Using Wearable Technology to Evaluate Sleep and Stress for Physicians

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Objectives: Physician stress and burnout are increasingly prevalent issues that often are exacerbated by chronic sleep deprivation. Poor sleep not only compromises the well-being of physicians but also can negatively affect patient care and safety. As wearable technology has become more advanced, the potential is growing to use these devices to monitor and analyze physiological metrics such as sleep and stress levels in real time. This systemic review aims to investigate the use of wearable technology to track sleep quality, stress, and burnout among physicians at various levels of training.

Methods: A systematic review was conducted according to Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines using Medline, Cochrane, and Embase to identify studies that used wearable technology to monitor sleep and stress outcomes in physicians. Inclusion criteria focused on studies that specifically measured sleep quality, stress, and burnout using wearable technology. Thirteen studies were included in this review. Data extracted from the included studies detailed study design, participant characteristics, type of wearable technology used, and measured sleep outcomes and heart rate variability (HRV) data.

Results: The data of 540 physicians were included in this study, with Emergency Medicine and Trauma Surgery representing the largest proportion of specialties assessed. Physicians not on call slept an average of 398.3 ± 49.0 minutes per night, whereas those on call slept an average of 226.0 ± 71.3 minutes per night. Physicians also spent 82.5 ± 13.4 minutes in rapid eye movement sleep per night and 41.3 ± 21.8 minutes awake in bed before falling asleep. HRV measures showed an average standard deviation of the R-R intervals across studies of 62.7 ± 28.8 milliseconds.

Conclusions: Wearable technology data indicate that physicians sleep less than the recommended amount per night and have reduced sleep quality measures. HRV data indicate increased levels of stress and burnout. The data provided by wearable technology may improve physician well-being and ultimately patient care.

Key Words: burnout, heart rate variability, physician, sleep quality, wearable technology

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Medicine is an inherently demanding profession that often causes physicians to experience acute and chronic sleep deprivation. This often can lead to poorer sleep quality and physician burnout.[1] Symptoms of burnout include emotional exhaustion, depersonalization, and feelings of decreased personal achievement.[2] Burnout not only affects the well-being of physicians but it also can have a large-scale impact on patient care and the overall healthcare system. Wali et al[1] found that interns who work more than 76 hours in a given week made 36% more medical errors. With 35% to 54% of attendings and 45% to 60% of residents experiencing burnout during their career, it is essential that physician sleep quality is addressed to maintain a healthy and effective healthcare team.[2]

Recent advances in wearable technology have improved real-time monitoring of sleep patterns and parameters such as total sleep, number of nighttime awakenings, and breakdown of time spent in each sleep phase. These devices have the potential to provide objective and actionable insights into the health status of physicians, enabling early intervention and personalized stress management strategies.

Despite growing interest in the use of wearable technology to monitor health parameters, there is a paucity of literature investigating the use of wearable technology to objectively evaluate physician sleep. Few studies have utilized wearable technology to provide insight into the sleep data of a variety of physicians. The purpose of this systematic review was to synthesize and analyze data from the literature regarding the use of wearable technology to evaluate physician sleep and sleep-related physiological data. We hypothesize that objective sleep measures recorded by wearable technology will show that a majority of physicians experience poor sleep

Key Points

- Physicians suffer from sleep deprivation, sleeping an average of 398.3 minutes per night while not on call and 226.0 minutes while on call.
- Using standard deviation of the R-R intervals, physicians were found to have poor heart rate variability data, which indicate increased levels of stress and burnout.
- Despite the 80-hour workweek cap, residents still get inadequate sleep, with an average of 401 minutes per night.
- Wearable technology provides objective, real-time data that could be used to improve physician health and well-being.

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#1 Wearable Technology
#2 Smartwatch
#3 WHOOP
#4 OURA RING
#5 FitBit
#6 Electronic Heart Rate Monitor
#7 1 OR 2 OR 3 OR 4 OR 5 OR 6
#8 Physician
#9 Resident
#10 Surgeon
#11 Fellow
#12 MD
#13 DO
#14 8 OR 9 OR 10 OR 11 OR 12 OR 13
#15 Sleep
#16 Sleep Deprivation
#17 Sleep Quality
#18 Insomnia
#19 Sleep Duration
#20 15 OR 16 OR 17 OR 18 OR 19
#21 Stress
#22 Heart Rate Varibility
#23 Burnout
#24 Heart Rate
#25 Resting Heart Rate
#26 Biomarkers
#27 21 OR 22 OR 23 OR 24 OR 25 OR 26
#28 Mood
#29 Depression
#30 Anxiety
#31 Mental Health
#32 28 OR 29 OR 30 OR 31
#33 Trials
#34 Randomized
#35 Controlled
#36 Random
#37 Groups
#38 Placebo
#39 33 OR 34 OR 35 OR 36 OR 37 OR 38
#40 7 AND 14 AND 20 AND 27 AND 32 AND 39

FIG. 1. Search algorithm implemented to locate relevant studies within each respective database (Cochrane, Embase, Medline).

and possess heart rate variability (HRV) that reflects increased stress and poor health.

METHODS

This review was performed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines for reporting systematic reviews.

Search Strategy

Before beginning the literature search, a search protocol was created and published online in the PROSPERO (International Prospective Register of Systematic Reviews) database. A search strategy was then implemented to query the Cochrane, Embase, and Medline databases with no restriction on publication date. The initial literature search was conducted on July 10, 2024. This search strategy aimed to identify all of the studies that investigated the sleep outcomes of physicians recorded by wearable technology. Search terms included "wearable technology," "physician," "sleep," and "stress" to identify the relevant articles. The full search strategy and keywords can be found in Figure 1. Inclusion criteria were primary studies that used wearable technology to evaluate physician sleep time, sleep quality measures, and HRV; specific measures of sleep quality and HRV had to appear in two separate studies and be published in English. Exclusion criteria were the grouping of physician and nonphysician sleep and HRV data;[3] wearable technology not used; and lack of quantitative outcome data concerning sleep time, sleep quality measures, and HRV that could be collated and analyzed, such as means and standard deviations (SDs).[4]

Assessment of Eligibility and Study Selection

The initial database search yielded 1962 papers matching the keywords found in Figure 1. After removing 81 duplicate studies, 1881 studies remained. Two independent reviewers applied the aforementioned exclusion criteria to the titles and abstracts of the studies, resulting in 1841 studies being removed. Following this, a full-text review of the remaining 40 articles was conducted by the same two reviewers based on the established inclusion criteria. Any disagreements encountered during this process were resolved by a third reviewer. Only studies that included tangible outcome data recorded by wearable devices were included. Following the search process, 12 papers

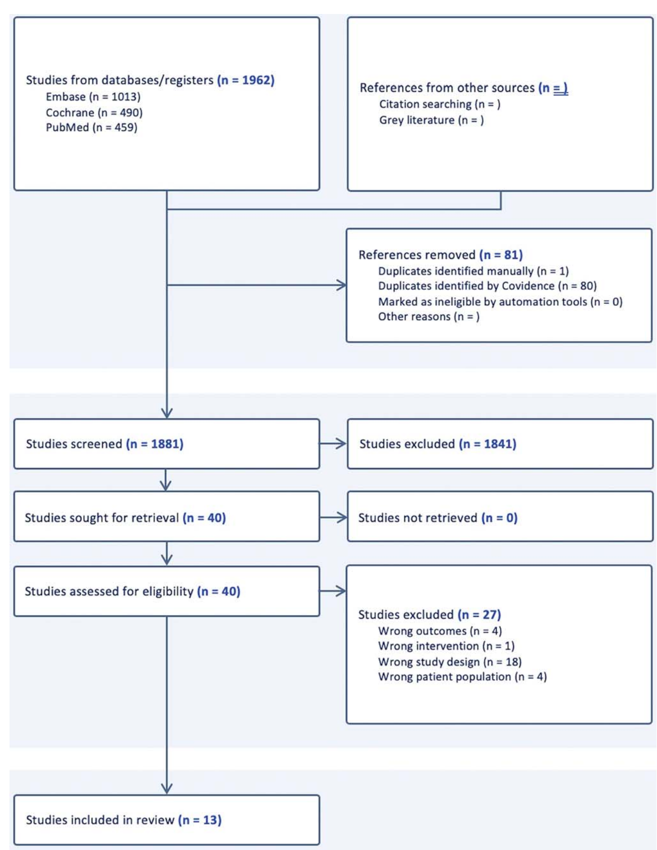

FIG. 2. PRISMA flow chart detailing inclusion and exclusion of studies in this systematic review. PRISMA, Preferred Reporting Items for Systematic reviews and Meta-Analyses.

were identified that fit the criteria for the systematic review. A Preferred Reporting Items for Systematic Reviews and Meta-Analyses flowchart detailing the search strategy is included in Figure 2.

Assessment of Study Quality

Study quality was assessed using the Critical Appraisal Skills Programme checklist. Scores of the included studies ranged from 6 to 10, with an average score of 8.3.

Data Extraction

Data extraction of the included studies was conducted by three reviewers. Extracted data included study characteristics: title, author, publication year, and study design; brand of the device; the location the device was worn; compliance rate; time worn; study population: number of participants, physician specialty, sex, body mass index (BMI), age; and outcomes: total time asleep, time spent in rapid eye movement (REM) sleep, time spent in bed awake, HRV, and heart rate data.

Data Analysis

Following data extraction, pooled data analysis was performed using Microsoft Excel version 16.86 (Redmond, WA) to calculate basic statistics such as weighted means, standard deviations (SDs), and confidence intervals (CIs). This allowed for comparison between groups for the desired outcomes stated above.

RESULTS

Study Characteristics

Descriptive characteristics of the 13 included studies are summarized in Table 1. Most of the studies were observational,

TABLE 1. Study characteristics

Study title	Authors	Year	Study design	Technology used	Location worn	Compliance rate, %	Time worn
Sleep Time and Characteristics Measured Using Fitbit Devices in Emergency Medicine Residents	Rivard et al[5]	2020	Observational	Fitbit Charge 3	Wrist, ankle, or bicep	100	3 mo
Heart rate variability and perception of mental stress among medical students and residents at an emergency department.	Schubert et al[6]	2024	Observational	Polar Verify Sense	Wrist	40	2 wk
iSleepFirst: burnout, fatigue, and wearable-tracked sleep deprivation among residents staffing the medical intensive care unit	Sagun et al[7]	2023	Observational	Fitbit Inspire 2	Wrist	80	4 wk
Resident Sleep During Traditional Home Call Compared to Night Float	Chowdhary et al[8]	2023	Observational	Fitbit Alta HR	Wrist	100	2 y
What Happens on Call Doesn't Stay on Call. The Effects of In-house Call on Acute Care Surgeons' Sleep and Burnout: Results of the Surgeon Performance (SuPer) Trial.	Coleman et al[9]	2023	Observational	WHOOP 2.0	Wrist	86	6 mo
The association between objectively-measured activity, sleep, call responsibilities, and burnout in a resident cohort	Marek et al[10]	2019	Observational	Fitbit Charge HR	Wrist	-	16 wk
The Measurement of Orthopaedic Surgeon Burnout Using a Validated Wearable Device	Sochacki et al[11]	2019	Observational	WHOOP	Wrist	81	4 wk
Impact of work-hours and sleep on well-being and burnout for physicians-in-training: The prospective RATE study	Mendelsohn et al[12]	2017	Observational	Fitbit	Wrist	100	2 wk
151 Analyzing Sleep by Shift Recorded on Fitbit Devices Worn by Emergency Medicine Residents	Hafycz et al[13]	2021	Prospective cohort	Fitbit Charge 3	Wrist	—	6 mo
Sleep and Exercise in Emergency Medicine Residents: An Observational Pilot Study Exploring the Utility of Wearable Activity Monitors for Monitoring Wellness.	Poonja et al[14]	2018	Observational	Fitbit Charge	Wrist	70	4 wk
Sleep Time Measured Using Fitbit Devices in Emergency Medicine Residents Based on Rotation	Rivard et al[15]	2021	Observational	Fitbit Charge 3	Wrist	97	3 mo
Tracking Physical Activity and Sleep Patterns in Emergency Medicine Residents Using Wearable Activity Monitors	Gunaga et al[16]	2019	Observational	Fitbit Flex	Wrist	80	2 wk
Stress Measurement in Surgeons and Residents Using a Smart Patch	Weenk et al[17]	2018	Observational	HealthPatch	Chest	—	48 h

with one prospective cohort study performed by Hafycz et al.[13] Weenk et al[17] used a patch worn on participants' chests, and all of the other studies used wearable technology worn on the wrist. In addition, Rivard et al[5] allowed for wearable technology to be placed in ankle and biceps locations. The most common wearable technology brand used was Fitbit (69%), with WHOOP (15%) following behind. Compliance with wearing the device ranged from 40% to 100% and all but two studies featuring greater than 80% compliance in wearing the device. The two studies with less than 80% compliance were Schubert et al[6] (40%) and Poonja et al[14] (70%). The amount of time that the device was worn and data were collected varied between studies from 48 hours to 2 years, with the majority of studies lasting between 2 and 16 weeks. Of note, five studies lasted at least 3 months.

Demographics and Outcomes

Full demographic data are found in Table 2. Overall, 540 physicians were included across studies in this review. The population comprised mainly males (59%), and the average age of participants was 34.5 ± 7.6 years. Resident physicians made up 65% of the participants. Emergency Medicine (36.9%) was the most represented specialty, followed by Trauma Surgery (33.5%). Participants also had an average BMI of 25.8 ± 2.8.

Outcomes

The full outcome data are found in Table 3.

Sleep Outcomes

Overall, the mean time asleep while not on call was 398.3 ± 49.0 minutes (95% CI 394.0–402.6). On call physicians slept an average of 226.0 ± 71.3 minutes per night (95% CI 215.7–236.2). Physicians in nonsurgical specialties (Anesthesia, Internal Medicine, Neurology, Emergency Medicine, and Radiology) slept an average of 409.8 ± 28.4 (95% CI 404.3–415.3) minutes, wheras those in surgical specialties (Trauma Surgery, Orthopedics, Ophthalmology, and General Surgery) who were not on call slept for 391.4 ± 56.0 minutes (95% CI 384.0–398.9). Resident physicians, specifically, slept an average of 401.3 ± 45.6 minutes when not on call (95% CI 396.2–406.3). Participants averaged 82.5 ± 13.4 minutes of REM sleep per night (95% CI 78.7–86.4) and spent 41.3 ± 21.8 minutes awake in their bed before falling asleep (95% CI 31.7–50.8).

Physiological Outcomes

Two studies assessed HRV using the SD of the R-R interval (SDNN). The average SDNN was 62.7 ± 28.8 ms (95% CI 58.1–67.3). The overall mean SDNN of the Schubert et al study[6] across the four time periods was 57.5 ± 31.3 ms (95% CI 51.1–63.9). The overall mean SDNN of the Weenk et al[17] study across the activities listed was 71.0 ± 24.4 ms (95% CI 64.7–71.0). The average heart rate across studies was 79.3 ± 9.4 beats per minute (bpm) (95% CI 77.8–80.8), and the mean heart rate (HR) of the Schubert et al study was 80.5 ± 10.2 bpm (95% CI 78.4–82.6). Lastly, the average HR in the Weenk et al[17] study across the three activities was 77.3 ± 7.9 (95% CI 75.3–79.4).

DISCUSSION

The most important finding of this systematic review is that the wearable technology data collected suggest that physicians do not get the minimum recommended amount of sleep. Furthermore, HRV data indicate that physicians suffer from

TABLE 2. Participant demographics

	Participant breakdown		Demographic data			
Authors	Total	Specialty	Males, n (%)	Females, n (%)	Mean age, y	BMI, kg/m^2
Rivard et al[5]	33	Emergency Medicine residents	23 (70)	10 (30)	—	—
Schubert et al[6]	24	Emergency Medicine residents	11 (46)	13 (54)	26.0 ± 2.0	22.7 ± 2.8
Sagun et al[7]	40	Residents in MICU	16 (47)	21 (53)	30.0	—
Chowdhary et al[8]	7	Ophthalmology residents	5 (71)	2 (29)	29.0	—
Coleman et al[9]	181	Attending trauma surgeons	111 (61.2)	70 (38.8)	43.3	26.9
Marek et al[10]	28	Emergency Medicine and General Surgery residents	14 (50)	14 (50)	30 ±2	—
Sochacki et al[11]	21	Orthopedic Surgery residents and attendings	15 (71)	6 (29)	37.2 ± 10.9	—
Hafycz et al[13]	34	Emergency Medicine residents	—	—	—	—
Mendelsohn et al[12]	19	General Surgery and Orthopaedic Surgery residents	12 (63)	7 (34)	28.2 ± 2.6	24.2 ± 2.7
	20	Internal Medicine and Neurology residents	15 (75)	5 (25)	28.1 ± 2.9	22.2 ± 2.4
	20	Anesthesiology and Radiology residents	12 (60)	8 (40)	29.3 ± 3.5	24.0 ± 3.2
Poonja et al[14]	22	Emergency Medicine residents	8 (40)	12 (60)	28.0	—
Rivard et al[15]	33	Emergency Medicine residents	23 (70)	10 (30)	—	—
Gunaga et al[16]	25	Emergency Medicine residents	15 (60)	10 (40)	30.0 ± 2.5	25.5 ± 5.7
Weenk et al[17]	20	Surgery attendings and residents	11 (55)	9 (45)	—	—

Mean age and BMI are presented as reported mean ± reported SD. See Table 1 for unnumbered reference citations. BMI, body mass index; MICU, medical intensive care unit; SD, standard deviation.

TABLE 3. Outcomes

Authors	Reported median time asleep ± SD, min	Reported mean time asleep ± SD, min	Reported average REM sleep ± SD, min	Reported average time spent in bed awake ± SD, min	HRV ± SD, ms	Heart rate ± SD, bpm
Rivard et al[5]	Overall: 423.1 Females: 450.1 Males: 411.4	—	Overall: 85.7 Females: 93.3 Males: 82.3	Overall: 56.5 Females: 62.9 Males: 53.7	—	—
Schubert et al[6]	—	378.0	—	—	[a]Before day shift: 50 ± 32 [a]After day shift: 51 ± 29 [a]Before night shift: 48 ± 35 [a]After night shift: 81 ± 9	Before day shift: 81 ± 12 After day shift: 77 ± 10 Before night shift: 83 ± 9 After night shift: 81 ± 9
Sagun et al[7]	—	402.0	—	—	—	—
Chowdhary et al[8]	—	No call: 426 ± 72 On call: 378 ± 126	—	—	—	—
Coleman et al[9]	—	No call: 394.2 ± 55.9 On call: 220.1 ± 61.7	No call: 98.52 ± 25.74 On call: 54.78 ± 21.24	—	—	—
Marek et al[10]	—	362.4 ± 97.9	—	23.3 ± 21.0	—	67.1 ± 6.2
Sochacki et al[11]	—	390.0 ± 48.0	—	—	—	—
Hafycz et al[13]	—	After night shift: 320.0 After day shift: 417.0 Day after night shift: 394.0 After evening shift: 389.0 Time off: 408	After night shift: 68 After day shift: 95 After evening shift: 84	—	—	—
Mendelsohn et al[12]	—	354.0 ± 44.4[b]	—	—	—	—
	—	412.8 ± 44.4[c]	—	—	—	—
	—	411.0 ± 59.4[d]	—	—	—	—
Poonja et al[14]	417.0	—	—	—	—	—
Rivard et al[15]	424.7	—	—	—	—	—
Gunaga et al[16]	—	426.0	—	—	—	—
Weenk et al[17]	—	—	—	—	[a]Baseline: 81.0 ± 27.9 [a]Surgery: 51.0 ± 12.1 [a]Outpatient clinic: 81.0 ± 9.1	[e]Baseline: 70.0 (48.7–84.7) [e]Surgery; 87.7 (62.3–120.4) [e]Outpatient clinic: 74.3 (61.3–83.0)

See Table 1 for unnumbered reference citations. bpm, beats per minute; HRV, heart rate variability; REM, rapid eye movement; SD, standard deviation.
[a]Recorded as SD of the R-R intervals.
[b]General Surgery and Orthopedic Surgery residents.
[c]Internal Medicine and Neurology residents.
[d]Anesthesiology and Radiology residents.
[e]Reported mean (range of values).

increased stress. The recommended minimum sleep for the public is 420 minutes (7 hours) per night, with 35.5% of Americans reaching this goal.[18,19] This review shows that physicians sleep much less than this. It was found that physicians slept an average of 398.3 ± 49.0 minutes while not on call; on call physicians slept an average of 226.0 ± 71.3 minutes. Medical decision making is often fast paced, complex, and cognitively demanding, with little room for error. Sleep deprivation among physicians causes fatigue, cognitive deficits, impaired performance, workplace errors and injuries, and poor communication.[20–22] As such, patient safety is compromised when physicians are sleep deprived.[23–26]

Another finding of this review was that physicians in nonsurgical specialties slept for 409.8 ± 28.4 minutes and surgeons slept for 391.4 ± 56.0 minutes, even when they were not on call. Although both groups slept less than the recommended amount of sleep for people, it is important to understand why this difference among fields exists. Emergency Medicine physicians made up the majority of the study's nonsurgical physicians. These physicians have stable work hours and typically go home when their shift is over. Surgeons, however, often experience prolonged days due to operating room inefficiencies, unexpected difficulties during cases, excess consultations, or taking calls. When on call, surgeons in this review slept for 226.0 ± 71.3 minutes. This level of sleep deprivation is detrimental not only to performance but also patient care. Rothschild et al[27] found that surgeons performing an elective procedure the day after they spent a night on call without at least 6 hours of sleep had an 83% increase in the risk of complications such as massive hemorrhage, organ injury, or wound failure. Although being on call is unavoidable in surgical specialties, providing these physicians with more time to recuperate and rest on postcall days could better the overall quality of patient care. Wearable technology may aid in this endeavor by allowing surgeons to gauge their level of recovery, stress, and sleep in real time before a busy day of operating.

Another notable finding in this study is that resident physicians slept an average of 401.3 ± 45.6 minutes per night. Although sleep consolidates memory and reinforces learning, sleep deprivation is destructive to learning and memory formation.[28,29] Residency is ultimately a learning environment, and sleep is crucial for residents to learn the skills necessary to become competent physicians. Residency programs have attempted to improve resident quality of life, sleep, and patient safety by implementing a maximum 80-hour work week, resulting in mixed outcomes.[30–33] Sephien et al[33] found improvements in resident sleep and overall well-being with the hours restrictions; however, Mauser et al[31] reported that attendings and residents believe that the quality of their training has been negatively affected. Overall, there is a lack of consensus surrounding the efficacy of the 80-hour work week, and more high-level, objective research needs to be conducted before a definitive conclusion is drawn.

In addition to understanding the total amount of sleep that physicians get, we also were able to analyze measures of sleep quality. We found that physicians average 82.5 ± 13.4 minutes of REM sleep per night. REM sleep typically comprises around one-fourth of a person's total time asleep.[34] Given the minimal total sleep recommendation of 420 minutes, the general population should get roughly 105 minutes of REM sleep. Although our participants did not achieve this amount of REM sleep, the consequences of REM deprivation are contested. Although REM sleep deprivation affects physiologic parameters such as hemodynamic measures and inflammatory responses, there is a lack of consensus on the effects of REM sleep on memory consolidation.[35–40] Sleep latency is another measure of sleep quality that we were able to analyze and is defined as the time that it takes a person to fall asleep. The typical sleep latency of an adult is 10 to 20 minutes, with variability depending on age, sex, and BMI.[41,42] We found that physicians averaged 41.3 ± 21.8 minutes awake in bed before falling asleep, which is much higher than what is considered normal. Prolonged sleep latency alone is associated with both physiological and psychological pathology.[43,44] When in conjunction with a sufficient duration of symptoms and subjective evaluation of sleep, increased sleep latency indicates difficulty falling asleep, which is a key component of insomnia.[45] As stated above, the effects of reduced total sleep quantity are detrimental not only to physician health but also to patient care. It also is a concern that when physicians do get the opportunity to sleep, they are experiencing a poor quality of sleep.

Aside from sleep, wearable technology can track a wide variety of physiologic data. Studies included in our review used it to track the HR and HRV of physicians. HRV provides an objective measure of physiological and psychological stress, fatigue, burnout, and recovery by measuring heartbeat-to-beat variation in a given period, typically 24 hours.[46–48] SDNN is the SD of the time between two heartbeats and is a reflection of HRV.[17] Our study showed that physicians averaged an SDNN of 62.7 ± 28.8 milliseconds. In a heart with no underlying pathology, SDNN represents the body's ability to adapt to stressors and has a negative relationship with overall stress.[49] Decreased SDNN/HRV results from neurocardiac modulation as the parasympathetic input to the heart is dampened, and the sympathetic input is increased when individuals are exposed to both physiological and psychological stressors.[50] As such, it is prudent to evaluate physician heart rate variability measures in the wake of the coronavirus disease 2019 pandemic, when physician burnout soared.[51–55] Unfortunately, HRV has no proven normative values because it is highly variable depending on factors such as age, sex, BMI, and health status.[56–59] HRV, however, has been implicated in predicting disease severity among a variety of pathologies.[60–64] There remains a need in cardiac electrophysiology to elucidate values for HRV that predict specific pathologies among individuals.

This study is not without limitations. The primary limitation of this study is the heterogeneity of the study participants and their environment, producing large amounts of uncontrolled variability, which made direct comparisons of groups challenging. Another large limitation of this study is the inaccuracy of wearable devices to accurately measure our desired outcomes.[65] Although wearable technology is much more convenient than the gold standard mechanisms of measuring sleep parameters and HRV, the inaccuracy of these devices limits the clinical application of data gathered by such devices. Other limitations include a wide range of study durations, small sample sizes, Hawthorne bias, observational nature of included studies, and variability in the wearable device used. Despite these limitations, this study provides valuable insights into the usage of wearable technology to uncover the objective lack of sleep that physicians receive and their increased measures of stress and burnout.

CONCLUSIONS

Wearable technology data indicate that physicians sleep less than the recommended amount per night and have reduced sleep quality measures, and HRV data indicate increased levels of stress and burnout. The data provided by wearable technology may help improve physician well-being and ultimately patient care.

REFERENCES

1. Wali SO, Qutah K, Abushanab L, et al. Effect of on-call-related sleep deprivation on physicians' mood and alertness. *Ann Thorac Med*. 2013;8:22–27.
2. Barac M, Scaletty S, Hassett LC, et al. Wearable technologies for detecting burnout and well-being in health care professionals: scoping review. *J Med Internet Res*. 2024;26:e50253.
3. Hassinger AB, Kwon M, Wang J, et al. Pilot study comparing sleep logs to a commercial wearable device in describing the sleep patterns of physicians-in-training. *PLoS ONE*. 2024; 19:e0305881.
4. Adler DA, Tseng VWS, Qi G, et al. Identifying mobile sensing indicators of stress-resilience. *Proc ACM Interact Mob Wearable Ubiquitous Technol*. 2021;5:1–32.
5. Rivard L, McKay B, Melanson S, et al. 208 sleep time and characteristics measured using Fitbit devices in emergency medicine residents. *Ann Emerg Med*. 2020;76:S80–S81.
6. Schubert DUC, Serfaty FM, Cunha MR, et al. Heart rate variability and perception of mental stress among medical students and residents at an emergency department. *Am J Emerg Med*. 2024;78:12–17.
7. Sagun S, DeCicco D, Badami V, et al. iSleepFirst: burnout, fatigue, and wearable-tracked sleep deprivation among residents staffing the medical intensive care unit. *Sleep Breath*. 2023; 27(6):2491–2497. doi:10.1007/s11325-023-02839-82.
8. Chowdhary A, Davis JA, Ding L, Taravati P, Feng S. Resident Sleep During Traditional Home Call Compared to Night Float. *J Acad Ophthalmol*. 2023;15(2):e204–e208. doi:10.1055/s-0043-17755783.
9. Coleman JJ, Robinson CK, von Hippel W, et al. What Happens on Call Doesn't Stay on Call. The Effects of In-house Call on Acute Care Surgeons' Sleep and Burnout: Results of the Surgeon Performance (SuPer) Trial. *Annals of Surgery*. 2023;278(4):497. doi:10.1097/SLA.00000000000059717.
10. Marek AP, Nygaard RM, Liang ET, et al. The association between objectively-measured activity, sleep, call responsibilities, and burnout in a resident cohort. *BMC Medical Education*. 2019;19(1):158. doi:10.1186/s12909-019-1592-08.
11. Sochacki KR, Dong D, Peterson L, McCulloch PC, Harris JD. The Measurement of Orthopaedic 8. Surgeon Burnout Using a Validated Wearable Device. *Arthroscopy, Sports Medicine, and Rehabilitation*. 2019;1(2):e115–e121. doi:10.1016/j.asmr.2019.09.0044.
12. Mendelsohn D, Despot I, Gooderham PA, Singhal A, Redekop GJ, Toyota BD. Impact of work hours and sleep on well-being and burnout for physicians-in-training: the Resident Activity Tracker Evaluation Study. *Medical Education*. 2019;53(3):306–315. doi:10.1111/medu.137575.
13. Hafycz J, Morley K, Melanson S, et al. 151 analyzing sleep by shift recorded on Fitbit devices worn by emergency medicine residents. *Ann Emerg Med*. 2021;78:S62.
14. Poonja Z, O'Brien P, Cross E, et al. Sleep and exercise in emergency medicine residents: an observational pilot study exploring the utility of wearable activity monitors for monitoring wellness. *Cureus*. 2018;10:e2973.
15. Rivard L, Perez C, Morley K, Melanson S, Hafycz J, Stankewicz H. 378 Sleep Time Measured Using Fitbit Devices in Emergency Medicine Residents Based on Rotation. *Annals of Emergency Medicine*. 2021;78(4):S152. doi:10.1016/j.annemergmed.2021.09.3936.
16. Gunaga S, Park J, Obrycki B, Hashim J, Spencer R, Jarski R. 280 Tracking Physical Activity and Sleep Patterns in Emergency Medicine Residents Using Wearable Activity Monitors. *Annals of Emergency Medicine*. 2019;74(4):S110–S111. doi:10.1016/j.annemergmed.2019.08.238.
17. Weenk M, Alken APB, Engelen LJLPG, et al. Stress measurement in surgeons and residents using a smart patch. *Am J Surg*. 2018;216:361–368.
18. National Heart, Lung, and Blood Institute. Sleep deprivation and deficiency. How much sleep is enough. https://www.nhlbi.nih.gov/health/sleep-deprivation/how-much-sleep. Published March 24, 2022. Accessed July 29, 2024.
19. America's Health Rankings. Insufficient sleep in United States. https://www.americashealthrankings.org/explore/measures/sleep. Accessed September 20, 2024.
20. Abrams RM. Sleep deprivation. *Obstet Gynecol Clin North Am*. 2015;42:493–506.
21. Gaba DM, Howard SK. Patient safety: fatigue among clinicians and the safety of patients. *N Engl J Med*. 2002;347:1249–1255.
22. Sandoval Y, Lobo AS, Somers VK, et al. Sleep deprivation in interventional cardiology: implications for patient care and physician-health. *Catheter Cardiovasc Interv*. 2018;91: 905–910.
23. Landrigan CP, Rothschild JM, Cronin JW, et al. Effect of reducing interns' work hours on serious medical errors in intensive care units. *N Engl J Med*. 2004;351:1838–1848.
24. Majekodunmi A, Landrigan CP. The effect of physician sleep deprivation on patient safety in perinatal-neonatal medicine. *Am J Perinatol*. 2011;29:43–48.
25. Olson EJ, Drage LA, Auger RR. Sleep deprivation, physician performance, and patient safety. *Chest*. 2009;136:1389–1396.
26. Zinner MJ, Fresichlag JA. Surgeons, sleep, and patient safety. *JAMA*. 2013;310:1807–1808.
27. Rothschild JM, Keohane CA, Rogers S, et al. Risks of complications by attending physicians after performing nighttime procedures. *JAMA*. 2009;302:1565–1572.
28. Khan MA, Al-Jahdali H. The consequences of sleep deprivation on cognitive performance. *Neurosciences*. 2023;28:91–99.
29. Killgore WDS. Effects of sleep deprivation on cognition. *Prog Brain Res*. 2010;185:105–129.
30. Harris JD, Staheli G, LeClere L, et al. What effects have resident work-hour changes had on education, quality of life, and safety? A systematic review. *Clin Orthop*. 2015;473: 1600–1608.
31. Mauser NS, Michelson JD, Gissel H, et al. Work-hour restrictions and orthopaedic resident education: a systematic review. *Int Orthop*. 2016;40:865–873.
32. Peets A, Ayas NT. Restricting resident work hours: the good, the bad, and the ugly. *Crit Care Med*. 2012;40:960–966.
33. Sephien A, Reljic T, Jordan J, et al. Resident duty hours and resident and patient outcomes: systematic review and meta-analysis. *Med Educ*. 2023;57:221–232.
34. Ohayon MM, Carskadon MA, Guilleminault C, et al. Meta-analysis of quantitative sleep parameters from childhood to old age in healthy individuals: developing normative sleep values across the human lifespan. *Sleep*. 2004;27:1255–1273.
35. Palagini L, Baglioni C, Ciapparelli A, et al. REM sleep dysregulation in depression: state of the art. *Sleep Med Rev*. 2013;17:377–390.
36. Morgenthaler J, Wiesner CD, Hinze K, et al. Selective REM-sleep deprivation does not diminish emotional memory consolidation in young healthy subjects. *PLoS ONE*. 2014;9: e89849.
37. Wiesner CD, Pulst J, Krause F, et al. The effect of selective REM-sleep deprivation on the consolidation and affective evaluation of emotional memories. *Neurobiol Learn Mem*. 2015; 122:131–141.
38. Boyce R, Williams S, Adamantidis A. REM sleep and memory. *Curr Opin Neurobiol*. 2017; 44:167–177.
39. Ruiz FS, Andersen ML, Martins RC, et al. Immune alterations after selective rapid eye movement or total sleep deprivation in healthy male volunteers. *Innate Immun*. 2012;18: 44–54.
40. Xu Y, Qu B, Liu F, et al. Sleep deprivation and heart rate variability in healthy volunteers: effects of REM and SWS sleep deprivation. *Comput Math Methods Med*. 2023;2023: 7121295.
41. Iskander A, Jairam T, Wang C, et al. Normal multiple sleep latency test values in adults: a systematic review and meta-analysis. *Sleep Med*. 2023;109:143–148.
42. Thomas D, Anderson MW. Assessment, methodology, training, and policies of sleep. In: Kushida CA, ed., *Encyclopedia of Sleep*. 1st ed. New York: Elsevier/Academic Press; 2013.
43. Omichi C, Kadotani H, Sumi Y, et al. Prolonged sleep latency and reduced REM latency are associated with depressive symptoms in a Japanese working population. *Int J Environ Res Public Health*. 2022;19:2112.
44. Zhong X, Gou F, Jiao H, et al. Association between night sleep latency and hypertension: a cross-sectional study. *Medicine (Baltimore)*. 2022;101:e31250.
45. American Psychiatric Association. Sleep-wake disorders. In: *Diagnostic and Statistical Manual of Mental Disorders*., Fifth Edition. Washington DC: American Psychiatric Association Publishing; 2022.
46. Immanuel S, Teferra MN, Baumert M, et al. Heart rate variability for evaluating psychological stress changes in healthy adults: a scoping review. *Neuropsychobiology*. 2023;82:187–202.
47. Lennartsson AK, Jonsdottir I, Sjörs A. Low heart rate variability in patients with clinical burnout. *Int J Psychophysiol*. 2016;110:171–178.
48. Tiwari R, Kumar R, Malik S, et al. Analysis of heart rate variability and implication of different factors on heart rate variability. *Curr Cardiol Rev*. 2021;17:e160721189770.
49. Shaffer F, Ginsberg JP. An overview of heart rate variability metrics and norms. *Front Public Health*. 2017;5:258.
50. Aubert AE, Seps B, Beckers F. Heart rate variability in athletes. *Sports Med*. 2003;33: 889–919.
51. Alkhamees AA, Aljohani MS, Kalani S, et al. Physician's burnout during the COVID-19 pandemic: a systematic review and meta-analysis. *Int J Environ Res Public Health*. 2023;20:4598.
52. Lazarides AL, Belay ES, Anastasio AT, et al. Physician burnout and professional satisfaction in orthopedic surgeons during the COVID-19 pandemic. *Work Read Mass*. 2021;69:15–22.
53. Melnikow J, Padovani A, Miller M. Frontline physician burnout during the COVID-19 pandemic: national survey findings. *BMC Health Serv Res*. 2022;22:365.
54. Shopen N, Schneider A, Aviv Mordechai R, et al. Emergency medicine physician burnout before and during the COVID-19 pandemic. *Isr J Health Policy Res*. 2022;11:30.
55. Zhang S, Ramalingam ND, Chandran C. Unmasking resident physician burnout during the COVID-19 era. *Perm J*. 2023;27:179–183.
56. Kobayashi H, Park BJ, Miyazaki Y. Normative references of heart rate variability and salivary alpha-amylase in a healthy young male population. *J Physiol Anthropol*. 2012;31:9.

57. Brinth LS, Jørgensen T, Mehlsen J, et al. Normative values of short-term heart rate variability in a cross-sectional study of a Danish population. The DanFunD study. *Scand J Public Health*. 2024;52:48–57.
58. Nunan D, Sandercock GRH, Brodie DA. A quantitative systematic review of normal values for short-term heart rate variability in healthy adults. *Pacing Clin Electrophysiol*. 2010;33: 1407–1417.
59. Kleiger RE, Miller JP, Bigger JT, et al. Decreased heart rate variability and its association with increased mortality after acute myocardial infarction. *Am J Cardiol*. 1987;59:256–262.
60. Nayyar S, Hasan MA, Roberts-Thomson KC, et al. Effect of loss of heart rate variability on T-wave heterogeneity and QT variability in heart failure patients: implications in ventricular arrhythmogenesis. *Cardiovasc Eng Technol*. 2017;8:219–228.
61. Senthinathan A, Mainwaring LM, Hutchison M. Heart rate variability of athletes across concussion recovery milestones: a preliminary study. *Clin J Sport Med*. 2017;27:288–295.
62. Musa SM, Adam I, Lutfi MF. Heart rate variability and autonomic modulations in preeclampsia. *PloS ONE*. 2016;11:e0152704.
63. Lutfi MF. Patterns of heart rate variability and cardiac autonomic modulations in controlled and uncontrolled asthmatic patients. *BMC Pulm Med*. 2015;15:119.
64. Zhang L, Zhou J, Ke L, et al. Role of heart rate variability in predicting the severity of severe acute pancreatitis. *Dig Dis Sci*. 2014;59:2557–2564.
65. Danzig R, Wang M, Shah A, et al. The wrist is not the brain: estimation of sleep by clinical and consumer wearable actigraphy devices is impacted by multiple patient- and device-specific factors. *J Sleep Res*. 2020;29:e12926.