Research Article

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The Measurement of Orthopaedic Surgeon Quality and Quantity of Sleep Using a Validated Wearable Device

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Abstract

Introduction: Recurrent episodes of partial sleep deprivation resulting from shift work or call schedules are commonly seen in physicians. This study measures the quantity and quality of sleep in orthopaedic surgeons and determines the factors that are correlated with decreased quantity and quality of sleep.

Methods: Orthopaedic surgery residents and attending surgeons at a single institution were prospectively enrolled and provided with a validated wearable device to objectively determine sleep quantity (total hours of sleep) and quality (sleep disturbances; sleep latency; sleep efficiency; and amount of rapid eye movement [REM] sleep, deep sleep, and light sleep). Sleep deprivation was defined as getting less than 7 hours of sleep per day. Bivariate correlations were determined using Spearman rank correlation. Multiple linear regression models were constructed to determine the effect of independent variables (age, attending physician, resident, postgraduate year [PGY] level, sex, number of calls, and total hours worked) and sleep quantity and quality. All P values were reported, and a significance level of $\alpha = 0.05$ was used (ie, $P < 0.05$).

Results: Of 26 enrolled subjects, 21 (80.8%; 12 residents and 9 attending surgeons, where 15 were men and 6 women, with mean age of 37.2 $\pm$ 10.9 years) completed the 4-week duration of the study. Orthopaedic surgeons obtained 6.5 $\pm$ 0.8 hours of sleep per night (17.7% REM, 19.4% deep sleep, and 62.6% light sleep; 4.5 $\pm$ 1.1 minutes of sleep latency; 4.9 $\pm$ 1.7 sleep disturbances; and 89.9% sleep efficiency). Fourteen orthopaedic surgeons (66.7%) of the 21 slept less than the recommended 7 hours of sleep per night. The total hours worked had a moderate negative correlation ($r = -0.550$; $P = 0.010$) with total sleep. PGY level had a moderate positive correlation with sleep latency ($r = 0.546$; $P = 0.010$).

Discussion: Diminished sleep quantity is considered sleeping less than 7 hours per night, whereas decreased sleep quality is associated with decreased REM sleep, decreased deep sleep, increased light sleep, decreased sleep latency, decreased sleep efficiency, and increased sleep disturbances. Sleep deprivation in orthopaedic surgeons poses notable health and safety risks for both surgeons and patients.

Conclusion: Orthopaedic surgeons demonstrate poor sleep quantity and quality which is markedly worse than the general population, with increased work hours markedly correlated with decreased hours of sleep.

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JAAOS Glob Res Rev 2018;2:e065

DOI: 10.5435/JAAOSGlobal-D-18-00065

Sleep is a complex homeostatic process of body restoration which is required for normal human functioning. As such, the American Academy of Sleep Medicine recommends that healthy adults should sleep 7 to 9 hours per night on a regular basis to promote optimal health.[1] Sleep quality, based on the amount of rapid eye movement (REM) sleep, deep sleep, light sleep, sleep latency, and sleep disturbances, has also been shown to be an important factor for restful sleep.[2]

A reduction in sleep time less than the recommended time is considered sleep deprivation. Recurrent episodes of partial sleep deprivation resulting from shift work or call schedules are commonly seen in physicians.[3] This has been shown to cause decreased mental effectiveness while at work, which corresponds with a blood alcohol level of 0.08%.[4] Sleep deprivation has been associated with adverse health events such as obesity, diabetes, hypertension, heart disease, stroke, depression, and increased risk of death.[1,3] Additionally, several studies have investigated the effect of sleep deprivation on clinical performance outcomes in surgeons, nonsurgeons, residents, and attending physicians, and found decreased surgical performance, increased errors, and greater risks of accidents.[4-11]

However, these studies were based on subjective reporting of sleep with no objective measure of the total hours of sleep and quality of sleep. Given this limited understanding of physician sleep patterns and the increasing interest in physician and patient safety, understanding the objective quality and quantity of sleep obtained by orthopaedic surgeons is important.[12,13] This study (1) determines sleep quantity (total hours of sleep) and quality (sleep disturbances; sleep latency; sleep efficiency; and amount of REM sleep, deep sleep, and light sleep) in orthopaedic surgery residents and attending surgeons using a validated wearable device and (2) determines whether a correlation exists between subject-specific variables and sleep quantity and quality. The authors hypothesized that (1) more than 50% of orthopaedic surgery residents and attending surgeons would have poor quantity (less than 7 hours) and quality (decreased sleep latency, decreased sleep efficiency, decreased REM sleep, increased light sleep, decreased deep sleep, and increased sleep disturbances) and (2) there would be a strong negative correlation between number of calls and hours worked and sleep quantity and quality.

Methods

Approval from the institutional review board was obtained for this study. Twenty-eight orthopaedic surgery residents (n = 14) and attending surgeons (n = 14) were assessed for study eligibility from October to November 2017 (Figure 1). All subjects signed informed consent before entering the study. Subjects were eligible for inclusion if they were American Board of Orthopaedic Surgery-certified attending surgeons or orthopaedic surgery residents from a single academic institution. Subjects were excluded from eligibility if they were not American Board of Orthopaedic Surgery certified (attending surgeon), were not currently a postgraduate year (PGY)-1 to PGY-5 orthopaedic surgery resident, chose not to participate, or did not complete the duration of the study. Individuals were not excluded if on medication which may affect sleep (eg, zolpidem, melatonin, diphenhydramine, caffeine).

All participants were provided with a WHOOP (WHOOP) wearable device ($2.54 \times 4.445 \times 0.635$ cm) to be worn at all times during the 4-week study period that measured data continuously. The device was worn on the wrist or biceps of the participant. The WHOOP is a validated device that uses photoplethysmography to measure five metrics: heart rate, heart rate variability, ambient temperature, motion and movement, and skin response to measure and analyze a person's sleep.[14] Sleep was recorded as "total sleep," "REM sleep," "deep sleep," "light sleep," "sleep latency," and "disturbances" based on the WHOOP data. Sleep quantity was defined as total hours of sleep. Total sleep was averaged as the total number for hours slept per day per week. Sleep quality consisted of REM sleep, deep sleep, light sleep, sleep latency, sleep efficiency, and sleep disturbances. REM sleep, deep sleep, and light sleep were averaged as the total number of hours per day per week and calculated as a percentage of total sleep. Sleep disturbance was the number of times a subject woke up during sleep. Sleep latency was the time (minutes) it takes to transition from wakefulness to sleep. Sleep efficiency was calculated

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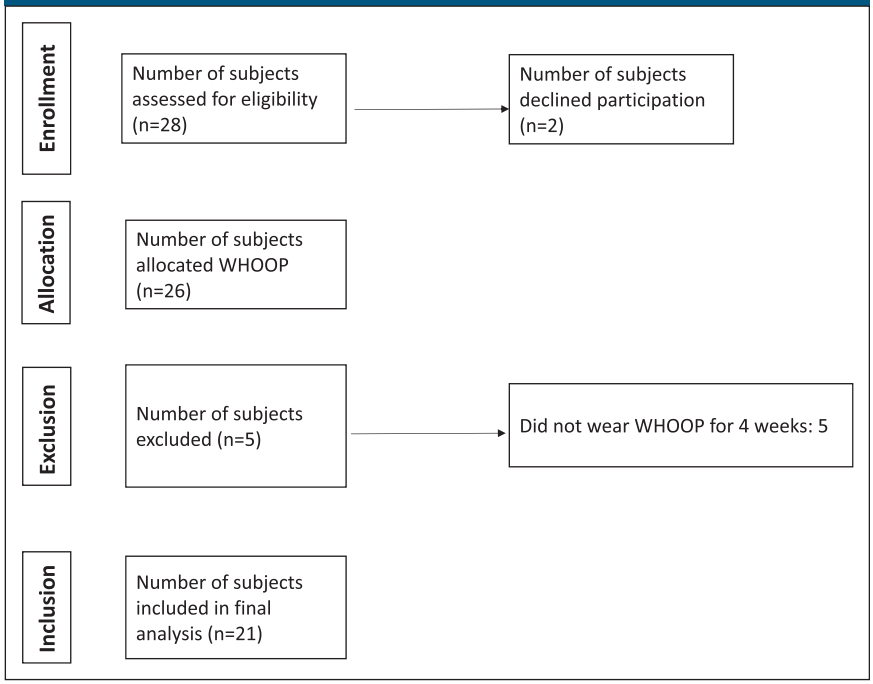
based on the amount of total sleep divided by the time in bed. Normalized data from the general population are shown in Table 1.[1,2,15-17]

Demographic information, such as age, sex (male/female), and PGY level (resident), was recorded for all subjects at the beginning of the study. All participants recorded the number of hours worked per day and number of days on call per week at the end of each week for the 4-week duration of the study. Compliance was defined as wearing the WHOOP daily for 4 weeks, with the WHOOP not worn less than 15 minutes per day.

Data analysis was performed using SPSS Statistics software, version 20 (IBM). The significance of differences in means of continuous variables between two groups was determined using Student *t*-test. Groupwise differences in count frequencies for categorical variables were tested using chi-squared tests, with Fisher exact test for *P* values. Bivariate correlations were determined using Spearman rank correlation. Correlation was defined as a perfect negative linear relationship ($r = -1$), strong negative linear relationship ($r = -0.70$), moderate negative relationship ($r = -0.50$), weak negative linear relationship ($r = -0.30$), no linear relationship ($r = 0$), weak positive linear relationship ($r = +0.30$), moderate positive relationship ($r = +0.50$), strong positive linear relationship ($r = +0.70$), and perfect positive linear relationship ($r = +1$). Multiple linear regression models were constructed to determine the effect of independent variables (age, attending physician, resident, PGY level, sex, number of calls, and total hours worked) on sleep quantity (total hours of sleep) and quality (sleep disturbances; sleep latency; sleep efficiency; and amount of REM sleep, deep sleep, and light sleep). Categorical variables were coded as dummy variables (ie, for sex, zero-male, 1-female). Individual models were built for all sleep parameters. A model building strategy was used in which we first performed univariate regression with each predictor considered. Univariate predictors whose $P < 0.25$ were then combined in a multiple variable model. All *P* values were reported, and a significance level of $\alpha = 0.05$ was used (ie, $P < 0.05$).

Figure 1



Flow diagram of patient exclusion and inclusion.

Table 1

Normal Values for Sleep Quality and Quantity per Night

Sleep Statistic	Normal
Total sleep (hr)	7-9
REM sleep (% total sleep)	20%-25%
Deep sleep (% total sleep)	13%-23%
Light sleep (% total sleep)	47%-60%
Sleep latency (min)	>10
Sleep efficiency (%)	>80%

REM = rapid eye movement

Results

Of the 28 patients assessed for eligibility, two declined to participate. Five subjects did not complete the minimum WHOOP compliance (4 weeks) and were excluded from the analysis. Of the 26 enrolled subjects, 21 (80.8%; 12 residents and 9 attending surgeons, where 15 were men and 6 women, with mean age of 37.2 ± 10.9 years) completed the minimum 4-week duration of the study and were included in the final analysis.

Subject demographics are shown in Table 2. Residents were significantly younger than attending surgeons

Table 2

Subject Demographics

Demographic	Residents	Attending Surgeons	Overall	*P* Value
Age (y)	29.8 ± 2.6	47.2 ± 9.5	37.2 ± 10.9	<0.001[a]
Sex (male/female)	7/5	8/1	15/6	0.125
No. of physicians	12	9	21	NA
PGY level (PGY5/PGY4/PGY3/PGY2/PGY1)	1/3/2/3/2	NA	1/3/2/3/2	NA
Total hours worked per week	62.3 ± 15.9	47.3 ± 6.4	55.9 ± 14.6	0.009[a]
Average number of overnight calls per week	0.8 ± 0.6	0.4 ± 0.7	0.6 ± 0.6	0.103

PGY = postgraduate year
[a] Statistically significant ($P < 0.05$)

Table 3

Sleep Quality and Quantity per Night

Sleep Statistic	Residents	Attending Surgeons	Overall	*P* Value
Total sleep (hr)	6.3 ± 0.9	6.7 ± 0.4	6.5 ± 0.8	0.214
REM sleep (% total sleep)	1.2 ± 0.5 (19.1%)	1.1 ± 0.7 (15.9%)	1.2 ± 0.6 (17.7%)	0.451
Deep sleep (% total sleep)	1.2 ± 0.3 (18.4%)	1.4 ± 0.6 (20.7%)	1.3 ± 0.4 (19.4%)	0.718
Light sleep (% total sleep)	3.9 ± 0.9 (62.1%)	4.2 ± 0.4 (63.3%)	4.1 ± 0.7 (62.6%)	0.883
Sleep latency (min)	3.9 ± 1.9	5.3 ± 2.5	4.5 ± 1.1	0.179
Sleep efficiency (%)	91.1 ± 4.0	88.3 ± 4.8	89.9 ± 4.5	0.159
Sleep disturbances	4.8 ± 2.1	4.9 ± 1.2	4.9 ± 1.7	0.889

REM = rapid eye movement

Table 4

Multivariate Analysis of the Effect of Subject Factors on Quantity and Quality of Sleep

Variable	Regression Coefficient	*P* Value
Total hours of sleep		
Total hours worked	−4.041	0.001[a]
Female sex	2.907	0.009[a]
REM sleep		
Female sex	2.840	0.010[a]
Light sleep		
Total hours worked	−2.418	0.026[a]
Sleep disturbances		
Total hours worked	−2.148	0.046[a]

REM = rapid eye movement
[a] Statistically significant ($P < 0.05$).

(29.8 ± 2.6 versus 47.2 ± 9.5 years; $P < 0.001$). Residents also worked markedly more hours per week than attending surgeons (68.5 ± 15.2 versus 49.9 ± 7.5 hours; $P = 0.009$). No other notable differences were observed in the demographics between residents and attending surgeons.

Orthopaedic surgeons obtained 6.5 ± 0.8 hours of sleep per night on average (17.7% REM sleep, 19.4% deep sleep, and 62.6% light sleep) (Table 3). Fourteen orthopaedic surgeons (66.7%) of the 21 slept less than the recommended 7 hours of sleep per night. Orthopaedic surgeons had an average sleep latency of 4.5 ± 1.1 minutes and sleep efficiency of 89.9%. Residents and attending surgeons also had similar quantity and quality of sleep ($P > 0.05$).

In the multivariate models (Table 4), the total hours worked had the strongest association with total sleep ($P = 0.001$), percentage of light sleep ($P = 0.026$), and number of sleep disturbances ($P = 0.046$). Female sex was also strongly associated with total sleep ($P = 0.009$) and REM sleep ($P = 0.010$). No other subject-specific variables

had any notable association with the quantity or quality of sleep.

In bivariate correlation analysis, total hours of work had a moderate negative correlation with total sleep (r = −0.550; P = 0.010) (Table 5). Female sex had weak to moderate positive correlations with total sleep (r = 0.460; P = 0.032) and REM sleep (r = 0.487; P = 0.025). PGY level had a moderate positive correlation with sleep latency (r = 0.546; P = 0.010). No other subject-specific variables demonstrated notable correlations with sleep quantity and quality.

Table 5

Bivariate Correlation of Subject Factors and Sleep Quantity and Quality

Variable	Correlation Coefficient	*P* Value
Total sleep		
Total hours worked	−0.550	0.010[a]
Female sex	0.460	0.032[a]
REM sleep		
Female sex	0.487	0.025[a]
Sleep latency		
PGY level	0.546	0.010[a]

PGY = postgraduate year, REM = rapid eye movement
[a] Statistically significant ($P < 0.05$).

Discussion

The study hypotheses were partially confirmed with orthopaedic surgery residents and attending surgeons demonstrating poor sleep quantity (6.5 hours per night) and quality (deceased sleep latency, decreased REM sleep, and increased light sleep). Additionally, increased hours worked was markedly correlated with decreased hours of sleep, and advanced PGY level was markedly correlated with increased sleep latency (less sleepiness). Female sex was also markedly correlated with increased hours of sleep and increased REM sleep.

Impaired sleep quantity is considered sleeping less than 7 hours per night, whereas decreased sleep quality is associated with decreased REM sleep, decreased deep sleep, increased light sleep, decreased sleep latency, decreased sleep efficiency, and increased sleep disturbances.[1,15,16,18] The current study found that orthopaedic surgeons obtained less (mean of 6.5 hours) than the recommended 7 hours of sleep per night.[1] Additionally, compared with the general population, orthopaedic surgeons have worse quality of sleep, with decreased REM sleep (17.7% versus 20% to 25% normal), increased light sleep (62.6% versus 47% to 60% normal), and decreased sleep latency (4.5 versus > 10 minutes normal), indicating severe sleepiness.[2,15,17] This decreased quality and quantity of sleep in orthopaedic surgeons may be because of the increased hours worked compared with the 40-hour work week seen in most professions. Additionally, shift work and overnight calls also likely play a major role in orthopaedic surgeons' sleep deprivation.

This poses notable health risks for surgeons, with sleep deprivation leading to increased rates of obesity, diabetes, hypertension, heart disease, stroke, depression, and risk of death.[1,3] Decreased sleep has also been shown to decrease surgical performance, increase errors, and increase the risk of accidents.[5-11] Because of the detrimental effect of decreased sleep on surgeon and patient health, the Accreditation Council for Graduate Medical Education in the United States and the European Working Time Directive in the European Union have attempted to restrict physician work hours with varying degrees of success.[19,20]

Lockley et al[20] demonstrated that reducing the number of hours worked per week by residents led to markedly increased total hours of sleep. This supports the findings of the present study because a notable association and correlation was observed between increased hours worked and decreased total hours of sleep. However, the study by Lockley et al relied solely on subjective sleep reporting with no objective measure of sleep quantity or quality. Interestingly, total hours worked did not have the same negative effect on sleep quality with increased hours worked markedly associated with decreased light sleep and decreased sleep disturbances. This is likely attributable to the indirect effect of working long hours leading to decreased sleep. As one would expect, this decreased sleep would therefore allow for fewer opportunities for sleep disturbances.

Female sex was also markedly correlated with increased total sleep (quantity) and REM sleep (quality) in the present study. This is not unexpected because previous investigations have demonstrated that women have better sleep quantity (more hours) and quality (more REM sleep, more deep sleep, and less light sleep) than men.[15,21-23] Despite the improved sleep quality and quantity observed in women, they have more subjective difficulties initiating and maintaining sleep.[24] Though not investigated in the current study, this may contribute to the high rate of dissatisfaction with work-life balance that has been reported in female surgeons.[25]

This study has a few limitations. The study was limited to only orthopaedic surgery residents and attending surgeons from a single academic institution, leading to a smaller sample size and selection bias. However, the authors tried to limit the bias through strict inclusion and exclusion criteria, with 80.8% follow-up. The conclusions therefore may not be generalizable to all orthopaedic surgeons and physicians in other subspecialties from different regions. Additionally, we conducted the study for 4 weeks. Therefore, we were unable to determine the effect of changes in patient volume, clinic, operating room, rotation (resident), and call schedules on sleep quality and quantity over an extended period of time. This inclusion of multiple residents from different rotations and PGY levels and attending surgeons from different subspecialties attempted to mitigate this. Hours worked were subjectively recorded at the end of each week. Although this eased data collection and increased response rates compared with daily recording, it is subject to recall bias and may lead to over- or underestimation of total hours worked. To decrease the subjectivity of sleep quantity and quality, the WHOOP device was used. Sleep polysomnography is the benchmark for objectively evaluating sleep. However, it is not well suited for long-term monitoring in multiple subjects. As such, the current sleep data are based on photoplethysmography that has been validated against polysomnography with moderate agreement.[14] Despite validation, the objective sleep measures may differ from data obtained using sleep polysomnography.

In conclusion, orthopaedic surgeons demonstrate poor sleep quantity and quality which are markedly worse than those of the general population, with increased work hours markedly correlated with decreased hours of sleep.

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