ASSOCIATION OF PHYSICAL ACTIVITY AND HUMAN SLEEP DISORDERS

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BACKGROUND: It is generally believed that exercise exerts a beneficial effect on the quality of sleep. However, most studies regarding exercise and sleep have been concerned with the influence of exercise on sleep architecture and efficiency, and not on its effects in the prevention and treatment of sleep disorders. Moreover, epidemiological evidence of the benefits of exercise on sleep are limited.

OBJECTIVE: To investigate the influence of moderate exercise or physical activity on self-reported sleep disorders among a randomly selected population of adults.

SUBJECTS AND METHODS: Study subjects were participants in the Tucson Epidemiological Study of Obstructive Airways Disease who in the 12th survey completed health questionnaires that included several questions on physical exercise and sleep disorders. Sleep disorders were classified as disorders in maintaining sleep, excessive daily sleepiness, nightmares, and any sleep disorder. Six questions regarding exercise and physical activity were asked. Analyses were performed using multivariate logistic regression models with selected measures of sleep disorders as dependent variables and measures of exercise and physical activity as the independent or predictor variables.

RESULTS: There were 319 men and 403 women included in the analyses. The results showed that more women than men reported participating in a regular exercise program and having sleep symptoms of disorders in maintaining sleep and nightmares and that more men than women did regular vigorous activity and walking at a brisk pace for more than 6 blocks per day. Both men and women had significantly reduced risk of disorders in maintaining sleep associated with regular activity at least once a week, participating regularly in an exercise program, and walking at a normal pace for more than 6 blocks per day. Reduced risk of any sleep disorder was associated with regular activity at least once a week, and for men, walking at a brisk pace for more than 6 blocks. Among women increases in age also reduced the risk of nightmares.

CONCLUSIONS: These data provide additional evidence that a program of regular exercise may be a useful therapeutic modality in the treatment of patients with sleep disorders.

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SYMPTOMS OF disturbed sleep are common in the general population, with overall prevalence rates of between 35% and 41%. This is especially true in the elderly, in whom up to 50% of those surveyed may express some dissatisfaction with the quality of their sleep. Factors contributing to poor sleep include concomitant medical problems, psychiatric and/or psychological conditions, and poor sleep hygiene. Furthermore, sleep disturbances are frequently chronic, with 56% of those affected continuing to have symptoms for years.

Exercise has been suggested as an activity that may improve sleep quality. A number of studies in healthy subjects have documented that acute and long-term exercise increase slow-wave sleep and total sleep time, as well as decrease sleep latency, ie, the time period between initial attempt to fall asleep and onset of sleep. However, the opinion that exercise promotes sleep is not universally held. Data from epidemiological studies are relatively limited. In a random sample of 1600 young to middle-aged Finnish adults, exercise was perceived to be a sleep promoting activity in 33% of men and 30% of women. A smaller survey of 51 subjects found a relationship between physical fitness and later bedtime, shorter sleep latency, less total time asleep, and awakening less tired. There is also evidence that more frequent exercise is associated with less daytime tiredness. These data suggest that exercise is associated with an im-
SUBJECTS AND METHODS

STUDY POPULATION

Subjects for this study were participants in the Tucson Epidemiological Study of Obstructive Airways Disease. Detailed description of the study design and methods of data collection have been previously reported. Briefly, the population in this ongoing prospective study is a random-stratified cluster in Tucson, Ariz, containing 3805 individuals in 1655 households enrolled in 1972-1973, with new enrollees being added by marriage and births. Subjects were included in this analysis if they had completed health questionnaire at the 12th survey, which was administered during 1991-1992, and were at least 40 years old. Subjects were excluded from analyses if in the 12th survey or any previous survey they had reported having a stroke, heart or lung surgery, or lung cancer.

SLEEP DISORDERS AND PHYSICAL ACTIVITY ASSESSMENT

In each of 12 surveys, health information was obtained from the study population using a self-administered questionnaire. Survey 12 included questions pertaining to complaints of sleep disturbances and current levels of physical activity. Subjects were asked: “Have you ever been troubled by any of the following problems: (1) trouble falling asleep, (2) trouble staying asleep, (3) not enough sleep, (4) too much sleep, (5) waking up too early and not being able to get back to sleep, (6) falling asleep during the day, and (7) nightmares (dreams that frighten you)?” Possible response categories were “Yes, still have the problem,” “Yes, but no longer have the problem,” and “No, have not had the problem.” These questions were adapted from those used in a previous epidemiological study of sleep. Four sleep disorder categories were constructed for subjects with a response of “yes, and still have the problem” to the above questions. Consistent with a previous study, subjects were classified as having disorders of initiating and maintaining sleep (DIMS) if they reported having trouble falling or staying asleep, not enough sleep, or waking too early, and not being able to get back to sleep. Those reporting falling asleep during the day were classified as having excessive daytime sleepiness (EDS); those reporting 1 or more of the 7 sleep disorders were classified as any sleep disorder (ASD); and those reporting nightmares (NM) were identified.

To assess physical activity we created dichotomous indicator variables using the following questions: “(1) How many city blocks or equivalent do you regularly walk each day? What is your pace of walking? (2) Are you participating in any exercise program specifically designed to improve your physical health? (3) On a usual weekday/weekend day, how much time do you spend doing vigorous activity (sports, jogging, sustained swimming, brisk walking, or bicycling)?” Based on the responses in question 1 we constructed 2 categories, subjects who walked more than 6 blocks per day at a brisk pace (<4.8 km/h) and subjects who walked more than 6 blocks per day at a casual or average pace (4.8 km/h). Subjects were classified as having done vigorous activity, either on weekdays or weekends (question 3), if they reported performing more than 1 hour per day of such activities.

Because respiratory diseases are known to be strongly related to sleep disorders, we identified all subjects who ever reported being told by a physician that they have asthma, chronic bronchitis, emphysema, or chronic obstructive pulmonary disease. Subjects with a positive response were classified as having “any respiratory problem.” We also determined each subject’s current smoking status, whether they reported using medications or alcohol to help them sleep, and computed each subject’s body mass index, which is a measure of weight in kilograms divided by the square of the height in meters. In addition, because chronic medical conditions may disrupt sleep, we identified subjects who reported seeing a physician for diabetes and heart problems. These variables were examined in the multivariate statistical analyses as potential confounders and/or effect modifiers.

RESULTS

There were 722 subjects who met the inclusion criteria for this analysis. There were more women (n = 403) than men (n = 319), which is generally the case when older age strata are included. Women participants reported having significantly more NM and DIMS than men (Table 1) and reported participating in exercise programs more often than men. In contrast, more men did vigorous activity for more than 1 hour per day on both weekdays and weekend days and walked for more than 6 blocks per day at a brisk pace.
Women subjects were significantly older than the men but the men had higher body mass indexes.

The results of the logistic regression modeling are listed in Table 2. No evidence of confounding was found when fitting the 2 logistic models to each of the sleep disorders (ie, significant coefficients related to exercise using model 1 were not substantially altered in model 2); thus, only the results that included both interactions and covariables are presented (model 2). For DIMS, walking more than 6 blocks per day, at an average pace, regular activity or exercise was associated with a reduced risk (OR, 0.50), while for women, the interaction term between vigorous activity on weekends and participating in an exercise program was associated with an increased risk (OR, 2.16). For both sexes, any respiratory trouble (OR, 1.63) and use of medications or alcohol to help sleep (OR, 10.47) increased the risk of DIMS. The sex indicator variable was borderline significant (P = .08), suggesting that men were at less risk of having DIMS than women. For ASD, subjects performing regular activities at least once a week (OR, 0.62) and men who walked more than 6 blocks per day at a brisk pace (OR, 0.45) both experienced significant beneficial effects. Other factors associated with an increased risk of ASD were use of medications or alcohol to help sleep (OR, 10.73), any respiratory trouble (OR, 1.53), and age (OR, 1.01). The OR estimate associated with age appears small but it represents the increased risk associated with a 1-year period.) For EDS, subjects reporting regular activity at least once a week had a borderline significant reduced risk (OR, 0.63). Use of medications or alcohol to help sleep (OR, 2.02) and age (OR, 1.02) were associated with significantly increased risks. There were not enough men reporting NM to warrant analysis. However, for women walking more than 6 blocks per day at a normal pace was associated with a significantly reduced risk (OR, 0.27), while use of medications (OR, 4.20) and any respiratory trouble (OR, 3.06) were related to an increased risk of NM. In contrast to the results found for ASD and EDS, in which age was associated with an increased risk, here it was associated with a significantly reduced risk (OR, 0.96).

Significance levels related to goodness of fit and improvement in each of the logistic models (Table 2) suggest that the models adequately describe or fit these data.

Since women who reported vigorous activity on weekends and participation in a regular exercise program had an increased risk of both DIMS and ASD, we compared their characteristics with those of the remaining population. In comparison with other women subjects, these women were younger (mean [± SD], 53.86 ± 12.3 vs 60.5 ± 14.5 years; P < .001) but had similar body mass indexes (mean [± SD], 23.5 ± 3.9 vs 24.9 ± 4.9 kg/m²; P = .10). They had similar rates of smoking and respiratory problems in comparison with the other women in the study.

In this study of a middle-aged to elderly population, DIMS and NM were more common in women than men. In both men and women, regular activity or exercise was associated with a reduced risk of DIMS, ASD, and EDS. Furthermore, concomitant use of medications or alcohol to aid sleep, coexistent respiratory disease, and increasing age were related to a greater prevalence and increased risk of disturbed sleep. In contrast, increasing age decreased NM risk among women.

We observed several differences between the men and women fulfilling selection criteria for this study. First, our cohort had a greater proportion of women who were slightly older than the men. This is observed in most longitudinal epidemiological studies that include elderly participants and reflects higher mortality rates among men. Second, as reported previously in this population and other studies, women were more likely to have DIMS and NM. Third, as expected, men weighed more than women. Fourth, men were more likely to engage in more vigorous exercise or activity, whereas women more frequently participated in a formal exercise program. This finding is consistent with previous studies that document a tendency for men to engage in vigorous exercise and women to engage in less physical activity. Differences in personality factors may partially explain these observations. Nonetheless, it is our contention that these differences did not influence our overall conclusions because with the exception of the associations between brisk walking and reduced DIMS and ASD in men, and the relationship between vigorous activity and increased DIMS and ASD in women, sex differences were not apparent.
The most important finding of this study is the association of regular exercise or physical activity with a lower prevalence of having symptoms of disturbed sleep. Although the type of exercise activities related to risk reduction differed by sex, their effect was observed in all categories of sleep symptoms surveyed, including NM. Regular exercise is promoted as a component of good sleep hygiene, ie, practices or behaviors that promote sleep, but there is little supporting clinical data. Previous epidemiological studies have demonstrated that exercise is perceived to be sleep promoting and associated with less daytime sleepiness. Our data are consistent with these previous findings and extend their relevance by suggesting that regular exercise or physical activity is associated with a reduced risk of having disturbed sleep. Furthermore, they provide indirect evidence to support a clinical prescription of exercise to treat symptoms of disturbed sleep so long as underlying primary sleep disorders such as obstructive sleep apnea or periodic limb movement disorder have been excluded.

A recent meta-analysis suggests that the effect of exercise on sleep is observed only if it exceeds 1 hour in duration. However, only studies related to acute exercise were included. The effect of regular exercise or physical activity on sleep such as that documented in our study may be different than after acute exercise.

The only exception to the consistency of our findings is the observation that women who exercised vigorously on weekends and who participated in a regular exercise program had a greater risk of DIMS and ASD. The explanation for this finding is not readily apparent. Detailed analysis of the characteristics of these participants show that these women were younger than other women cohort members. Exercise occurring late in the evening, especially if vigorous and prolonged, may be detrimental to sleep. It is possible that a greater proportion of this subgroup engaged in a regular exercise program in the late evening. However, our survey does not have information to either confirm or refute this hypothesis.

The mechanisms by which regular exercise may improve sleep appear to be related to alterations in sleep architecture (ie, duration, frequency, and pattern of occurrence of various stages of sleep) and efficiency (ie, the amount of time spent asleep as a percentage of the total time attempting to sleep). A number of studies have shown that both acute and long-term exercise reduce sleep latency and increase total time spent asleep and time spent in slow-wave sleep. However, others have failed to show such effects. These discrepancies may be related to confounding factors such as the timing of the exercise in relation to sleep or the fitness level of the subjects. It has been hypothesized that exercise produces changes in sleep architecture by producing an increase in central nervous system temperature. The empirical observations that warm baths are sleep promoting would support this theory. However, exercise in close proximity to bedtime is disruptive to sleep and evidence suggests that increased body temperature after exercise returns to normal within 90 minutes after cessation. It also has been suggested that increases in lean body mass or maximal oxygen consumption induced by exercise promote sleep. However, attempts to produce corroborative data have yielded conflicting results. Thus, the effect of exercise on altering sleep architecture and increasing total sleep time provide a possible explanation for our observations of an exercise-related decrease in risk of sleep disturbances. However, the underlying physiological mechanisms are still not clear.

A novel finding is the association of exercise with a reduction in NM in women. Stress, anxiety, and various personality traits appear to increase the frequency of NM. We have previously demonstrated in this population that NM occur more frequently in women than men. Furthermore, we observed that individuals with NM have higher scores on the SCL-90R General Severity Index, a global measure of psychological distress. Thus, it is possible that a greater proportion of this subgroup engaged in a regular exercise program in the late evening. However, our survey does not have information to either confirm or refute this hypothesis.

### Table 2. Odds Ratios (ORs) and 95% Confidence Intervals (CIs) From Logistic Regression Analyses

<table>
<thead>
<tr>
<th>Exercise Categories</th>
<th>DIMS</th>
<th>ASD</th>
<th>EDS</th>
<th>NM†</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walk &gt;6 blocks per day</td>
<td>0.67 (0.46-0.97)</td>
<td>...</td>
<td>...</td>
<td>0.27 (0.08-0.86)</td>
</tr>
<tr>
<td>Average pace</td>
<td>0.50 (0.27-0.93)</td>
<td>0.45 (0.26-0.76)</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Brisk pace‡</td>
<td>0.71 (0.50-0.99)</td>
<td>0.62 (0.44-0.87)</td>
<td>0.63 (0.39-1.03)</td>
<td>...</td>
</tr>
<tr>
<td>Regular activity, at least once a week</td>
<td>0.52 (0.30-0.92)</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Participate in exercise program</td>
<td>2.16 (1.02-4.58)</td>
<td>2.15 (1.02-4.60)</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Vigorous activity (weekends) and participate in exercise program†</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>

*DIMS indicates difficulty in maintaining sleep; ASD, any sleep disorder; EDS, excessive daytime sleepiness; NM, nightmares; and ellipses, not applicable. All results are for males and females except where otherwise indicated.
†Women only.
‡Men only.
sible in women who appear to have a predisposition to NM that a reduction in stress and anxiety may occur as a result of regular exercise.

Consistent with previous studies, we observed that use of medications or alcohol as aids to sleep and the presence of respiratory disease were associated with an increased risk of disturbed sleep. The finding that use of aids to sleep is associated with sleep disturbances is to be expected and was strong (OR range, 2.2-10.7). The relationship between aids to sleep and poor sleep is not surprising. People who sleep poorly naturally will tend to use sleep-promoting compounds. However, some of our findings may be related to the effect of long-term use of both hypnotics and alcohol to alter sleep architecture, exacerbate insomnia symptoms on withdrawal, and promote dependency. Nevertheless, despite the overwhelming influence of this factor, the findings related to exercise were still remarkable even after adjusting for this effect. We have previously reported that respiratory disease adversely affects sleep in this population. This effect appears to be related to the sleep-disruptive effects of cough, sputum production, and wheezing, and not to poor lung function by itself.

Except for NM, increasing age in our study was associated with an increase in prevalence and risk of disturbed sleep. This is consistent with previous reports but does not appear to mitigate the beneficial effects of exercise on sleep.

In summary, we have demonstrated in a large study of a middle-aged to elderly population that regular exercise is associated with a reduction in the prevalence and risk of symptoms of disturbed sleep. We acknowledge, however, that participants with prior stroke, heart or lung surgery, and lung cancer were excluded, and that our conclusions do not necessarily extend to groups with such individuals. Furthermore, although we included data concerning respiratory disease, heart problems, and diabetes in our analysis, information concerning other concurrent medical problems such as arthritis was not available from this survey of the population. Therefore, it is possible that some of the reduced risk of sleep disturbance observed in this study may be related to decreased physical activity among those with other chronic medical conditions. Nonetheless, these data provide additional evidence that a program of regular exercise may be a useful therapeutic modality in the treatment of patients with sleep disorders.

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