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# Sleep disturbance in persistent allergic rhinitis measured using actigraphy

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**Background:** Tiredness, fatigue, and impaired quality of life are common in patients with persistent allergic rhinitis (PAR). These symptoms may also be associated with reduced sleep quality in individuals with rhinitis.

**Objective:** To determine whether sleep disturbance can be detected using actigraphy in patients with PAR.

**Methods:** Ten house dust mite–allergic rhinitic patients and 10 nonallergic nonrhinitic control subjects were studied for 5 consecutive days and night. Continuous activity monitoring during the study period using actigraphy was used to obtain markers of sleep quality, such as sleep onset, sleep duration, and sleep fragmentation. In addition, participants recorded in a sleep diary the time they went to bed, the time they went to sleep, the time they awoke, and the quality of their sleep.

**Results:** Allergic rhinitic patients were found to have an increased fragmentation index value, indicative of reduced sleep quality and increased sleep disturbance, compared with the control group ( $P = .007$ ).

**Conclusions:** Using actigraphy, we identified specific sleep disturbances in patients with PAR that may result in the increased tiredness, fatigue, and impaired quality of life typically experienced in such patients.

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## INTRODUCTION

Rhinitis is a common condition in Australia, with more than 40% of adults in coastal areas reporting symptoms of rhinitis.<sup>1</sup> In addition, more than 40% of these individuals also have positive skin test reactions to house dust mite. In a 12-month study of patients with persistent allergic rhinitis (PAR), their fortnightly reported symptoms were greater than those of controls for 63% of the year.<sup>2</sup> Reduced quality of life (QoL) and impaired cognitive function and productivity are also experienced by individuals with rhinitis.<sup>3–5</sup> Although most studies of QoL in patients with allergic rhinitis (AR) have focused on intermittent AR, with acute and relatively short-lived symptoms, research has shown that impaired QoL also occurs in patients with PAR who have chronic and persistent symptoms.<sup>2</sup>

Reduced QoL may be caused by a variety of symptoms, including lack of a good night's sleep, difficulty getting to sleep, increased wakefulness, feelings of fatigue or tiredness, reduced productivity, and poor concentration. Such symptoms may be generated from allergic disease, potentially hypothesizing that impaired QoL is related to the sleep disturbance experienced by rhinitic individuals. Several subjective studies<sup>6–8</sup> have determined that AR also manifests in poor sleep quality and increased sleep disturbance. These symptoms are less likely to be due to the effects of medica-

tion because use of the new-generation nonsedating antihistamines increases daytime vigilance.<sup>9</sup> It is, therefore, likely that the inflammatory effects of rhinitis result in poor-quality sleep. Allergen exposure may also play a role because more than 40% of patients with PAR have positive skin test reactions to house dust mite, and a recent study<sup>10</sup> has shown that more than 60% of house dust mite exposure occurs in the bed.

Measurement of sleep disturbance in rhinitis is difficult and expensive. Polysomnography is considered the gold standard diagnostic test measuring a variety of physiologic variables, including electroencephalography, breathing, and leg movements to evaluate sleep and wakefulness. Studies using polysomnography<sup>11,12</sup> have shown that rhinitic patients tend to have reduced sleep duration and quality. However, laboratory-based polysomnography studies do not reflect normal sleeping conditions because allergen levels in hospital-based sleep laboratories are much lower than those found in houses and, thus, do not accurately reflect the effect of rhinitis on sleep behavior. Furthermore, the “first night effect,” in which normal sleep patterns are altered by the instrumentation and the unfamiliar laboratory environment, often requires patients to stay 1 to 2 nights to acclimatize to sleeping in such an environment. Home-based polysomnography allows patients to sleep in a familiar environment, exposed to their usual allergen load; however, the instrumentation, even for home-based polysomnography, is likely to interfere with participants' normal sleep patterns.<sup>13,14</sup> These difficulties, plus the expense of these studies, make polysomnography unsuitable for either diagnosis of sleep disturbance or evaluation of the effects of treatment in rhinitic individuals.

An alternative approach is the use of actigraphy, which uses an accelerometer to measure movement above or below a given threshold across several days to evaluate sleep and

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Figure 1. The Actiwatch actigraphy device is similar to a normal wristwatch. It is worn on the nondominant hand during sleep. The watch face contains the accelerometer, which records movement.

circadian rhythm.<sup>15</sup> Figure 1 shows the Actiwatch actigraphy device (Mini Mitter Co Inc, Bend, Oregon). The accelerometer is programmed to detect movement, and, depending on the selected scoring algorithm, the resulting data correlate the degree of movement with sleep and wake states as well as calculating various variables, such as sleep efficiency, sleep onset latency (SOL), mean sleep bout time (MSBT), mean wake bout time (MWBT), and the fragmentation index (FI).<sup>16</sup> Actigraphy has the advantage that it can measure sleep in the home environment across several nights and is relatively inexpensive. There have been no direct comparisons between polysomnography and actigraphy, but 2 separate studies in healthy individuals, 1 using home polysomnography<sup>17</sup> and 1 using actigraphy,<sup>13</sup> found similar outcomes for important sleep variables. It has also been reported that sleep measures observed using actigraphy correlate with those observed with polysomnography by approximately 90%.<sup>18</sup> Furthermore, the American Academy of Sleep Medicine<sup>19</sup> recently published an update on the practice parameters of actigraphy use, stating the usefulness of this monitoring method for characterizing sleep patterns and treatment responses.

To date, the effect of rhinitis on sleep has not been investigated using actigraphy. We, therefore, piloted an in-home short-term study of sleep patterns in patients with PAR using an Actiwatch device.

## METHODS

### Participants

Ten patients with PAR and 10 nonrhinitic control subjects were recruited from research staff at the Woolcock Institute of Medical Research and from advertisements in local newspapers and on the campus of the University of Sydney. All the participants had similar professional capacities and were expected to have similar levels of work-related stress. Participants underwent an allergen skin prick test (SPT) with 14 aeroallergens; histamine and saline solutions were used as

positive and negative controls, respectively. Maximal diameter measurements of inflammatory wheals caused by reaction to allergen were recorded. The inclusion criterion for patients with PAR was sensitivity to either of the house dust mites *Dermatophagoides farinae* (Der f 1) or *Dermatophagoides pteronyssinus* (Der p 1) (mean wheal size by SPT,  $\geq 4$  mm) in a standard inhalant battery. Patients were also required to have a history of rhinitis symptoms for most of the year for at least the previous 2 years irrespective of any treatment and were otherwise well. The exclusion criteria for nonrhinitic control subjects were a recent history of rhinitis symptoms, chronic disease, regular medication use, and a wheal size of 4 mm or larger to any of the allergens on the SPT panel. The exclusion criteria for all the participants were a clinical history of asthma, current smoking, an upper respiratory tract infection in the past 4 weeks, and any clinical history of sleep apnea or sleep disorder. Participants were also examined and excluded for any significant structural nasal abnormalities that may confound findings.

### Study Design

Each participant wore an Actiwatch continuously for 1 period of 5 days and 5 nights starting on a Friday, Saturday, or Sunday. The Actiwatch was worn on the nondominant wrist. In addition, participants were asked to complete a generic sleep diary each morning of the 5-day study. At the end of the 5-day period, the Actiwatches and sleep diaries were returned to the study site for data analysis.

### Actiwatch Variables

The Actiwatch was set to a sensitivity level equivalent to 40 activity counts, and a 15-second sampling interval (epoch) was selected. The data were analyzed using the Actiware sleep algorithm to define periods of sleep and wakefulness. The detection of 40 or more activity counts by the Actiwatch in 1 epoch was considered a wake bout, and an epoch that had fewer than 40 activity counts was considered a sleep bout. The software provided measurements of the total time in bed (awake and asleep), total sleep time (TST), actual sleep, actual wake time, sleep bouts, wake bouts, MSBT, MWBT, total activity score, mean activity score, SOL, and the FI. Data from Actiwatches were downloaded using Actiware version 3.1 software (Mini Mitter Co Inc). From these measurements, the outcome variables were calculated as defined in Table 1.

### Sleep Diary

Participants were asked to complete a sleep diary each morning describing the previous night's sleep. They recorded the time they went to bed, the time they went to sleep, and the time they awoke. This was used to calculate TST and SOL. In addition, participants were also asked to complete a scoring chart to rate how well they slept, how refreshed they felt from their sleep, the calmness of their sleep, how easy it was to go to sleep, how easy it was to awaken, and the amount of dreaming their sleep involved.

Table 1. Summary and Definition of the Study Variables

| Measured variable                      | Definition                                                                                                  |
|----------------------------------------|-------------------------------------------------------------------------------------------------------------|
| Total sleep time, h <sup>a</sup>       | Time between sleep start and sleep end scored according to the Actiware sleep algorithm                     |
| Sleep efficiency, % <sup>b</sup>       | An index of the amount of time in bed that is actually spent sleeping                                       |
| Sleep onset latency <sup>a</sup>       | The time required for sleep onset after going to bed                                                        |
| Mean sleep bout time, min <sup>b</sup> | Average duration of a sleep bout                                                                            |
| Mean wake bout time, min <sup>b</sup>  | Average duration of a wake bout                                                                             |
| Time in bed <sup>a</sup>               | Time spent in bed in awake and asleep                                                                       |
| Fragmentation index <sup>b</sup>       | An index of restlessness. Summation of the number of minutes moving (%) with immobility phases of 1 min (%) |

<sup>a</sup> Measured using actigraphy and sleep diaries.

<sup>b</sup> Measured using actigraphy only.

### Data Analysis

Actiwatch data were downloaded using Actiware version 3.1 software. Actiwatch and sleep diary data were tested for normality using the Kolmogorov-Smirnov equation. All the variables except SOL and the FI were found to follow a Gaussian distribution. Parametric data were tested for significance using a 2-tailed paired *t* test, whereas nonparametric data were tested for significance using the Mann-Whitney test. A *P* < .05 was considered to be statistically significant. Analysis was performed using Analyze-it + General 1.68 software (Analyze-it Software Ltd, Leeds, England).

### RESULTS

Ten patients with PAR (mean [SD] age, 31 [10.6] years) and 10 nonrhinitic control subjects (mean [SD] age, 42 [13.2] years) participated in the study. The age difference between the 2 groups was not significant (*P* = .055). The mean (SD) SPT wheal size of patients with PAR to Der p 1 was 5.3 (1.5) mm and to Der f 1 was 6.3 (1.5) mm.

Mean actigraphy measurements from the 5 nights are listed in Table 2. Measurements were obtained from 10 control subjects and 10 rhinitic patients. It was found that there was significantly more disturbed sleep as measured using the FI in the rhinitic group compared with the control group (*P* = .007). There were no significant differences in TST, sleep efficiency, SOL, MSBT, or MWBT between the rhinitic and control groups as measured by means of actigraphy.

The TST and SOL variables were also calculated from the daily recordings in the sleep diaries (Table 3). The TST measurements were obtained from 10 control subjects and 9 rhinitic patients, and the SOL measurements were obtained from 9 control subjects and 9 rhinitic patients. No significant differences in measurements were observed between the PAR and control groups for either variable. It was observed that no significant differences in measurements were obtained when TST and SOL data from the Actiwatch were compared with data calculated from sleep diaries (Table 4).

### DISCUSSION

In this pilot study, we found that individuals with PAR experienced significantly increased sleep fragmentation compared with controls. This finding concurs with findings from another actigraphy study assessing the sleep patterns of asthmatic patients.<sup>20</sup> Jankelowitz et al define the FI as a measure of the number of times an individual moves rather than the percentage of time they spend awake during the sleep period and have described it as “a more useful measure to examine sleep disturbance because it may better detect repetitive short events that disrupt sleep.”<sup>21(p1597)</sup> The finding of increased sleep fragmentation in the present study supports the hypothesis that patients with PAR have more disturbed sleep than nonrhinitic control subjects and suggests that actigraphy may be a useful tool for detecting and monitoring sleep disturbance associated with rhinitis. Similar findings have been shown in conditions such as cystic fibrosis.<sup>21</sup>

Increased FI values in rhinitic patients may be explained by the mechanisms underlying nasal obstruction. It has been suggested that an increase in hydrostatic pressure in the head is induced when the body is in the supine position, the position the body is normally in during sleep.<sup>22</sup> This change

Table 2. Comparison of Variables Measured Using Actigraphy Across a 5-Day Period

| Variable                               | Control group<br>(n = 10) | PAR group<br>(n = 10) | <i>P</i> value |
|----------------------------------------|---------------------------|-----------------------|----------------|
| TST, mean (SD), min                    | 415.6 (43.0)              | 425.5 (31.4)          | .56            |
| SE, mean (SD), (%)                     | 95.1 (2.0)                | 93.1 (0.10)           | .10            |
| SOL, median (95% CI), min <sup>a</sup> | 14.8 (8.7–25.4)           | 12.9 (8.0–16.6)       | .33            |
| MSBT, mean (SD), s                     | 854.7 (377.7)             | 724.4 (281.0)         | .39            |
| MWBT, median (95% CI), s <sup>a</sup>  | 35.5 (28.5–39.8)          | 38.5 (33.0–47.5)      | .28            |
| FI, mean (SD)                          | 21.2 (3.7)                | 29.5 (7.8)            | .007           |

Abbreviations: CI, confidence interval; FI, fragmentation index; MSBT, mean sleep bout time; MWBT, mean wake bout time; PAR, persistent allergic rhinitis; SE, sleep efficiency; SOL, sleep onset latency; TST, total sleep time.

<sup>a</sup> Both SOL and MWBT were determined to be of a nonparametric distribution and were tested using a Mann-Whitney test.

Table 3. Comparison of SOL and TST Recorded in Sleep Diaries in the Control and Rhinitic Groups During a 5-Day Period

| Variable                               | Control group   | PAR group        | P value |
|----------------------------------------|-----------------|------------------|---------|
| TST, mean (SD), min                    | 440.4 (38.9)    | 424.27 (64.295)  | .52     |
| SOL, median (95% CI), min <sup>a</sup> | 28.6 (9.7–49.7) | 22.0 (13.8–38.2) | >.99    |

Abbreviations: CI, confidence interval; PAR, persistent allergic rhinitis; SOL, sleep onset latency; TST, total sleep time.

<sup>a</sup> The SOL was determined to be of a nonparametric distribution and was tested using a Mann Whitney test.

Table 4. Comparison of Actiwatch and Sleep Diary Measurements

| Variable | Group    | P value |
|----------|----------|---------|
| TST      | Control  | .30     |
| TST      | Rhinitic | .08     |
| SOL      | Control  | .13     |
| SOL      | Rhinitic | .05     |

Abbreviations: SOL, sleep onset latency; TST, total sleep time.

in pressure causes the nasal airway to reduce in size. Non-rhinitic individuals have to contend with this postural change only when sleeping, whereas nasal obstruction in rhinitic patients may be further exacerbated by the effect of inflammatory cytokines.<sup>23</sup> Considering the present findings, it seems that nasal obstruction in rhinitic patients contributes to increased FI values.

The present findings are important because this is the first study, to our knowledge, to investigate the association between PAR and sleep quality using an objective means in a PAR population. The only previous PAR and sleep study<sup>24</sup> used polysomnography to evaluate the effect of nasal dilation strips on a PAR group when sleeping and did not investigate any relationship between PAR and rhinitis. The present findings are consistent with those of previous polysomnography studies<sup>11,12,23–25</sup> that have found evidence of sleep disturbance in rhinitis. Sleep in rhinitic populations is characterized by longer and more frequent apneas and “microarousals,”<sup>12,26</sup> and nasal obstruction due to allergy has been associated with increased sleep-disordered breathing, habitual snoring, apnea, and hypopnea.<sup>25</sup> By using actigraphy, the present participants could be evaluated in their home environment, with their normal domestic allergen exposure. There was no evidence of any first night effect,<sup>27</sup> allowing all the data from the 5 nights to be included in the analysis. Previous studies<sup>18,28,29</sup> have found that actigraphy has a lower detection sensitivity for wake events, resulting in overscoring of sleep events, but this is unlikely to have biased the present findings regarding comparison between the rhinitic and control groups. The sleep variables from control subjects were similar to those reported in previous actigraphy studies.<sup>13,14</sup> Thus, the sleep disturbance detected by actigraphy in the present rhinitic patients is likely to be a true reflection of abnormal sleep patterns in these individuals.

Although polysomnography remains the gold standard approach to sleep monitoring, actigraphy has been established as a useful tool for measuring sleep patterns across time.<sup>30,31</sup> The present study is the first of its kind to evaluate sleep disturbance in rhinitic patients using actigraphy. It would be

prudent in any further research in this field to validate actigraphy findings against polysomnography findings for all patients.

The effect of the ages of participants also may limit the findings of this study. Despite a nonsignificant age difference existing between the rhinitic and control groups, it has been observed previously that sleep is more fragmented with increasing age because there are more sleep stage shifts and because sleep is not as consolidated and is prone to more arousals and awakenings.<sup>32</sup> The same amount of sleep is required with increasing age, but it becomes increasingly more difficult to obtain enough of it at night. Therefore, at an individual level, adjustment for the effect of sleep fragmentation due to age may be required to evaluate the independent effect of rhinitis.

The other main limitation of this study was that small sample populations were used. These small numbers may potentially limit the generalizability of the findings; thus, it would be of interest to pursue further research with larger rhinitic and control cohorts.

## CONCLUSION

In conclusion, this pilot study shows that sleep disturbance is significantly increased in patients with PAR and that this disturbance can be detected in a few patients using actigraphy. Although polysomnography remains the gold standard technique for sleep monitoring, this finding raises the possibility that actigraphy may have a role in monitoring sleep disturbance noninvasively in a home setting to evaluate the effects of local allergen exposure on sleep or to evaluate the effects of pharmacologic or environmental interventions designed to improve QoL in patients with PAR.

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