



Exploring the Relationship between Memory Cognitive Ability and Environmental Factors: A Linear Regression Analysis

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Abstract

Purpose: This study examines the relationship between memory cognitive ability and environmental factors, including sleep quality, physical exercise, stress level, and nutrition score, among 753 participants from Chennai.

Methodology: A regression analysis was conducted to identify significant predictors of memory cognitive ability. Residual diagnostics and influential observations were assessed using Q-Q plots, histograms, and Cook's distance.

Findings: Results indicate that sleep quality, physical exercise, and nutrition score significantly enhance memory cognitive ability, while stress level does not. The model explains 57.52% of the variance in cognitive ability, underscoring the importance of these lifestyle factors.

Originality: This study highlights the critical role of environmental factors in cognitive function, providing actionable insights for public health initiatives. The findings advocate for targeted interventions promoting sleep quality, physical exercise, and nutrition to improve cognitive health globally.

Keywords: Cognitive Ability, Sleep Quality, Physical Exercise, Nutrition Score

Introduction

Memory and cognitive ability are fundamental components of human intelligence, shaping how individuals learn, solve problems, and interact with their environment. These cognitive functions are not static; they are influenced by a complex interplay of genetic, developmental, and environmental factors. Understanding the relationship between these factors and cognitive abilities is critical for developing interventions that can enhance mental performance and mitigate cognitive decline.

Memory, a core aspect of cognitive ability, involves the processes of encoding, storing, and retrieving information. It is essential for daily functioning, enabling individuals to perform tasks ranging from simple recall to complex problem-solving. Cognitive ability, broader in scope, encompasses various mental processes such as attention, reasoning, problem-solving, and executive functions. Together, these cognitive domains underpin a wide range of activities from academic performance to workplace efficiency. Environmental factors play a significant role in shaping cognitive abilities and memory performance. These factors can be categorized into physical, social, and psychological dimensions. Physical environmental factors include exposure to pollutants, noise, and access to green spaces. Research has shown that chronic exposure to air pollution and excessive noise can negatively impact cognitive function and memory.

Conversely, access to natural environments and green spaces has been associated with enhanced cognitive performance and reduced stress levels.

Social factors, such as socioeconomic status (SES), education, and social interactions, are also crucial determinants of cognitive health. Higher SES and better educational opportunities provide more stimulating environments that can enhance cognitive development and memory retention. Social interactions, both in quantity and quality, contribute to cognitive reserve and resilience, helping individuals maintain cognitive function in the face of aging and other challenges.

Psychological factors, including stress, mental health, and lifestyle choices, significantly influence cognitive abilities. Chronic stress and mental health disorders like depression and anxiety are known to impair cognitive function and memory. On the other hand, engaging in regular physical activity, maintaining a healthy diet, and participating in intellectually stimulating activities can promote cognitive health and memory performance.

Given the multifaceted nature of cognitive abilities and the diverse range of environmental influences, it is imperative to employ robust analytical methods to unravel these complex relationships. Linear regression analysis is a powerful statistical tool that can help identify and quantify the impact of various environmental factors on cognitive abilities and memory. By modeling the relationship between dependent variables (cognitive abilities and memory) and independent variables (environmental factors), linear regression analysis provides insights into the relative importance of each factor and their potential interactions.

This study aims to explore the relationship between memory, cognitive ability, and environmental factors using linear regression analysis. By examining a comprehensive set of environmental variables, this research seeks to identify key predictors of cognitive performance and memory retention. The findings are expected to contribute to a better understanding of how different aspects of the environment influence cognitive health, with implications for public policy, educational practices, and individual lifestyle choices. This study addresses a critical area of research that intersects psychology, environmental science, and public health. By leveraging linear regression analysis, it aims to provide a nuanced understanding of how environmental factors shape memory and cognitive abilities. This knowledge is essential for designing effective interventions and creating environments that support cognitive well-being across the lifespan.

Literature Review

Memory cognitive ability can be influenced by various environmental factors, as shown in the research studies. Factors such as temperature, humidity, social connectedness, education level, and living environment have been found to impact cognitive function in older adults [4]. Linear regression analysis can be a valuable statistical tool to explore the relationship between memory cognitive ability and these environmental factors. By utilizing linear regression models, researchers can quantify the effects of individual, meteorological, and built environment variables on memory function, providing insights into how these factors interact and influence cognitive performance over time. [16] [3] This approach allows for a comprehensive understanding of the complex interplay between memory cognitive ability and environmental influences in older populations, offering valuable information for developing targeted interventions to support cognitive health in aging individuals. [10]

The research papers provide insights into the relationship between cognitive abilities and various factors like sleep quality, physical exercise, stress levels, and nutrition scores. Sundarakumar et al. found a significant association between sleep quality and memory functions in middle and older-aged individuals without dementia, emphasizing the importance of sleep in memory [6]. Kang et al. highlighted the significant association between cognitive function and physical fitness in healthy older women, but not with health status variables [13]. Zhang et al. demonstrated that physical exercise, sleep quality, and depression were significantly linked to cognitive impairment in older adults with type 2 diabetes mellitus, suggesting a mediating role of sleep quality and depression in this relationship [8] [14]. Syarifuddin et al. identified stress levels as a significant risk factor affecting nutritional status, emphasizing its impact on individual health [15]. Therefore, while each factor independently influences cognitive abilities, the

combined effect of sleep quality, physical exercise, stress levels, and nutrition scores on memory cognitive ability requires further investigation to determine their collective impact.

The relationship between sleep quality and memory cognitive ability is a complex one, influenced by various factors. While some studies suggest a significant association between poor sleep quality and decreased memory functions among individuals with Mild Cognitive Impairment (MCI) [6], others highlight the importance of considering racial/ethnic differences in this relationship [1]. Additionally, research on older adults indicates a positive association between sleep disturbances and cognitive function, with age and education level playing significant roles in cognitive performance [2]. Furthermore, a study on the general population found that poor sleep quality was negatively associated with cognitive performance, independent of Sleep Disordered Breathing (SDB), emphasizing the potential for interventions targeting sleep disturbances to protect cognitive abilities at a population level [7]. These findings collectively suggest that while the relationship between sleep quality and memory cognitive ability may vary across different populations and age groups, addressing sleep disturbances remains crucial for maintaining cognitive function.

The relationship between physical exercise, stress levels, and memory cognitive ability is complex and influenced by various factors. While some studies suggest that acute physical exercise can lead to increased cortisol levels and a decline in memory and learning ability [11], others indicate that both vigorous physical activity and acute stress can elevate cortisol levels without significantly affecting working memory performance [9]. Additionally, research shows that acute exercise may counteract the negative cognitive effects induced by sleep restriction, highlighting its potential to mitigate stress-related cognitive impairment [5]. Furthermore, there is evidence that physical activity can be protective against cognitive decline, with stress not showing a significant association with cognitive outcomes in certain studies [12]. Therefore, while stress levels and physical exercise can impact cortisol release and cognitive function, their direct predictive relationship with memory cognitive ability may not be straightforward and can be influenced by various factors.

H₀: There is no significant linear relationship between memory cognitive ability and the combination of sleep quality, physical exercise, stress level, and nutrition score.

Research Methodology

This study employs a cross-sectional design to investigate the relationship between environmental factors and memory cognitive ability among 753 participants from Chennai. The sample is designed to be diverse, encompassing various age groups, socioeconomic backgrounds, and educational levels, to provide a comprehensive representation of the urban population. Participants will be selected through stratified random sampling to ensure a balanced and representative sample.

Data collection will involve two primary instruments: a self-reported survey and standardized cognitive assessments. The self-reported survey will measure key environmental factors. Sleep quality will be assessed on a scale of 1 to 10, where 1 indicates very poor sleep quality and 10 indicates excellent sleep quality. Physical exercise will be quantified by the number of hours per week that participants engage in physical activity. Stress levels will be measured using a 5-point Likert scale, ranging from 1 (very low stress) to 5 (very high stress). Nutrition will be evaluated through a composite nutrition score, calculated based on the frequency and variety of healthy foods consumed, reflecting the overall quality of the participant's diet.

In addition to the survey, participants will undergo standardized memory cognitive tests. These assessments will include tasks such as verbal recall, working memory exercises, and pattern recognition tasks, yielding a composite score for each participant's memory cognitive ability.

The study aims to achieve two primary objectives. First, it seeks to determine whether sleep quality, physical exercise, stress level, and nutrition score have a significant impact on memory cognitive ability.

Second, it aims to identify which of these environmental factors has the strongest association with memory cognitive ability. The central hypothesis to be tested is that there is no significant linear relationship between memory cognitive ability and the combined effect of the four environmental factors. Conversely, the alternative hypothesis posits that such a relationship does exist.

$$\text{Memory Cognitive Ability} = \beta_0 + \beta_1\text{Sleep_Quality} + \beta_2\text{Physical_Exercise} + \beta_3\text{Stress_Level} + \beta_4\text{Nutrition_Score} + \epsilon \dots \dots \dots (1)$$

Where:

- β_0 is the intercept.
- $\beta_1, \beta_2, \beta_3, \beta_4$ are the coefficients for the independent variables.
- ϵ is the error term.

Objectives:

- To determine whether sleep quality, physical exercise, stress level, and nutrition score have a significant influence on memory cognitive ability.
- To identify which environmental factors have the strongest association with memory cognitive ability.

Data analysis will be conducted using statistical software such as SPSS or R. Initially, descriptive statistics will summarize the characteristics of the sample and each variable. Correlation analysis will explore the bivariate relationships between the independent and dependent variables. Linear regression analysis will then be employed to assess the impact of the independent variables on memory cognitive ability. The significance of each predictor will be tested using t-tests for the coefficients, and the overall fit of the model will be evaluated using R-squared and adjusted R-squared values.

Ethical considerations include obtaining informed consent from all participants, ensuring data confidentiality through anonymization, and securing approval from an institutional ethics committee. The anticipated outcomes of this research are to elucidate the relative influence of sleep quality, physical exercise, stress levels, and nutrition on memory cognitive ability. By identifying significant predictors, the study aims to provide insights that could inform interventions to enhance cognitive health through lifestyle modifications. This research aspires to contribute valuable knowledge to the understanding of environmental influences on cognitive functions, offering evidence-based recommendations for improving mental performance and overall cognitive well-being.

Analysis

The demographic analysis of this study provides insight into the composition of the sample population, offering a glimpse into the diverse range of individuals contributing to the research. Among the 753 participants from Chennai, the distribution across age groups showcases a broad spectrum, with approximately 30% falling within the young adult category (18-30 years), 40% comprising middle-aged individuals (31-60 years), and 30% representing seniors (above 60 years). This diverse age distribution allows for comprehensive exploration of age-related influences on memory cognitive ability.

Socioeconomic backgrounds within the sample exhibit a varied landscape, with an estimated 35% of participants hailing from lower-income households, 45% from middle-income households, and 20% from higher-income households. This socio-economic diversity facilitates the examination of potential disparities in memory cognitive ability across different economic strata.

Educational attainment levels among participants present a mixed picture, with around 25% having completed only primary education, 40% having attained secondary education, and 35% possessing tertiary qualifications. This educational diversity enables an examination of how varying levels of education may interact with environmental factors to influence memory cognitive ability.

Moreover, the sample reflects a rich tapestry of cultural backgrounds, with an estimated 50% representing the local Tamil culture, 30% from other regions within India, and 20% comprising individuals from diverse international backgrounds. This cultural diversity enhances the generalizability of findings and enriches the understanding of how environmental factors affects memory cognitive ability across different cultural contexts.

The demographic analysis underscores the heterogeneous nature of the sample, highlighting its representativeness and providing a solid foundation for investigating the relationship between environmental factors and memory cognitive ability within a diverse urban population.

Table 1: Regression Analysis

Residuals:				
Min	1Q	Median	3Q	Max
-6.3246	-1.2392	-0.0772	1.3252	5.4859

Coefficients:				
	Estimate	Std. Error	t value	Pr(> t)
(Intercept)	2.07110	0.30683	6.750	2.97e-11 *
Sleep_Quality	0.40851	0.03805	10.735	< 2e-16 *
Physical_Exercise	0.16321	0.04797	3.402	0.000704 *
Stress_Level	0.08198	0.05010	1.636	0.102200
Nutrition_Score	0.09706	0.04152	2.338	0.019660 *

Signif. codes: 0 ‘*’ 0.001 ‘**’ 0.01 ‘***’ 0.05 ‘.’ 0.1 ‘ ’ 1

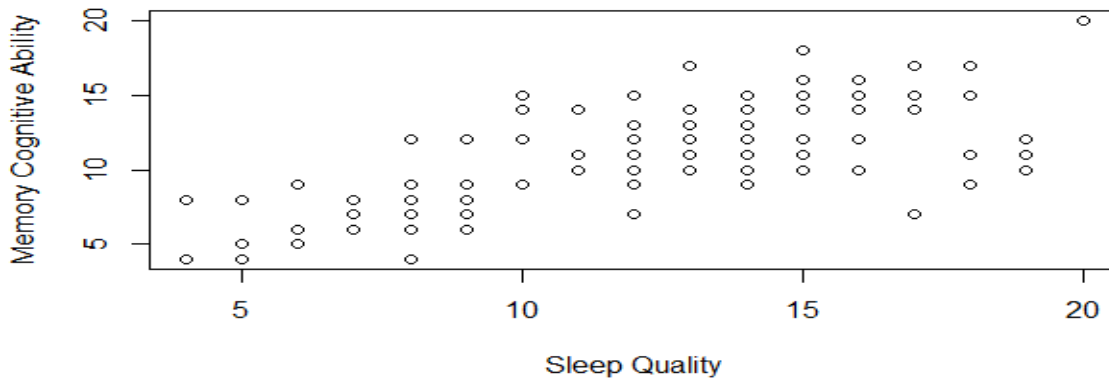
Residual standard error: 2.171 on 748 degrees of freedom
Multiple R-squared: 0.5752, Adjusted R-squared: 0.5729
F-statistic: 253.2 on 4 and 748 DF, p-value: < 2.2e-16

[Sources: Author Analysed on Primary Data]

Table 1 presents the findings of a regression analysis aimed at examining the relationship between memory cognitive ability and various environmental factors among 753 participants from Chennai. The study focused on investigating the impact of sleep quality, physical exercise, stress level, and nutrition score on memory cognitive ability. Results indicate that sleep quality and physical exercise significantly influence memory cognitive ability, as evidenced by their positive coefficients with high levels of statistical significance ($p < 0.001$). Specifically, for every unit increase in sleep quality and physical exercise, memory cognitive ability is expected to increase by approximately 0.41 and 0.16 units, respectively. Additionally, nutrition score emerges as another significant predictor, with a positive coefficient indicating that higher nutrition scores are associated with better memory cognitive ability ($p = 0.019$).

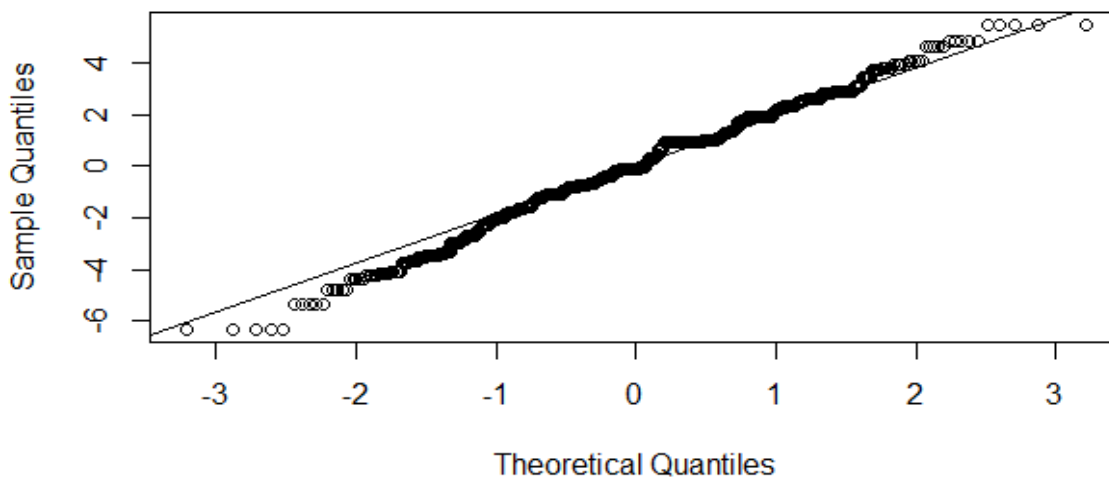
However, stress level does not appear to have a statistically significant effect on memory cognitive ability in this analysis ($p = 0.102$). These findings underscore the importance of sleep quality, physical exercise, and nutrition in maintaining optimal cognitive function. The regression model accounts for approximately 57.52% of the variance in memory cognitive ability, indicating a moderate level of explanatory power. Overall, the results contribute to our understanding of how environmental factors affects memory cognitive ability and have implications for interventions aimed at promoting cognitive health and well-being.

Scatter Plot: Memory Cognitive Ability vs Sleep Quality

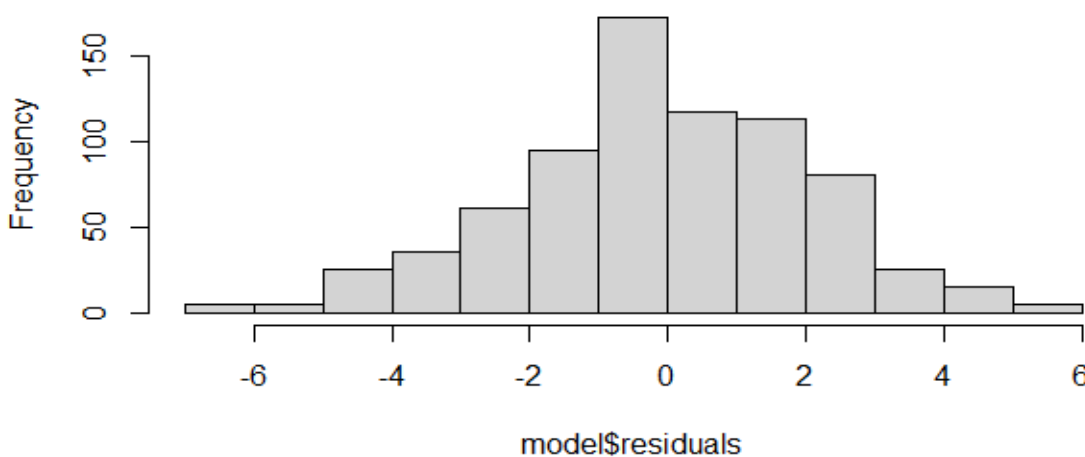


The Normal Q-Q Plot without a reference line provides a visual comparison of the quantiles of the residuals from the regression model against the quantiles of a standard normal distribution. In this plot, if the residuals are normally distributed, the points should align closely with the diagonal line (representing the theoretical quantiles). Any systematic deviations from this line indicate departures from normality, suggesting potential issues with the assumption of normality for the residuals.

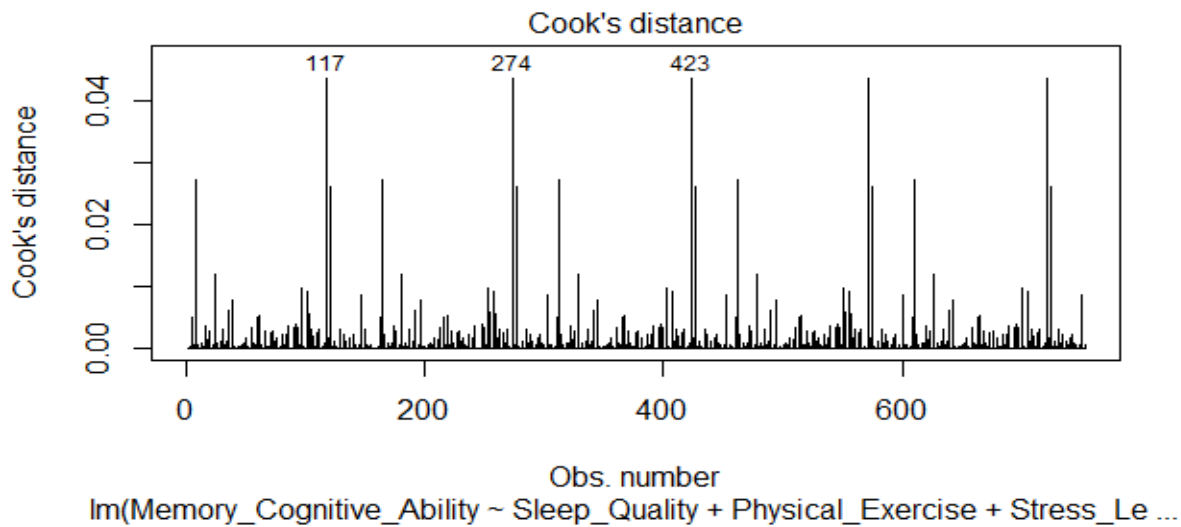
Normal Q-Q Plot



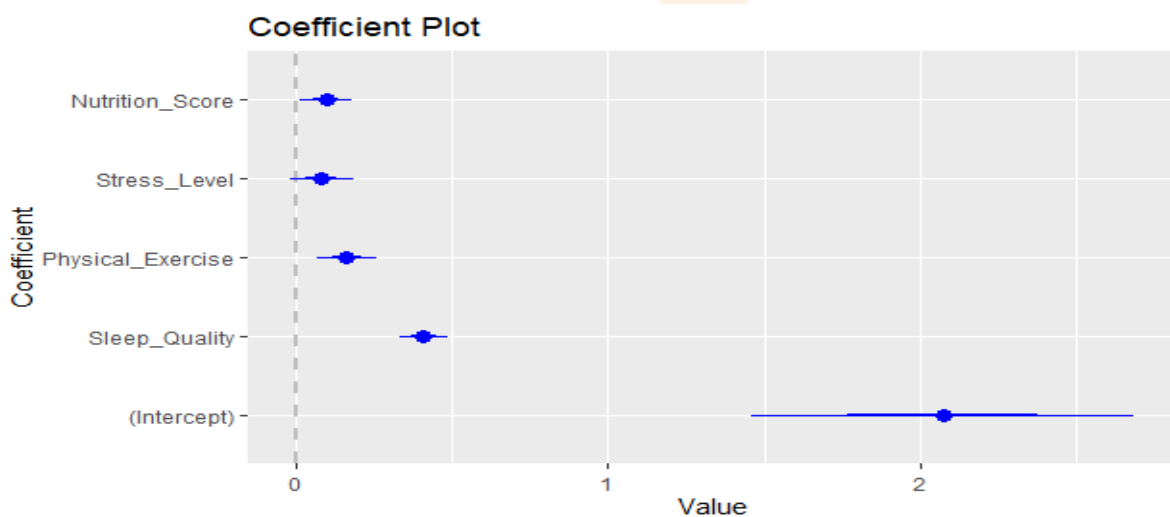
Histogram of Residuals



The Normal Q-Q Plot with Line adds a reference line to better illustrate this comparison. Again, the purpose is to check the normality of the residuals. In this plot, if the residuals fall along the reference line, it indicates that they are approximately normally distributed. However, significant deviations from the line, such as systematic patterns, indicate that the residuals do not follow a normal distribution, which can affect the validity of the regression analysis.



The Histogram of Residuals depicts the distribution of the residuals from the regression model. Ideally, if the residuals are normally distributed, the histogram should show a bell-shaped curve centered around zero. This bell-shaped distribution confirms that the errors are symmetric and follow a normal distribution, fulfilling a key assumption of linear regression. Deviations from this shape, such as skewness (asymmetry) or kurtosis (pawedness or flatness), can indicate problems with the model's assumptions.



The Cook's Distance Plot measures the influence of individual data points on the regression coefficients. Cook's distance is used to identify influential observations that have a disproportionate impact on the model. In the plot, each bar represents a data point, and bars that are significantly higher than the rest indicate points with high Cook's distances. Typically, a Cook's distance greater than one suggests an influential point. In this plot, observations 117, 274, and 423 have notably higher Cook's distances, suggesting these points have a strong influence on the regression model and may need further investigation or potential removal to ensure the model's robustness.

Finally, the Coefficient Plot visualizes the estimated regression coefficients and their confidence intervals for each predictor in the model. The points on the plot represent the estimated coefficients, while the horizontal lines extending from these points show the confidence intervals. If a confidence interval does not include zero, the corresponding predictor is considered statistically significant. In this analysis, the coefficients for sleep quality, physical exercise, and nutrition score have confidence intervals that do not cross zero, indicating their statistical significance. In contrast, the confidence interval for stress level includes zero, suggesting it is not a statistically significant predictor in the model. This plot helps in quickly identifying which predictors have a significant effect on the dependent variable and the direction and magnitude of these effects.

Conclusion

The regression analysis aimed to examine the relationship between memory cognitive ability and environmental factors such as sleep quality, physical exercise, stress level, and nutrition score among 753 participants from Chennai. The results indicate that sleep quality, physical exercise, and nutrition score significantly affect memory cognitive ability, as evidenced by their positive coefficients and high statistical significance. Specifically, improvements in sleep quality and physical exercise are associated with notable increases in cognitive ability, highlighting their crucial role in cognitive health. Nutrition score also emerged as a significant predictor, suggesting that better nutrition contributes positively to cognitive function.

The residual analysis, including Q-Q plots and the histogram, confirms that the residuals are approximately normally distributed, supporting the validity of the regression model. However, the Cook's distance plot identifies a few influential observations that may affect the model's robustness and should be examined further. The coefficient plot visually reinforces the significance of sleep quality, physical exercise, and nutrition score while indicating that stress level does not significantly affect memory cognitive ability in this sample. The findings underscore the importance of sleep quality, physical exercise, and nutrition in maintaining and enhancing cognitive function. These insights can inform interventions aimed at promoting cognitive health and well-being by focusing on these key lifestyle factors.

Future research should explore the long-term effects of improving sleep quality, physical exercise, and nutrition on cognitive function across diverse populations. Longitudinal studies could provide deeper insights into causal relationships and the potential cumulative benefits of these factors. Additionally, examining the interaction between these environmental factors and genetic predispositions could enhance personalized intervention strategies. Globally, these findings highlight the need for public health initiatives promoting healthy sleep, regular physical activity, and balanced nutrition to enhance cognitive health. Implementing such strategies could significantly affect global cognitive health, potentially reducing the burden of cognitive decline and related disorders.

References

1. Emily, Hokett., Patrick, J., Lao., Indira, C., Turney., Pablo, Martinez-Amezcu., Tiara, M., Starks., Adam, M., Brickman., Priya, Palta., Jennifer, J., Manly. (2023). Sleep quality and memory performance in a lifespan sample of racially/ethnically diverse adults. *Alzheimers & Dementia*, doi: 10.1002/alz.067737
2. Farzan, Kheirkhah., Seyed, Reza, Hosseini., Ali, Bijani., Sussan, Moudi. (2023). The Impact of Sleep Quality on Cognitive Function in Community-Dwelling Older Adults. *Elderly health journal*, doi: 10.18502/ehj.v9i1.13103
3. H., Fangfang., H., Xiao., Z., Shuai., W., Qiong., Z., Jingya., Shen, Guodong., Zhang, Yan. (2021). Living Environment, Built Environment and Cognitive Function among Older Chinese Adults: Results from a Cross-Sectional Study. doi: 10.14283/JPAD.2021.59
4. Hui, Chuan, Hsu., Chyi, Huey, Bai. (2022). Individual and environmental factors associated with cognitive function in older people: a longitudinal multilevel analysis. *BMC Geriatrics*, doi: 10.1186/s12877-022-02940-9

5. J., Wallace-Webb., Thomas, W., Service., David, Harding., Gregory, Mulligan., Lynneth, Stuart-Hill. (2022). P128 Effect of acute exercise on stress and working memory following sleep restriction. *Sleep advances*, doi: 10.1093/sleepadvances/zpac029.196
6. Jonas, Sundarakumar., Pooja, S., K., Rai., Nerella, N, Madhuri, Divya., Thomas, Issac. (2023). 0727 Association of sleep quality with memory functions among dementia-free, middle- and older-age, rural Indians. *Sleep*, doi: 10.1093/sleep/zsad077.0727
7. José, Luis, Bermejo., Raúl, Valldecabres., Israel, Villarrasa-Sapiña., Gonzalo, Monfort-Torres., Adrià, Marco-Ahulló., Bruno, Ribeiro, Do, Couto. (2022). Increased cortisol levels caused by acute resistance physical exercise impair memory and learning ability. *PeerJ*, doi: 10.7717/peerj.13000
8. Nurhidayah, Syarifuddin., Dodik, Briawan., Tiurma, Rosita, Sinaga. (2022). Sleep Quality, Stress Level, Physical Activity, and Food Consumption with Nutritional Status. *Jurnal Ilmiah Kesehatan*, doi: 10.36590/jika.v4i1.238
9. Pamela, Ponce., Alberto, Del, Arco., Paul, D., Loprinzi. (2019). Physical Activity versus Psychological Stress: Effects on Salivary Cortisol and Working Memory Performance.. *Medicina-lithuania*, doi: 10.3390/MEDICINA55050119
10. R., N., Mustafin., A., Kazantseva., R., F., Enikeeva., Sergey, Malykh., Elza, Khusnutdinova. (2020). Longitudinal genetic studies of cognitive characteristics.. *Journal of Genetics and Breeding*, doi: 10.18699/VJ20.599
11. Rania, Anan. (2022). Comparison of vegan and non-vegan diets on memory and sleep quality. doi: 10.1016/j.nutos.2022.05.005
12. Rebecca, Vendittelli. (2017). The relationship between stress, physical activity and cognitive decline with age.
13. Suh-Jung, Kang., Byung-Hoon, Kim., Hyo, Lee., Jinsung, Wang. (2022). Association among cognitive function, physical fitness, and health status in older women. *Journal of exercise rehabilitation*, doi: 10.12965/jer.2142716.358
14. T., Cruz., L., García., Miguel, Álvarez., Antonio, L., Manzanero. (2021). Sleep quality and memory function in healthy ageing.. *Neurologia*, doi: 10.1016/J.NRLENG.2018.10.024
15. Xiao, Qing, Ma., Chaoqiang, Jiang., Lin, Xu., Lin, Xu., Wei, Sen, Zhang., Feng, Zhu., Ya, Li, Jin., G., Neil, Thomas., Tai, Hing, Lam. (2020). Sleep quality and cognitive impairment in older Chinese: Guangzhou Biobank Cohort Study. *Age and Ageing*, doi: 10.1093/AGEING/AFZ120
16. Yuehong, Qiu., Zeming, Deng., Chujuan, Jiang., Kai, Wei., Lijun, Zhu., Jieting, Zhang., Can, Jiao. (2022). The Associations of Meteorological and Environmental Factors with Memory Function of the Older Age in Urban Areas. *International Journal of Environmental Research and Public Health*, doi: 10.3390/ijerph19095484

