Resting Heart Rate Is A Key Indicator Of Overall Health

STA302 Final Project Part 3

Brandon Kim, Niloshan Suseendran, Emily Pan

Contributions

Emily Pan was involved in all aspects of the project, concentrating on data cleaning, descriptive statistics, model methods, and result interpretation. Brandon Kim concentrated on introduction revision, result interpretation, conclusion, limitations, and demonstration of editing. Niloshan Suseendran concentrated on the interpretation and revision of results, as well as revising the conclusion.

Introduction

The human resting heart rate (RHR) ranges between 60 and 100 beats per minute (bpm) and is influenced by lifestyle factors such as body mass index (BMI), sleep duration, physical activity, and age (Olshansky et al., 2023). High RHR is associated with increased risks of chronic illnesses and mortality. Understanding how lifestyle factors affect RHR is key to developing preventive health strategies. By grasping this relationship, we can make informed choices that improve our well-being and reduce health risks.

RHR is an indicator of long-term health, as shown by the MATISS Project (Seccareccia et al., 2001) which followed 2,533 men over 24,457 person-years and recorded 393 deaths. The study found that for every increase in RHR, the risk of all-cause mortality increased by 52%, cardiovascular mortality by 63%, and noncardiovascular mortality by 47%. Seviiri et al. (2017) analyzed data from the Melbourne Collaborative Cohort Study (MCCS) and found that for every 10 bpm increase in RHR, the risk of cardiovascular disease, cancer, and other causes of death increased by 11%, 10%, and 20%, respectively. Sleep patterns also influence RHR. Bredeli et al. (2022) found that intraindividual variability in sleep patterns was associated with higher insomnia severity, and BMI, stressing the role of consistent lifestyles in maintaining healthy RHR levels.

This study uses multiple linear regression to identify and interpret the lifestyle factors that affect RHR. The resulting model will provide insights into lifestyle changes that can improve and sustain healthy RHR levels, thereby reducing health risks.

Methods

We analyzed data from the National Health and Nutrition Examination Survey (NHANES) conducted between 2009 and 2012 by the National Center for Health Statistics. This survey collected nationally representative data through structured home interviews and mobile examination centers. For this study, we selected variables relevant to our research question and addressed any missing values, resulting in a final dataset of 3,340 participants for analysis.

For our initial model, we fitted a multiple linear regression model using R, with Pulse (RHR) as the response variable and Age, BMI, SleepHrsNight, PhysActiveDays, and HealthGen as predictors. HealthGen was converted into dummy variables (HealthPoor, HealthFair, HealthGood, HealthVGood, HealthExcellent), with HealthGood as the reference category. Model assumptions were validated using diagnostic tools. Residuals vs. Fitted plots displayed no apparent patterns, indicating that the assumptions of linearity were satisfied. The Standardized Residuals vs. Fitted plot showed a consistent spread of residuals, supporting the assumption of constant variance. Q-Q plots and histograms of residuals evaluated the normality of residuals, revealing that the residuals were approximately normally distributed with a right skew. Minor deviations were noted at the tails due to the presence of outliers as shown in Figure 1. To improve the model, a log transformation was applied to the response.

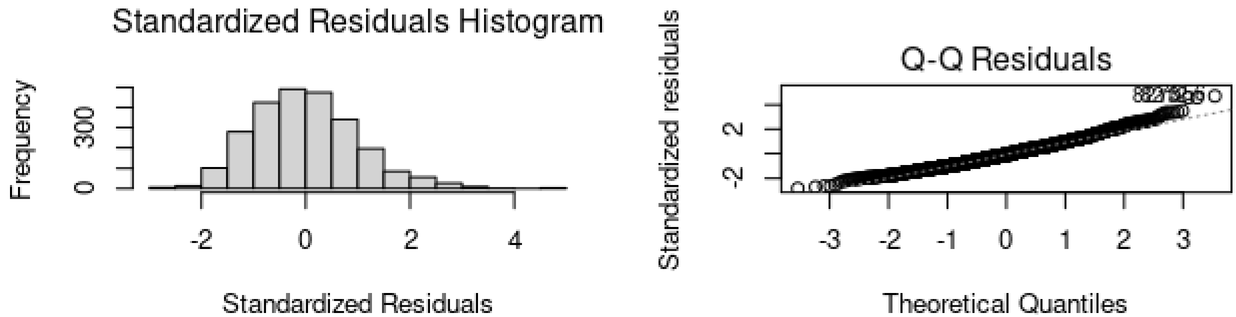

Figure 1. Diagnostic plots of the initial model: Q-Q plots and histograms of residuals indicated an approximately normal distribution with a right skew, and minor tail deviations due to outliers.

Statistical tests assessed the model and its predictors. The F-test evaluated the regression model's overall significance, while t-tests assessed individual predictors' contributions. The ANOVA test compared the full model, which included PhysActiveDays, to reduced models, revealing that PhysActiveDays was an insignificant predictor. Confidence intervals for the coefficient estimates were calculated to measure precision, with intervals including zero indicating insignificance. Multicollinearity was checked using the Variance Inflation Factor (VIF). Values were below 5 and confirmed for minimal collinearity among predictors. The goodness-of-fit between the full and reduced models was evaluated using the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC), both criteria favoured the reduced model.

Additional diagnostic tools validated the model further. Scatterplot matrices examined correlations among continuous predictors, ensuring minimal redundancy, while Cook's Distance identified influential points. Observations exceeding the threshold of 4/n were flagged as high-leverage points and retained as they represented meaningful and relevant cases for the analysis. Finally, we interpreted the model by analyzing its coefficients and their confidence intervals.

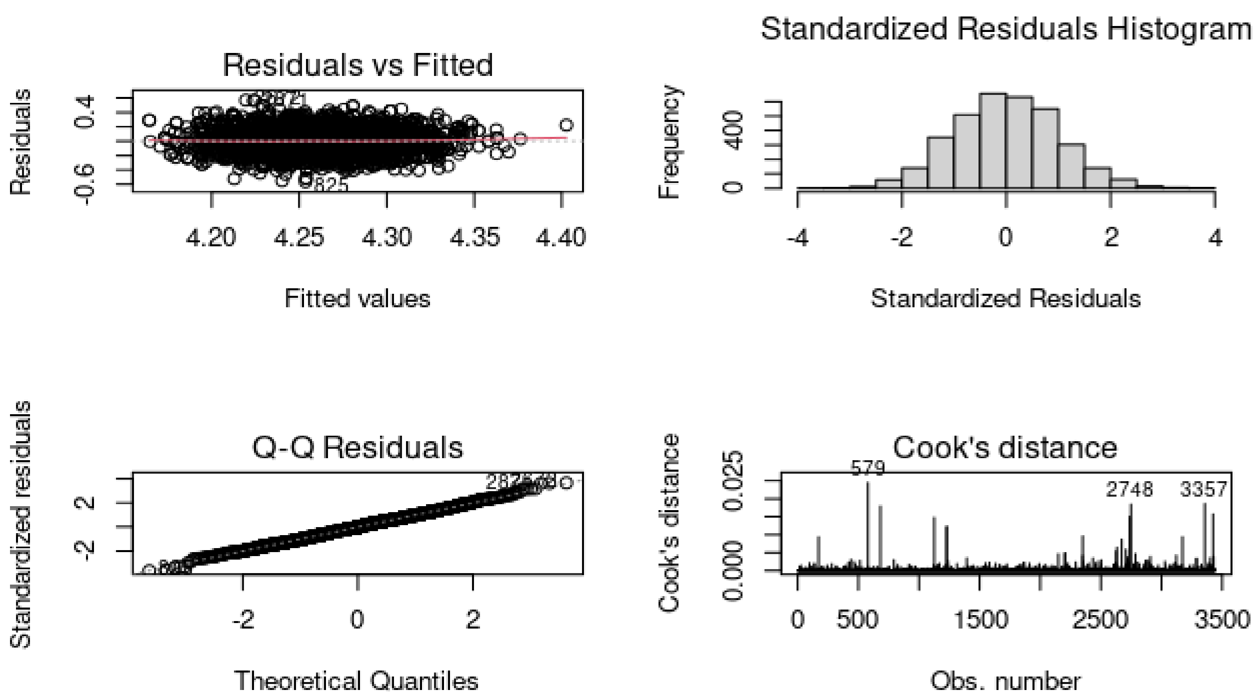

Figure 2. This figure presents diagnostic plots for evaluating the assumptions of the final model with response variable log(Pulse). The plots identify influential observations, with points 579, 2748, and 3357.

This process led to the development of a final model that used Pulse as the response variable, with predictors including Age, BMI, SleepHrsNight, and HealthGen (categorized as HealthPoor, HealthFair, HealthVGood, and HealthExcellent, with HealthGood serving as the reference category). By addressing potential issues and ensuring that the assumptions of linear regression were met, the model provided reliable and interpretable insights into the lifestyle factors that influenced RHR.

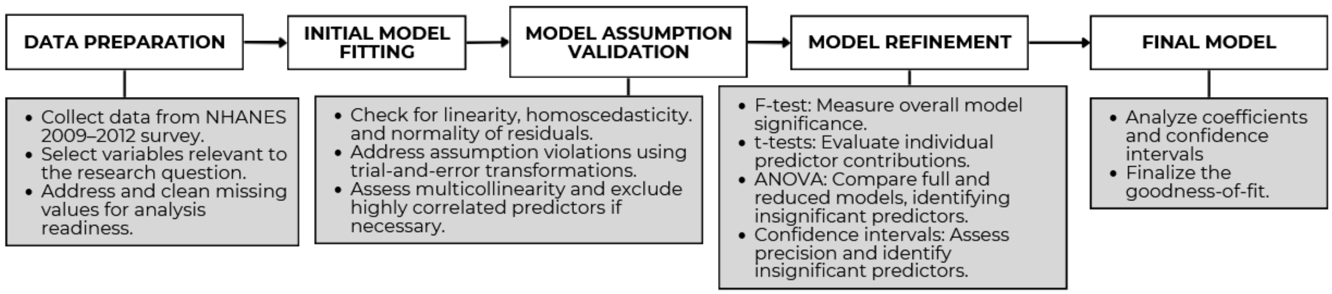

Figure 3. Methods of Analysis Flow Diagram

Results

	Min.	**1st Qu.**	**Median**	**Mean**	**3rd Qu.**	**Max.**
Pulse	40.00	64.00	70.00	71.80	78.00	120.00
Age	16.00	29.00	43.00	43.72	57.00	80.00
BMI	15.02	23.50	26.91	27.96	31.28	63.30
SleepHrsNight	2.000	6.000	7.000	6.968	8.000	12.000
PhysActiveDays	1.000	2.000	3.000	3.714	5.000	7.000
	Poor	**Fair**	**Good**	**Vgood**	**Excellent**	
HealthGen	45	377	1315	1253	450	

Table 1. This table presents descriptive statistics for the key variables used in the analysis.

Preliminary statistics (see Table 1) indicated that Pulse (RHR) ranged from 44 to 120 beats per minute (bpm), with a mean of 71.80 bpm. Participants' ages ranged from 16 to 80 years, with an average age of 43.72 years. BMI varied from 15.02 to 63.30 kg/m², averaging 27.96 kg/m². Sleep duration (SleepHrsNight) ranged from 2 to 12 hours, averaging 6.97 hours. Physical activity (PhysActiveDays) varied from 1 to 7 days per week, with an average of 3.71 days. Most participants self-reported their health status as "Good" or "Very Good."

The F-test for the initial model ($F = 18.02$, $p < 2.2e\text{-}16$) indicates that the predictors are meaningful as a group. Individual predictors were evaluated using t-tests, revealing that Age ($p < 2e{-}16$), BMI ($p = 1.23e{-}05$), SleepHrsNight ($p = 0.0003$), and HealthGen categories were significant. Specifically, HealthPoor ($p = 0.032$), HealthFair ($p = 0.031$), HealthVGood ($p = 0.021$), and HealthExcellent ($p = 0.0003$) demonstrated statistically significant contributions relative to the reference category, HealthGood. PhysActiveDays was found to be insignificant ($p = 0.291$), and its exclusion in the final model ($F = 21.23$, $p < 2e\text{-}16$) was justified based on its lack of contribution. The Residual Standard Error is 0.156, and the Adjusted R^2 is 0.03956. These figures indicate that the final model only accounts for a small portion of the variation in RHR. This low Adjusted R^2 suggests that there may be many factors influencing RHR that are not included in the model.

Confidence intervals and p-values were used to assess predictor significance. Age has a negative and significant coefficient, with a 95% confidence interval of (-0.00166, -0.00106), indicating that for each year increase, log(Pulse) decreases by 0.0014 units, suggesting older individuals have lower resting heart rates. BMI shows a positive coefficient with a 95% confidence interval of (0.00105, 0.00279), indicating that each unit increase in BMI raises log(Pulse) by 0.0019 units, suggesting higher heart rates in individuals with greater BMI. SleepHrsNight also has a positive coefficient and 95% confidence interval of (0.00346, 0.01153), suggesting that each additional hour of sleep increases log(Pulse) by 0.0075 units, indicating sleep quality may influence RHR. Further exploration of sleep quality or health indicators could provide more insights.

Participants with "Poor" health had a log(Pulse) that was 0.0509 units higher than those in "Good" health, according to a positive coefficient with a 95% confidence interval of (0.00404, 0.09727). Those in "Fair" health also had a higher log(Pulse), with a coefficient of 0.0199 units greater than "Good" health. Conversely, individuals in "Very Good" health showed a negative coefficient, indicating their log(Pulse) was 0.0145 units lower than the "Good" health group, with a confidence interval of (-0.02667, -0.00215). Finally, participants in "Excellent" health experienced the largest decrease in log(Pulse) at 0.0318 units lower than those in "Good" health, as shown by a negative coefficient and a confidence interval of (-0.04839, -0.01428).

These results indicated that poorer health was linked to higher resting heart rates (RHR), while better health was related to lower rates when compared to those categorized as "Good" health. This emphasized the importance of self-perceived health in predicting RHR. Efforts to improve general health could have positively affected heart rates and overall well-being.

We identified three influential points: 579, 2748, and 3357 (see Figure 2). Observation 579 had a high pulse rate (116 bpm), a BMI of 40.76, was 64 years old, active daily, and reported "Poor" health. Observation 2748 had a low RHR (52 bpm), a high BMI (30.20), was 52 years old, active 5 days a week, and also reported "Poor" health. Observation 3357 had a high pulse rate (108 bpm), a normal BMI (25.2), was active 7 days a week and reported "Poor" health. Observations 579 and 2748 shared poor health and high BMI, while 3357 was notable for its normal BMI but high pulse rate. Retaining these observations enhanced analytical accuracy, revealing potential underlying medical or lifestyle factors.

The results showed that a higher BMI and longer sleep durations are linked to an increased RHR. Conversely, older age and better self-reported health are associated with a lower RHR. These findings suggest that lifestyle factors significantly influence RHR, which may have implications for health interventions aimed at improving cardiovascular outcomes.

Conclusions and Limitations

This study aimed to investigate how lifestyle factors such as age, BMI, sleep duration, and physical activity influence RHR, a proven indicator of long-term overall health. Using our final model, we conclude that RHR declines with an increase in age, and perceived health, while RHR increases with an increase in BMI and sleep duration per night. Number of physical activity days was found to be insignificant. While this study identifies the significance of certain lifestyle factors, some limitations to the model include the lack of generalizability and scope, omitted variables, survey accuracy, and sampling bias. The NHANES dataset includes U.S. individuals, which could result in the lack of generalizability to other populations with varying genetics, demographics, and lifestyles. Omitting variables for statistical relevance could reduce our model's accuracy by leaving out potential correlations between predictors. For example, gender, as an omitted variable, may have shown some significant correlation concerning RHR. In addition, perceived health, number of physical activity days, and self-reported sleep duration introduce inevitable variability, bias, and human error. These three predictors may not capture the whole picture of each variable either, with nuanced answers that could vary due to day-specific feeling, exercise intensity, or sleep quality. Concerning the literature cited thus far, our results are consistent, except for sleep and physical activity, which is likely due to sampling error and omitted confounding variables. To conclude, for individuals to maintain a low RHR, they can employ the lifestyle changes of lowering BMI by eating less and healthier, and by proxy having a greater day-to-day perceived health; thereby increasing longevity and reducing health risks. Further analysis may be done to investigate the counter-intuitive sleep duration and physical activity with RHR, highlighting the potential confounding interaction variables such as sleep quality with BMI, and physical activity with age. Therefore, by decreasing RHR through natural aging and increasing perceived health in their lifestyle, individuals can reduce health risks and sustain healthy well-being.

Bibliography

Bredeli, E., Vestergaard, C. L., Sivertsen, B., Kallestad, H., Øverland, S., Ritterband, L. M., Glozier, N., Pallesen, S., Scott, J., Langsrud, K., & Vedaa, Ø. (2022). Intraindividual variability in sleep among people with insomnia and its relationship with sleep, health and Lifestyle Factors: An exploratory study. *Sleep Medicine*, *89*, 132–140. https://doi.org/10.1016/j.sleep.2021.12.006

Centers for Disease Control and Prevention. (2023). *NHANES survey methods and analytic guidelines*. https://wwwn.cdc.gov/nchs/nhanes/analyticguidelines.aspx

Olshansky, B., Ricci, F., & Fedorowski, A. (2023). Importance of resting heart rate. *Trends in Cardiovascular Medicine*, *33*(8), 502–515. https://doi.org/10.1016/j.tcm.2022.05.006

Pruim, R. (2022). Data from the US National Health and Nutrition Examination Study. Centers for Disease Control and Prevention. https://cran.r-project.org/web/packages/NHANES/NHANES.pdf

Seccareccia, F., Pannozzo, F., Dima, F., Minoprio, A., Menditto, A., Lo Noce, C., & Giampaoli, S. (2001). Heart rate as a predictor of mortality: The MATISS project. *American Journal of Public Health*, *91*(8), 1258–1263. https://doi.org/10.2105/ajph.91.8.1258

Seviiri, M., Lynch, B. M., Hodge, A. M., Yang, Y., Liew, D., English, D. R., Giles, G. G., Milne, R. L., & Dugué, P.-A. (2017). Resting heart rate, temporal changes in resting heart rate, and overall and cause-specific mortality. *Heart*, *104*(13), 1076–1085. https://doi.org/10.1136/heartjnl-2017-312251