Effects of exercise on sleep

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Walker, J. M., T. C. Floyd, G. Fein, C. Cavness, R. Lualhati, and I. Feinberg. Effects of exercise on sleep. J. Appl. Physiol.: Respirat. Environ. Exercise Physiol. 44(6): 945-951, 1978. — We tested the hypothesis that EEG sleep stages 3 and 4 (slow-wave sleep, SWS) would be increased as a function of either acute or chronic exercise. Ten distance runners were matched with 10 nonrunners, and their sleep was recorded under both habitual (runners running and nonrunners not running, 3 nights) and abruptly changed (runners not running and nonrunners running, 1 night) conditions. Analyses of both visually scored SWS and computer measures of delta activity during non-rapid eye-movement (NREM) sleep failed to support the SWS-exercise hypothesis. The runners showed a significantly higher proportion and a greater absolute amount of NREM sleep than the nonrunners. The runners showed less rapid eye movement activity during sleep than the nonrunners under both experimental conditions, indicating a strong and unexpected effect of physical fitness on this measure. Modest afternoon exercise in nonrunners was associated with a strong trend toward elevated heart rate during sleep. Mood tests and personality profiles revealed few differences, either between groups or within groups, as a function of exercise.

distance running; slow-wave sleep; computer analysis; REM density; mood; personality

Oswald (33) and Roffwarg et al. (35) were among the first to propose that the phase of sleep characterized by dense, high-voltage, slow EEG activity (stages 3 and 4 in the Dement and Kleitman (14) classification system) would be increased with exercise. Empirical studies of this question have produced conflicting results. In assessing this literature, one must consider several methodological issues. These include the nature and quantification of the exercise, whether it represents a drastic change in activity level on a single night's sleep. More recently, Boland and Dewsbury (9) reported increased amounts of NREM sleep in 4-h periods after forced wheel-running in the rat.

The SWS-exercise hypothesis is also of considerable practical importance. Sleep studies permit noninvasive, empirical investigations of hitherto unexplored aspects of brain electrophysiology. In many such studies, the sleep patterns of institutionalized patients with functional or organic disorders of the central nervous system are compared to those of ambulatory normal subjects. Differences in activity level would confound these comparisons. Studies of the effects of psychoactive drugs, to which the sleep EEG is remarkably sensitive, raise similar problems since changes in physical activity are often produced by the drugs being studied. Because our laboratory is involved in both kinds of investigation, and because we are especially interested in whether sleep serves mainly the brain or the body, we studied sleep patterns in long-distance runners and matched control subjects. Our main interest was in comparing the effects of chronically different levels of activity on sleep. In addition, we studied the effect of an acute change in exercise level on a single night's sleep.

METHOD

Subjects

Following a screening procedure, 10 male cross-country (or distance) runners were selected from a commu-
The estimated oxygen consumption (V\textsubscript{o}.) during running was 3.7 l/min (40) representing approximately 634 kcal (26). These activities were logged each day. The mean daily running distance that time-of-day effects were controlled. These activities were logged each day. The mean daily running distance was 10.2 km, completed in an average time of 35.5 min. Evenings, no EM activity increased after exercise discontinued for 1 mo. Increased arousals indicate stress effect. States that subjects slept longer after exercise, but no data presented. Subjects isolated for 10-14 days w/o time cues; sleep ad lib.

The runners carried out this routine for the first 3 days of the study. They did not run on the 4th day. The nonrunners carried out their usual activities on the first 3 days. They were not entirely sedentary and engaged in occasional sports such as softball and swimming, but with no sustained exertion or training. On the afternoon of the 4th day, they ran or jogged 2.4 km between 1300 and 1600 h at a self-regulated pace. The mean time required to cover 2.4 km was 13.6 min (estimated \( V_o = 2.7 \text{l/min} \times 40 \)); approximate energy expenditure 177 kcal (26)). Although this amount of exercise would seem minimal, it was felt to be a reasonable request of the nonrunners and did, in fact, produce a measurable physiological effect (elevated heart rate) during sleep (see below).

Sleep and other measures. Sleep recordings were carried out on four consecutive nights for each subject beginning on either a Sunday or Monday night. Four subjects were recorded each night in a yoked control paradigm: two runners matched with two nonrunners. The 1st night in the laboratory served for adaptation to the experimental situation and its data were not analyzed. Subjects went to bed at 11:30 and were awakened 8 h later. Oral temperature and the Profile of Mood States (32) were taken prior to sleep; blood pressure, heart rate, oral temperature, and responses to a sleep questionnaire were obtained the following morning. The sleep questionnaire included ordinal ratings of goodness of sleep, sleep discomfort, and amount of dream recall. During the course of the study, the California Personality Inventory was administered to each subject.

One electroencephalogram (EEG), one electrocardiogram (ECG), and one or two eye-movement (EM) channels were recorded for each subject on a Beckman type R dynograph run throughout the night at a paper speed of 15 mm/s, a gain of 8 mm/50 µV and a time constant of 0.3 s. The preamplifier output of the dynograph was amplified and recorded on a Vetter model A

### TABLE 1. Previous studies of the effects of exercise on human sleep

<table>
<thead>
<tr>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Baekeland &amp; Lasky (4)</td>
<td>10</td>
<td>Repeated</td>
<td>Basketball, track, swimming</td>
<td>Afternoon and evening</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Increased stage 4 found w/ afternoon but not evening exercise.</td>
</tr>
<tr>
<td>Zloty et al. (46)</td>
<td>16</td>
<td>Single group</td>
<td>Long distance running</td>
<td>Not recorded</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No control group; results compared to literature.</td>
</tr>
<tr>
<td>Shapiro et al. (38)</td>
<td>2</td>
<td>Repeated</td>
<td>Bicycle ergometer</td>
<td>Between 1300 and 1400</td>
<td>Yes</td>
<td>Yes, by ( V_o \times 10^{3} )</td>
<td>Yes</td>
<td>Yes</td>
<td>Strongest positive results in the literature, but low n.</td>
</tr>
<tr>
<td>Baekeland (3)</td>
<td>14</td>
<td>Repeated</td>
<td>Basketball, track, swimming</td>
<td>Not mentioned</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No activity increased after exercise discontinued for 1 mo.</td>
</tr>
<tr>
<td>Hauri (27)</td>
<td>15</td>
<td>Repeated</td>
<td>Bicycle ergometer, weight lifting</td>
<td>Evening</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Only 1st 3 h of sleep compared.</td>
</tr>
<tr>
<td>Adamson et al. (11)</td>
<td>12</td>
<td>Repeated</td>
<td>Athletic activities</td>
<td>Before 1400</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Increased arousals indicate stress effect.</td>
</tr>
<tr>
<td>Zir et al. (45)</td>
<td>10</td>
<td>Mixed</td>
<td>Bicycle ergometer, weight lifting, etc.</td>
<td>800-1100, 1300-1600</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>States that subjects slept longer after exercise, but no data presented.</td>
</tr>
<tr>
<td>Webb &amp; Agnew (43)</td>
<td>14</td>
<td>Mixed</td>
<td>Bicycle ergometer</td>
<td>Ad lib.</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Subjects isolated for 10-14 days w/o time cues; sleep ad lib.</td>
</tr>
<tr>
<td>Horne &amp; Porter (29, 30)</td>
<td>8</td>
<td>Repeated</td>
<td>Bicycle ergometer</td>
<td>Morning and afternoon (29: 1000-1200 and 1600-1800; 30)</td>
<td>No</td>
<td>Yes, by ( V_o \times 10^{3} )</td>
<td>Yes</td>
<td>No</td>
<td>No control group; results compared to literature.</td>
</tr>
</tbody>
</table>

### Procedure

**Exercise routine.** The athletes in this study were primarily distance runners. However, they were studied during the sprinting season and a typical exercise routine was as follows: 3.2-km warm-up run, several trials at the particular person's specialty (e.g., 440- or 880-yd dash), and a 4.8-km "warm-down" period. The running was carried out between 1300 and 1600 h so that time-of-day effects were controlled. These activities were logged each day. The mean daily running distance was 10.2 km, completed in an average time of 35.5 min. The estimated oxygen consumption (V\textsubscript{o}.) during running was 3.7 l/min (40) representing approximately 634 kcal (26). The runners carried out this routine for the first 3 days of the study. They did not run on the 4th day. The nonrunners carried out their usual activities on the first 3 days. They were not entirely sedentary and engaged in occasional sports such as softball and swimming, but with no sustained exertion or training. On the afternoon of the 4th day, they ran or jogged 2.4 km between 1300 and 1600 h at a self-regulated pace. The mean time required to cover 2.4 km was 13.6 min (estimated \( V_o = 2.7 \text{l/min} \times 40 \)); approximate energy expenditure 177 kcal (26)). Although this amount of exercise would seem minimal, it was felt to be a reasonable request of the nonrunners and did, in fact, produce a measurable physiological effect (elevated heart rate) during sleep (see below).

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FM tape recorder. Ink-written sleep records were coded and scored "blind" in 20-s epochs by an investigator who did not participate in the recording procedure. Stages 2, 3, and 4 were scored according to the criteria of Rechtschaffen and Kales (34). REM sleep was analyzed according to methods previously described (22). This REM analysis includes measures of eye movement (EM) activity as well as of time in REM sleep. The eye movement measures reported below are for the horizontal lead (L outer canthus-R outer canthus) only; most of the EM activity in young adults is seen in this lead (19). The visually scored sleep variables were tabulated, analyzed, and stored in retrievable form by use of a computer program previously described (39).

Computer analysis of EEG. The C3-A2 (left central-right mastoid) EEG lead was recorded on FM tape and subjected to off-line computer analysis with a Digital Equipment PDP 12 computer. The analog tape was played through a high-pass (0,15 Hz) Krohn-Hite filter and digitized at an effective sampling rate of 200 times/s. A period and amplitude analysis program (PANV 35) computed time in band, number of zero crossings, curve length, and integrated amplitude in each amplitude of nine frequency bands for each 20-s epoch (see Ref. 12) for data obtained with a preliminary version of this program. The PANV 35 output was written on Linctape and subsequently transcribed to industry-compatible nine-track tape for analysis with the IBM360 system. Epochs that had been visually classified as representing NREM sleep could be located on the basis of a computer read time code. For each NREM period, the measures described above were summed and also averaged by 20-s epochs. Thus, we obtained totals and mean values for these measures for all NREM sleep epochs and for the NREM epochs in the successive NREM periods. This system for analysis of the sleep EEG has been under development in our laboratory during the past 5 yr (23). Its aim is to supplement the visual scoring of EEG sleep records by direct measurement of the underlying wave forms. Within NREM sleep we include measurements of the number, size, density, and frequency of the delta waves whose variation determines the classification of NREM into stages 2, 3, and 4.

RESULTS

A large number of statistical tests were performed on these data. To avoid type I errors, the alpha level adapted was 0.01. Differences between groups with alpha levels between 0.05 and 0.01 will be cited as trends. Significance levels are two tailed unless otherwise noted.

Total Sleep Time (TST) and Awakening

Table 2 gives results for TST and related measures for runners and nonrunners in both exercise and nonexercise conditions. There was a trend (i.e., 0.01 < P < 0.05) toward higher TST in runners than in nonrunners in the exercise condition. Inspection of the data in Table 2 suggested that this difference resulted from a slight difference in sleep latency and a more marked (but statistically insignificant) difference in time awake after onset.

NREM Sleep

In the nonexercise condition, the runners showed significantly more NREM sleep than the nonrunners in either condition. This difference was also significant for the comparison of NREM sleep between runners in exercise and nonrunners in nonexercise conditions. To rule out any possible contribution of age to these results, an analysis of covariance was carried out. This analysis revealed that NREM sleep was greater in the runners independently of age (F = 9.023; P < 0.01).

Since the groups differed in total sleep, and since the proportion of NREM changes as a function of sleep duration, we further explored the difference in NREM proportions by matching the sleep durations of runners to those of the nonrunners for their habitual conditions (runners during exercise, nonrunners not exercising). This was done by limiting TST for both subjects in each matched pair to the lower TST value (mean TST = 428.3 min for both groups). This analysis revealed a near-significant trend (P = 0.02) toward a higher percentage of NREM sleep in the runners (76.7 vs. 71.2).

Stages 3 and 4 (SWS)

Table 3 shows that the trend toward increased NREM sleep in the runners reflected a trend toward more time in stage 2 sleep. However, the absolute amounts of stage 4 sleep were virtually identical for both groups in

<table>
<thead>
<tr>
<th>TABLE 3. Measures of NREM sleep for each group</th>
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<tbody>
<tr>
<td>Nonrunners</td>
</tr>
<tr>
<td>-----------------</td>
</tr>
<tr>
<td>Nonexercise (base line)</td>
</tr>
<tr>
<td>NREM sleep, min</td>
</tr>
<tr>
<td>% NREM sleep</td>
</tr>
<tr>
<td>Stage 3 sleep, %</td>
</tr>
<tr>
<td>Stage 4 (stage 3)</td>
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<tr>
<td>NREM</td>
</tr>
<tr>
<td>Stage 3 (stage 3)</td>
</tr>
<tr>
<td>NREM</td>
</tr>
<tr>
<td>Stage 4 (stage 4)</td>
</tr>
<tr>
<td>NREM</td>
</tr>
<tr>
<td>Delta sleep (min of stages 3 and 4)</td>
</tr>
</tbody>
</table>

Values are means ± SD. * Differs from nonrunners in the nonexercise condition P < 0.01. † Differs from nonrunners in the exercise condition P < 0.01.
both conditions. Stage 3 was 3-6 min greater in runners than in nonrunners. It is of interest that stage 3 in the nonrunners declined (insignificantly) in the exercise condition, perhaps reflecting a stress effect. When the separate NREM stages 2, 3, and 4 were expressed as percentages of total NREM sleep, the values in both groups for each of the three measures were virtually identical across both experimental conditions (Table 3).

Thus, visually-scored sleep stage data did not support the hypothesis that exercise increases the absolute amount or the proportion of stage 3-4 sleep. They did raise the possibility that chronic exercise is associated with a higher proportion and greater absolute amount of NREM (as opposed to REM) sleep.

**Computer Analysis**

Computer analysis of the EEG (Table 4) also failed to detect a difference in measures we have found to be sensitive to variations in stage 4 sleep (21). For the 0.5-2 Hz band, mean values per 20-s epoch and number of zero crossings did not differ significantly between groups for either condition. However, as noted above, TST was greater in the runners, as a result of increased EEG stage 2. Since stage 2 epochs show less 0.5-2 Hz activity than stages 3-4, the mean values for total NREM sleep in the runners might have been reduced by their increased EEG stage 2. To evaluate this possibility, computer measures of delta EEG were compared separately for the first two NREM periods, which normally contain about 75% of the stage 4 sleep. Again, no significant differences between groups were observed (Table 4).

In view of the greater amount of NREM sleep in the runners, we would expect higher values of total 0.5-2 Hz activity/night in this group. While the baseline means for integrated amplitude, baseline crossings, and time in band and curve length were, in fact, consistently greater in the runners, only the difference in the last variable showed a trend toward significance ($P = 0.03$). Thus, in spite of the large difference in NREM sleep, there were surprisingly small differences in total delta activity. We have observed a similar result (relative constancy of delta activity) in a study of the effects of flurazepam on sleep (21).

**REM Sleep Variables**

Table 5 shows that REM latency (the amount of NREM sleep preceding the first REM period) did not differ significantly between the two groups. There was a trend for the percentage of REM sleep (REM/TST × 100) to be lower for the runners while running compared with the nonrunners in the nonexercise condition. This finding is a corollary of the difference in NREM sleep described above. The main differences between groups in REM variables were observed in measures of EM activity during REM sleep. In both the exercise and nonexercise conditions, the runners showed significantly smaller amounts of EM activity than nonrunners in exercise.

In the comparison of the nonexercise condition for both groups, the difference was significant for total EM activity and EM expressed as a percentage of total sleep; a trend toward lower EM values in the runners was found for the other two measures. The fact that the differences in EM existed for both the exercise and nonexercise conditions suggests a stable difference between groups rather than a dynamic sleep response to daytime activity level.

The effects of age on eye movement activity also were examined. The runners showed a negative correlation between eye movement density and age and the nonrunners showed a positive correlation. While neither correlation coefficient was itself statistically significant, the interaction of these effects was ($F = 9.321; P < 0.01$). Thus, the runners and nonrunners showed significantly different relations between eye movement density and age.

**Measurements of Autonomic Activity**

Oral temperature, taken before and after sleep, and systolic and diastolic blood pressure, taken after sleep, did not differ in relation to subject group or daytime.
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Personality and Mood Measures

The California Personality Inventory (CPI) and the Minnesota Multiphasic Personality Inventory (MMPI) are intended to measure stable characteristics of the individual (personality traits). In contrast, the Profile of Mood States (POMS) is intended to measure variation in mood (states rather than traits). Comparisons of scores on personality and mood tests were made with the nonparametric Wilcoxon matched-pairs signed-ranks test.

The POMS data are presented in Table 6. The runners showed less “depression-dejection” and more “vigor” than the nonrunners. The runners also had lower scores for “total mood disturbance.” These results were either statistically significant ($P < 0.01$) or trends ($P < 0.05$) under both conditions.

Analysis of the POMS data within groups revealed that the runners showed significantly less “fatigue” and a trend toward less “total mood disturbance” under the nonexercise condition. The nonrunners showed trends toward less “tension-anxiety” and more “vigor” under exercise.

Of the 13 MMPI comparisons between groups, only one was significant. The Hs (hysteria) scale was higher for the nonrunners (61.6 vs. 53.1; $P < 0.01$). This scale is intended to measure neurotic concern for specific bodily functions coupled with an exaggerated denial of neurosis in general. Scores between 55 and 65 are unusual in college students (25). The Pd (psychopathic deviancy) scale, which measures nonconformist tendencies, tended to be higher in nonrunners (66.3 vs. 58.10; $P < 0.05$). Finally, the only significant differences among the 18 CPI scales indicated less “socialization” in the nonrunners (39.9 vs. 52.0; $P < 0.01$). In view of the large number of statistical comparisons carried out, these results are rather unimpressive.

DISCUSSION

The primary hypothesis tested in this study, that higher levels of exercise are associated with higher levels of stages 3 and 4 sleep (SWS), received no support from our data. There were no consistent differences in EEG stages 3 and 4, considered separately or together, between runners and nonrunners (Fig. 1). When runners stopped exercising for 1 day, SWS was unaffected. The results with visual scoring were corroborated by computer analysis (Fig. 1). When nonrunners engaged in quite modest afternoon exercise, EEG stage 3 tended to decline rather than increase while stage 4 was unaffected. In view of the elevated pulse rate which persisted throughout sleep after exercise in the nonrunners, even this limited activity appears to have constituted a physiologically significant stress.

The absence of an effect of exercise on SWS in our study is consistent with most previous investigations of this issue (Table 1). As noted above, two of the three studies with positive results had serious methodological difficulties. However, we cannot readily account for the differences between our findings and those of Shapiro et al. (38). They found graded increases in SWS associated with graded increases in exercise in two subjects. The difference may be a function of the differing types of exercise (ergometer vs. running), the strenuousness or degree of exhaustion produced by the exercise, or the acuteness with which it was carried out. It is also possible that Shapiro's results were not due to the exercise itself but to some correlated factor (e.g., altered body temperature) absent in the study. The two subjects employed in the Shapiro study were not described except for the statement that they were highly trained. These subjects had somewhat unusual sleep habits, retiring at 1945–2000 h. Although further studies of the effects of acute changes in exercise level on sleep in conditioned subjects might shed light on the discrepancy between our results and those of Shapiro et al., we are confident that matched subjects, habitually engaged in different levels of exercise of the magnitude we studied,
do not differ in amounts of stage 3-4 sleep. The situation is less clear with respect to total sleep (TST). In our study, with time in bed carefully controlled, there was a trend for TST to be higher in the runners as a result of increased stage 2 sleep. Zir et al. (45) mentioned that TST increased on their subjects’ exercise night but quantitative results were not presented. The absence of a difference in TST in Webb and Agnew’s (43) study adds to the uncertainty on this question. They employed a repeated-measures design and permitted ad lib. sleep around the clock; we studied matched groups with bed time limited to 8 h. If exercise enhances the continuity of sleep (for example, by reducing arousal level or promoting relaxation) but does not alter total sleep need, the difference between Webb and Agnew’s and our results could be accounted for by the difference between ad lib. and fixed sleep periods.

There were two strong differences in sleep pattern between the runners and nonrunners in our study. The runners showed more NREM sleep and less eye movement activity during REM sleep.

An effect of exercise on amount of NREM sleep has not previously been described in studies of human subjects. However, Boland and Dewsbury (9) recently reported increased NREM sleep in rats after forced wheelrunning. Two other studies of exercise in rats did not yield this result (28, 31). Thus, the animal studies remain equivocal.

If one considers stage 2 sleep a less intense form of the processes represented by NREM stages 3–4 sleep (16), the finding of increased stage 2 in human subjects after chronic exercise might support the view that some aspects of NREM sleep are a function of peripheral (i.e., non-central nervous system) metabolic rate. However, it must be kept in mind that the central nervous system states associated with sustained exercise have not been investigated. It remains a possibility, although we believe a remote one, that it is this variable which might underlie a NREM sleep-exercise relation. It is equally possible, of course, that the present finding should be interpreted as REM suppression by exercise, rather than NREM augmentation, especially since REM density as well as duration was reduced in the runners.

The difference between runners and nonrunners in eye movement activity during sleep is the second positive finding in this study and was entirely unexpected. It was detected because EM activity—in addition to time in REM sleep—has always been routinely measured in our laboratory. Other sleep scoring systems in current use (34, 44) do not include this variable even though it has proved extremely sensitive to drug effects (17) and other alterations in a brain state, e.g., Down’s syndrome (19).

In the present study, significantly lower levels of EM activity in the runners were found in both the exercise and nonexercise conditions. These differences cannot therefore result from a dynamic response to daytime activity level, but must represent a “chronic” difference—presumably due to physical conditioning or fitness. Of the other studies of sleep and exercise, only those of Baekeland and Lasky (4) and Baekeland (3) have included measures of EM activity in addition to time in the REM stage. Baekeland and Lasky (4) found that discontinuing exercise for 1 day had no effect on EM activity, a result consistent with the findings reported here. Baekeland’s observations in his second (3) study are of greater interest and relevance. He found that when exercise was discontinued by trained athletes, there was no immediate increase in EM density. However, by the 4th wk, EM density was significantly increased. This result is consistent with the data reported here. The time course of the EM change appears similar to that followed by resting heart rate after exercise is discontinued (37) in physically fit subjects.

The different directions of the correlations of EM density with age in runners and nonrunners might also be explained by difference in fitness. Thus, it would be plausible to assume that in nonathletes physical fitness tends to decline with age and that in athletes who train regularly fitness tends to improve. We found that the older athletes in our sample had been in training for a longer period, a fact consistent with this possibility.

The functional significance of EM activity during sleep remains unknown. EM measures such as total EM and EM density show high night-to-night reliability (13, 17). Early impressions that EM activity follows the action of the dream (“scanning hypothesis,” Ref. 36) or reflects the intensity of dream action (8, 15) have not been confirmed (see Ref. 24 for a review of the literature and a careful study with negative results). Berger (5) has hypothesized that EM activity during REM sleep counteracts the deleterious effects of “disuse” (ocular quiescence) during NREM sleep and therefore helps maintain binocular coordination. In patients with certain kinds of brain impairment, there appears to be a relation between level of EM activity and intellectual function (11, 19).

The present data suggest that fitness is associated with reduced EM activity in normal subjects. A physiological basis for this relation is not obvious. One possibility, suggested by our colleague, Prof. John Severinghaus, is that the differences in Pco2 sensitivity between trained and untrained subjects (10) may be implicated. Higher Pco2 sensitivity might produce greater excitatory input to oculomotor centers during sleep. Whatever the ultimate explanation, further investigation of REM sleep in relation to exercise may shed light on some of the factors which determine the consistent individual differences in EM density during sleep in human subjects, and may also provide clues to the physiological mechanisms involved.

The data from the personality and mood tests were not striking. They could all be subsumed under the rather parsimonious interpretation that exercise promotes feelings both of well-being and fatigue and that persons who exercise have fewer neurotic complaints. The trend toward less “total mood disturbance” in runners on a single day of exercise withdrawal would not be expected to persist. Baekeland (3) found a dysthymic reaction in runners required to refrain from exercise for a much longer (30 days) period. Failure to find consistency between the MMPI depression scale which did not differentiate the two groups, and the
POMS depression-dejection scale, which tended to be lower for runners, is not surprising considering the different nature (trait vs. state) of the two tests.

Finally, we were impressed by the sustained elevation of heart rate during sleep in nonathletic subjects after quite modest afternoon exercise. This finding may merit further investigation by those concerned with cardiovascular correlates of physical fitness.

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