Linear Regression Analysis Reveal Minimal Association Between Biological Age and Dementia Onset*

A deep dive on the relationship between patient age and length before dementia onset

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Dementia is a multifacted set of conditions whose prevalence is strongly associated with age. A simple linear regression model on Korea Health Panel survey data using biological age at the baseline is constructed to examine the isolated influence on time until dementia onset. Results show a lack of linear relationship, with age alone only explaining a small proportion of the variation in time until onset. Future studies of age's impact on dementia require more complex modeling techniques and data transformations.

1 Introduction

Dementia refers to a set of conditions related to cognitive decline with various causes and risk factors ("Dementia - Symptoms and Causes" (2025)). Symptoms may include memory loss, disorientation, poor coordination, depression, and anxiety. As populations all around the world continue to age, the increasing physical and financial impact of dementia is a public health issue that should be thoroughly investigated. In the past, the highest risk factor has been recognized as chronological age as dementia prevalence increases with it (Daviglus et al. (2010)). However, subsequent research suggests that subjective age, the difference between one's biological age and how old they feel, may hold greater influence on risk of dementia (Kotter-Grühn (2016)).

Because dementia is a complicated condition, a simple linear regression model with the predictor variable of age will be insufficient in capturing nuanced associations but serves as a valuable starting point. Previous research tackled dementia modeling more holistically, but it remains

*Project repository available at: https://github.com/christiecngo/math261a_project1.

important to fully understand the relationship with biological age. Subjective age is a qualitative assessment and is often not reported. In China, a team of researchers studied dementia risk among rural seniors using Cox models but kept education, marital status, self-rated AD8 score, and stroke history in addition to age (Liu et al. (2025)).

This paper aims to isolate the usefulness of considering the more widely available demographic, biological age, for determining time of dementia onset. We will first introduce the dementia study dataset of interest followed by construction of a simple linear regression model. After this, we assess the model's fit and discuss implications of these results.

2 Data

The data is a subset from the Korea Health Panel (KHP) surveys from 2006 to 2018 (Islam et al. (2025)). This computer-assisted data collection process is conducted by the Korea Institute for Health and Social Affairs and the National Health Insurance Service (NHIS); it occurs annually for households selected using clustered probability sampling on population census data (Chung 2022). More comprehensive alternative sources of this survey would include more participants of interest with other additional survey responses included.

For the question of interest, filtering this dataset to only distinct participants who have developed dementia at some point in the study. This led to only 2% of the original cohort remaining (216/10811 rows). Each row represents one participant's response during each survey wave since the study started. We are only interested in the age of the first recorded onset, discarding all prior and subsequent rows based on participant's unique identifiers; thus, our scope does track the mortality of the participants. The participants are all over 65 years old and may have had multiple rows originally listed if they have been observed for more than one period. The original cohort had also included many other seniors who have not developed dementia, who were all excluded.

Because our data was collected using computer technology, we may be excluded results of those in more remote areas and less Internet access. The data is extremely right skewed with the minimum age being 65 years old and median of 70. We cannot extrapolate to earlier onsets of dementia, likely accelerated by other conditions.

It should be noted that the interquartile range of biological age at baseline is only 7 years. The distribution of dementia onset days is almost uniform with a small peak in the middle of the range and a large one near the maximum.

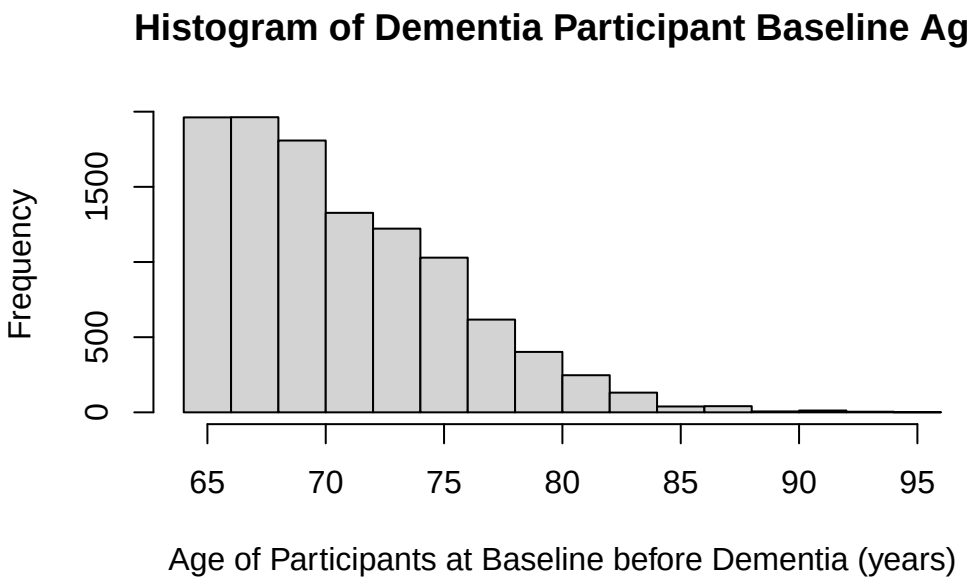


Figure 1: A histogram for distribution of participant biological age at baseline recording.

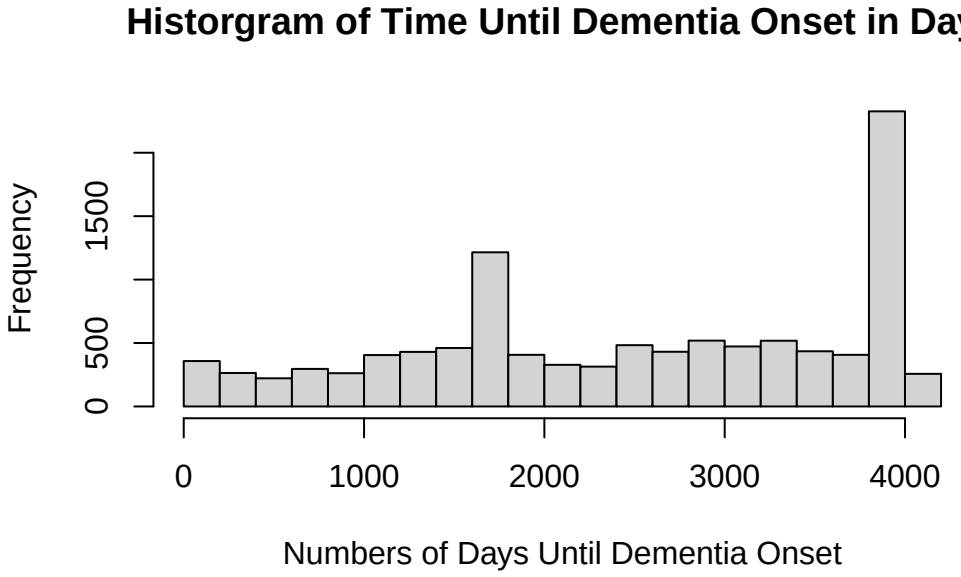
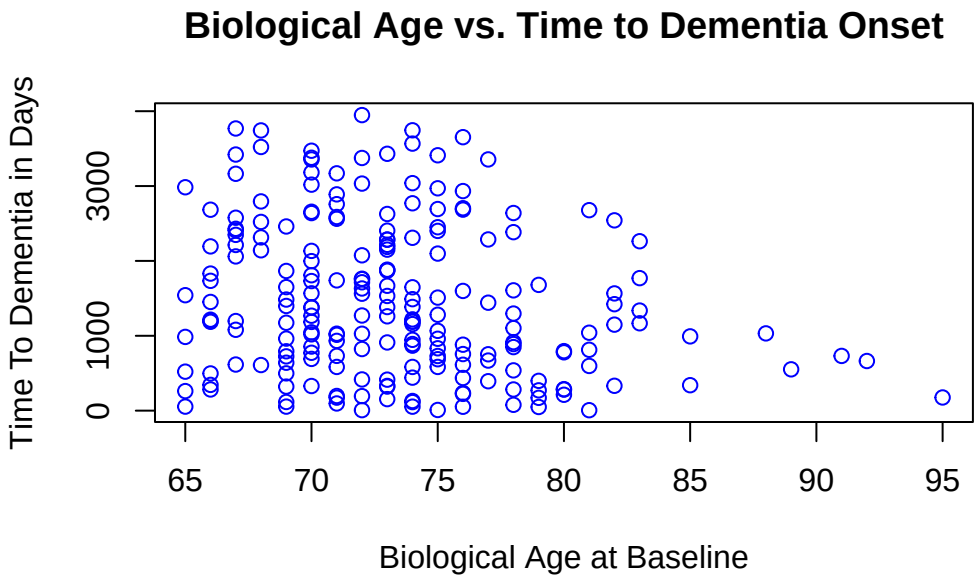


Figure 2: A histogram for the distribution of days until first dementia onset in days.

3 Methods

Model fitting was completed using R Core Team (2020)'s "lm()" function and data was preprocessed with help of the package "dplyr". The final cohort is obtained by filtering for the earliest instance of a dementia recording for patients who eventually developed dementia. This led to a data size of 216 distinct participants.

OpenAI (2025) was also used to better understand implications of linear regression violations.



The motivation for using a simple linear regression model is to utilize a formal mean to express a statistical relationship between two variables, where there is a probability distribution for the response Y for each level of predictor X; the means for the probability distributions vary with X in a systematic way (Kutner et al. (2005)). A linear regression model is considered "simple" when there is only one predictor variable. The chosen model is linear in both parameters and predictor variables because all parameters appear without a mathematical operation and the predictor exists only in the first power. In our case, the sole predictor is the age of the participant at the baseline date before the onset of dementia. Our measured response is duration in days until the onset of dementia from the initial baseline date. This overall model takes the form:

$$Y_i = \beta_0 + \beta_1 X_i + \epsilon_i$$

i ranges from 1 to the number of observations in the dataset. The term ϵ_i captures the noise or randomness within the real-world observations that is not included in the regression model.

β_0 is the intercept that corresponds to the value if the participant's age were 0. β_1 is the slope of the model, representing the change in response Y when there is a unit increase in predictor X.

In order to consider how well our linear regression model fit the data, we will consider residuals. Residuals are the difference between the actual observed value and what the linear regression predicted. They are given by this formula:

$$e_i = Y_i - \hat{Y}_i$$

Summing up all residuals will give us the SSE, or error sum of squares. SSR is the regression sum of squares and accounts for the variation of the fitted values around the mean of observed values. SSTO is the total sum of squares, a combination of the two previous metrics.

$$SSTO = SSR + SSE$$

$$\sum (Y_i - \bar{Y})^2 = \sum (\hat{Y}_i - \bar{X})^2 + \sum (Y_i - \hat{Y}_i)$$

The amount of deviation explained by SSR, or regression line, out of the total deviation gives rise to the R^2 metric. We will be using this to determine how well the model fits the data.

$$R^2 = \frac{SSR}{SSTO} = 1 - \frac{SSE}{SSTO}$$

4 Results

A simple linear regression model revealed that using age alone only accounts for a trivial proportion of relationship between dementia onset duration and biological age. Only approximately 5% of the variation in onset length was explained after factoring in age (R^2= 0.0499767).

If the residual plot is randomly scattered, it implies that the model contributes to errors all around 0, without bias. Our residuals appear to be randomly scattered; thus, linear modeling is appropriate as shown in Figure 3, meaning our linear modeling is appropriate. In order to achieve reliable, accurate confidence intervals and p-values, we require the errors to be independent, normal, and have constant variance. Confidence intervals at level $1 - \alpha$ imply that repeating the sampling process will result in the true population parameter captured in $(1 - \alpha)\%$ of the intervals The p-value represents the probability of observing a sample statistic as or more extreme under the null hypothesis.

Disregarding a small section on left side of the plot, the rest of the residuals seem to uphold constant variance. Errors are also independent as we have filtered to a unique entry per

participant, each with their own healthcare regimen. The Quantile Quantile-plot is showing only a bit of deviation towards the tail ends, implying normality is mostly unviolated (Figure 4). This plots compares the actual quantiles to the proposed normal distribution with the red line representing perfect fit.

Overall, the summary report of the linear model does reveal a notable negative association between participant's biological age and the time it takes for them to develop dementia. β_1 is -42.9052266, meaning that there is an expected decrease of 43 days in dementia onset time given a 1 year increase in age. If we construct a hypothesis test to examine if the slope of age is 0 (that is, there exists a linear association with time to dementia onset), we obtain significant p-value of 9.3805132×10^{-4}.

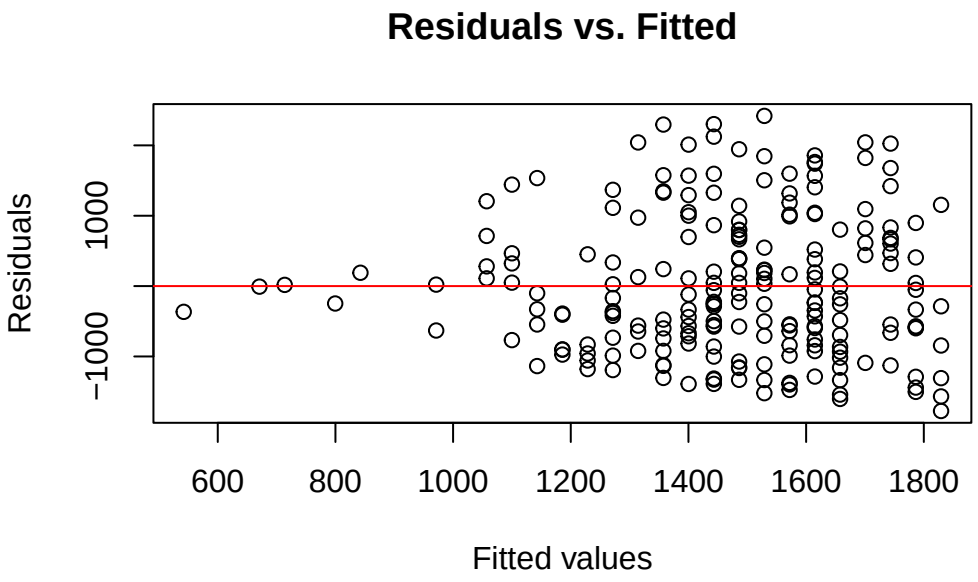


Figure 3: The residuals of the linear regression model appear to be randomly scattered

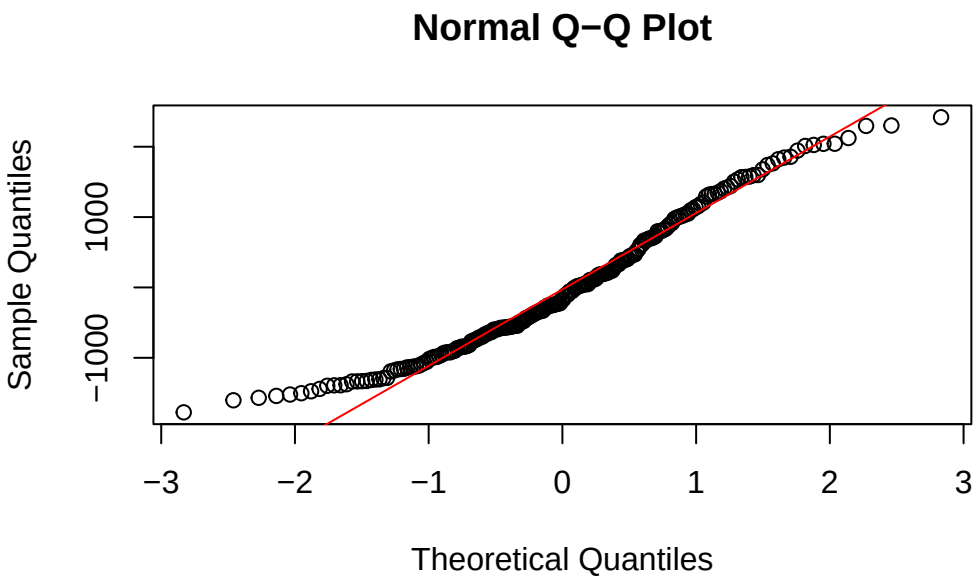


Figure 4: The QQ-plot shows only slight curvature towards the tail ends

5 Discussion

Since there is low explainability from this simple linear regression model, more advanced models that include interaction terms and data transformations may reveal more accurate inference of dementia onset using a participant's health profile. Due to lack of linear assumption violations, continuation with more complex parametric techniques seems most appropriate for this dataset. Though biological age has a significant negative association, there is still a lack of ability to predict dementia onset duration. Our limited dataset of dementia participants hinders the generalizability of these regression results. Additionally, since age is a factor that can contribute confounding relationships with other comorbidities, studying interaction terms can help improve the model.

Ultimately, the issue of predicting time to dementia onset based on only biological age oversimplifies the complicated set of conditions with many possible influences. To consider the impact of varying health stages, the subjective age approach suggested by Kotter-Grühn (2016) is a reasonable proxy to explore next.

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