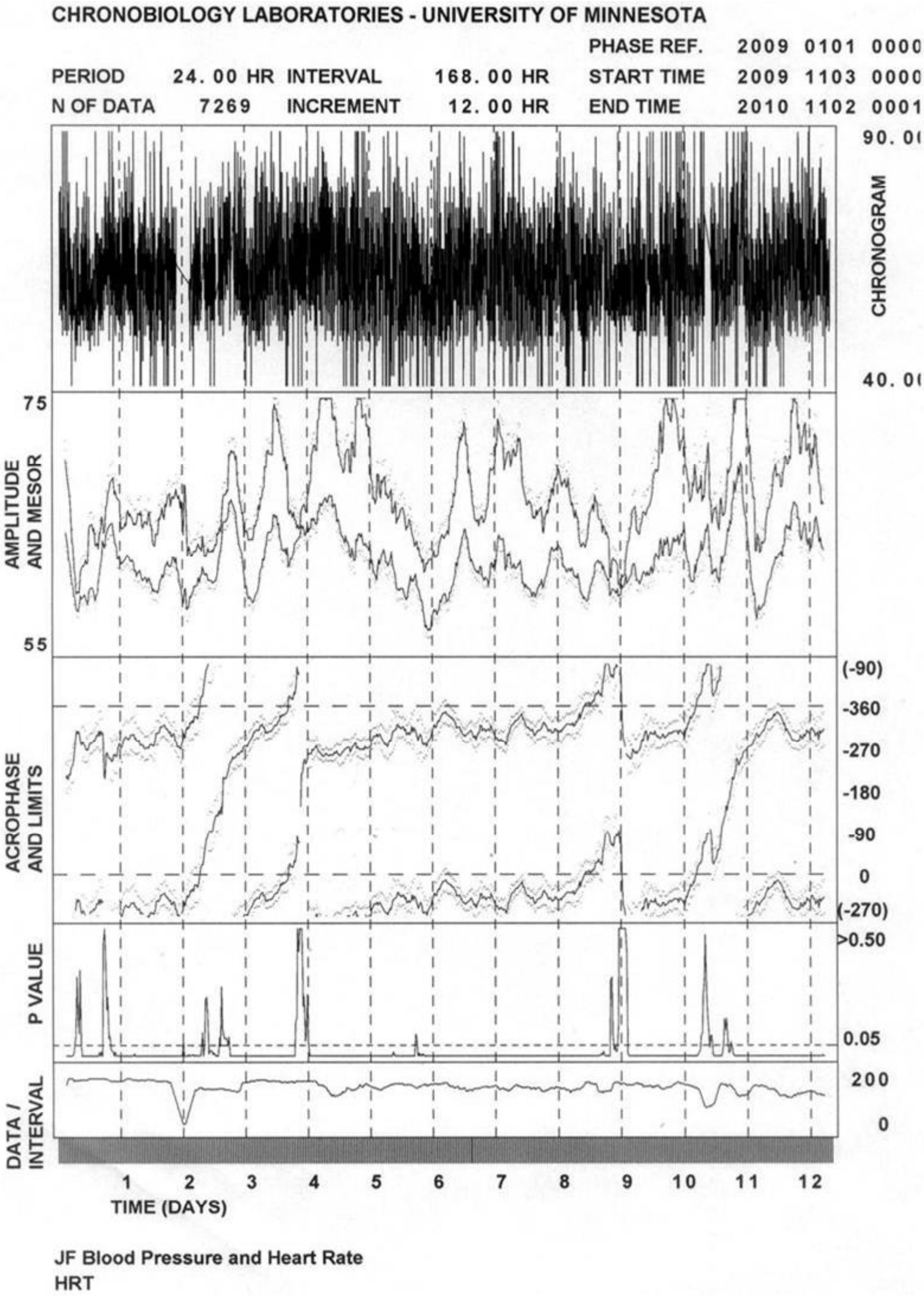

Figure 3. Chronobiologic serial section of heart rate of JF. Note resynchronization in cycle 4, while systolic and diastolic blood pressure are still desynchronized. © Halberg.

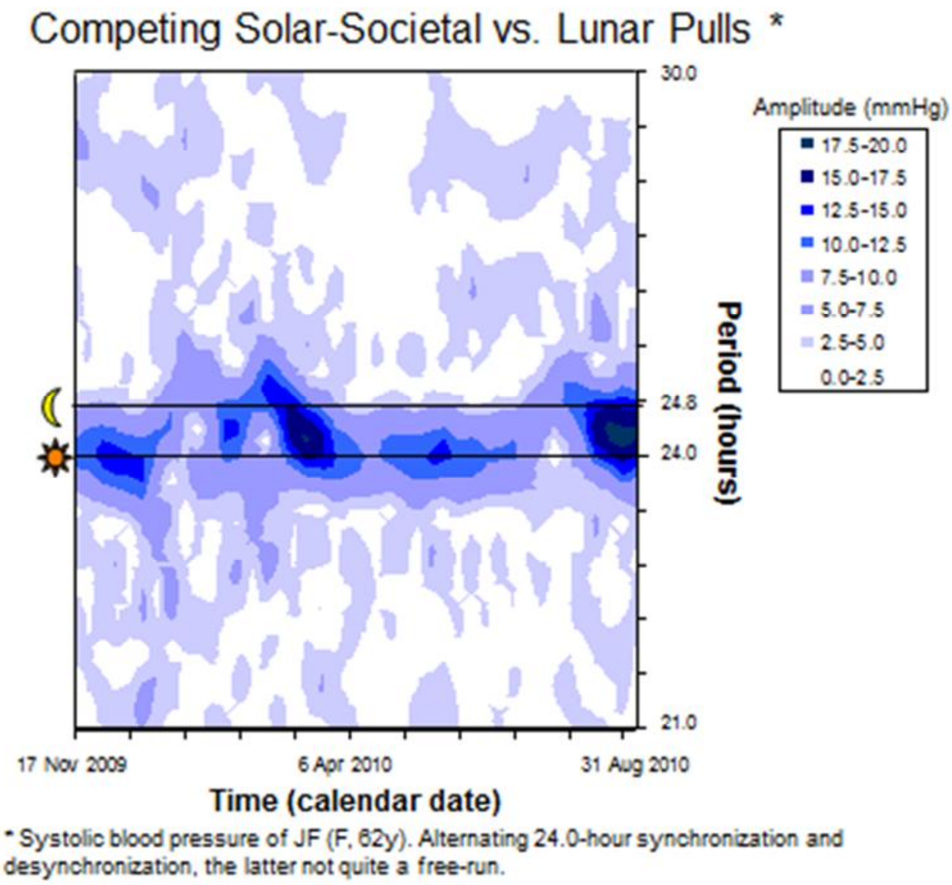

Figure 4. Gliding spectrum of systolic blood pressure of JF. Note occasional 2 components suggested by open space between darker shadings. © Halberg.

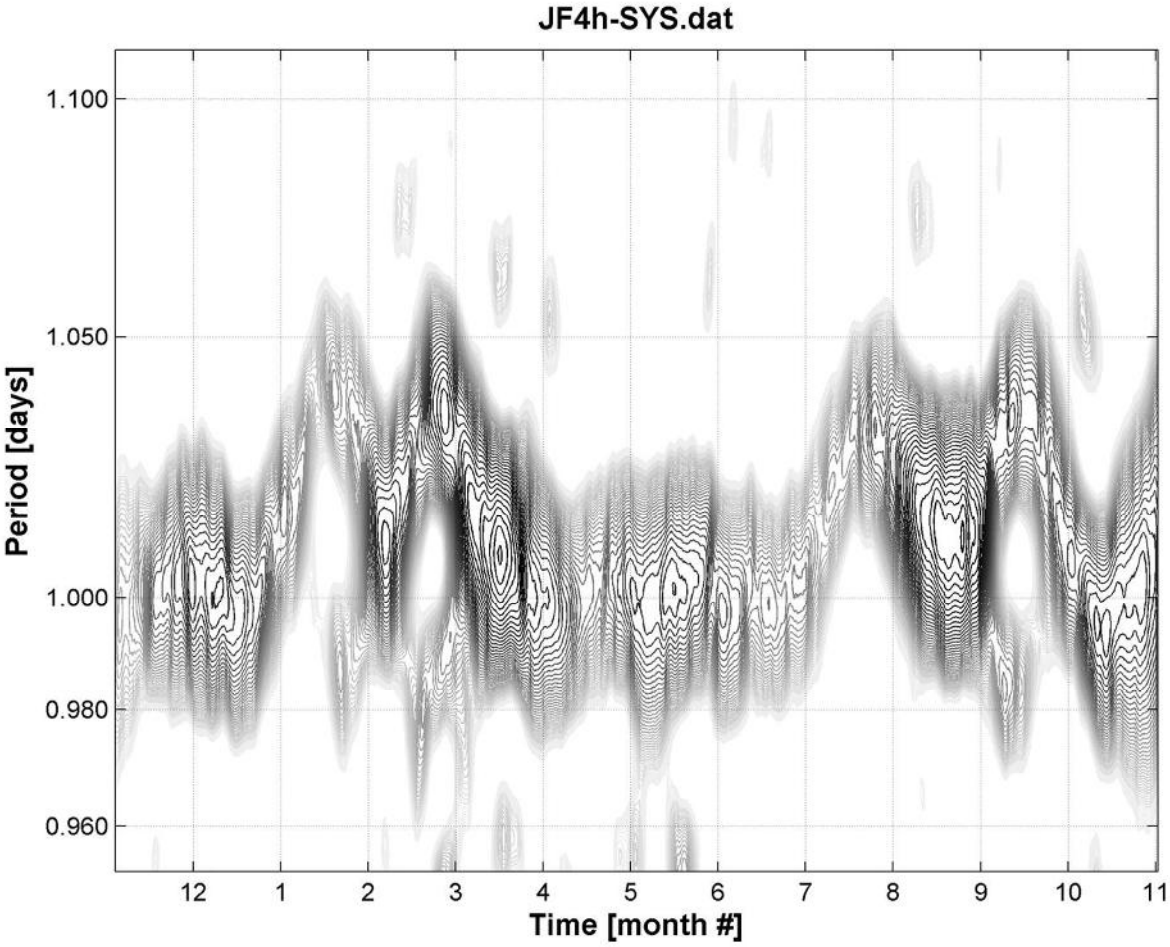

Figure 5. As in Figure 4, but by a different method, a spectrogram of systolic blood pressure of JF suggests occasional 2 components. © Halberg.

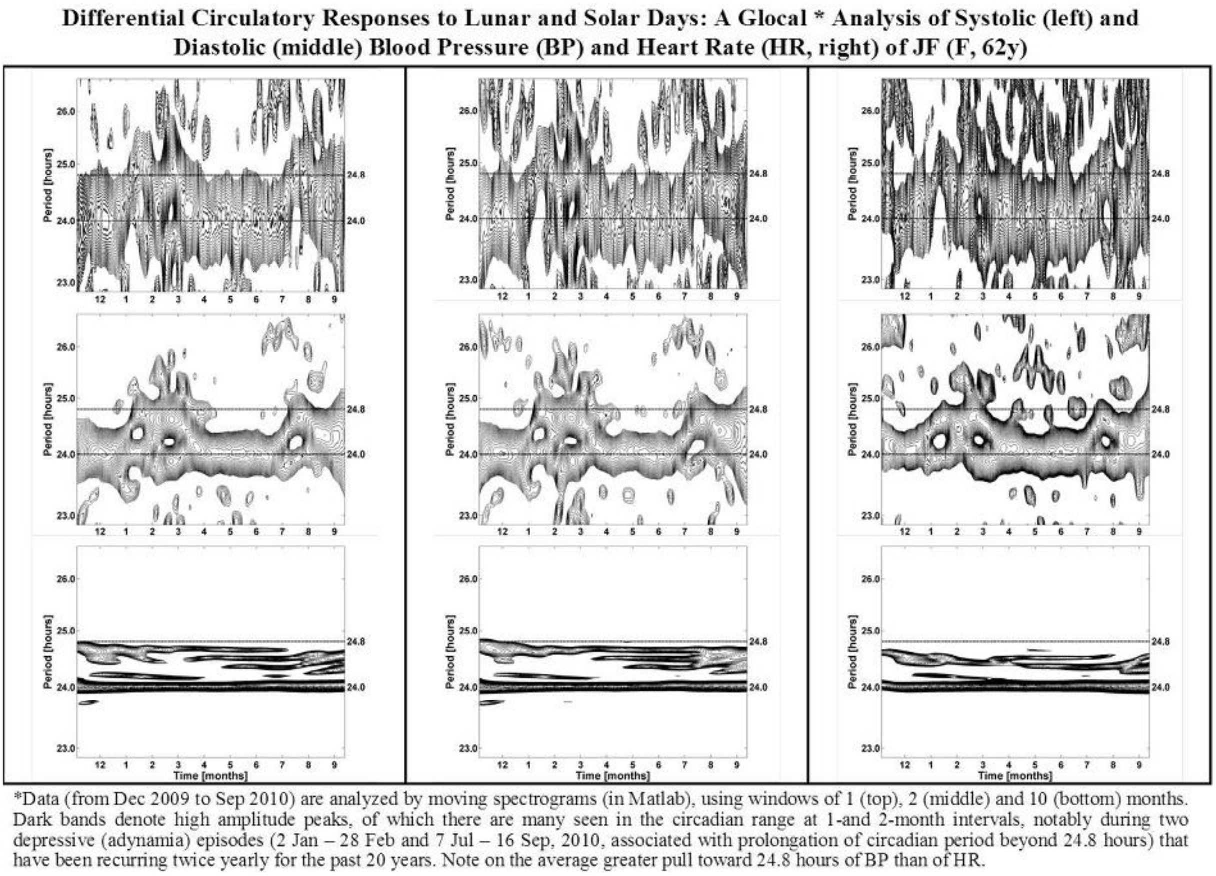

Figure 6. Multiple circadian components at different resolutions by different intervals used for consecutive analyses for BP and HR. © Halberg.

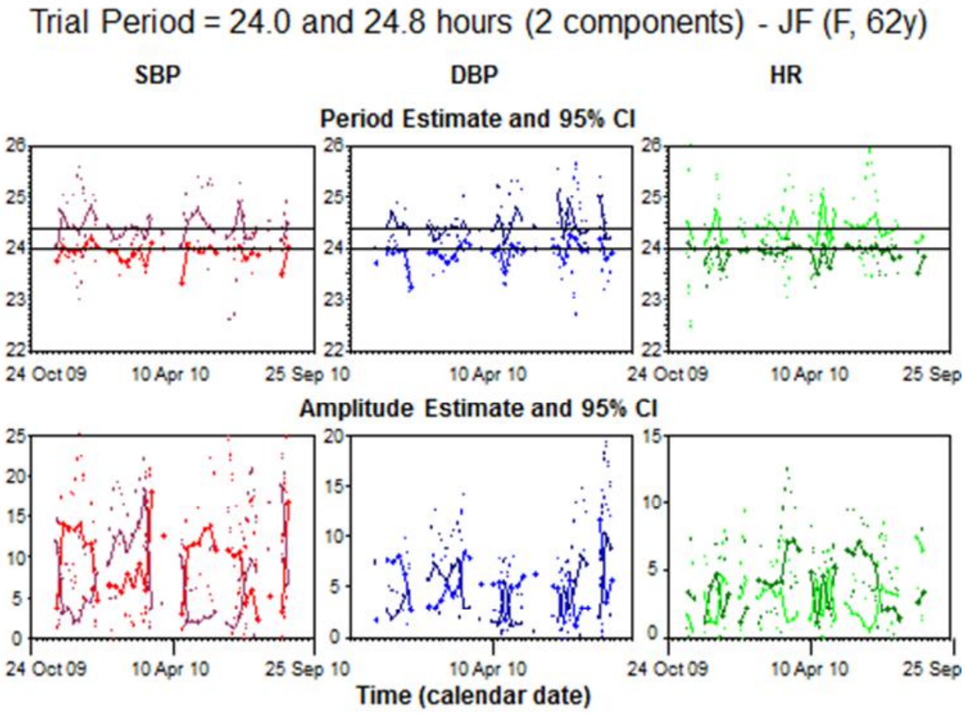

Figure 7. Demonstration by nonlinear serial sections in two trial periods of two components in systolic (S) and diastolic (D) blood pressure (BP) and heart rate (HR). © Halberg.

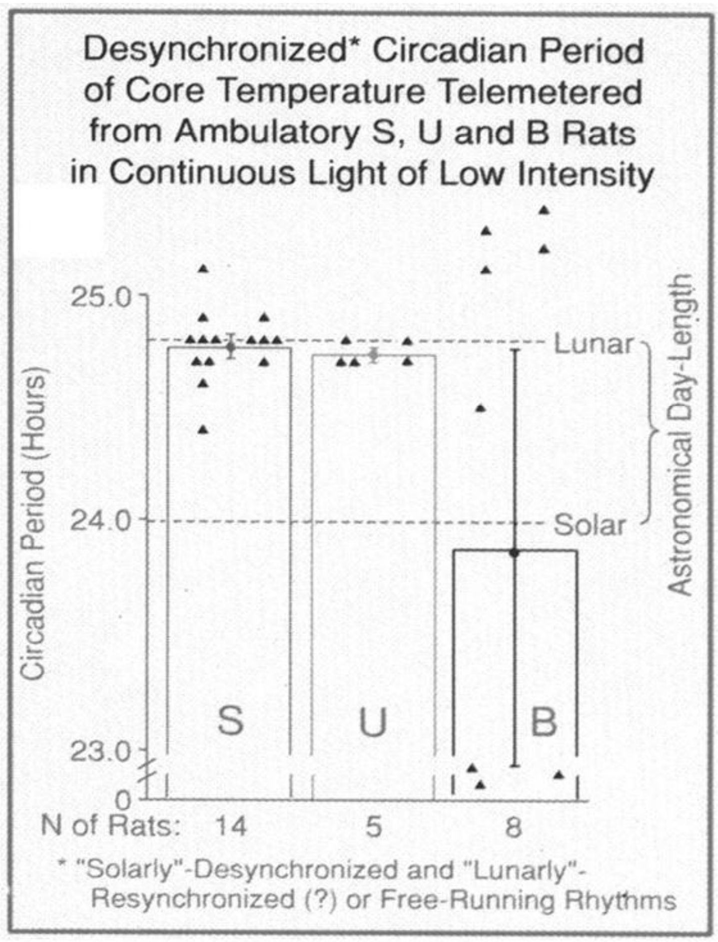

Figure 8. Sham-operated control rats (S) kept in ~5 lux continuous light (LL) have an average period (τ) of 24.8 hours in their telemetered core temperature; so do rats with a unilateral ablation of a suprachiasmatic nucleus (SCN) (U). No 24.8-hour τ is seen in rats in LL with bilateral SCN ablation (B). In view of Figures 4-7, a lunar synchronization seems likely and "free-running" refers only to the difference vs. lighting or other societal 24-hour schedule, and is best replaced by lunar synchronization, in this case of laboratory investigation and in the clinical data of JF. © Halberg.

Table 1: Recorded recurrent adynamia (A), overall self-rated vigor spectrum (B), lunar-cycle-related summaries (C) and endocrines during part of an adynamic episode (D)*

A. Start-end dates, lunar phase (f: date of full moon; n: date of new moon) and length (weeks) of spans of adynamia when recorded in winter (W) and summer (S)

	2002	2003	2004	2005	2006	2007	2008	2009	2010
		01.18 f	01.12	01.05	12.25 n	01.03 f	01.08 n	12.26 n	01.02 f
W	-	02.17 f	02.20 n	02.15	02.14 n	03.03 f	02.21 f	02.23 n	02.28 f
		(4)	(5)	(5)	(7)	(8)	(6)	(8)	(8)
	06.09	06.15 f	06.17 n	06.20 f	06.04	05.31 f	?	06.09 f	07.08
S	08.07	08.12 f	08.18 n	08.09	08.28	08.12 n	08.18 f	08.08 f	09.16
	(8)	(8)	(8)	(7)	(11)	(10)	(?)	(8)	(10)

*90 and 95% prediction intervals in 2010, computed from dates listed, are May 26-June 10 (90% PI) and May 22-June 29 (95% PI), respectively.

B. Periods from extended cosinor characterizing self-rated vigor of JF, F, 62-63 years of age during 2009.03.07-2010.04.01

	Period, τ (CI)	Units	Amplitude, A (CI)* (arbitrary units)
1	0.526 (0.521, 0.532)	year	26.01 (23.41, 28.60)
2	51.58 (50.60, 52.56)	days	3.29 (0.75, 5.84)
3	25.99 (25.72, 26.27)	"	3.00 (0.45, 5.54)
4	22.70 (22.50, 22.90)	"	3.18 (0.65, 5.71)
5	15.64 (15.53, 15.76)	"	2.63 (0.09, 5.16)
6	7.03 (7.001, 7.05)	"	2.28 (1.47, 3.08)
7	3.61 (3.60, 3.62)	"	1.77 (0.97, 2.58)
8	23.99 (23.97, 24.02)	hours	1.19 (0.48, 2.10)

*Note magnitude of the macroscopically obvious half-yearly component in comparison with the circadian component. Apparent deviation from 6 months requires scrutiny based on further analyses over a span longer than the single beat cycle here investigated.

C. Nonlinear circadian-infradian windows of JF's vigor, systolic (S) and diastolic (D) blood pressure (BP) and heart rate (HR) during consecutive lunar months (between full moons) starting on March 10, 2009, reveal 24-h synchronized (underlined) and desynchronized (**bold**) circadian periods (τ), the latter with loss of vigor and unwellness

Lunar cycle	vigor		SBP		DBP		HR	
	period, τ (CI)	amplitude, A (CI)	period, τ (CI)	amplitude, A (CI)	period, τ (CI)	amplitude, A (CI)	period, τ (CI)	amplitude, A CI)
1	24.22 (23.89, 24.54)	4.38 (0.91, 7.86)						
2	24.61 (24.32, 24.90)	7.17 (2.16, 12.19)						
3	24.97 (24.22, 25.72)	1.79 (0.00, 4.37)						
			Manual self-measurements every 30 min with gaps starting 2009/06/09 0000; 3-hourly starting 2009/06/16 0000					
4	24.92 (24.69, 25.12)	11.22 (6.75, 15.89)	24.92 (24.50, 25.34)	4.59 (0.45, 8.74)	23.93 (23.51, 24.35)	3.19 (0.32, 6.06)	24.00 (23.40, 24.60)	1.25 (0.20, 2.30)
5	24.82 (24.15, 25.49)	1.11 (1.22, 3.44)	25.24 (24.91, 25.57)	6.73 (2.26, 11.20)	25.08 (24.51, 25.66)	3.02 (0.85, 5.18)	24.75 (24.29, 25.21)	1.74 (0.03, 3.45)

Lunar cycle	vigor		SBP		DBP		HR	
	period, τ (CI)	amplitude, A (CI)	period, τ (CI)	amplitude, A (CI)	period, τ (CI)	amplitude, A (CI)	period, τ (CI)	amplitude, A CI)
6	<u>24.09 (23.65, 24.52)</u>	4.25 (0.12, 8.39)	23.19 (22.82, 23.56)	5.40 (0.40, 10.40)	<u>23.96 (22.74, 25.18)</u>	1.37 (2.03, 4.76)	<u>24.05 (23.74, 24.37)</u>	3.14 (0.25, 6.02)
7	<u>24.49 (23.80, 25.18)</u>	1.60 (2.08, 5.29)	<u>23.83 (23.14, 24.52)</u>	2.64 (1.72, 7.00)	<u>23.51 (23.03, 24.00)</u>	2.77 (0.79, 4.76)	<u>23.88 (23.60, 24.17)</u>	4.26 (1.45, 7.06)
8	<u>24.16 (23.54, 24.77)</u>	1.72 (0.00, 4.04)	<u>24.13 (23.82, 24.43)</u>	6.57 (1.41, 11.73)	<u>24.48 (23.65, 25.30)</u>	1.95 (1.60, 5.51)	<u>24.17 (23.62, 24.72)</u>	1.95 (0.63, 3.26)
			Hourly automatic measurements (C-ABPM) starting 2009/11/03 2011					
9	<u>24.62 (22.87, 26.35)</u>	0.52 (0.00, 2.43)	<u>23.99 (23.82, 24.16)</u>	10.90 (6.79, 15.02)	<u>24.00 (23.84, 24.18)</u>	7.35 (4.76, 9.94)	<u>24.16 (23.81, 24.51)</u>	2.91 (0.68, 5.14)
10	<u>24.06 (23.54, 24.57)</u>	1.79 (0.00, 3.82)	<u>23.89 (23.73, 24.06)</u>	13.26 (8.85, 17.67)	<u>23.87 (23.70, 24.04)</u>	7.16 (4.67, 9.66)	<u>24.02 (23.79, 24.26)</u>	3.96 (2.09, 5.82)
11	24.87 (24.28, 25.46)	2.82 (0.00, 6.33)	25.01 (24.73, 25.29)	8.88 (4.12,13.65)	25.08 (24.81, 25.36)	5.33 (2.60, 8.06)	24.92 (24.57, 25.26)	2.83 (0.94, 4.72)
12	25.04(23.69, 26.39)*	1.75 (3.04, 6.54)	24.57 (24.40, 24.75)	12.55 (7.98, 17.12)	24.67 (24.45, 24.89)	6.41 (3.52, 9.30)	24.39 (24.18, 24.59)	4.81 (2.74, 6.88)
13	<u>24.20 (23.64, 24.74)</u>	1.87 (0.42, 3.33)	24.23 (24.08, 24.38)	19.08(14.13,24.02)	24.31 (24.11, 24.51)	9.38 (6.25, 12.52)	<u>24.02 (23.84, 24.20)</u>	6.69 (4.60, 8.78)

Note that the CI of the τ for vigor, when not covering the precise 24-hour span, covers 24.8 hours. An overshoot of readjusting SBP is seen in lunar cycle 6. In lunar cycle 13, BP is not yet fully readjusted.

D. Societal (24-hour) and lunar asynchronization of circadian blood pressure (BP), heart rate (HR) and adrenocortical function, and synchronization of vigor of JF during 41 days (of a longer span) of adynamia and unwellness for which cortisol data are available (N: 236; 2010/01/18-2010/03/01)

Variable (unit)	Period, τ_1 (CI) (hours)	Amplitude, A_1 (95% CI)	τ_2 (days)	A_2	A_2/A_1
Vigor/wellness rating*	24.71 (24.10, 25.32)	2.01 (0.00, 5.66)	16.21	12.60 (8.98, 16.23)	6.27
Systolic BP† (mm Hg)	24.55 (24.44, 24.66)	10.83 (7.21, 14.45)	15.77	5.18 (1.43, 8.94)	0.48
Diastolic BP† (mm Hg)	24.63 (24.50, 24.77)	6.07 (3.63, 8.50)	14.06	2.05 (0.38, 4.47)	0.34
Heart rate† (beats/min)	24.36 (24.24, 24.49)	4.08 (2.52, 5.65)	18.41	3.45 (1.82, 5.09)	0.85
Cortisol (nmol/L)	24.57 (24.44, 24.70)	2.97 (1.82, 4.12)	14.73	0.23 (0.00, 1.35)	0.08
DHEA (ng/ml)	24.56 (24.46, 24.67)	3.21 (1.18, 5.25)	7.48	0.73 (0.09, 1.36)	0.23

Note that only vigor's CI overlaps 24.84 h, the double tidal τ, which τ was found in a first analysis of the first of JF's adynamic episodes investigated.

*CI: ordering 95% confidence interval. All reliance on decimals is qualified by the nonstationarity of the data. When the CI of the circadian τ covers 24 hours, the estimate of τ is <u>underlined</u> except for lunar cycle 12, for which a serial section reveals a span of 24-hour synchronization shown by horizontal acrophases, bracketed by desynchronized spans. When, according to Marquardt (J Soc Indust Appl Math 1963; 11: 431-441), the conservative CI of the A is a negative value, the 1-parameter limit (broken underlined) is given and the ordering nature of the uncertainty estimate is thereby particularly emphasized.

**Guidelines for determining which number is used to assess vigor/wellness: 0: Multiple symptoms / Not out of bed; 10: Multiple symptoms / Bed – Chair – Bathroom; 20: Multiple symptoms / Very minor accomplishment (prepare simple meal); 30: Multiple symptoms / Sedentary accomplishment (limited computer work); 40: Multiple symptoms / Increased accomplishment with limitation; 50: Multiple symptoms / Push for productivity followed by post-exertion stress; 60: Short spurts of productivity requiring pacing; 70: Productivity + Minor dysautonomia or headache; 80: Productivity or rest with no symptoms at all; 90: High productivity; 100: High productivity + Euphoria. If improvement has taken place, but symptoms do not yet rank the next number, .5 is used.

Table 2: Periods (τ) characterizing rectal temperature of RBS* during isolation from society in bunker during 14 days from 196709130900-196709270900:**

MESOR (SE)	τ (CI***)	2A (CI)	Acrophase (CI)
37.582 (0.007)	24.817 (24.713, 24.921)	0.74 (0.67, 0.82)	-129.186 (-123.293, -135.078)
	12.374 (12.299, 12.448)	0.26 (0.18, 0.33)	-184.282 (-167.363, -201.201)

*A clinically healthy man born 30 October 1946

**Andechs, Bavaria (Germany)

***CI: 95% confidence interval

When shorter spans are analyzed, the period deviates

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