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Determinants of Sleep Quality and Its Association with Cognitive and Emotional Functioning: A Cross-Sectional Study Across Gender and Age

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Abstract. Sleep is often regarded as a passive state of rest, yet this long-standing misconception overlooks its broader purposes and the intricate ways in which different aspects of sleep influence executive functions. This study aspires to dispel such misunderstandings by emphasizing the importance of acknowledging counterintuitive findings to improve sleep quality and social functioning. A cross-sectional study of 371 participants collected data on multiple sleep indicators, including duration, difficulty initiating sleep, nighttime awakenings, and medication use, alongside measures of attention, memory, executive functioning, emotion, and behavior. Findings revealed that poor sleep quality was consistently linked to worse next-day functioning, but in surprising ways: duration showed weak associations, while initiation problems, nighttime awakenings, and reliance on medication emerged as the strongest contributors to this relationship. Age also moderated these effects: younger participants experienced the most pronounced deficits, suggesting that poor sleep may be particularly damaging early in life, whereas older age groups displayed greater resilience. By emphasizing quality over quantity and uncovering age-specific vulnerabilities, this study reframes common assumptions about sleep. The results underscore that safeguarding cognitive and emotional health requires greater attention to sleep quality, particularly among youth. B These findings carry vital implications for individual cognitive health, productivity, and societal well-being.

Keywords: Sleep quality, Next-day functioning, Cognitive and emotional regulation

1. Introduction

Sleep follows a cyclical pattern across the night, consisting of non-rapid eye movement (NREM) and rapid eye movement (REM) sleep, with NREM divided into three stages. These cycles are regulated by the circadian rhythm, which responds to environmental light exposure and operates on an approximately 24-hour cycle [1]. Through this organization, sleep supports higher-order cognitive and emotional processes, including memory consolidation, sustained attention, executive functioning, and emotional regulation [2,3]. Although sleep is a shared biological behavior, sleep quality varies widely across individuals and demographic groups, and such variation has been linked to differences in daytime cognitive and emotional functioning [4]. While some studies support an

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optimal range of sleep duration for cognitive performance [5], growing evidence suggests that sleep health is multidimensional, encompassing continuity, timing, and subjective sleep quality beyond total sleep time alone [6]. Population-based and longitudinal studies further show that poor sleep quality and sleep disturbances are associated with lower cognitive performance and declines in memory and executive functioning independent of sleep duration [7,8]. Despite these findings, it remains unclear how specific components of sleep quality differentially affect functioning or how these relationships vary across age and gender, particularly given evidence that older adults may show greater emotional resilience despite age-related changes in sleep architecture [4].

2. Method

This research is conducted through the online dispersal of surveys, focusing on quantitative collection of data. Surveys were chosen as the main method of data collection because they are easy to distribute and require a short response time. This helped increase efficiency while still keeping the quality of responses. Survey links are scattered through social media platforms. Participants were able to join the study voluntarily. Before responses were collected, consent was obtained with a promise of anonymity and confidentiality. The survey design involved two main pathways. One pathway examined the relationship between demographic factors, including age and gender, and sleep quality. The second pathway focused on the association between sleep quality and cognitive and emotional outcomes. However, these pathways were not separated within the survey itself. This was done to maintain objectivity and reduce response bias. Question formats aimed to limit response options to fewer than five choices. This allowed the answers to be quantitatively evaluated. Most questions required self-reported responses. Participants reflected on their sleep habits and next-day experiences. Evaluations of sleep quality and daytime functioning were based on personal perceptions and individual lifestyles.

3. Results & analysis

When grouping data, all personal judgements were converted into unified numerical values for better ease of analysis. Spectrum-based responses were categorized into a scale of 1–5, and statistical significance was derived from the numerical values. Correlations between independent and dependent variables were then computed using Python-based analysis, with statistical significance evaluated at a threshold of $p = 0.05$.

3.1. Correlation #1: sleep quality predicts next-day impact

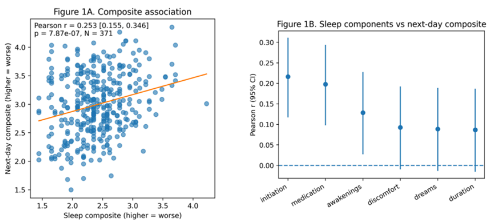

Figure 1. Sleep quality predicts next-day impact. Figure 1A. Scatter plot of the correlation between sleep composite and next-day composite. Higher sleep composite values indicate worse sleep quality. Each dot represents one participant.Figure 1B. Forest plot of Pearson correlation coefficients between sleep quality components and next-day functioning, with 95% confidence intervals

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In Figure 1A, correlations between sleep composition and next-day composition are represented by a scatter plot. Sleep composition stems from results gathered regarding self-reported sleep quality, with a higher value on the X-axis indicating worse sleep quality. On the Y-axis, next-day composition, stemming from self-reported quality of next-day functioning, is represented in numerical values, with a higher number indicating worse next-day functioning. Each dot represents one participant. The upward trend indicates the presence of a positive correlation between sleep composite and next-day composite, with a Pearson r value of 0.25. This correlation is demonstrated through the orange best-fit line. Such results demonstrate that there exists a directional relationship between sleep quality and next-day functioning, meaning that with poorer reported sleep quality, respondents are more likely to report worse next-day functioning as well, which corresponds to common understanding of the effects of sleep. In Figure 1B, a forest plot represents the relationship between components of sleep quality evaluation and their corresponding Pearson r values in relation to the patterns shown in Figure 1A. Results are presented with a confidence interval of 95%. A higher Pearson r value represents a more significant contribution to the patterns demonstrated in Figure 1A. As observed, sleep components such as difficulty initiating sleep (initiation) and sleep medication usage (medication) have higher Pearson r values, while factors such as nighttime awakenings (awakening), experienced sleep discomfort (discomfort), disruptions from dreams (dreams), and sleep duration (duration) have observably lower Pearson r values. Deviations in Pearson r values showcase how factors such as difficulty initiating sleep and sleep medication usage are more influential in their effect on sleep quality, thus contributing to reported next-day functioning as well. Unexpectedly, the common societal measure of sleep quality, sleep duration, presents itself as one of the least influential factors regarding its role in determining sleep quality. Alongside dream disruptions, experienced sleep discomfort, and nighttime awakenings, sleep duration does not contribute as strongly to an individual's evaluation of sleep quality or its effects on next-day functioning, showcasing how components related to sleep quality are more influential than sleep quantity. Combined, Figure 1 demonstrates that there exists a notable positive correlation between self-reported sleep quality and next-day functioning, which presents itself in a linear pattern. Within this context, factors such as difficulty initiating sleep and sleep medication usage gain prevalence regarding their role in sleep quality, while remaining components, particularly sleep duration, do not demonstrate as much influence, thereby showing that sleep quality is more influential to next-day functioning than sleep quantity.

3.2. Correlation #2: age patterns are domain-specific

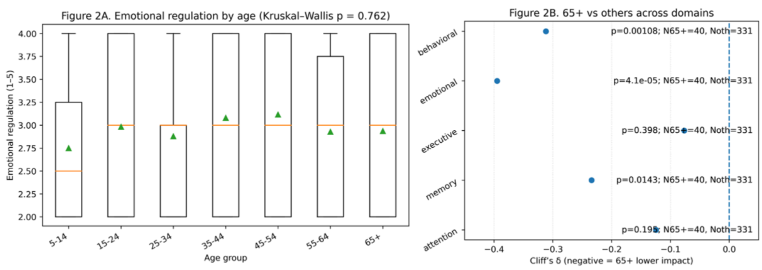

Figure 2. Age patterns are domain specific. Figure 2A. Box plot of emotional regulation after poor sleep across age groups (1–5 scale). Figure 2B. Cliff's δ values for next-day cognitive components following poor sleep

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Figure 2A is a box plot demonstrating the relationship between different age groups and levels of emotional regulation after a night of poor sleep. Emotional regulation is represented with numeric values within the interval 1–5 and is considered a part of next-day cognitive/emotional functioning. Overall, the observed emotional regulation values showed an upward trend as age increases, indicating that age has a slightly directional correlation regarding emotional regulation the following day after a night of poor sleep. The most prominent demonstration of this pattern is the 65+ category, with emotional regulation levels remaining mostly consistent regardless of the sleep quality of the previous day. The calculated Kruskal–Wallis value is 0.762, signifying that there exists a significant difference between age groups regarding the demonstrated value of emotional regulation. Such patterns demonstrate that one's resilience regarding emotional regulation under the influence of poor sleep increases with age, most evident in the highest age category, 65 years or older. Such patterns might be attributed to amygdala–prefrontal cortex development as well as increased levels of experience regarding social dynamics. Figure 2B shows Cliff's δ values calculated for components of next-day cognitive function after a night of poor sleep, including behavior, emotional regulation, ability to perform executive functions, memory retention, and attention span. A negative Cliff's δ was observed for all five categories, notably in emotional regulation and behavioral regulation. These two categories also had p-values of less than 0.01, signifying that they present a statistically significant difference compared to other age groups. Negative Cliff's δ values, in the given context, mean a lower effect in the presence of poor sleep. Hence, considering how Cliff's δ is negative for all five components of next-day functioning for the 65+ age group, the data signify that this age group presents significantly lower influence on next-day functioning after a night of poor sleep compared to other age groups, validating the conclusions presented in Figure 2A. Specifically, in domains of emotional regulation and behavioral regulation, such effects are more prominent. Combined, Figure 2 shows that poor sleep affects everyone's next-day functioning. Despite this holistic effect, respondents in older age groups retain more resilience, notably in categories such as behavioral and emotional regulation. Likely causes of such deviations include better coping strategies developed with more experience, as well as higher levels of lifestyle stability leading to fewer changes in sleep architecture.

3.3. Correlation #3: gender moderation: the counter-intuitive null

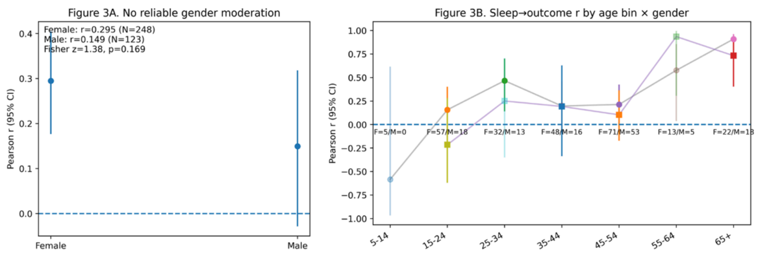

Figure 3. Gender moderation: the counter-intuitive null. Figure 3A. Pearson correlations between sleep quality and next-day functioning for males and females (95% CI). Figure 3B. Pearson correlations by age group; circles indicate females and squares indicate males. Negative values indicate inverse associations

Figure 3A demonstrates the relationship between two gender domains and their respective Pearson r values calculated with 95% confidence. Pearson r values compare sleep quality and next-day functioning between males and females. While females showed a higher correlation,

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overlapping error bars indicate that there exists no statistically significant difference between the calculated correlation values of poor sleep and next-day functioning across genders, signifying that, though biological differences are present, males and females are approximately equally susceptible to the effects of poor sleep on next-day functioning. Figure 3B further supports the conclusions presented by Figure 3A by analyzing these patterns within each age interval. Negative values signify that sleep quality and next-day functioning are inversely correlated. Each dot represents the Pearson r value in its corresponding age group, with circles representing females and squares representing males. Trend lines demonstrate that, for most age groups, females present a higher correlation compared to males. However, all error bars overlap, indicating that there exists no statistical difference between genders across all age categories, further confirming the conclusions presented through Figure 3A. Figure 3 demonstrates that, unlike common societal beliefs that there exists a difference between genders regarding the effects of poor sleep due to physiological differences, statistical analysis shows that although minor differences are present, they are negligible, as they do not reach statistical significance.

4. Discussion

By examining whether sleep quality mediates the relationship between demographic factors and cognitive outcomes and testing a model where gender and age influence sleep, which in turn impacts daytime functioning, this study presents three major findings. First, sleep quality matters more than sleep duration. Factors that mediate sleep quality, such as sleep medication usage, contribute more to next-day functioning than sleep duration. Hence, instead of blindly relying on sleep duration as a measure of restfulness, public campaigns should emphasize consistent sleep schedules as well as reduced sleep medication usage for maximized next-day outcomes. Second, age-specific vulnerability is observed. Young individuals are especially susceptible to the cognitive and behavioral effects of poor sleep, while adults over the age of 65 demonstrate minimal deviations compared to regular days. Such conclusions call for greater emphasis on sleep quality in younger generations, such as through promoting changes in lifestyle, as the consequences of poor sleep are greater. In comparison, for adults aged above 65, approaches might differ, with efforts to increase sleep quality focusing more on reducing nighttime awakenings to maintain overall physical health rather than protecting cognitive function. Finally, the role of gender appears nonspecific. Both genders are equally susceptible to the effects of poor sleep, which challenges stereotypical conclusions that women are more vulnerable to sleep-related impairment. Some reasons for such conclusions might stem from the fact that this study has more female participants. However, the present conclusion implies that methods for mediating the effects of poor sleep should be universal across genders, alleviating an additional factor to consider when developing sleep therapy.

5. Conclusion

This study shows that sleep quality plays a more important role in next-day cognitive and emotional functioning than sleep duration alone. Disrupted sleep features, especially difficulty initiating sleep and sleep medication use, are more strongly linked to functional impairment than total sleep time. Age-related differences are evident, with younger individuals showing greater vulnerability to poor sleep, while adults aged 65 and older demonstrate relative resilience, particularly in emotional and behavioral regulation. Gender does not significantly moderate these relationships, suggesting that sleep-related impairment is broadly shared across genders.

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