Piercy, J. & Lack, L. (1988). Daily exercise can shift the endogenous circadian phase. *Sleep Research, 17*, 393. (2nd Annual Meeting of the Association of Professional Sleep Societies, San Diego, California, U.S.A.)

DAILY EXERCISE CAN SHIFT THE ENDOGENOUS CIRCADIAN PHASE

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Body temperature is elevated during and for a short time following strenuous exercise. The general question of interest is whether habitual exercise can have an entraining effect on the circadian rhythm of body temperature and other rhythms of the circadian system. It is important to evaluate the relative strengths of potential circadian zeitgebers for their possible use in treating the effects of shift work, jet lag and delayed sleep phase syndrome. Bright light appears to be an effective zeitgeber.[1,2] Can physical exercise be one as well?

Method: To maximize the chance of finding an effect of exercise we used physically fit runners who could expend energy at a relatively high level for an extended period. Six fit (mean estimated VO_2 max. = 57) males ranging in age from 19-55 years, who were good sleepers with regular sleep/wake schedules, served as paid volunteers. Subjects ran 8-12 km for a duration of 35-55 minutes/day on at least five days/week. The independent variable was the time of day at which running occurred - between 6-8 am before breakfast (AM condition) or between 5-7 pm before the evening meal (PM condition). Subjects ran in each condition for three weeks and after each condition entered the sleep lab to have sleep recorded at their normal sleep time followed immediately by 26 hours continuous bedrest in a wakeful constant routine as described by Czeisler et al.[3] During the constant routine, rectal temperature was recorded at 3 min intervals with a Vitalog PMS-8 recorder and urine formation rate was recorded with 2-hourly voidings. Subjects were instructed to maintain the same sleep/wake schedule throughout the experiment and to maintain the same exposure to sunlight in the two conditions. According to their diaries, subjects generally adhered well to the experimental instructions. Best fit 24-hour Fourier curves (including 24-hour fundamental and 12-hour harmonic component) were fitted to group average temperature data and urine formation rate data from each constant routine session. The AM and PM condition curves were compared statistically with a Fourier Analysis of Variance procedure as described by Bliss.[4]

Results: With the group temperature curves there was a phase delay in the PM condition as evidenced by significant ($p < .001$) delays of estimated fundamental acrophase of 2.1 hours, delay of Fourier curve acrophase of 1.38 hours and delay of Fourier curve minimum of 3.58 hours. The group mean temperature curves are shown in Fig. 1 as ± 1 standard error limits about the mean and the best fit Fourier curves are superimposed as solid and dashed lines for AM and PM exercise conditions respectively.

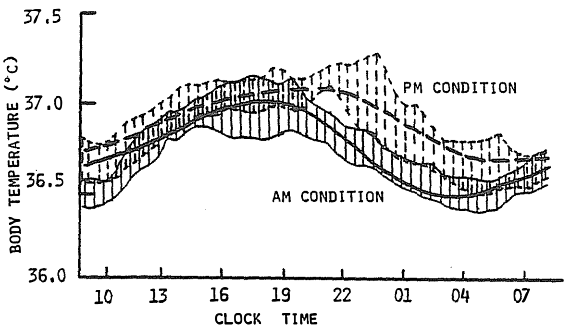

FIGURE 1. BODY TEMPERATURE RHYTHMS

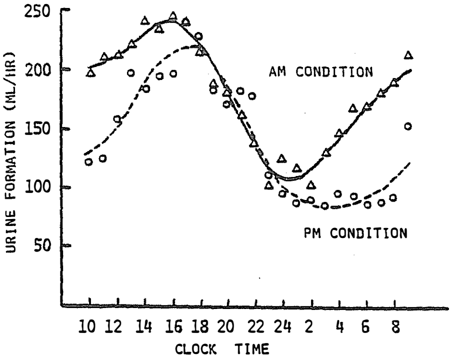

FIGURE 2. URINE FORMATION RATE RHYTHMS

With a constant fluid intake throughout the 24-hour constant routine there were, nevertheless, robust circadian rhythms of urine formation rate with maxima obtained generally between 1400-1800 hrs at a level three to six times greater than the minimums which occurred between 2400 hrs and 0400 hrs. The phases of the urine formation rate rhythms were generally delayed in the PM exercise condition compared to the AM condition. The best fit Fourier curves to the group mean values (AM - triangles, PM - circles in Figure 2) showed significant ($p < .001$) delays of the 24-hour component acrophase of 2.7 hours, of the Fourier curve maximum of 1.2 hours and Fourier minimum of 2.15 hours. The only significant difference in sleep parameters between conditions was a seven minute increased latency to the first REM period in the PM condition.

Conclusions: A change of 10-12 hours in the time of day of regular vigorous exercise produces the same directional change of the endogenous circadian system as indicated by approximately a 2-hour phase change of the body temperature and urine formation rate rhythms and change of REM sleep onset latency.

1. Czeisler, C.A. & Allan, J.S. Sleep Research, 1987, 16: 605.
2. Dawson, D. & Lack, L. Can the position of the x-oscillator be shifted while the sleep-wake cycle is held constant? Sleep Research, 1988, 17.
3. Czeisler, C.A. et al. Sleep Res., 1985, 14: 295
4. Bliss, C.I. Statistics in Biology, Vol. II. N.Y., McGraw-Hill, 1970.