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RESEARCH ARTICLE

The relationships between multidimensional sleep health and work productivity in individuals with neurological conditions

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Summary

Numerous studies have reported the negative impacts of poor sleep on work productivity in the general population. However, despite the known sleep issues that individuals living with neurological conditions experience, no study has explored its impact on their work productivity. Sleep health is a concept that includes multiple domains of sleep, measured with a combination of objective and subjective measures. Therefore, this study aimed to ascertain the associations between sleep health and its domains and work productivity in individuals with neurological conditions. Sleep health domains were determined through actigraphy data collected over 1 week and sleep questionnaires. Work productivity was assessed via the Work Productivity and Activity Impairment Questionnaire. A comparison of sleep health scores between demographic variables was performed using Mann–Whitney *U* and Kruskal–Wallis tests. Associations between the sleep health domains and work productivity were performed using linear regression models. There were no significant differences in sleep health scores between sex, smoking status, education level, employment status or any work productivity domain. Individuals with non-optimal sleep timing had greater absenteeism (22.99%) than the optimal group. Individuals with non-optimal sleep quality had an increase in presenteeism (30.85%), work productivity loss (26.44%) and activity impairment (25.81%) compared to those in the optimal group. The findings from this study highlight that self-reported sleep quality has the largest impact on work productivity. Improving individuals' sleep quality through triage for potential sleep disorders or improving their sleep hygiene (sleep behaviour and environment) may positively impact work productivity.

KEYWORDS
absenteeism, presenteeism, sleep duration, sleep quality, timing

1 | INTRODUCTION

Sleep issues are both common in individuals with neurological conditions and associated with greater symptom severity (Hashim et al., 2020; Jozwiak et al., 2017; Lucke-Wold et al., 2015; Siengsukon et al., 2018; Zhang et al., 2020). Worse sleep outcomes are linked with poorer cognition, mood, and health-related quality of life in people with multiple sclerosis (MS), Parkinson's disease (PD) and acquired

brain injury (ABI) (Bamer et al., 2008; Grima et al., 2017; Zhang et al., 2021). Recently, studies have been using 'sleep health', which incorporates numerous sleep domains (Buysse, 2014), to evaluate the sleep of individuals with a neurological condition (Khot et al., 2023; Whibley et al., 2021). A novel method of measuring sleep health is the multidimensional sleep health framework, which encompasses subjective and objective data to identify sleep domains of concern (Bowman et al., 2020; Chung et al., 2021; Wallace et al., 2018; Whibley et al., 2021). Sleep health provides a continuum to allow the exploration of the impact of sleep on lifestyle factors, including employment and work productivity. The influence of sleep health on work productivity in individuals with a neurological condition is yet to be robustly explored, despite the known economic impact on affected individuals and society.

Unemployment, absence from work (i.e., absenteeism) and decreased productivity at work (i.e., presenteeism) are common in people living with a neurological condition. In a recent study, 56% of Australians living with MS reported 2.5 days (14.2%) in lost work productivity over a 4-week period, mainly attributed to presenteeism, with cost per person and Australia estimated to be AU $6707 and AU$66 million/year, respectively (Chen et al., 2019). A systematic review revealed that people living with PD retire on average 4–7 years earlier than the general population (Koerts et al., 2016), with most young-onset individuals giving up work within 10 years of diagnosis (Mehanna & Jankovic, 2019). In another systematic review, the return-to-previous-work prevalence was found to be 33% in individuals with moderate-to-severe traumatic brain injury (Gormley et al., 2019). Given this large societal impact, furthering our understanding of how clinical factors influence employment and work productivity outcomes is of vital importance.

Strong associations exist between sleep health, employment, and work productivity outcomes in the general population (Barnes & Watson, 2019; Hafner et al., 2017). A recent investigation in Australia reported the economic cost of inadequate sleep (encompassing those with insufficient sleep and sleep disorders) to be AU $17.9 billion annually, with 68% of productivity losses attributed to absenteeism and presenteeism (Hillman et al., 2018). Similar associations may exist in people with neurological conditions and warrant investigation.

This study investigated, for the first time, associations between sleep health, employment, and work productivity outcomes in a community sample of individuals living with a neurological condition.

2 | METHODS

2.1 | Ethics statement

Data collected in this study was approved by the Human Research Ethics Committee at Edith Cowan University (2019-00970-LAWS). All testing procedures were conducted in line with the Declaration of Helsinki. Written informed consent was obtained by all participants prior to commencement of study procedures.

2.2 | Study design

The present study uses baseline data captured as part of the Systematic Profiling in Neurological Conditions (SPIN) Registry. The SPIN Registry is a new natural history study investigating clinical, lifestyle and biological changes over time in individuals living with a diagnosed neurological condition.

2.3 | Participants

A total of 70 individuals living with a neurological condition undertook the below-listed assessment procedures. Inclusion criteria for the study were as follows: (1) verified diagnosis of a neurological condition, (2) aged between 18 and 85 years, and (3) the capacity to provide written informed consent. The exclusion criterion was anyone with an unstable medication regime (<4 weeks). While it is uncommon, several studies have included a mixed neurological sample (Cormack et al., 2017; Herrero Babiloni et al., 2021; Iverson et al., 2007). This sample represents a variety of common neurological conditions (e.g., MS, PD, and ABI) and rare neurological conditions that are often excluded from research studies (e.g., neuromyelitis optica and cerebellar ataxia). While the mechanisms causing potential sleep issues may differ, the sleep health scores were similar between neurological conditions (see Figure S1 of supporting information).

2.4 | Measures

2.4.1 | Sleep–Wake behaviour

Sleep–wake behaviour data was captured over 7 nights using the consensus sleep diary (CSD) and a wrist-worn activity monitor (GT3X, ActiGraph, Pensacola, FL USA).

2.4.2 | Consensus sleep diary

The CSD comprises 21 items that evaluate sleep quality, sleep–wake timings, and factors that influence sleep, such as alcohol, caffeine, and medication. The CSD has been shown to be valid in a variety of populations, including MS (Cederberg et al., 2022). In accordance with Ancoli-Israel et al. (2015), the CSD was used to confirm the sleep–wake behaviours of participants as captured by wrist-worn activity monitors.

2.4.3 | Wrist-worn activity monitors

Wrist-worn activity monitors are routinely used to capture sleep–wake behaviours in individuals living with MS (Block et al., 2019; Hsu et al., 2021; Opelt et al., 2023). In the present study, participants were asked to wear a wrist-worn activity monitor on their non-dominant wrist 30 min before bed to 30 min following their final awakening. A low pass extension filter was applied, and data were captured in 60-s

epochs, with wake and sleep periods identified according to the Cole-Kripke algorithm (Cole et al., 1992). Total sleep time, sleep efficiency, awakenings, time in bed, wake after sleep onset (WASO), sleep fragmentation index, sleep onset latency, and time of awakening was captured for each night and then averaged across the 7-night assessment period.

2.4.4 | Epworth Sleepiness Scale (ESS)

The ESS was used to measure daytime somnolence. The ESS is an eight-item questionnaire measuring participants' perceived propensity to doze during common daytime activities. The ESS has commonly been used to measure daytime somnolence in MS (Devos et al., 2021; Johansson et al., 2021; Kołtuniuk et al., 2022). A score of >10 is indicative of excessive daytime sleepiness.

2.4.5 | Pittsburgh Sleep Quality Index (PSQI)

The PSQI was used to measure subjective sleep quality. The PSQI is a reliable and valid measure for subjective sleep quality in individuals living with MS (Jerković et al., 2022). The PSQI comprises seven components relating to subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleep medication, and daytime dysfunction. A single item from the PSQI was used to assess sleep quality as the global score encompasses other components of sleep health (Wallace et al., 2018). The item asked participants 'During the past month, how would you rate your sleep quality overall?', which they rated on a 4-point Likert scale.

2.4.6 | Work productivity

Work productivity was evaluated using the Work Productivity and Activity Impairment Questionnaire: General Health version 2.0 (WPAI: GH; Reilly et al., 1993). The WPAI was selected because of its widespread use, including in those living with MS (Glanz et al., 2012; Neuberger et al., 2021). The WPAI-GH is a self-administered measure comprising six questions on the effect of general health on the capacity to work over a 7-day period. The resultant domains include absenteeism (work time missed), presenteeism (impairment at work/reduced on-the-job effectiveness), work productivity loss (overall work impairment/absenteeism plus presenteeism), and activity impairment. Employment and activity impairment were assessed for all participants. Remaining domains were assessed only in employed participants.

TABLE 1 Sleep health domain characteristics.

Sleep health domain	Median (interquartile range)	Non-optimal category cut-off values	Categories count, *n* (%)
Duration	441.58 (408.36, 488.07)	≤403.68 (non-optimal) Optimal ≥496.28 (non-optimal)	12 (17.14) 45 (64.29) 13 (18.57)
Continuity	43.86 (30.22, 63.93)	≥56.22 (non-optimal) <56.22 (optimal)	24 (34.29) 46 (65.71)
Timing	2.44 (1.76, 3.15)	≤2:00 a.m. (non-optimal) Optimal >4:00 a.m. (non-optimal)	24 (34.29) 39 (55.71) 7 (10.00)
Regularity	0.76 (0.51, 1.27)	<1.07 (optimal) ≥1.07 (non-optimal)	45 (64.29) 25 (35.71)
Rhythmicity	55.04 (48.07, 58.52)	≤51.00 (non-optimal) >51.00 (optimal)	23 (32.86) 47 (67.14)
Sleepiness/alertness	8.00 (5.00, 11.00)	≤10 (optimal) >10 (non-optimal)	51 (72.86) 19 (27.14)
Quality	1.00 (1.00, 2.00)	≤1 (optimal) >1 (non-optimal)	40 (57.14) 30 (42.86)
Sleep health composite	2.00 (1.00, 4.00)	0	6 (8.57)
		1	16 (22.86)
		2	16 (22.86)
		3	14 (20.00)
		4	8 (11.43)
		5	6 (8.57)
		6	3 (4.29)
		7	1 (1.43)

2.5 | Data analyses

2.5.1 | Multidimensional sleep health

Multidimensional sleep health was determined using the methods described by Whibley et al. (2021), which are a combination of methods from Phillips et al. (2017) and Wallace et al. (2018). Multidimensional sleep health uses actigraphy-derived variables as well as the ESS and a single item from the PSQI to produce seven domains of sleep health: duration, continuity, timing, regularity, rhythmicity, sleepiness/alertness, and quality.

Cut-off ranges, as described by Wallace et al. (2018) and Whibley et al. (2021), were determined for each sleep health domain. The cut-off ranges for each domain are described below and the cut-off values can be seen in Table 1.

- **Duration:** lowest and highest sixth of the sample.
- **Continuity:** highest third of WASO values in the sample.
- **Timing:** a sleep mid-point less than 2:01 a.m. or greater than 4:00 a.m.
- **Regularity:** highest third of standard deviation in wake time values in the sample.
- **Rhythmicity:** lowest third of percentage values, representing the probability of being asleep or awake at the same time 24 h apart, in the sample.
- **Sleepiness/alertness:** a score of ≥10 on the ESS.
- **Quality:** a participant response of 'fairly bad' or 'very bad' on the PSQI item.

2.5.2 | Statistical analysis

Descriptive data, including age and sex were presented as median and interquartile range (IQR). Data were checked for normality using a Shapiro–Wilk test. A Pearson's correlation analysis was performed to assess the independence of the sleep domains used to comprise the sleep health composite score. Mann–Whitney *U* and Kruskal–Wallis tests were conducted to determine the differences in sleep health composite scores between demographic variables. Linear regressions were performed to establish associations between sleep health and work productivity domains. Several sleep health domains were treated as continuous (indicated in Table 2). The non-optimal sleep health domains, described in the above data analysis section were treated as categorical variables, with the optimal group being used as the reference group (Whibley et al., 2021). All data and statistical analyses were conducted using Python (version 3.9.7).

3 | RESULTS

The demographic information, including age, sex, smoking status, education level and employment status of the sample is provided in Table 2. There were more females than males with most being non- or ex-smokers. Most individuals either had a bachelor's degree or a technical and further education (TAFE) qualification. Half of the sample were currently employed while the other half were either unemployed or retired. The sleep health domains and composite score, separated by neurological conditions and employment status can be seen in Figure S1 of the supporting information.

TABLE 2 Demographic information for the sample of individuals living with a neurological condition.

Variable	Value
Age, years, median (IQR)	52.00 (45.00, 62.75)
Sex, *n* (%)	
Male	26 (37.14)
Female	43 (61.43)
Intersex or intermediate[a]	1 (1.43)
Smoking status, *n* (%)	
Non-smoker	37 (52.86)
Ex-smoker	23 (32.86)
Smoker	10 (14.29)
Highest education level, *n* (%)	
Master's degree	4 (5.80)
Bachelor's degree with honours	4 (5.80)
Bachelor's degree without honours	21 (30.43)
Partial university (≥1 year) or specialised training	9 (13.04)
TAFE	22 (31.88)
High school graduate (Year 12)	7 (10.14)
Partial high school (Year 10/11)	2 (2.90)
Currently employed, *n* (%)	
Yes	35 (50.00)
No	35 (50.00)
Neurological condition, *n* (%)	
Acquired brain injury	17 (24.29)
Multiple sclerosis	16 (22.86)
Functional neurological disorder	8 (11.43)
Parkinson's disease	4 (5.71)
Other neurological conditions	25 (35.71)

Abbreviations: IQR, interquartile range; TAFE, technical and further education.
[a]Not included in analysis.

3.1 | Sleep health composite score

The correlations between the seven sleep domains that were used to comprise the sleep health composite score can be found in Figure S2 of the supporting information. There were correlations between several domains, including duration, continuity, timing, regularity, and rhythmicity.

There was no significant ($p = 0.189$) difference in sleep health composite scores between males (median [IQR] 2.00 [1.00, 3.00]) and females (median [IQR] 3.00 [1.50, 4.00]). There was no significant ($p = 0.396$) difference in sleep health composite scores between non-smokers (median [IQR]

2.00 [1.00, 3.00]), ex-smokers (median [IQR] 3.00 [2.00, 4.00]) and smokers (median [IQR] 2.50 [2.00, 3.75]). There was also no significant ($p = 0.482$) difference in sleep health composite scores between education levels.

There was no significant ($p = 0.194$) difference in sleep health composite scores between those currently employed (median [IQR] 2.00 [1.00, 3.00]) and those who are not (median [IQR] 3.00 [2.00, 4.00]). Additionally, Figure 1 shows that there were no significant associations between sleep health composite score and any of the work productivity domains.

3.2 | Associations between sleep health domains and work productivity

The associations between sleep health and work productivity domains are shown in Table 3. Individuals in the non-optimal sleep timing group reported 22.99% more absenteeism than those in the optimal group. Individuals in the non-optimal sleep quality group (fairly or very bad sleep quality) disclosed 30.85% more presenteeism, 26.44% loss in work productivity and 25.81% activity impairment, than those in the optimal group.

4 | DISCUSSION

The primary aim of the present study was to explore how the sleep health domains of individuals with a neurological condition were associated with their employment status and work productivity. The results of this study showed no significant difference in sleep health composite scores between participants who were working compared to those who were not. This result indicated that the employment status of individuals with a neurological condition is likely predicated by factors other than their sleep health.

Numerous studies have investigated the role of sleep health domains on work productivity, including absenteeism and presenteeism, in the general population (Dean et al., 2010; Ishibashi & Shimura, 2020; Philip et al., 2001; Rosekind et al., 2010; Swanson et al., 2011). All these studies have shown significant reductions in work productivity when sleep health domains are impaired. However, these studies have all used subjective questionnaires to measure the sleep health of participants. In contrast, the present study used a combination of subjective questionnaires and objective wearable devices to comprehensively characterise the sleep health of participants with a neurological condition.

Findings of this study support the inference that sleep health is related to work productivity. However, contrary to the previous studies on sleep health and work productivity in the general population, this study found no significant relationship between sleepiness (often referred to as daytime somnolence) or sleep duration and work productivity (Dean et al., 2010; Philip et al., 2001; Rosekind et al., 2010; Swanson et al., 2011). The results of this study, similar to those by Ishibashi and Shimura (2020), found that sleep quality was the most influential sleep health factor on work productivity for individuals living with a neurological condition. This result is particularly important given the poor sleep quality often observed in the neurological community.

Research studies have consistently demonstrated a significant association between poor sleep quality and reduced work productivity in the general community (Doi et al., 2003; Ishibashi & Shimura, 2020;

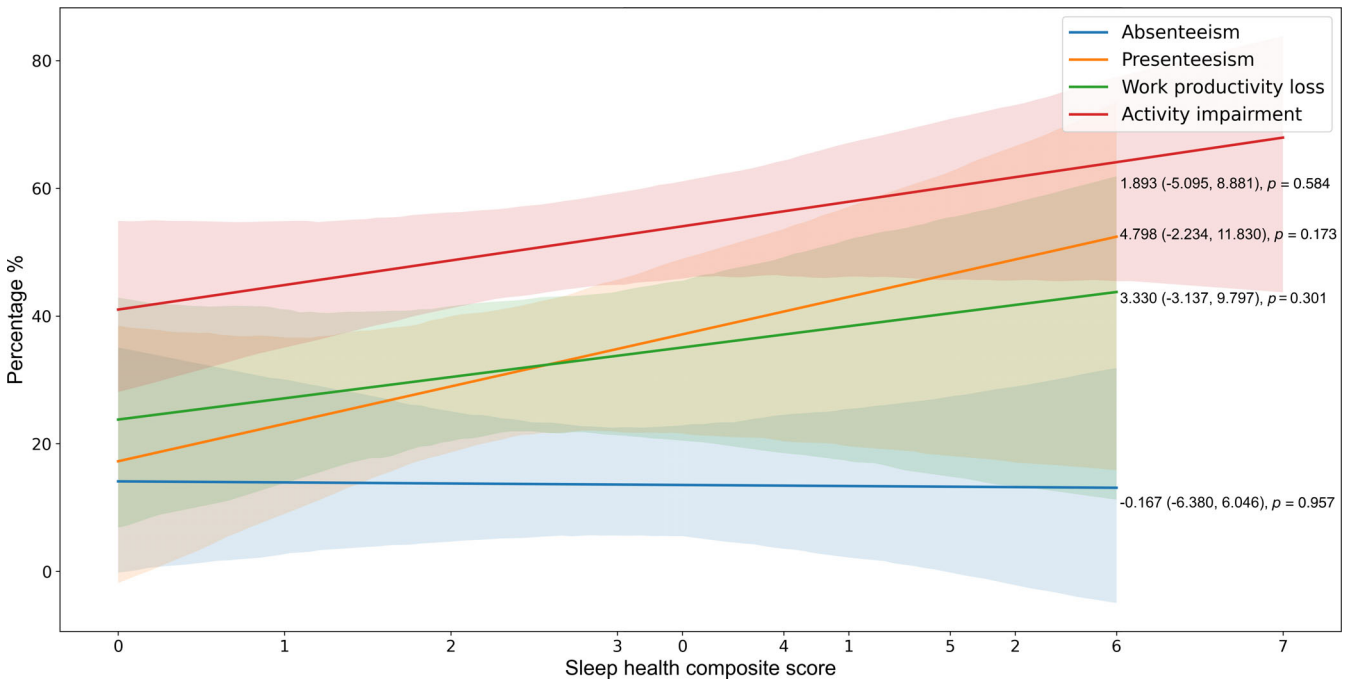

FIGURE 1 Linear regression plot for the sleep health composite score and work productivity domains. The regression line and 95% confidence intervals (shaded area) are displayed for each work productivity domain.

TABLE 3 The unadjusted associations between sleep health and work productivity domains.

	Absenteeism ($n = 35$)	Presenteeism ($n = 35$)	Work productivity loss ($n = 35$)	Activity impairment ($n = 70$)
Duration non-optimal category	15.99 (−5.11, 37.09), $p = 0.132$	2.12 (−23.53, 27.78), $p = 0.867$	−2.56 (−25.82, 20.71), $p = 0.824$	5.10 (−19.65, 29.85), $p = 0.676$
Continuity (continuous)	−0.27 (−0.71, 0.17), $p = 0.221$	0.38 (−0.13, 0.89), $p = 0.134$	0.39 (−0.07, 0.84), $p = 0.095$	0.38 (−0.11, 0.87), $p = 0.121$
Continuity non-optimal category	−8.38 (−30.1, 13.34), $p = 0.437$	14.65 (−10.41, 39.7), $p = 0.242$	17.53 (−4.78, 39.85), $p = 0.119$	12.93 (−11.4, 37.26), $p = 0.286$
Timing non-optimal category	**22.99 (4.49, 41.49), $p = 0.017$**	−2.98 (−26.88, 20.91), $p = 0.800$	−7.25 (−28.77, 14.27), $p = 0.496$	6.36 (−16.65, 29.37), $p = 0.576$
Regularity (continuous)	−8.13 (−24.84, 8.57), $p = 0.328$	−0.55 (−20.42, 19.31), $p = 0.955$	−1.07 (−19.08, 16.95), $p = 0.904$	−12.0 (−30.66, 6.66), $p = 0.199$
Regularity non-optimal category	−13.61 (−33.4, 6.19), $p = 0.170$	3.82 (−20.06, 27.69), $p = 0.746$	2.47 (−19.21, 24.14), $p = 0.818$	−9.96 (−32.78, 12.86), $p = 0.380$
Rhythmicity (continuous)	0.38 (−0.58, 1.35), $p = 0.423$	0.44 (−0.69, 1.57), $p = 0.436$	0.45 (−0.57, 1.48), $p = 0.374$	0.87 (−0.19, 1.93), $p = 0.103$
Rhythmicity non-optimal category	−13.22 (−33.43, 6.99), $p = 0.191$	3.27 (−21.05, 27.59), $p = 0.785$	1.84 (−20.24, 23.92), $p = 0.866$	−10.05 (−33.28, 13.19), $p = 0.384$
Sleepiness (continuous)	−0.25 (−2.62, 2.11), $p = 0.828$	1.55 (−1.16, 4.26), $p = 0.252$	1.17 (−1.3, 3.65), $p = 0.341$	0.03 (−2.65, 2.71), $p = 0.983$
Sleepiness non-optimal category	7.21 (−16.47, 30.88), $p = 0.539$	11.79 (−15.72, 39.29), $p = 0.388$	6.07 (−19.1, 31.24), $p = 0.626$	−0.65 (−27.6, 26.29), $p = 0.961$
Quality non-optimal category	−6.32 (−26.38, 13.73), $p = 0.524$	**30.85 (10.36, 51.35), $p = 0.005$**	**26.44 (7.53, 45.36), $p = 0.008$**	**25.81 (5.19, 46.43), $p = 0.016$**

Note: significance ($p < 0.05$) indicated in bold.

Park et al., 2018). This suggests that sleep quality, irrespective of neurological symptomology, may play a key role in determining work productivity. Neurological conditions can have a negative impact on sleep quality due to a variety of reasons such as changes in the parasympathetic nervous system caused by elevated intracranial pressure, decreased secretion of melatonin, altered expression of clock genes, increased cortisol levels, impairment to brain areas that regulate the circadian rhythm like the hypothalamus, changes in vascular tone, motor symptoms or medications (Bamer et al., 2008; Lucke-Wold et al., 2015; Zhang et al., 2020). Based on the prevailing evidence, it is reasonable to conclude that neurological conditions can adversely affect sleep quality and that this effect can be aggravated with disease severity thereby leading to impaired work productivity. However, more longitudinal studies are needed to establish the precise influence of neurological conditions on work productivity.

To date, only one study has investigated the relationship between sleep timing and work productivity (Ishibashi & Shimura, 2020). Sleep timing, measured by sleep mid-point, was significantly associated with presenteeism. Similarly, the results from this study found a 23% increase in absenteeism with non-optimal sleep timing (also measured with sleep mid-point). Most of the participants with non-optimal sleep timings had a sleep mid-point before 2:00 a.m. (34% of sample), compared to after 4:00 a.m. (10% of sample); demonstrating that early, compared to late chronotypes, are more prevalent in the neurological community. This may be due to an increase in fatigue throughout the day, resulting in earlier sleep and wake times; nevertheless, these results suggest that the current sleep timings of the neurological community have a detrimental effect on absenteeism.

This study also characterised the sleep health of the neurological community utilising a recently developed multidimensional sleep heath framework; revealing a sleep health composite score, defined as the number of non-optimal sleep domains, of a median (IQR) of 2.00 (1.00, 4.00). Similar values (median [IQR] 2.00 [2.00, 4.00]) were reported in a study using the same method in individuals with MS (Whibley et al., 2021). This finding indicates that the sleep health characteristics may be similar across neurological conditions; further research is needed to confirm this.

The sleep duration found in this study (441.58 min) was within the recommended range (420–540 min) described by the National Sleep Foundation (NSF; Hirshkowitz et al., 2015). It is also similar to or greater than the sleep durations reported in studies with a neurological population (Högl et al., 2003; Stanton et al., 2006; Whibley et al., 2021). Previous literature across various neurological conditions, including MS (32%), stroke (20.6%) and PD (33%), have reported non-optimal ESS scores (Högl et al., 2003; Klobučníková et al., 2016; Stanton et al., 2006). Similar to these studies, our study found 27% of individuals with a neurological condition experienced excessive sleepiness (ESS score >10). Interestingly, only 43% of participants reported having poor sleep quality, despite the median (IQR) sleep continuity (WASO) score of 43.86 (30.22, 63.93) being well above the NSF recommendations of <20 min (Ohayon et al., 2017).

This study has several limitations that should be considered when evaluating its findings. First, the study sample consist of various neurological conditions, resulting in greater heterogeneity. Therefore, caution should be given when interpreting these findings for any specific neurological condition. Second, data were collected cross-sectionally, leading to potential bias. Finally, the number of individuals that were employed at the time of testing was 35. The small sample of employed participants will have decreased the ability to achieve statistical significance. Therefore, future studies with larger sample sizes should further explore the sleep health and work productivity relationship. Nevertheless, this exploratory study is the first to investigate the relationship between sleep health and work productivity in the neurological community.

This study explored the relationship between sleep health and work productivity in the neurological community using the novel and robust multidimensional sleep health framework. The findings are particularly relevant given the number of individuals in Australia who are living with a neurological condition and the impact that impaired work productivity, such as absenteeism and presenteeism, could have on the economy. Further research with larger numbers is needed to confirm and build upon the present findings. Greater emphasis on sleep quality and timing should be given for individuals with a neurological condition to optimise their work productivity.

AUTHOR CONTRIBUTIONS

Mitchell Turner: Conceptualization; investigation; writing – original draft; methodology; visualization; writing – review and editing; formal analysis. **Manja Laws:** Writing – original draft; methodology; writing – review and editing; investigation. **Madeline Griffiths:** Writing – review and editing; methodology; investigation. **Kate Turner:** Investigation; methodology; writing – review and editing. **Leah Dempsey:** Methodology; writing – review and editing; investigation. **Simon Laws:** Funding acquisition; writing – review and editing; project administration. **Travis Cruickshank:** Conceptualization; writing – original draft; writing – review and editing; methodology; investigation.

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CONFLICT OF INTEREST STATEMENT

None declared.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from SPIN Research Program. Restrictions apply to the availability of these data, which were used under license for this study. Data are available from the author(s) with the permission of SPIN Research Program.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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