ORIGINAL ARTICLE

Association between Sleep Spindles and IQ of College Students

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Abstract

Introduction: Sleep spindles are short burst-like waveform of signals generated in the electroencephalogram (EEG) recorded during sleep, and these are the electrical representation of an oscillatory neuronal activity of thalamic neurons. Some studies have linked different sleep spindle parameters with intelligence quotient (IQ). But there is a lack of uniformity in different studies, as spindle parameters may be positively associated with cognition variables in one study, but those same parameters might be negatively associated or even unrelated in other studies. The present study was conducted to further throw light on the correlation of sleep spindle activity with IQ.

Objective: To find the association between different sleep spindle parameters and IQ.

Method: The sleep spindle data of 50 healthy young medical students aged between 18 and 23 years were taken from previously conducted sleep studies (polysomnography), which were available in the sleep lab in the department of physiology (King George's Medical University). The participating students underwent a Wechsler IQ test. The result of the test was correlated with sleep spindle parameters available with us to see any correlation.

Results and conclusion: Sleep spindle frequency was negatively correlated with the IQ, and the number of spindles in deep sleep (N3) was positively associated with the IQ of an individual.

Keywords: Electroencephalogram, Intelligence quotient, Polysomnography, Sleep spindle.

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Introduction

Sleep spindles are short burst-like waveform of signals generated in the electroencephalogram (EEG) recorded during sleep, and these are the electrical representation of oscillatory neuronal activity in thalamic neurons.[1] These neuronal oscillations are observed more commonly during stage 2 non-rapid eye movement (NREM) of sleep, commonly observed in the frequencies between 11 and 16 Hz and have a duration between 0.5 and 3 seconds.[2-5] The frequency range of sleep spindles has further been divided by researchers into slow spindles (11–13.5 Hz) and fast spindles (13.6–16 Hz).[6] Although it is generally accepted and shown in different studies that sleep spindles occur primarily in stage 2 sleep, some studies have also found that sleep spindles are also present in rapid eye movement (REM) of sleep.[2,7,8]

Sleep spindles are generated from the complex interaction between thalamic reticular nuclei and thalamocortical neurons, and they together make the thalamocortical loop.[9] Other functions of sleep spindles are that they facilitate the development of somatosensory system and also involve in thalamocortical sensory gating, synaptic plasticity, and offline memory consolidation.[14–17] Sleep spindles also regulate the interactions between the brain and its external environment; they control the responsiveness of the brain to sensory stimuli during sleep.[15–17]

Sleep spindles have previously been linked to IQ, and various studies had also shown that it can be considered as a biological marker of cognitive abilities, learning potential, and memory processing.[6,8] Many researchers had demonstrated that different spindle properties are correlated with the IQ, memory consolidation, processing speed and learning potential.[8–13] In some study done on children,[19] it has been found that memory performance is negatively correlated with sleep spindle density, which is opposite to the effect that had been shown in some studies in adults.[20,21] Due to lack of uniformity in the results of different studies, it is important to conduct further studies on this topic in different age-groups and in different regions of the world to provide a significant ground for a correlation that might be occurring or to discover and prove the other correlations. A study on young adults might give more understanding about the correlations in this age-group. So the current study aims to further explore the association between different sleep spindle variables and IQ of young college students.

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Objective

To study the association between sleep spindles parameters and the IQ of medical college students.

Method

The sleep spindle data of 50 healthy young medical students aged between 18 and 23 years were taken from previously conducted sleep studies (polysomnography), which were available in the sleep lab in the department of physiology (King George's Medical University). The present research is a part of a larger research project pertaining to polysomnographic findings on healthy young college students. Overnight polysomnogram of the available subjects was conducted using SOMNOscreen plus EEG32 video of polysomnography with a resolution of 16 bit, sampling rate up to 512 Hz, and band-pass filters of 0.1 to 128 Hz; standard electrode electroencephalography montage of F4-M1, C4-M1, and O2-M1 with a backup of F3-M2, C3-M2, and O1-M2; and EOG of E1 M2 and E2 M2. The other channels included a submental EMG and ECG (lead ii) for recording cardiac activity and other airflow and respiratory parameters according to the American Academy of Sleep Medicine guidelines. The studies were conducted for a time duration of at least 7 hours at night. The data pertaining to sleep spindle had never been analyzed previously and were used exclusively for the present research. Fifty sleep studies of medical students were randomly taken from the available data. These subjects were informed of the research, and consent was obtained. The participating students underwent a Wechsler IQ test. The Wechsler IQ test is used to measure the intelligence and cognitive ability in adults and older adolescents. It consists of 10 core subtests based on verbal comprehension, perceptual reasoning, working memory, and processing speed along with five supplemental subtests. The 10 core subtests yield scaled scores that sum to derive IQ. The result of the test was correlated with sleep spindle parameters available with us to see any correlation. Sleep spindles are characteristic waveforms seen in the EEG during the stage N2 of sleep due to complex thalamocortical interactions. They have a frequency between 12 and 16 Hz. The spindle frequency is measured by counting the number of EEG waves in 1 second using the 10-second epoch. A due ethical clearance was obtained before starting the research. Different spindle detection algorithms have been used for research purposes; however, since we relied on previously conducted polysomnographic studies, we analyzed the spindle parameters available in the polysomnography reports.

Results

The study had 50 subjects of which 34 were males and 16 were females. Twenty-two percent had below-average IQ, 46% had average IQ, and 32% had above-average IQ (Table 1). Most of them (80%) were not doing any meditation or yoga and nearly 72% did not do any daily physical exercise. Most of the participants belonged to the middle-class or upper socioeconomic background (Table 2). The mean value for spindle frequency was 14.4 Hz; the mean value for the number of spindles in REM sleep was 133.78 and in deep sleep was 64.88; the mean value for the total number of spindles was 654.86; and the mean IQ was 106.12. The mean total sleep time was 324.34 minutes (Table 3). A statistically significant negative correlation ($r = -0.625$) was obtained between sleep spindle frequency (Hz) and IQ (Fig. 1). No statistically significant correlation ($r = -0.041$) was obtained between the number of spindles in REM and IQ score (Fig. 2).

Table 1: IQ of subjects

IQ range	*IQ classification*	*No. of subjects*	*Percent*
Above 132	Superior	0	0
116–132	High average	16	32.0
96–113	Average	23	46.0
77–93	Low average	11	22.0
63 and below	Borderline	0	0

Table 2: Gender, socioeconomic, and lifestyle-related variables

Variable		*N*	*Percent*
Male/female	M	34	68.0
	F	16	32.0
Meditation/yoga	N	40	80.0
	Y	10	20.0
Gym/physical exercise (Y/N)	N	36	72.0
	Y	14	28.0
Socioeconomic status	L	5	10.0
	M	31	62.0
	U	14	28.0

Table 3: Mean value of sleep parameters

				95% CI	
Total	*N = 50*	*Mean*	*SD*	*Lower*	*Upper*
	Spindle frequency (Hz)	14.40	1.09	14.09	14.71
	No. of spindles in REM	133.78	34.27	124.04	143.52
	No. of spindles in deep sleep	64.88	12.76	61.25	68.51
	Total no. of spindles	654.86	166.53	607.53	702.19
	IQ scores	106.12	15.04	101.85	110.39
	Total time of sleep (in minutes)	324.34	29.55	315.94	332.74

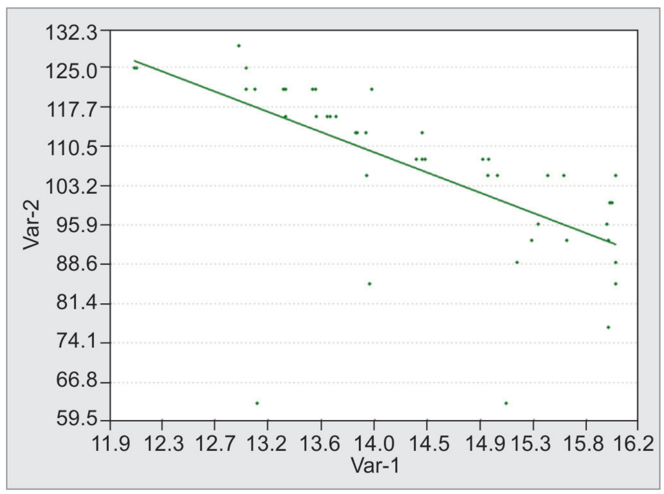

Fig. 1: Relationship between sleep spindle frequency (Hz) and IQ (var1, sleep spindle frequency and var2, IQ)

A positive correlation ($r = 0.807$) was obtained between the number of spindles in deep sleep and IQ (Fig. 3). No statistically no significant correlation ($r = 0.309$) was obtained between the total number of spindles and IQ of the participants (Fig. 4).

Discussion

Researches conducted on the correlation of sleep spindle frequency and number with cognitive variables have yielded mixed results. Sleep spindle frequency is influenced by age, gender, and other comorbid conditions. The present study shows a negative association between the frequency of sleep spindles and IQ score. There are other previous studies in which negative relationships

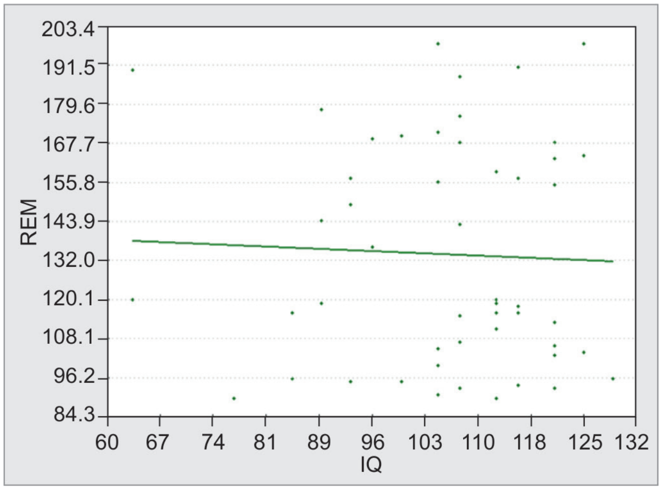

Fig. 2: Relationship between the number of spindles in REM and IQ

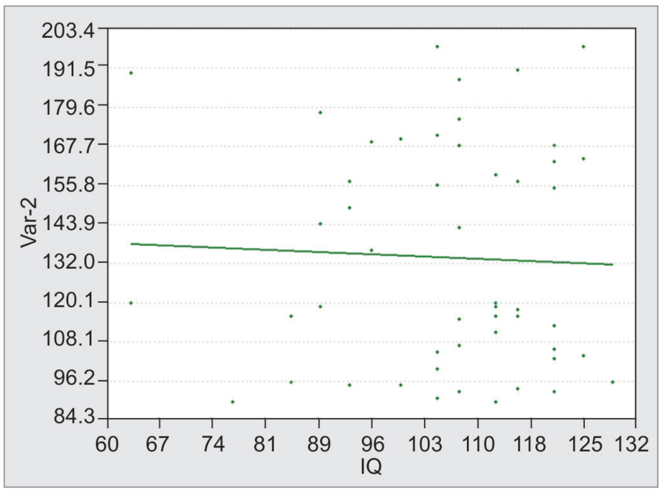

Fig. 3: Relationship between the number of spindles in deep sleep and IQ (var2, no. of spindles in deep sleep; var1, IQ score)

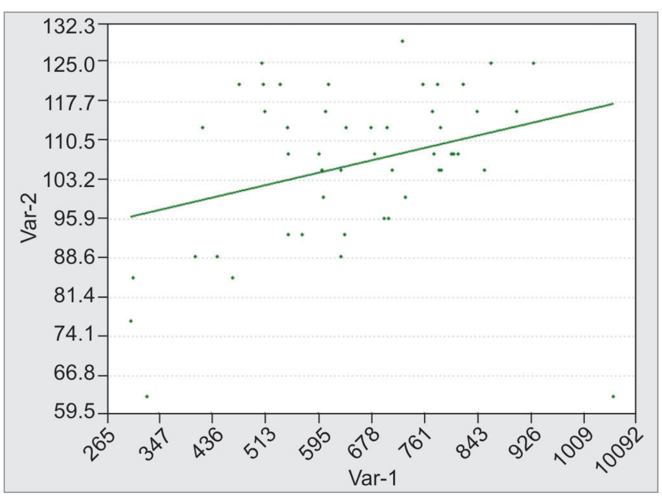

Fig. 4: Relationship between the total number of spindles and IQ (var1, total no. of spindles; var2, IQ score)

were found with peak frequency and spindle density.[8,18,22,23] Geiger et al.[26] found full IQ was negatively associated with spindle peak frequency. But Schabus M et al.[4] observed that the faster (or higher frequency) spindle activity was associated with more extensive cortical activation; their study suggested that it is the faster (or higher frequency) spindle activity that was associated with some forms of intelligence. Similarly, in many other studies, moderate positive relationships were seen for spindle frequency, sigma power, total number, and spindle activity.[17,22,24]

In this study, the number of spindles in deep sleep (N3) had shown a positive association with the IQ, but both the number of spindles in REM and the total number of spindles had shown no association with the IQ.[8] It can be seen in many other studies that in adults, the total number of spindles and spindle density have shown the strongest relationships with the performance IQ tests, whereas the weaker or statistically nonsignificant relationships were seen for verbal IQ.[10,11] The relationship between full IQ and spindle duration had shown less uniformity in different studies, as both positive and negative correlations had been observed.[23,24]

Further research is needed in this area, especially in young adults to increase our understanding of how spindles and cognition are related in different age-groups, particularly in an age-group that, on average, achieves significantly less sleep than that is recommended for optimal daytime functioning.[25,26] In some studies, sleep spindles have shown associations in children, which was beyond their IQ scores, such that in those studies, the higher spindle activity has been associated with some psychological attributes like better adaptive coping strategies in stressful conditions.[27,28] Keeping in mind the results of these studies in future, the sleep spindles can be used as a marker that infers the mental status and the psychological behaviors of an individual, especially the young adults who are in the present world scenario at more risk to mental disorders like stress, anxiety, depression, and other social problems.

The present study found an association between the number of sleep spindles during deep sleep and IQ, which could suggest the complex thalamocortical interplay generating sleep spindles differs in their dynamics during different sleep stages; however, the study was limited by the homogenous nature of the sample consisting of young medical students with mostly average and above-average IQ from a middle- to upper-middle-class socioeconomic background. The study limited itself to only two spindle parameters, and a further research into other parameters like spindle amplitude, density, and spectral distribution could lead to more findings. Further research studies and experiments have to be done to prove the overall relationships between sleep spindle and cognition variables.[29,30]

Conclusion

The present study shows that the sleep spindle frequency has a negative association with the IQ. The number of spindles in deep sleep had a positive correlation with the IQ of an individual, whereas the number of spindles in REM sleep and the total number of spindles had no association with the IQ.

References

1. Fernandez LMJ, Lüthi A. Sleep spindles: mechanisms and functions. Physiol Rev 2020;100(2):805–868. DOI: 10.1152/physrev.00042.2018.
2. Zeitlhofer J, Gruber G, Anderer P, et al. Topographic distribution of sleep spindles in young healthy subjects. J Sleep Res 1997;6(3): 149–155. DOI: 10.1046/j.1365-2869.1997.00046.x.
3. DeGennaro L, Ferrara M. Sleep spindles: an overview. Sleep Med Rev 2003;7(5):423–440. DOI: 10.1053/smrv.2002.0252.

4. Schabus M, Dang-Vu TT, Albouy G, et al. Hemodynamic cerebral correlates of sleep spindles during human nonrapid eye movement sleep. Proc Natl Acad Sci USA 2007;104(32):13164–13169. DOI: 10. 1073/pnas.0703084104.
5. Peters KR, Ray L, Smith V, et al. Changes in the density of stage 2 sleep spindles following motor learning in young and older adults. J Sleep Res 2008;17:23–33. DOI: 10.1111/j.1365-2869.2008.00634.x.
6. Fogel SM, Smith CT. The function of the sleep spindle: a physiological index of intelligence and a mechanism for sleep-dependent memory consolidation. Neurosci Biobehav Rev 2011;35(5):1154–1165. DOI: 10.1016/j. neubiorev.2010.12.003.
7. Gaillard JM, Blois, R. Spindle density in sleep of normal subjects. Sleep 1981;4(4):385–391. DOI: 10.1093/sleep/4.4.385.
8. Nader RS, Smith CT. Correlations between adolescent processing speed and specific spindle frequencies. Front Hum Neurosci 2015;9:30. DOI: 10.3389/fnhum.2015.00030.
9. Steriade M. Grouping of brain rhythms in corticothalamic systems. Neuroscience 2006;137(4):1087–1106. DOI: 10.1016/j. neuroscience.2005.10.029.
10. Nader R, Smith C. A role for stage 2 sleep in memory processing. In: Maquet P, Smith C, Stickgold R, editors. Sleep and synaptic plasticity. Oxford: Oxford University Press; 2003. p. 87–98.
11. Fogel SM, Nader R, Cote KA, et al. Sleep spindles and learning potential. Behav Neurosci 2007;121(1):1–10. DOI: 10.1037/0735-7044. 121.1.1.
12. Fogel SM, Smith CT. Learning-dependent changes in sleep spindles and Stage 2 sleep. J Sleep Res 2006;15(3):250–255. DOI: 10.1111/j.1365-2869.2006.00522.x.
13. Schabus M, Hödlmoser K, Gruber G, et al. Sleep spindle-related activity in the human EEG and its relation to general cognitive and learning abilities. Eur J Neurosci 2006;23(7):1738–1746. DOI: 10.1111/j.1460-9568.2006.04694.x.
14. Buzsaki G. Two-stage model of memory trace formation: a role for "noisy" brain states. Neuroscience 1989;31(3):551–570. DOI: 10.1016/0306-4522(89)90423-5.
15. Rosanova M, Ulrich D. Pattern-specific associative long-term potentiation induced by a sleep spindle-related spike train. J Neurosci 2005;25(41):9398–9405. DOI: 10.1523/JNEUROSCI.2149-05.2005.
16. Genzel L, Kroes MC, Dresler M, et al. Light sleep versus slow wave sleep in memory consolidation: a question of global versus local processes? Trends Neurosci 2014;37(1):10–19. DOI: 10.1016/j.tins.2013.10.002.
17. Hoedlmoser K, Heib DPJ, Roell J, et al. Slow sleep spindle activity, declarative memory, and general cognitive abilities in children. Sleep 2014;37(9):1501–1512. DOI: 10.5665/sleep.4000.
18. Gruber R, Wise MS, Frenette S, et al. The association between sleep spindles and IQ in healthy school-age children. Int J Psychophysiol 2013;89(2):229–240. DOI: 10.1016/j.ijpsycho.2013.03.018.
19. Kurdziel L, Duclos K, Spencer RMC. Sleep spindles in midday naps enhance learning in preschool children. Proc Natl Acad Sci USA 2013;110(43):17267–17272. DOI: 10.1073/pnas.1306418110.
20. Cox R, van Driel J, de Boer M, et al. Slow oscillations during sleep coordinate interregional communication in cortical networks. J Neurosci 2014;34(50):16890–16901. DOI: 10.1523/jneurosci.1953-14.2014.
21. Lafortune M, Gagnon JF, Martin N, et al. Sleep spindles and rapid eye movement sleep as predictors of next morning cognitive performance in healthy middle-aged and older participants. J Sleep Res 2014;23(2):159–167. DOI: 10.1111/jsr.12108.
22. Geiger A, Huber R, Kurth S, et al. The sleep EEG as a marker of intellectual ability in school age children. Sleep 2011;34(2):181–189. DOI: 10.1097/wnr.0b013e32834e7e8f.
23. Tessier S, Lambert A, Chicoine M, et al. Intelligence measures and stage 2 sleep in typically-developing and autistic children. Int J Psychophysiol 2015;97(1):58–65. DOI: 10.1016/j.ijpsycho.2015.05.003.
24. Chatburn A, Coussens S, Lushington K, et al. Sleep spindle activity and cognitive performance in healthy children. Sleep 2013;36(2):237–243. DOI: 10.5665/sleep.2380.
25. Gibson ES, Powles ACP, Thabane L, et al. "Sleepiness" is serious in adolescence: two surveys of 3235 Canadian students. Pediatr North Am 2006;58:637–647. DOI: 10.1186/1471-2458-6-116.
26. Lo JC, Ong JL, Leong RLF, et al. Cognitive performance, sleepiness, and mood in partially sleep deprived adolescents: the need for sleep study. Sleep 2016;39(3):687–698. DOI: 10.5665/sleep.5552.
27. Mikoteit T, Brand S, Beck J, et al. Visually detected NREM Stage 2 sleep spindles in kindergarten children are associated with stress challenge and coping strategies. World J Biol Psychiatry 2012;13(4):259–268. DOI: 10.3109/15622975.2011.562241.
28. Mikoteit T, Brand S, Beck J, et al. Visually detected NREM Stage 2 sleep spindles in kindergarten children are associated with current and future emotional and behavioural characteristics. J Sleep Res 2013;22(2):129–136. DOI: 10.1111/j.1365-2869.2012.01058.x.
29. Hartman DE. Wechsler Adult Intelligence Scale IV (WAIS IV): return of the gold standard. Appl Neuropsychol 2009;16(1):85–87. DOI: 10.1080/09084280802644466.
30. Bright P, Hale E, Gooch VJ, et al. The National Adult Reading Test: restandardisation against the Wechsler Adult Intelligence Scale—Fourth edition. Neuropsychol Rehabil 2018;28(6):1019–1027. DOI: 10.1080/09602011.2016.1231121.