Advanced Epidemiological Analysis

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2021-08-16

Contents

Chapter 1

Overview

This is a the coursebook for the Colorado State University course ERHS 732, Advanced Epidemiological Analysis. This course provides the opportunity to implement theoretical expertise through designing and conducting advanced epidemiologic research analyses and to gain in-depth experience analyzing datasets from the environmental epidemiology literature.

This book is in development over the Fall 2021 semester.

1.1 License

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Chapter 2

Course information

This is a the coursebook for the Colorado State University course ERHS 732, Advanced Epidemiological Analysis. This course provides the opportunity to implement theoretical expertise through designing and conducting advanced epidemiologic research analyses and to gain in-depth experience analyzing datasets from the environmental epidemiology literature. This course will complement the student's training in advanced epidemiological methods, leveraging regression approaches and statistical programming, providing the opportunity to implement their theoretical expertise through designing and conducting advanced epidemiologic research analyses. During the course, students will gain in-depth experience analyzing two datasets from the environmental epidemiology literature—(1) time series data with daily measures of weather, air pollution, and cardiorespiratory outcomes in London, England and (2) a dataset with measures from the Framingham Heart Study. Additional datasets and studies will be discussed and explored as a supplement.

This class will utilize a variety of instructional formats, including short lectures, readings, topic specific examples from the substantive literature, discussion and directed group work on in-course coding exercises putting lecture and discussion content into practice. A variety of teaching modalities will be used, including group discussions, student directed discussions, and in-class group exercises. It is expected that before coming to class, students will read the required papers for the week, as well as any associated code included in the papers' supplemental materials. Students should come to class prepared to do statistical programming (i.e., bring a laptop with statistical software, download any datasets needed for the week etc). Participation is based on in-class coding exercises based on each week's topic. If a student misses a class, they will be expected to complete the in-course exercise outside of class to receive credit for participation in that exercise. Students will be required to do mid-term and final projects which will be presented in class and submitted as a written write-up describing the project.

Prerequisites for this course are:

- ERHS 534 or ERHS 535 and
- ERHS 640 and
- STAR 511 or STAT 511A or STAT 511B

2.1 Course learning objectives

The learning objectives for this proposed course complement core epidemiology and statistics courses required by the program and provide the opportunity for students to implement theoretical skills and knowledge gained in those courses in a more applied setting.

Upon successful completion of this course students will be able to:

1. List several possible statistical approaches to answering an epidemiological research questions. (*Knowledge*)
2. Choose among analytical approaches learned in previous courses to identify one that is reasonable for an epidemiological research question. (*Application*)
3. Design a plan for cleaning and analyzing data to answer an epidemiological research question, drawing on techniques learned in previous and concurrent courses. (*Synthesis*)
4. Justify the methods and code used to answer an epidemiological research question. (*Evaluation*)
5. Explain the advantages and limitations of a chosen methodological approach for evaluating epidemiological data. (*Evaluation*)
6. Apply advanced epidemiological methods to analyze example data, using a regression modeling framework. (*Application*)
7. Apply statistical programming techniques learned in previous courses to prepare epidemiological data for statistical analysis and to conduct the analysis. (*Application*)
8. Interpret the output from statistical analyses of data for an epidemiological research question. (*Evaluation*)
9. Defend conclusions from their analysis. (*Comprehension*)
10. Write a report describing the methods, results, and conclusions from an epidemiological analysis. (*Application*)
11. Construct a reproducible document with embedded code to clean and analyze data to answer an epidemiological research question. (*Application*)

2.2 Meeting time and place

The class will meet on Mondays, 2:00–3:40 PM on the Colorado State University campus in MRB 312.

2.3 Class Structure and Expectations

- **Homework/preparation:** Every two weeks we will focus on a different topic. It is expected that *before* coming to class, students will read the required papers for the week, as well as any associated code included in the papers' supplemental materials. Students should come to class prepared to prepared to do statistical programming (i.e., bring in a laptop with statistical software, download any datasets needed for the week).
- **In-class schedule:**
  - Topic overview: Each class will start with a vocabulary quiz on a select number of the words from the chapter's vocabulary list.
  - Discussion of analysis and coding points: Students and faculty will be divided into small groups to discuss the chapter and think more deeply about the content. This is a time to bring up questions and relate the chapter concepts to other datasets and/or analysis methods you are familiar with.
  - Group work: In small groups, students will work on designing an epidemiological analysis for the week's topic and developing code to implement that analysis. Students will use the GitHub platform to work collaboratively during and between class meetings.
  - Wrap-up: We will reconvene as one group at the end to discuss topics that came up in small group work and to outline expectations for students before the next meeting.

2.4 Course grading

Assessment Components	Percentage of Grade
Midterm written report	30
Midterm presentation	15
Final written report	30
Final presentation	15
Participation in in-course exercises	10

2.5 Textbooks and Course Materials

Readings for this course will focus on peer-reviewed literature that will be posted for the students in the class. Additional references that will be useful to students throughout the semester include:

- Garrett Grolemund and Hadley Wickham, *R for Data Science*, O'Reilly, 2017. (Available for free online at https://r4ds.had.co.nz/ and in print through most large book sellers.)
- Miguel A. Hernán and James M. Robins, *Causal Inference: What If*, Boca Raton: Chapman & Hall/CRC, 2020. (Available for free online at https://cdn1.sph.harvard.edu/wp-content/uploads/sites/1268/2021/01/ciwha

tif_hernanrobins_31jan21.pdf with a print version anticipated in 2021.)
- Francesca Dominici and Roger D. Peng, *Statistical Methods for Environmental Epidemiology with R*, Springer, 2008. (Available online through the CSU library or in print through Springer.)

Chapter 3

Time series / case-crossover study designs

We'll start by exploring common characteristics in time series data for environmental epidemiology. In the first have of the class, we're focusing on a very specific type of study—one that leverages large-scale vital statistics data, collected at a regular time scale (e.g., daily), combined with large-scale measurements of a climate-related exposure, with the goal of estimating the typical relationship between the level of the exposure and risk of a health outcome. For example, we may have daily measurements of particulate matter pollution for a city, measured daily at a set of Environmental Protection Agency (EPA) monitors. We want to investigate how risk of cardiovascular mortality changes in the city from day to day in association with these pollution levels. If we have daily counts of the number of cardiovascular deaths in the city, we can create a statistical model that fits the exposure-response association between particulate matter concentration and daily risk of cardiovascular mortality. These statistical models—and the type of data used to fit them—will be the focus of the first part of this course.

3.1 Readings

The required readings for this chapter are:

- Bhaskaran et al. (2013) This paper provides an overview of time series regression in environmental epidemiology.
- Vicedo-Cabrera et al. (2019) This paper provides a tutorial of all the steps for a projecting of health impacts of temperature extremes under climate change. One of the steps is to fit the exposure-response association using present-day data (the section on "Estimation of Exposure-Response Associations" in the paper). In this chapter, we will go into details on

that step, and that section of the paper is the only required reading for this chapter. Later in the class, we'll look at other steps covered in this paper. Supplemental material for this paper is available to download by clicking http://links.lww.com/EDE/B504. You will need the data in this supplement for the exercises for class.

The following are supplemental readings (i.e., not required, but may be of interest) associated with the material in this chapter:

- Armstrong et al. (2012) Commentary that provides context on how epidemiological research on temperature and health can help inform climate change policy.
- Armstrong et al. (2014) This paper describes different data structures for case-crossover data, as well as how conditional Poisson regression can be used in some cases to fit a statistical model to these data. Supplemental material for this paper is available at https://bmcmedresmethodol.biomedcentral.com/articles/10.1186/1471-2288-14-122#Sec13.
- Imai et al. (2015) Typically, the time series study design covered in this chapter is used to study non-communicable health outcomes. This paper discusses opportunities and limitations in applying a similar framework for infectious disease.
- Lu and Zeger (2007) Heavier on statistics. This paper shows how, under conditions often common for environmental epidemiology studies, case-crossover and time series methods are equivalent.
- Gasparrini (2014) Heavier on statistics. This provides the statistical framework for the distributed lag model for environmental epidemiology time series studies.

3.2 Time series data

Let's start by exploring the type of dataset that can be used for these time series–style studies in environmental epidemiology. In the examples in this chapter, we'll be using data that comes as part of the Supplemental Material in on of this chapter's required readings, Vicedo-Cabrera et al. (2019) . Follow the link for the supplement for this article and then look for the file "lndn_obs.csv". This is the file we'll use as the example data in this chapter.

These data are saved in a csv format (that is, a plain text file, with commas used as the delimiter), and so they can be read into R using the `read_csv` function from the `readr` package (part of the tidyverse). For example, you can use the following code to read in these data, assuming you have saved them in a "data" subdirectory of your current working directory:

```
library(tidyverse) # Loads all the tidyverse packages, including readr
obs <- read_csv("data/lndn_obs.csv")
obs
```

```
## # A tibble: 8,279 x 14
##    date        year month   day   doy dow     all all_0_64 all_65_74 all_75_84
##    <date>     <dbl> <dbl> <dbl> <dbl> <chr> <dbl>    <dbl>     <dbl>     <dbl>
##  1 1990-01-01  1990     1     1     1 Mon     220       38        38        82
##  2 1990-01-02  1990     1     2     2 Tue     257       50        67        87
##  3 1990-01-03  1990     1     3     3 Wed     245       39        59        86
##  4 1990-01-04  1990     1     4     4 Thu     226       41        45        77
##  5 1990-01-05  1990     1     5     5 Fri     236       45        54        85
##  6 1990-01-06  1990     1     6     6 Sat     235       48        48        84
##  7 1990-01-07  1990     1     7     7 Sun     231       38        49        96
##  8 1990-01-08  1990     1     8     8 Mon     235       46        57        76
##  9 1990-01-09  1990     1     9     9 Tue     250       48        54        96
## 10 1990-01-10  1990     1    10    10 Wed     214       44        46        62
## # ... with 8,269 more rows, and 4 more variables: all_85plus <dbl>,
## #   tmean <dbl>, tmin <dbl>, tmax <dbl>
```

This example dataset shows many characteristics that are common for datasets for time series studies in environmental epidemiology. Time series data are essentially a sequence of data points repeatedly taken over a certain time interval (e.g., day, week, month etc). General characteristics of time series data for environmental epidemiology studies are:

- Observations are given at an aggregated level. For example, instead of individual observations for each person in London, the `obs` data give counts of deaths throughout London. The level of aggregation is often determined by geopolitical boundaries, for example, counties or ZIP codes in the US.
- Observations are given at regularly spaced time steps over a period. In the `obs` dataset, the time interval is day. Typically, values will be provided continuously over that time period, with observations for each time interval. Occasionally, however, the time series data may only be available for particular seasons (e.g., only warm season dates for an ozone study), or there may be some missing data on either the exposure or health outcome over the course of the study period.
- Observations are available at the same time step (e.g., daily) for (1) the health outcome, (2) the environmental exposure of interest, and (3) potential time-varying confounders. In the `obs` dataset, the health outcome is mortality (from all causes; sometimes, the health outcome will focus on a specific cause of mortality or other health outcomes such as hospitalizations or emergency room visits). Counts are given for everyone in the city for each day (`all` column), as well as for specific age categories (`all_0_64` for all deaths among those up to 64 years old, and so on). The exposure of interest in the `obs` dataset is temperature, and three metrics of this are included (`tmean`, `tmin`, and `tmax`). Day of the week is one time-varying factor that could be a confounder, or at least help explain variation in the outcome (mortality). This is included through the `dow` variable in the `obs` data. Sometimes, you will also see a marker for holidays included as a potential time-varying confounder, or other exposure variables (temperature

is a potential confounder, for example, when investigating the relationship between air pollution and mortality risk).

- Multiple metrics of an exposure and / or multiple health outcome counts may be included for each time step. In the `obs` example, three metrics of temperature are included (minimum daily temperature, maximum daily temperature, and mean daily temperature). Several counts of mortality are included, providing information for specific age categories in the population. The different metrics of exposure will typically be fit in separate models, either as a sensitivity analysis or to explore how exposure measurement affects epidemiological results. If different health outcome counts are available, these can be modeled in separate statistical models to determine an exposure-response function for each outcome.

3.3 Exploratory data analysis

When working with time series data, it is helpful to start with some exploratory data analysis. This type of time series data will often be secondary data—it is data that was previously collected, as you are re-using it. Exploratory data analysis is particularly important with secondary data like this. For primary data that you collected yourself, following protocols that you designed yourself, you will often be very familiar with the structure of the data and any quirks in it by the time you are ready to fit a statistical model. With secondary data, however, you will typically start with much less familiarity about the data, how it was collected, and any potential issues with it, like missing data and outliers.

Exploratory data analysis can help you become familiar with your data. You can use summaries and plots to explore the parameters of the data, and also to identify trends and patterns that may be useful in designing an appropriate statistical model. For example, you can explore how values of the health outcome are distributed, which can help you determine what type of regression model would be appropriate, and to see if there are potential confounders that have regular relationships with both the health outcome and the exposure of interest. You can see how many observations have missing data for the outcome, the exposure, or confounders of interest, and you can see if there are any measurements that look unusual. This can help in identifying quirks in how the data were recorded—for example, in some cases ground-based weather monitors use -99 or -999 to represent missing values, definitely something you want to catch and clean-up in your data (replacing with R's `NA` for missing values) before fitting a statistical model!

The following applied exercise will take you through some of the questions you might want to answer through this type of exploratory analysis. In general, the `tidyverse` suite of R packages has loads of tools for exploring and visualizing data in R. The `lubridate` package from the `tidyverse`, for example, is an excellent tool for working with date-time data in R, and time series data will typically have at least one column with the timestamp of the observation (e.g., the date for daily data). You may find it worthwhile to explore this package some more. There is a helpful chapter in Wickham and Grolemund (2016), https://r4ds.had.co.nz/dates-and-times.html, as well as a cheatsheet at https://evoldyn.gitlab.io/evomics-2018/ref-sheets/R_lubridate.pdf. For visualizations, if you are still learning techniques in R, two books you may find useful are Healy (2018) (available online at https://socviz.co/) and Chang (2018) (available online at http://www.cookbook-r.com/Graphs/).

Applied: Exploring time series data

Read the example time series data into R and explore it to answer the following questions:

1. What is the study period for the example `obs` dataset? (i.e., what dates / years are covered by the time series data?)
2. Are there any missing dates (i.e., dates with nothing recorded) within this time period? Are there any recorded dates where health outcome measurements are missing? Any where exposure measurements are missing?
3. Are there seasonal trends in the exposure? In the outcome?
4. Are there long-term trends in the exposure? In the outcome?
5. Is the outcome associated with day of week? Is the exposure associated with day of week?

Based on your exploratory analysis in this section, talk about the potential for confounding when these data are analyzed to estimate the association between daily temperature and city-wide mortality. Is confounding by seasonal trends a concern? How about confounding by long-term trends in exposure and mortality? How about confounding by day of week?

Applied exercise: Example code

1. **What is the study period for the example `obs` dataset? (i.e., what dates / years are covered by the time series data?)**

In the `obs` dataset, the date of each observation is included in a column called `date`. The data type of this column is "Date"—you can check this by using the `class` function from base R:

```
class(obs$date)
```

```
## [1] "Date"
```

Since this column has a "Date" data type, you can run some mathematical function calls on it. For example, you can use the `min` function from base R to get the earliest date in the dataset and the `max` function to get the latest.

```
min(obs$date)
```

```
## [1] "1990-01-01"
```

```
max(obs$date)
```

```
## [1] "2012-08-31"
```

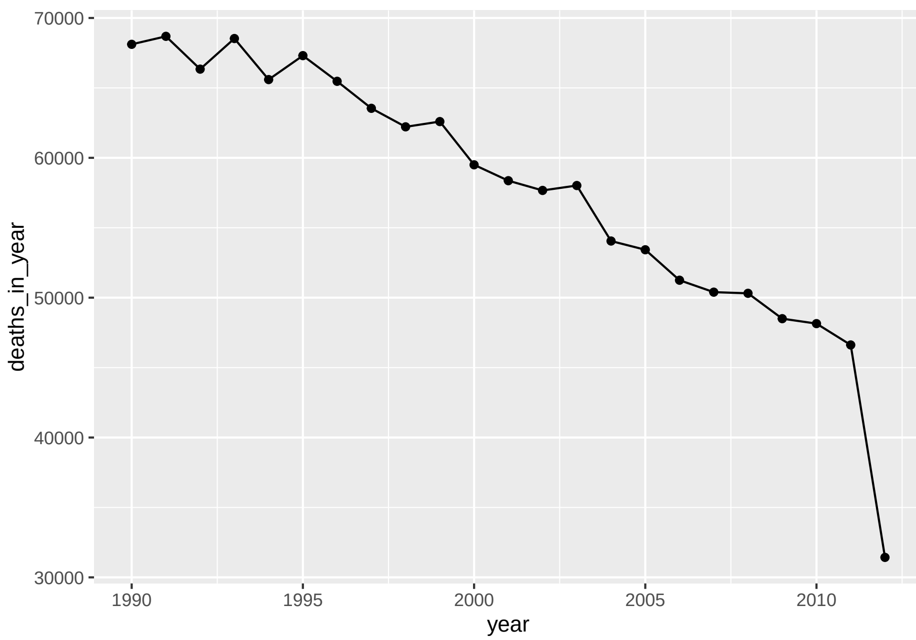
You can also run the `range` function to get both the earliest and latest dates with a single call:

```
range(obs$date)
```

```
## [1] "1990-01-01" "2012-08-31"
```

This provides the range of the study period for these data. One interesting point is that it's not a round set of years—instead, the data ends during the summer of the last study year. This doesn't present a big problem, but is certainly something to keep in mind if you're trying to calculate yearly averages of any values for the dataset. If you're getting the average of something that varies by season (e.g., temperature), it could be slightly weighted by the months that are included versus excluded in the partial final year of the dataset. Similarly, if you group by year and then count totals by year, the number will be smaller for the last year, since only part of the year's included. For example, if you wanted to count the total deaths in each year of the study period, it will look like they go down a lot the last year, when really it's only because only about half of the last year is included in the study period:

```
obs %>%
  group_by(year) %>%
  summarize(deaths_in_year = sum(all)) %>%
  ggplot(aes(x = year, y = deaths_in_year)) +
  geom_line() +
  geom_point()
```



2. **Are there any missing dates within this time period? Are there any recorded dates where health outcome measurements are missing? Any where exposure measurements are missing?**

There are a few things you should check to answer this question. First (and easiest), you can check to see if there are any `NA` values within any of the observations in the dataset. This helps answer the second and third parts of the question. The `summary` function will provide a summary of the values in each column of the dataset, including the count of missing values (`NA`s) if there are any:

```
summary(obs)
```

```
##       date                 year          month             day
##  Min.   :1990-01-01   Min.   :1990   Min.   : 1.000   Min.   : 1.00
##  1st Qu.:1995-09-01   1st Qu.:1995   1st Qu.: 3.000   1st Qu.: 8.00
##  Median :2001-05-02   Median :2001   Median : 6.000   Median :16.00
##  Mean   :2001-05-02   Mean   :2001   Mean   : 6.464   Mean   :15.73
##  3rd Qu.:2006-12-31   3rd Qu.:2006   3rd Qu.: 9.000   3rd Qu.:23.00
##  Max.   :2012-08-31   Max.   :2012   Max.   :12.000   Max.   :31.00
##       doy           dow                 all          all_0_64
##  Min.   :  1.0   Length:8279        Min.   : 81.0   Min.   : 9.0
##  1st Qu.: 90.5   Class :character   1st Qu.:138.0   1st Qu.:27.0
##  Median :180.0   Mode  :character   Median :157.0   Median :32.0
##  Mean   :181.3                      Mean   :160.2   Mean   :32.4
##  3rd Qu.:272.0                      3rd Qu.:178.0   3rd Qu.:37.0
```

```
##  Max.   :366.0                      Max.   :363.0   Max.   :64.0
##    all_65_74      all_75_84        all_85plus         tmean
##  Min.   : 6.00   Min.   : 17.00   Min.   : 17.00   Min.   :-5.503
##  1st Qu.:23.00   1st Qu.: 41.00   1st Qu.: 39.00   1st Qu.: 7.470
##  Median :29.00   Median : 49.00   Median : 45.00   Median :11.465
##  Mean   :30.45   Mean   : 50.65   Mean   : 46.68   Mean   :11.614
##  3rd Qu.:37.00   3rd Qu.: 58.00   3rd Qu.: 53.00   3rd Qu.:15.931
##  Max.   :70.00   Max.   :138.00   Max.   :128.00   Max.   :29.143
##       tmin             tmax
##  Min.   :-8.940   Min.   :-3.785
##  1st Qu.: 3.674   1st Qu.:10.300
##  Median : 7.638   Median :14.782
##  Mean   : 7.468   Mean   :15.058
##  3rd Qu.:11.438   3rd Qu.:19.830
##  Max.   :20.438   Max.   :37.087
```

Based on this analysis, all observations are complete for all dates included in the dataset. There are no listings for `NA`s for any of the columns, and this indicates no missing values in the dates for which there's a row in the data.

However, this does not guarantee that every date between the start date and end date of the study period are included in the recorded data. Sometimes, some dates might not get recorded at all in the dataset, and the `summary` function won't help you determine when this is the case. One common example in environmental epidemiology is with ozone pollution data. These are sometimes only measured in the warm season, and so may be shared in a dataset with all dates outside of the warm season excluded.

There are a few alternative explorations you can do to check this. Perhaps the easiest is to check the number of days between the start and end date of the study period, and then see if the number of observations in the dataset is the same:

```
# Calculate number of days in study period
obs %>%             # Using piping (%>%) throughout to keep code clear
  pull(date) %>%    # Extract the `date` column as a vector
  range() %>%       # Take the range of dates (earliest and latest)
  diff()            # Calculate time difference from start to finish of study
```

```
## Time difference of 8278 days
```

```
# Get number of observations in dataset---should be 1 more than time difference
obs %>%
  nrow()
```

```
## [1] 8279
```

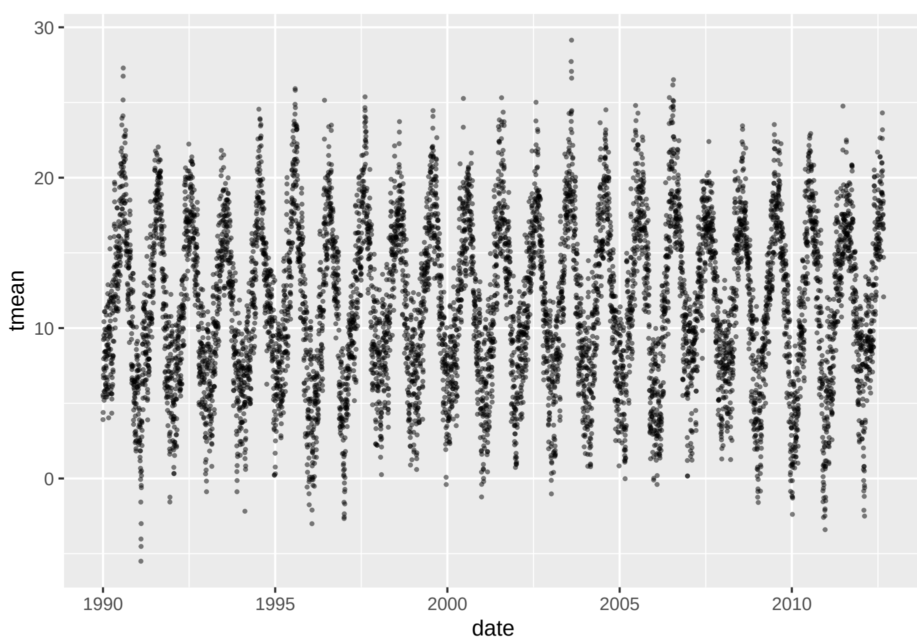
This indicates that there is an observation for every date over the study period, since the number of observations should be one more than the time difference.

In the next question, we'll be plotting observations by time, and typically this will also help you see if there are large chunks of missing dates in the data.

3. **Are there seasonal trends in the exposure? In the outcome?**

You can use a simple plot to visualize patterns over time in both the exposure and the outcome. For example, the following code plots a dot for each daily temperature observation over the study period. The points are set to a smaller size (`size = 0.5`) and plotted with some transparency (`alpha = 0.5`) since there are so many observations.

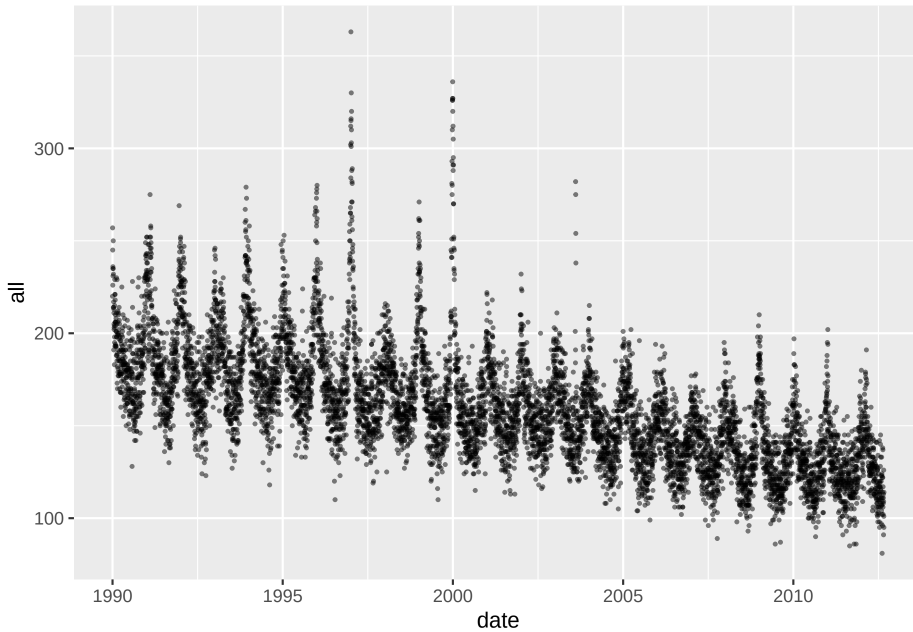
```
ggplot(obs, aes(x = date, y = tmean)) +
  geom_point(alpha = 0.5, size = 0.5)
```



There is (unsurprisingly) clear evidence here of a strong seasonal trend in mean temperature, with values typically lowest in the winter and highest in the summer.

You can plot the outcome variable in the same way:

```
ggplot(obs, aes(x = date, y = all)) +
  geom_point(alpha = 0.5, size = 0.5)
```

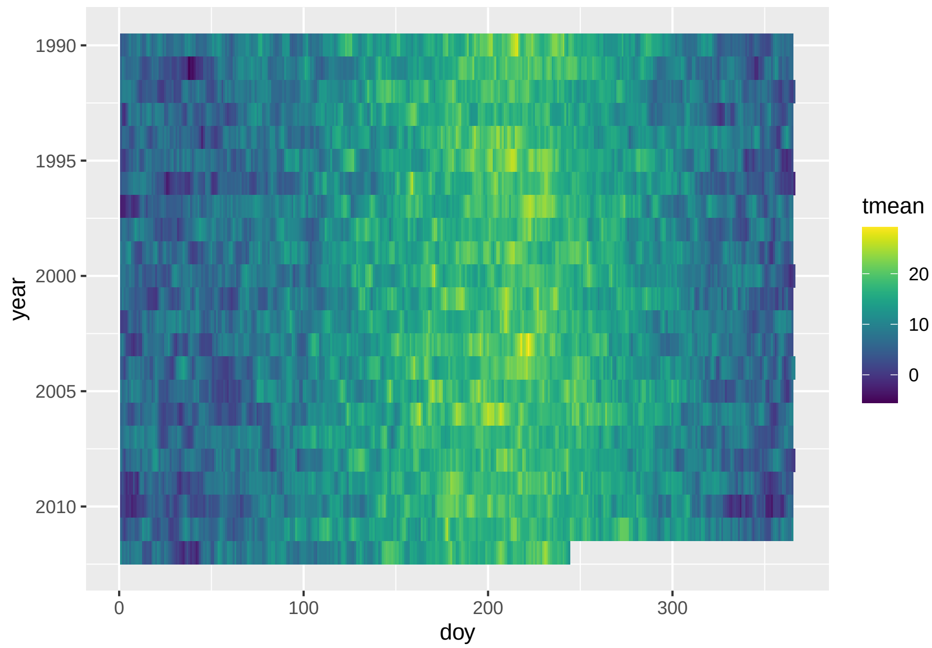


Again, there are seasonal trends, although in this case they are inversed. Mortality tends to be highest in the winter and lowest in the summer. Further, the seasonal pattern is not equally strong in all years—some years it has a much higher winter peak, probably in conjunction with severe influenza seasons.

Another way to look for seasonal trends is with a heatmap-style visualization, with day of year along the x-axis and year along the y-axis. This allows you to see patterns that repeat around the same time of the year each year (and also unusual deviations from normal seasonal patterns).

For example, here's a plot showing temperature in each year, where the observations are aligned on the x-axis by time in year. We're using the `doy`—which stands for "day of year" (i.e., Jan 1 = 1; Jan 2 = 2; … Dec 31 = 365 as long as it's not a leap year) as the measure of time in the year. We've reversed the y-axis so that the earliest years in the study period start at the top of the visual, then later study years come later—this is a personal style, and it would be no problem to leave the y-axis as-is. We've used the `viridis` color scale for the fill, since that has a number of features that make it preferable to the default R color scale, including that it is perceptible for most types of color blindness and be printed out in grayscale and still be correctly interpreted.

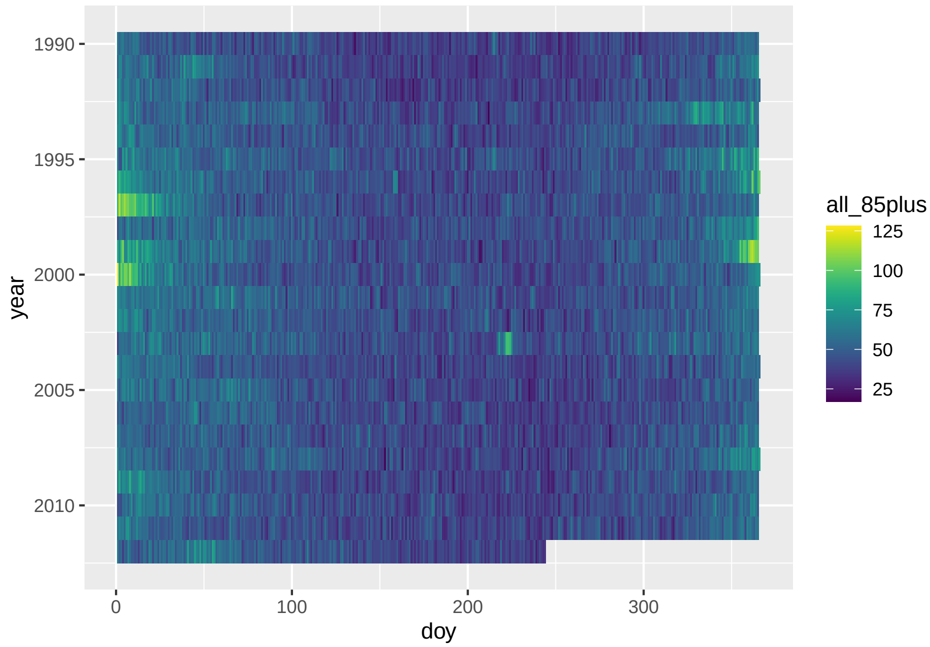
```
library(viridis)
ggplot(obs, aes(x = doy, y = year, fill = tmean)) +
  geom_tile() +
  scale_y_reverse() +
  scale_fill_viridis()
```



From this visualization, you can see that temperatures tend to be higher in the summer months and lower in the winter months. "Spells" of extreme heat or cold are visible—where extreme temperatures tend to persist over a period, rather than randomly fluctuating within a season. You can also see unusual events, like the extreme heat wave in the summer of 2003, indicated with the brightest yellow in the plot.

We created the same style of plot for the health outcome. In this case, we focused on mortality among the oldest age group, as temperature sensitivity tends to increase with age, so this might be where the strongest patterns are evident.

```
ggplot(obs, aes(x = doy, y = year, fill = all_85plus)) +
  geom_tile() +
  scale_y_reverse() +
  scale_fill_viridis()
```

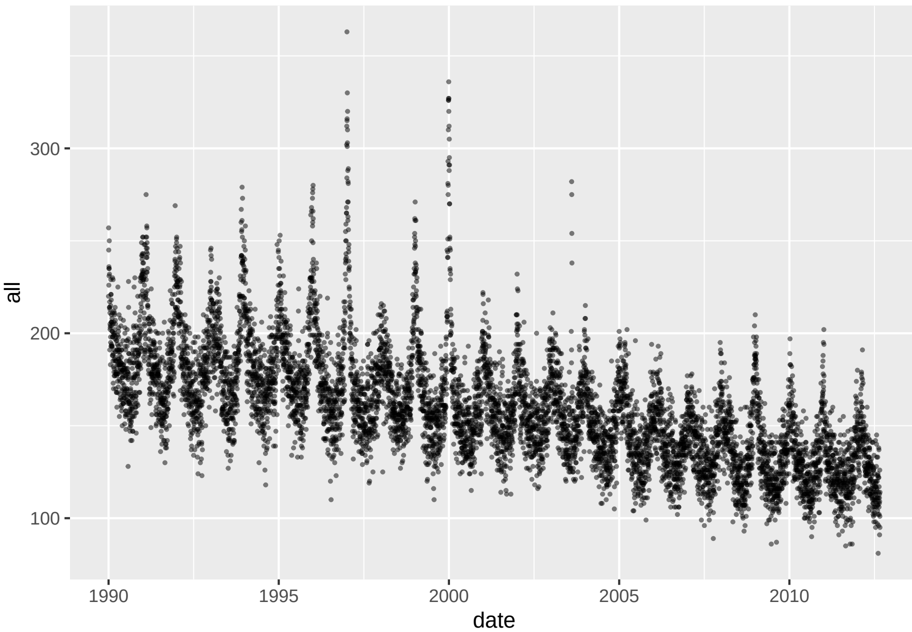


For mortality, there tends to be an increase in the winter compared to the summer. Some winters have stretches with particularly high mortality—these are likely a result of seasons with strong influenza outbreaks. You can also see on this plot the impact of the 2003 heat wave on mortality among this oldest age group—an unusual spot of light green in the summer.

4. **Are there long-term trends in the exposure? In the outcome?**

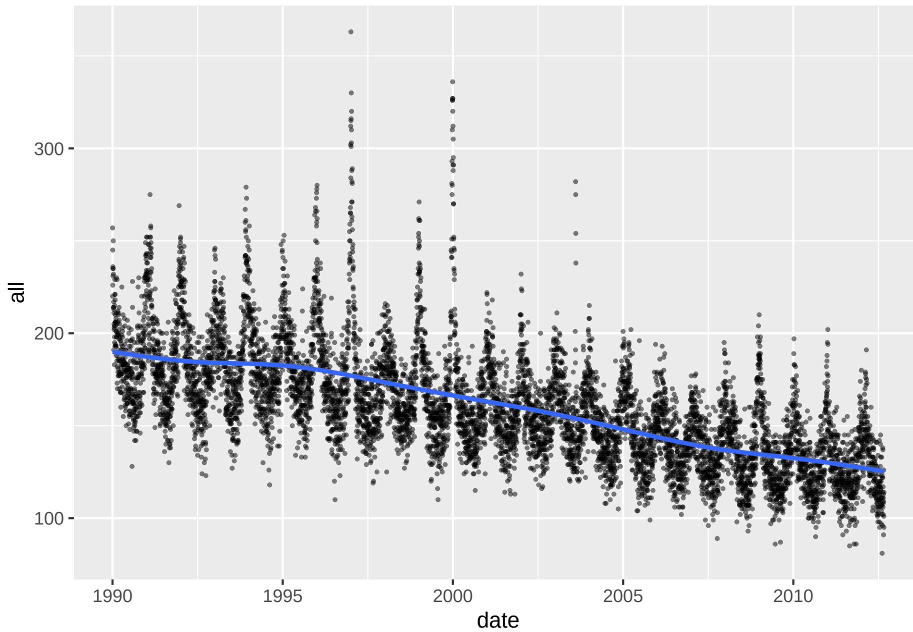
Some of the plots we created in the last section help in exploring this question. For example, the following plot shows a clear pattern of decreasing daily mortality counts, on average, over the course of the study period:

```
ggplot(obs, aes(x = date, y = all)) +
  geom_point(alpha = 0.5, size = 0.5)
```



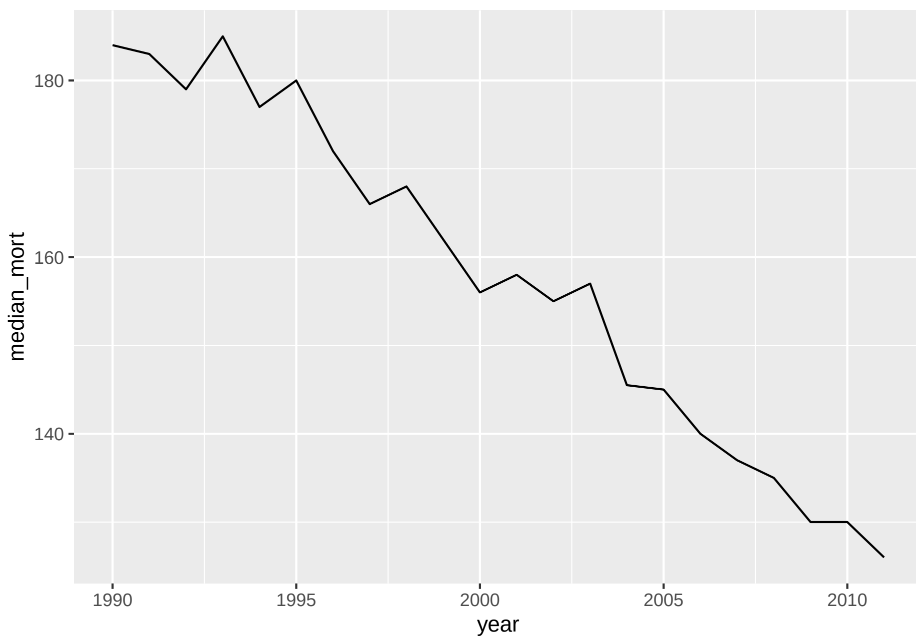
It can be helpful to add a smooth line to help detect these longer-term patterns, which you can do with `geom_smooth`:

```
ggplot(obs, aes(x = date, y = all)) +
  geom_point(alpha = 0.5, size = 0.5) +
  geom_smooth()
```



You could also take the median mortality count across each year in the study period, although you should take out any years without a full year's worth of data before you do this, since there are seasonal trends in the outcome:

```
obs %>%
  group_by(year) %>%
  filter(year != 2012) %>% # Take out the last year
  summarize(median_mort = median(all)) %>%
  ggplot(aes(x = year, y = median_mort)) +
  geom_line()
```



Again, we see a clear pattern of decreasing mortality rates in this city over time. This means we need to think carefully about long-term time patterns as a potential confounder. It will be particularly important to think about this if the exposure also has a strong pattern over time. For example, air pollution regulations have meant that, in many cities, there may be long-term decreases in pollution concentrations over a study period.

5. **Is the outcome associated with day of week? Is the exposure associated with day of week?**

The data already has day of week as a column in the data (`dow`). However, this is in a character data type, so it doesn't have the order of weekdays encoded (e.g., Monday comes before Tuesday). This makes it hard to look for patterns related to things like weekend / weekday.

```
class(obs$dow)
```

```
## [1] "character"
```

We could convert this to a factor and encode the weekday order when we do it, but it's even easier to just recreate the column from the `date` column. We used the `wday` function from the `lubridate` package to do this—it extracts weekday as a factor, with the order of weekdays encoded (using a special "ordered" factor type):

```
library(lubridate)
obs <- obs %>%
  mutate(dow = wday(date, label = TRUE))
```

```
class(obs$dow)
```

```
## [1] "ordered" "factor"
```

```
levels(obs$dow)
```

```
## [1] "Sun" "Mon" "Tue" "Wed" "Thu" "Fri" "Sat"
```

We looked at the mean, median, and 25th and 75th quantiles of the mortality counts by day of week:

```
obs %>%
  group_by(dow) %>%
  summarize(mean(all),
            median(all),
            quantile(all, 0.25),
            quantile(all, 0.75))
```

```
## # A tibble: 7 x 5
##   dow   `mean(all)` `median(all)` `quantile(all, 0.25)` `quantile(all, 0.75)`
## * <ord>       <dbl>         <dbl>                 <dbl>                 <dbl>
## 1 Sun          156.           154                   136                   173
## 2 Mon          161.           159                   138                   179
## 3 Tue          161.           158                   139                   179
## 4 Wed          160.           157                   138.                  179
## 5 Thu          161.           158                   139                   179
## 6 Fri          162.           159                   141                   179
## 7 Sat          159.           156                   137                   178
```

Mortality tends to be a bit higher on weekdays than weekends, but it's not a dramatic difference.

We did the same check for temperature:

```
obs %>%
  group_by(dow) %>%
  summarize(mean(tmean),
            median(tmean),
            quantile(tmean, 0.25),
            quantile(tmean, 0.75))
```

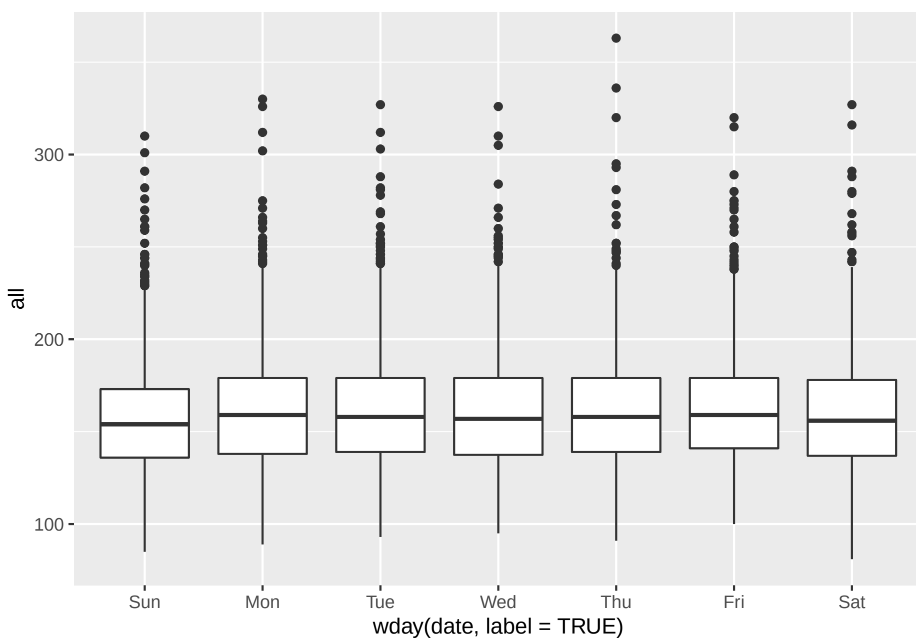
```
## # A tibble: 7 x 5
##   dow   `mean(tmean)` `median(tmean)` `quantile(tmean, 0.2~ `quantile(tmean, 0.~
## * <ord>         <dbl>           <dbl>                 <dbl>                <dbl>
## 1 Sun            11.6            11.3                  7.48                 15.9
## 2 Mon            11.6            11.4                  7.33                 15.8
## 3 Tue            11.5            11.4                  7.48                 15.9
## 4 Wed            11.7            11.7                  7.64                 16.0
## 5 Thu            11.6            11.5                  7.57                 16.0
```

```
## 6 Fri          11.6          11.6          7.41          15.8
## 7 Sat          11.6          11.5          7.53          15.9
```

In this case, there does not seem to be much of a pattern by weekday.

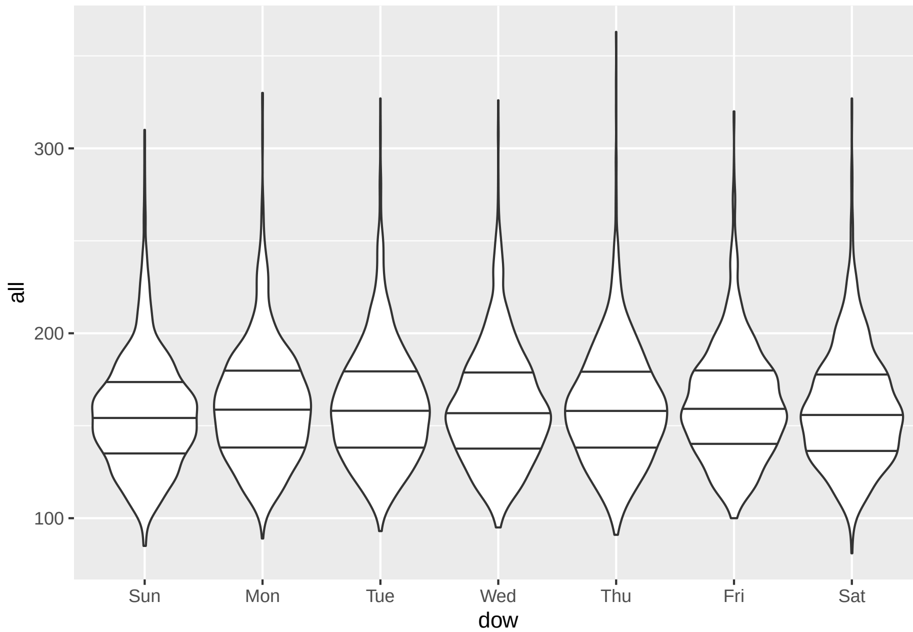
You can also visualize the association using boxplots:

```
ggplot(obs, aes(x = wday(date, label = TRUE), y = all)) +
  geom_boxplot()
```



You can also try violin plots—these show the full distribution better than boxplots, which only show quantiles.

```
ggplot(obs, aes(x = dow, y = all)) +
  geom_violin(draw_quantiles = c(0.25, 0.5, 0.75))
```



All these reinforce that there are some small differences in weekend versus weekday patterns for mortality. There isn't much pattern by weekday with temperature, so in this case weekday is unlikely to be a confounder (the same is not true with air pollution, which often varies based on commuting patterns and so can have stronger weekend/weekday differences). However, since it does help some in explaining variation in the health outcome, it might be worth including in our models anyway, to help reduce random noise.

3.4 Fitting models

One of the readings for this week, Vicedo-Cabrera et al. (2019), includes a section on fitting exposure-response functions to describe the association between daily mean temperature and mortality risk. This article includes example code in its supplemental material, with code for fitting the model to these time series data in the file named "01EstimationERassociation.r". The model may at first seem complex, but it is made up of a number of fairly straightforward pieces (although some may initially seem complex):

- The model framework is a *generalized linear model (GLM)*
- This GLM is fit assuming an *error distribution* and a *link function* appropriate for count data
- The GLM is fit assuming an *error distribution* that is also appropriate for data that may be *overdispersed*
- The model includes control for day of the week by including a *categorical variable*

- The model includes control for long-term and seasonal trends by including a *spline* (in this case, a *natural cubic spline*) for the day in the study
- The model fits a flexible, non-linear association between temperature and mortality risk also using a spline
- The model fits a flexible non-linear association between temperature on a series of preceeding days and current day and mortality risk on the current day using a *distributed lag approach*
- The model jointly describes both of the two previous non-linear associations by fitting these two elements through one construct in the GLM, a *cross-basis term*

In this section, we will work through the elements, building up the code to get to the full model that is fit in Vicedo-Cabrera et al. (2019).

Fitting a GLM to time series data

The GLM framework unites a number of types of regression models you may have previously worked with. One basic regression model that can be fit within this framework is a linear regression model. However, the framework also allows you to also fit, among others, logistic regression models (useful when the outcome variable can only take one of two values, e.g., success / failure or alive / dead), Poisson regression models (useful when the outcome variable is a count or rate).

This generalized framework brings some unity to these different types of regression models. From a practical standpoint, it has allowed software developers to easily provide a common interface to fit these types of models. In R, the common function call to fit GLMs is `glm`.

Within the GLM framework, the elements that separate different regression models include the link function and the error distribution. The error distribution encodes the assumption you are enforcing about how the errors after fitting the model are distributed. If the outcome data are normally distributed (a.k.a., follow a Gaussian distribution), after accounting for variance explained in the outcome by any of the model covariates, then a linear regression model may be appropriate. For count data—like numbers of deaths a day—this is unlikely, unless the average daily mortality count is very high (count data tend to come closer to a normal distribution the further their average gets from 0). For binary data—like whether each person in a study population died on a given day or not—normally distributed errors are also unlikely. Instead, in these two cases, it is typically more appropriate to fit GLMs with Poisson and binomial "families", respectively, where the family designation includes an appropriate specification for the variance when fitting the model based on these outcome types.

The other element that distinguishes different types of regression within the GLM framework is the link function. The link function applies a transformation on the combination of independent variables in the regression equation when fitting the model. With normally distributed data, an *identity link* is often appropriate—with this link, the combination of independent variables remain unchanged (i.e., keep their initial "identity"). With count data, a *log link* is often more appropriate, while with binomial data, a *logit link* is often used.

Finally, data will often not perfectly adhere to assumptions. For example, the Poisson family of GLMs assumes that variance follows a Poisson distribution (The probability mass function for Poisson distribution $X \sim \mathsf{Poisson}(\mu)$ is denoted by $f(k;\mu) = Pr[X = k] = \frac{\mu^k e^{-\mu}}{k!}$, where k is the number of occurences, and μ is equal to the expected number of cases). With this distribution, the variance is equal to the mean ($\mu = E(X) = Var(X)$). With real-life data, this assumption is often not valid, and in many cases the variance in real life count data is larger than the mean. This can be accounted for when fitting a GLM by setting an error distribution that does not require the variance to equal the mean—instead, both a mean value and something like a variance are estimated from the data, assuming an overdispersion parameter ϕ so that $Var(X) = \phi E(X)$. In environmental epidemiology, time series are often fit to allow for this overdispersion. This is because if the data are overdispersed but the model does not account for this, the standard errors on the estimates of the model parameters may be artificially small. If the data are not overdispersed ($\phi = 1$), the model will identify this when being fit to the data, so it is typically better to prefer to allow for overdispersion in the model (if the size of the data were small, you may want to be parsimonious and avoid unneeded complexity in the model, but this is typically not the case with time series data).

In the next section, you will work through the steps of developing a GLM to fit the example dataset `obs`. For now, you will only fit a linear association between mean daily temperature and mortality risk, eventually including control for day of week. In later work, especially the next chapter, we will build up other components of the model, including control for the potential confounders of long-term and seasonal patterns, as well as advancing the model to fit non-linear associations, distributed by time, through splines, a distributed lag approach, and a cross-basis term.

Applied: Fitting a GLM to time series data

In R, the function call used to fit GLMs is `glm`. Most of you have likely covered GLMs, and ideally this function call, in previous courses. If you are unfamiliar with its basic use, you will want to refresh yourself on this topic. [Add some online resources that go over basics of GLMs in R.]

1. Fit a GLM to estimate the association between mean daily temperature (as the independent variable) and daily mortality count (as the dependent variable), first fitting a linear regression. (Since the mortality data are counts, we will want to shift to a different type of regression within the GLM framework, but this step allows you to develop a simple `glm` call, and to remember where to include the data and the independent and dependent variables within this function call.)
2. Change your function call to fit a regression model in the Poisson family.

3. Change your function call to allow for overdispersion in the outcome data (daily mortality count). How does the estimated coefficient for temperature change between the model fit for #2 and this model? Check both the central estimate and its estimated standard error.
4. Change your function call to include control for day of week.

Applied exercise: Example code

1. **Fit a GLM to estimate the association between mean daily temperature (as the independent variable) and daily mortality count (as the dependent variable), first fitting a linear regression.**

This is the model you are fitting:

$Y_t = \beta_0 + \beta_1 X1_t + \epsilon$

where Y_t is the mortality count on day t, $X1_t$ is the mean temperature for day t and ϵ is the error term. Since this is a linear model we are assuming a Gaussian error distribution $\epsilon \sim \mathsf{N}(0, \sigma^2)$, where σ^2 is the variance not explained by the covariates (here just temperature).

To do this, you will use the `glm` call. If you would like to save model fit results to use later, you assign the output a name as an R object (`mod_linear_reg` in the example code). If your study data are in a dataframe, you can specify these data in the `glm` call with the `data` parameter. Once you do this, you can use column names directly in the model formula. In the model formula, the dependent variable is specified first (`all`, the column for daily mortality counts for all ages, in this example), followed by a tilde (`~`), followed by all independent variables (only `tmean` in this example). If multiple independent variables are included, they are joined using `+`—we'll see an example when we start adding control for confounders later.

```
mod_linear_reg <- glm(all ~ tmean, data = obs)
```

Once you have fit a model and assigned it to an R object, you can explore it and use resulting values. First, the print method for a regression model gives some summary information. This method is automatically called if you enter the model object's name at the console:

```
mod_linear_reg
```

```
##
## Call:  glm(formula = all ~ tmean, data = obs)
##
## Coefficients:
## (Intercept)        tmean
##     187.647       -2.366
##
## Degrees of Freedom: 8278 Total (i.e. Null);  8277 Residual
## Null Deviance:       8161000
```

```
## Residual Deviance: 6766000   AIC: 79020
```

More information is printed if you run the `summary` method on the model object:

```
summary(mod_linear_reg)
```

```
##
## Call:
## glm(formula = all ~ tmean, data = obs)
##
## Deviance Residuals:
##     Min       1Q   Median       3Q      Max
## -77.301  -20.365   -1.605   17.502  169.280
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) 187.64658    0.73557  255.10   <2e-16 ***
## tmean        -2.36555    0.05726  -41.31   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for gaussian family taken to be 817.4629)
##
##     Null deviance: 8161196  on 8278  degrees of freedom
## Residual deviance: 6766140  on 8277  degrees of freedom
## AIC: 79019
##
## Number of Fisher Scoring iterations: 2
```

Make sure you are familiar with the information provided from the model object, as well as how to interpret values like the coefficient estimates and their standard errors and p-values. These basic elements should have been covered in previous coursework (even if a different programming language was used to fit the model), and so we will not be covering them in great depth here, but instead focusing on some of the more advanced elements of how regression models are commonly fit to data from time series and case-crossover study designs in environmental epidemiology. For a refresher on the basics of fitting statistical models in R, you may want to check out Chapters 22 through 24 of Wickham and Grolemund (2016), a book that is available online.

Finally, there are some newer tools for extracting information from model fit objects. The `broom` package extracts different elements from these objects and returns them in a "tidy" data format, which makes it much easier to use the output further in analysis with functions from the "tidyverse" suite of R packages. These tools are very popular and powerful, and so the `broom` tools can be very useful in working with output from regression modeling in R.

The `broom` package includes three main functions for extracting data from regression model objects. First, the `glance` function returns overall data about the model fit, including the AIC and BIC:

```
library(broom)
glance(mod_linear_reg)
```

```
## # A tibble: 1 x 8
##   null.deviance df.null  logLik    AIC    BIC deviance df.residual  nobs
##           <dbl>   <int>   <dbl>  <dbl>  <dbl>    <dbl>       <int> <int>
## 1      8161196.    8278 -39507. 79019. 79041. 6766140.        8277  8279
```

The `tidy` function returns data at the level of the model coefficients, including the estimate for each model parameter, its standard error, test statistic, and p-value.

```
tidy(mod_linear_reg)
```

```
## # A tibble: 2 x 5
##   term        estimate std.error statistic p.value
##   <chr>          <dbl>     <dbl>     <dbl>   <dbl>
## 1 (Intercept)   188.      0.736      255.        0
## 2 tmean          -2.37    0.0573     -41.3       0
```

Finally, the `augment` function returns data at the level of the original observations, including the fitted value for each observation, the residual between the fitted and true value, and some measures of influence on the model fit.

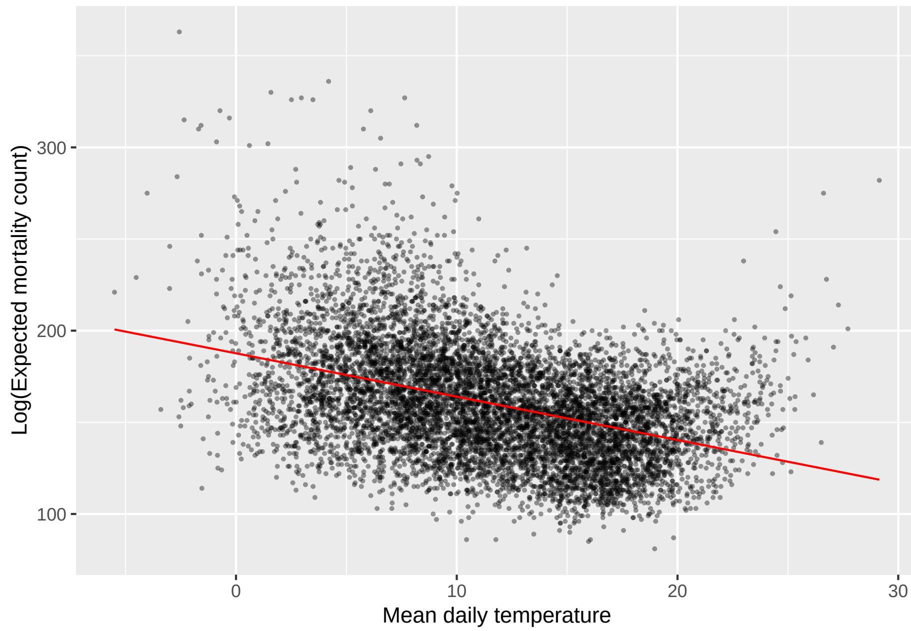
```
augment(mod_linear_reg)
```

```
## # A tibble: 8,279 x 8
##      all tmean .fitted .resid .std.resid     .hat .sigma  .cooksd
##    <dbl> <dbl>   <dbl>  <dbl>      <dbl>    <dbl>  <dbl>    <dbl>
##  1   220  3.91    178.   41.6       1.46 0.000359   28.6 0.000380
##  2   257  5.55    175.   82.5       2.89 0.000268   28.6 0.00112
##  3   245  4.39    177.   67.7       2.37 0.000330   28.6 0.000928
##  4   226  5.43    175.   51.2       1.79 0.000274   28.6 0.000440
##  5   236  6.87    171.   64.6       2.26 0.000211   28.6 0.000539
##  6   235  9.23    166.   69.2       2.42 0.000144   28.6 0.000420
##  7   231  6.69    172.   59.2       2.07 0.000218   28.6 0.000467
##  8   235  7.96    169.   66.2       2.31 0.000174   28.6 0.000467
##  9   250  7.27    170.   79.5       2.78 0.000197   28.6 0.000761
## 10   214  9.51    165.   48.9       1.71 0.000139   28.6 0.000202
## # ... with 8,269 more rows
```

One way you can use `augment` is to graph the fitted values for each observation after fitting the model:

```
mod_linear_reg %>%
  augment() %>%
  ggplot(aes(x = tmean)) +
```

```
  geom_point(aes(y = all), alpha = 0.4, size = 0.5) +
  geom_line(aes(y = .fitted), color = "red") +
  labs(x = "Mean daily temperature", y = "Log(Expected mortality count)")
```



For more on the `broom` package, including some excellent examples of how it can be used to streamline complex regression analyses, see Robinson (2014). There is also a nice example of how it can be used in one of the chapters of Wickham and Grolemund (2016), available online at https://r4ds.had.co.nz/many-models.html.

2. **Change your function call to fit a regression model in the Poisson family.**

A linear regression is often not appropriate when fitting a model where the outcome variable provides counts, as with the example data. A Poisson regression is often preferred.

For a count distribution were $Y \sim \text{Poisson}(\ )$ we typically fit a model such as

$g(Y) = \beta_0 + \beta_1 X1$, where $g()$ represents the link function, in this case a log function so that $log(Y) = \beta_0 + \beta_1 X1$. We can also express this as $Y = exp(\beta_0 + \beta_1 X1)$.

In the `glm` call, you can specify this with the `family` parameter, for which "poisson" is one choice.

```
mod_pois_reg <- glm(all ~ tmean, data = obs, family = "poisson")
```

One thing to keep in mind with this change is that the model now uses a non-identity link between the combination of independent variable(s) and the dependent variable. You will need to keep this in mind when you interpret the estimates of the regression coefficients. While the coefficient estimate for `tmean` from the linear regression could be interpreted as the expected increase in mortality counts for a one-unit (i.e., one degree Celsius) increase in temperature, now the estimated coefficient should be interpreted as the expected increase in the natural log-transform of mortality count for a one-unit increase in temperature.

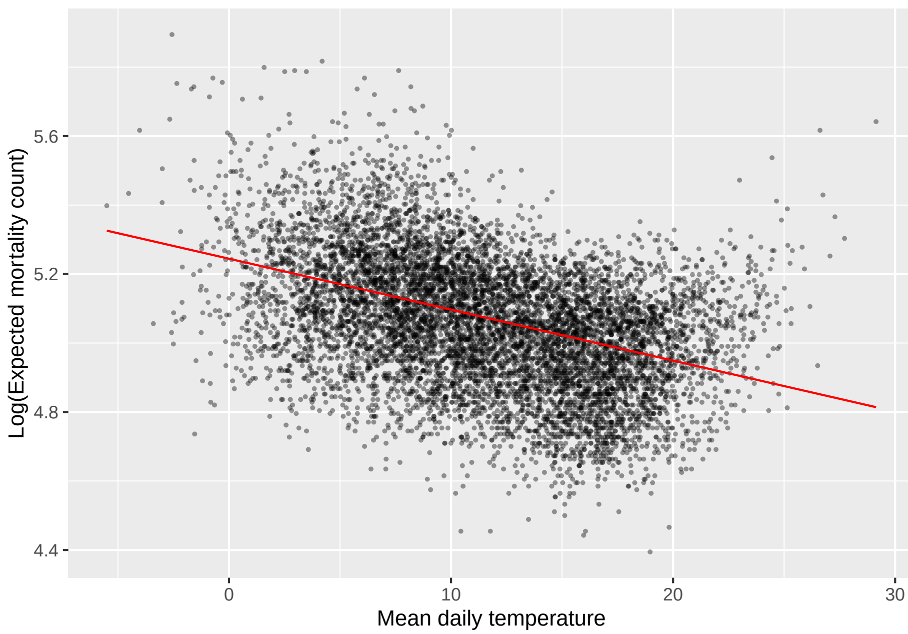
```
summary(mod_pois_reg)
```

```
##
## Call:
## glm(formula = all ~ tmean, family = "poisson", data = obs)
##
## Deviance Residuals:
##     Min       1Q   Median       3Q      Max
## -6.5945  -1.6365  -0.1167   1.3652  12.2221
##
## Coefficients:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept)  5.2445409  0.0019704 2661.67   <2e-16 ***
## tmean       -0.0147728  0.0001583  -93.29   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for poisson family taken to be 1)
##
##     Null deviance: 49297  on 8278  degrees of freedom
## Residual deviance: 40587  on 8277  degrees of freedom
## AIC: 97690
##
## Number of Fisher Scoring iterations: 4
```

You can see this even more clearly if you take a look at the association between temperature for each observation and the expected mortality count fit by the model. First, if you look at the fitted values without transforming, they will still be in a state where mortality count is log-transformed. You can see by looking at the range of the y-scale that these values are for the log of expected mortality, rather than expected mortality, and that the fitted association is linear:

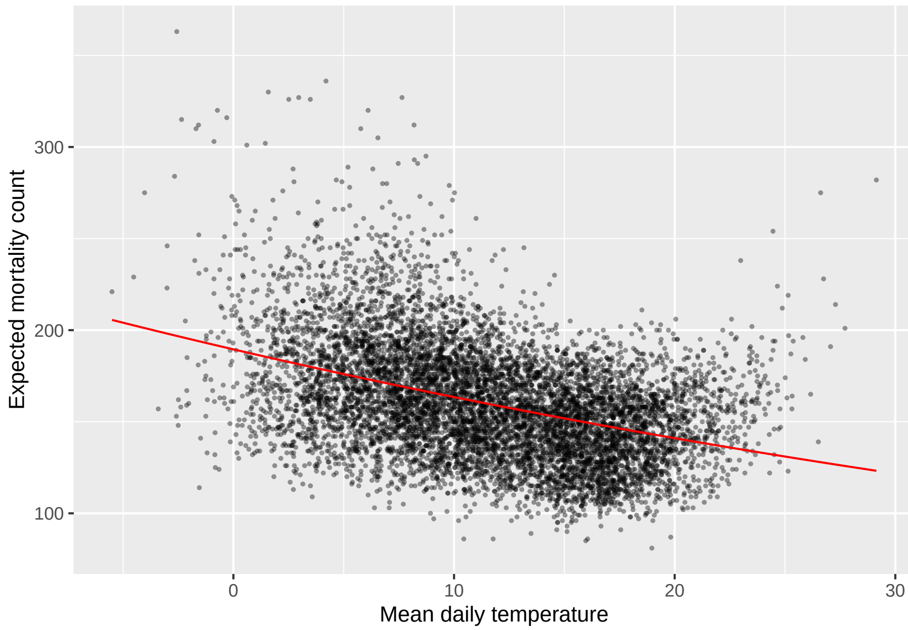
```
mod_pois_reg %>%
  augment() %>%
  ggplot(aes(x = tmean)) +
  geom_point(aes(y = log(all)), alpha = 0.4, size = 0.5) +
  geom_line(aes(y = .fitted), color = "red") +
```

```
  labs(x = "Mean daily temperature", y = "Log(Expected mortality count)")
```



You can use exponentiation to transform the fitted values back to just be the expected mortality count based on the model fit. Once you make this transformation, you can see how the link in the Poisson family specification enforced a curved relationship between mean daily temperature and the untransformed expected mortality count.

```
mod_pois_reg %>%
  augment() %>%
  ggplot(aes(x = tmean)) +
  geom_point(aes(y = all), alpha = 0.4, size = 0.5) +
  geom_line(aes(y = exp(.fitted)), color = "red") +
  labs(x = "Mean daily temperature", y = "Expected mortality count")
```



3. **Change your function call to allow for overdispersion in the outcome data (daily mortality count). How does the estimated coefficient for temperature change between the model fit for #2 and this model? Check both the central estimate and its estimated standard error.**

In the R `glm` call, there is a family that is similar to Poisson (including using a log link), but that allows for overdispersion. You can specify it with the "quasipoisson" choice for the `family` parameter in the `glm` call:

```
mod_ovdisp_reg <- glm(all ~ tmean, data = obs, family = "quasipoisson")
```

When you use this family, there will be some new information in the summary for the model object. It will now include a dispersion parameter (ϕ). If this is close to 1, then the data were close to the assumed variance for a Poisson distribution (i.e., there was little evidence of overdispersion). In the example, the overdispersion is around 5, suggesting the data are overdispersed (this might come down some when we start including independent variables that explain some of the variation in the outcome variable, like long-term and seasonal trends).

```
summary(mod_ovdisp_reg)
```

```
##
## Call:
## glm(formula = all ~ tmean, family = "quasipoisson", data = obs)
##
## Deviance Residuals:
```

```
##     Min       1Q   Median       3Q      Max
## -6.5945  -1.6365  -0.1167   1.3652  12.2221
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept)  5.2445409  0.0044087  1189.6   <2e-16 ***
## tmean       -0.0147728  0.0003543   -41.7   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for quasipoisson family taken to be 5.006304)
##
##     Null deviance: 49297  on 8278  degrees of freedom
## Residual deviance: 40587  on 8277  degrees of freedom
## AIC: NA
##
## Number of Fisher Scoring iterations: 4
```

If you compare the estimates of the temperature coefficient from the Poisson regression with those when you allow for overdispersion, you'll see something interesting:

```
tidy(mod_pois_reg) %>%
  filter(term == "tmean")
```

```
## # A tibble: 1 x 5
##   term  estimate std.error statistic p.value
##   <chr>    <dbl>     <dbl>     <dbl>   <dbl>
## 1 tmean  -0.0148  0.000158     -93.3       0
```

```
tidy(mod_ovdisp_reg) %>%
  filter(term == "tmean")
```

```
## # A tibble: 1 x 5
##   term  estimate std.error statistic p.value
##   <chr>    <dbl>     <dbl>     <dbl>   <dbl>
## 1 tmean  -0.0148  0.000354     -41.7       0
```

The central estimate (`estimate` column) is very similar. However, the estimated standard error is larger when the model allows for overdispersion. This indicates that the Poisson model was too simple, and that its inherent assumption that data were not overdispersed was problematic. If you naively used a Poisson regression in this case, then you would estimate a confidence interval on the temperature coefficient that would be too narrow. This could cause you to conclude that the estimate was statistically significant when you should not have (although in this case, the estimate is statistically significant under both models).

4. **Change your function call to include control for day of week.**

Day of week is included in the data as a categorical variable, using a data type in R called a factor. You are now essentially fitting this model:

$log(Y) = \beta_0 + \beta_1 X1 + \gamma' X2,$

where $X2$ is a categorical variable for day of the week and γ' represents a vector of parameters associated with each category.

It is pretty straightforward to include factors as independent variables in calls to `glm`: you just add the column name to the list of other independent variables with a `+`. In this case, we need to do one more step: earlier, we added order to `dow`, so it would "remember" the order of the week days (Monday before Tuesday, etc.). However, we need to strip off this order before we include the factor in the `glm` call. One way to do this is with the `factor` call, specifying `ordered = FALSE`. Here is the full call to fit this model:

```
mod_ctrl_dow <- glm(all ~ tmean + factor(dow, ordered = FALSE),
                    data = obs, family = "quasipoisson")
```

When you look at the summary for the model object, you can see that the model has fit a separate model parameter for six of the seven weekdays. The one weekday that isn't fit (Sunday in this case) serves as a baseline —these estimates specify how the log of the expected mortality count is expected to differ on, for example, Monday versus Sunday (by about 0.03), if the temperature is the same for the two days.

```
summary(mod_ctrl_dow)
```

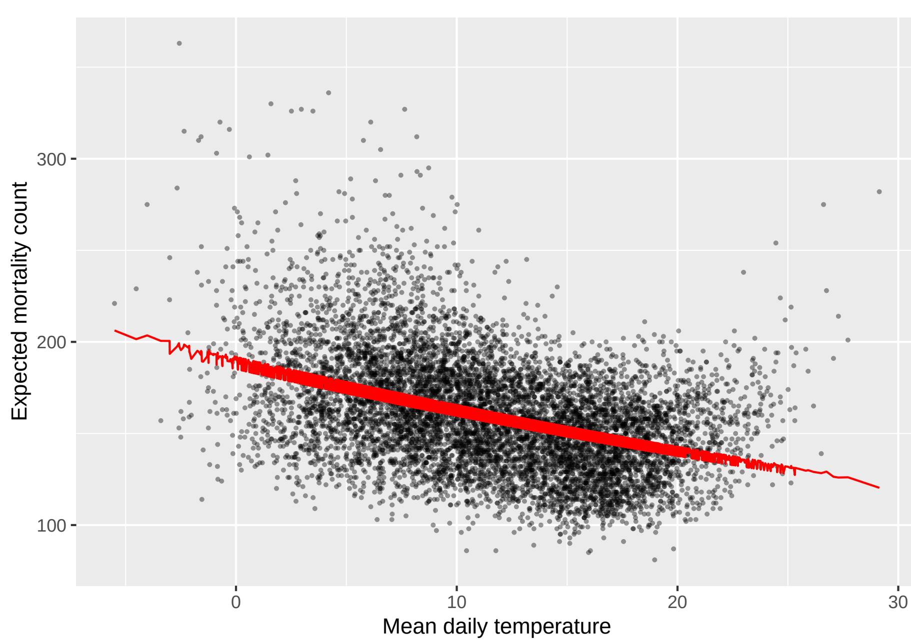
```
##
## Call:
## glm(formula = all ~ tmean + factor(dow, ordered = FALSE), family = "quasipoisson",
##     data = obs)
##
## Deviance Residuals:
##     Min       1Q   Median       3Q      Max
## -6.3211  -1.6476  -0.1313   1.3549  12.5286
##
## Coefficients:
##                                  Estimate Std. Error t value Pr(>|t|)
## (Intercept)                     5.2208502  0.0065277 799.804  < 2e-16 ***
## tmean                          -0.0147723  0.0003538 -41.750  < 2e-16 ***
## factor(dow, ordered = FALSE)Mon  0.0299282  0.0072910   4.105 4.08e-05 ***
## factor(dow, ordered = FALSE)Tue  0.0292575  0.0072920   4.012 6.07e-05 ***
## factor(dow, ordered = FALSE)Wed  0.0255224  0.0073020   3.495 0.000476 ***
## factor(dow, ordered = FALSE)Thu  0.0269580  0.0072985   3.694 0.000222 ***
## factor(dow, ordered = FALSE)Fri  0.0355431  0.0072834   4.880 1.08e-06 ***
## factor(dow, ordered = FALSE)Sat  0.0181489  0.0073158   2.481 0.013129 *
## ---
```

```
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for quasipoisson family taken to be 4.992004)
##
##     Null deviance: 49297  on 8278  degrees of freedom
## Residual deviance: 40434  on 8271  degrees of freedom
## AIC: NA
##
## Number of Fisher Scoring iterations: 4
```

You can also see from this summary that the coefficients for the day of the week are all statistically significant. Even though we didn't see a big difference in mortality counts by day of week in our exploratory analysis, this suggests that it does help explain some variance in mortality observations and will likely be worth including in the final model.

The model now includes day of week when fitting an expected mortality count for each observation. As a result, if you plot fitted values of expected mortality versus mean daily temperature, you'll see some "hoppiness" in the fitted line:

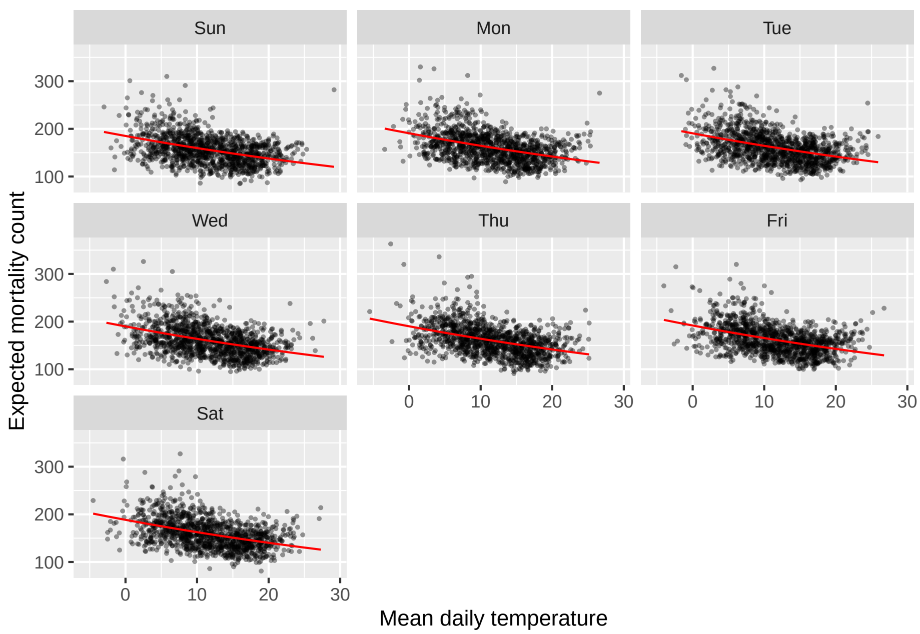
```
mod_ctrl_dow %>%
  augment() %>%
  ggplot(aes(x = tmean)) +
  geom_point(aes(y = all), alpha = 0.4, size = 0.5) +
  geom_line(aes(y = exp(.fitted)), color = "red") +
  labs(x = "Mean daily temperature", y = "Expected mortality count")
```



This is because each fitted value is also incorporating the expected influence of day of week on the mortality count, and that varies across the observations (i.e., you could have two days with the same temperature, but different expected mortality from the model, because they occur on different days).

If you plot the model fits separately for each day of the week, you'll see that the line is smooth across all observations from the same day of the week:

```
mod_ctrl_dow %>%
  augment() %>%
  ggplot(aes(x = tmean)) +
  geom_point(aes(y = all), alpha = 0.4, size = 0.5) +
  geom_line(aes(y = exp(.fitted)), color = "red") +
  labs(x = "Mean daily temperature", y = "Expected mortality count") +
  facet_wrap(~ obs$dow)
```



Wrapping up

At this point, the coefficient estimates suggests that risk of mortality tends to decrease as temperature increases. Do you think this is reasonable? What else might be important to build into the model based on your analysis up to this point?

3.5 Chapter vocabulary

Each class will start with a vocabulary quiz on a select number of the words from the chapter's vocabulary list. The vocabulary words for this chapter are:

- time-series study design
- case-crossover study design
- exposure
- health outcome
- confounder
- study period
- seasonal trends
- long-term trends
- error distribution
- generalized linear model (GLM)
- link function
- overdispersed
- categorical variable
- spline
- natural cubic spline
- distributed lag
- cross-basis term

Chapter 4

Generalized linear models

The readings for this chapter are the same as for the last chapter:

- Vicedo-Cabrera et al. (2019), with supplemental material available to download by clicking http://links.lww.com/EDE/B504
- Armstrong et al. (2014), with supplemental material available at https://bmcmedresmethodol.biomedcentral.com/articles/10.1186/1471-2288-14-122#Sec13

4.1 Splines in GLMs

We saw from the latest model with a linear for mean daily temperature that the suggested effect on mortality is a decrease in daily mortality counts with increasing temperature. However, as you've probably guessed that's probably not entirely accurate. A linear term for the effect of exposure restricts us to an effect that can be fitted with a straight line (either a null effect or a monotonically increasing or decreasing effect with increasing exposure).

This clearly is problematic in some cases. One example is when exploring the association between temperature and health risk. Based on human physiology, we would expect many health risks to be elevated at temperature extremes, whether those are extreme cold or extreme heat. A linear term would be inadequate to describe this kind of U-shaped association. Other effects might have a threshold—for example, heat stroke might have a very low risk at most temperatures, only increasing with temperature above a certain threshold. [Maybe add images of these kinds of associations?]

We can capture non-linear patterns in effects, by using different functions of X. Examples are $\sqrt{X}$, X^2, or more complex smoothing functions, such as polynomials or splines. Polynomials might at first make a lot of sense, especially since you've likely come across polynomial terms in mathematics classes since grade school. However, it turns out that they have some undesirable properties. A key one is that they can have extreme behavior, particularly when using a high-order polynomial, and particularly outside the range of data that are available to fit the model.

An alternative that is generally preferred for environmental epidemiology studies is the regression spline. Regression splines are simple parametric smoothing function, which fit separate polynomial in each interval of the range of the predictor; these can be linear, quadratic, and cubic. An example of a (in this case cubic) spline function is $X + X^2 + X^3 + I((X > X_0) * (X - X_0)^3)$.This particular function is a cubic spline with four degrees of freedom ($df = 4$) and one not (X_0). A special type of spline called a natural cubic spline is particularly popular. Unlike a polynomial function, a natural cubic spline "behaves" better outside the range of the data used to fit the model—they are constrained to continue on a [linear?] trajectory once they pass beyond the range of the data. [Maybe add more / clarify / add references on the point of why splines versus polynomials.]

Regression splines can be fit in a GLM via the package `splines`. Two commonly used examples of regression splines are b-splines and natural cubic splines. Vicedo-Cabrera et al. (2019) uses natural cubic splines.

Applied: Including a spline in a GLM

For this exercise, you will continue to build up the model that you began in the examples in the previous chapter. The example uses the data provided with one of this chapter's readings, Vicedo-Cabrera et al. (2019).

1. Start by fitting a somewhat simple model—how are daily mortality counts associated with (a) a linear and (b) a non-linear function of time? Is a linear term appropriate to describe this association? What types of patterns are captured by a non-linear function that are missed by a linear function?
2. In the last chapter, the final version of the model used a GLM with an overdispersed Poisson distribution, including control for day of week. Start from this model and add control for long-term and seasonal trends over the study period.
3. Refine your model to fit for a non-linear, rather than linear, function of temperature in the model. Does a non-linear term seem to be more appropriate than a linear term?

Applied exercise: Example code

1. **Start by fitting a somewhat simple model—how are daily mortality counts associated with (a) a linear and (b) a non-linear function of time?**

It is helpful to start by loading the R packages you are likely to need, as well as the example dataset. You may also need to re-load the example data and perform the steps taken to clean it in the last chapter:

```
# Load some packages that will likely be useful
library(tidyverse)
library(viridis)
library(lubridate)
library(broom)

# Load and clean the data
obs <- read_csv("data/lndn_obs.csv") %>%
  mutate(dow = wday(date, label = TRUE))
```

For this first question, the aim is to model the association between time and daily mortality counts within the example data. This approach is often used to explore and, if needed, adjust for temporal factors in the data.

There are a number of factors that can act over time to create patterns in both environmental exposures and health outcomes. For example, there may be changes in air pollution exposures over the years of a study because of changes in regulations or growth or decline of factories and automobile traffic in an area. Changes in health care and in population demographics can cause patterns in health outcomes over the study period. At a shorter, seasonal term, there are also factors that could influence both exposures and outcomes, including seasonal changes in climate, seasonal changes in emissions, and seasonal patterns in health outcomes.

It can be difficult to pinpoint and measure these temporal factors, and so instead a common practice is to include model control based on the time in the study. This can be measured, for example, as the day since the start of the study period.

You can easily add a column for day in study for a dataset that includes date. R saves dates in a special format, which we're using the in `obs` dataset:

```
class(obs$date)
```

```
## [1] "Date"
```

However, this is just a fancy overlay on a value that's ultimately saved as a number. Like most Unix programs, the date is saved as the number of days since the Unix "epoch", January 1, 1970. You can take advantage of this convention—if you use `as.numeric` around a date in R, it will give you a number that gets one unit higher for every new date. Here's the example for the first date in our example data:

```
obs$date[1]
```

```
## [1] "1990-01-01"
```

```
as.numeric(obs$date[1])
```

```
## [1] 7305
```

And here's the example for the next date:

```
obs$date[2]
```

```
## [1] "1990-01-02"
```

```
as.numeric(obs$date[2])
```

```
## [1] 7306
```

You can use this convention to add a column that gives days since the first study date. While you could also use the `1:n()` call to get a number for each row that goes from 1 to the number of rows, that approach would not catch any "skips" in dates in the data (e.g., missing dates if only warm-season data are included). The use of the dates is more robust:

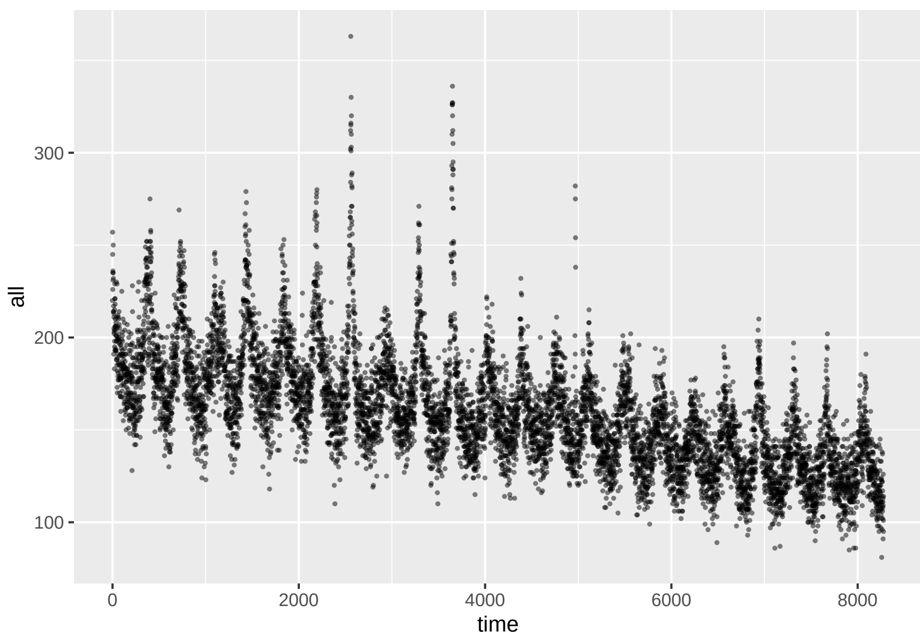
```
obs <- obs %>%
  mutate(time = as.numeric(date) - first(as.numeric(date)))

obs %>%
  select(date, time)
```

```
## # A tibble: 8,279 x 2
##    date        time
##    <date>     <dbl>
##  1 1990-01-01     0
##  2 1990-01-02     1
##  3 1990-01-03     2
##  4 1990-01-04     3
##  5 1990-01-05     4
##  6 1990-01-06     5
##  7 1990-01-07     6
##  8 1990-01-08     7
##  9 1990-01-09     8
## 10 1990-01-10     9
## # ... with 8,269 more rows
```

As a next step, it is always useful to use exploratory data analysis to look at the patterns that might exist for an association, before you start designing and fitting the regression model.

```
ggplot(obs,
       aes(x = time, y = all)) +
  geom_point(size = 0.5, alpha = 0.5)
```



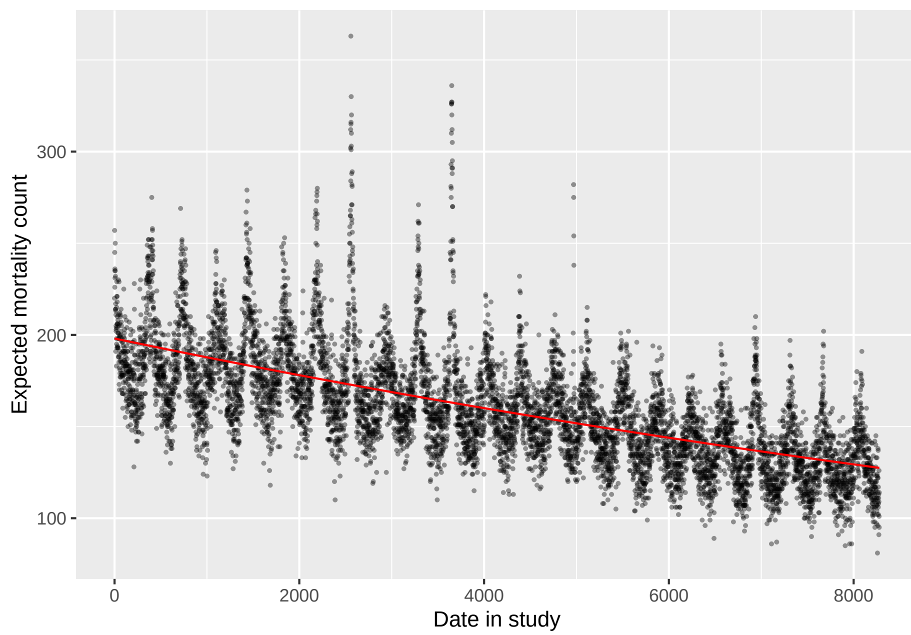
There are clear patterns between time and daily mortality counts in these data. First, there is a clear long-term pattern, with mortality rates declining on average over time. Second, there are clear seasonal patterns, with higher mortality generally in the winter and lower rates in the summer.

To model this, we can start with fitting a linear term. In the last chapter, we determined that the mortality outcome data can be fit using a GLM with a Poisson family, allowing for overdispersion as it is common in real-life count data like these. To include time as a linear term, we can just include that column name to the right of the ~ in the model formula:

```
mod_time <- glm(all ~ time,
                data = obs, family = "quasipoisson")
```

You can use the `augment` function from the `broom` package to pull out the fitted estimate for each of the original observations and plot that, along with the observed data, to get an idea of what this model has captured:

```
mod_time %>%
  augment() %>%
  ggplot(aes(x = time)) +
  geom_point(aes(y = all), alpha = 0.4, size = 0.5) +
  geom_line(aes(y = exp(.fitted)), color = "red") +
  labs(x = "Date in study", y = "Expected mortality count")
```



[Check for `termplot`]

This linear trend captures the long-term trend in mortality rates fairly well in this case. This won't always be the case, as there may be some health outcomes—or some study populations—where the long-term pattern over the study period might be less linear than in this example. Further, the linear term is completely unsuccessful in capturing the shorter-term trends in mortality rate. These oscillate, and so would be impossible to capture over multiple years with a linear trend.

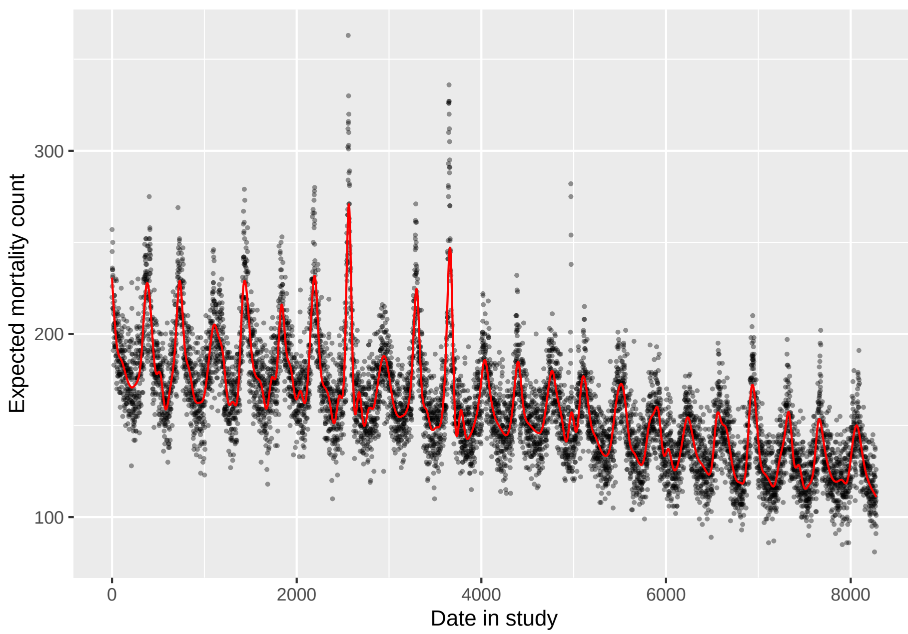
Instead, it's helpful to use a non-linear term for time in the model. We can use a natural cubic spline for this, using the `ns` function from the `splines` package. You will need to clarify how flexible the spline function should be, and this can be specified through the degrees of freedom for the spline. A spline with more degrees of freedom will be "wigglier" over a given data range compared to a spline with fewer degrees of freedom. Let's start by using 158 degrees of freedom, which translates to about 7 degrees of freedom per year:

```
library(splines)
mod_time_nonlin <- glm(all ~ ns(time, df = 158),
                       data = obs, family = "quasipoisson")
```

You can visualize the model results in a similar way to how we visualized the last model. However, there is one extra step. The `augment` function only carries through columns in the original data (`obs`) that were directly used in fitting the model. Now that we're using a transformation of the `time` column, by wrapping it in `ns`, the `time` column is no longer included in the `augment` output.

However, we can easily add it back in using `mutate`, pulling it from the original `obs` dataset, and then proceed as before.

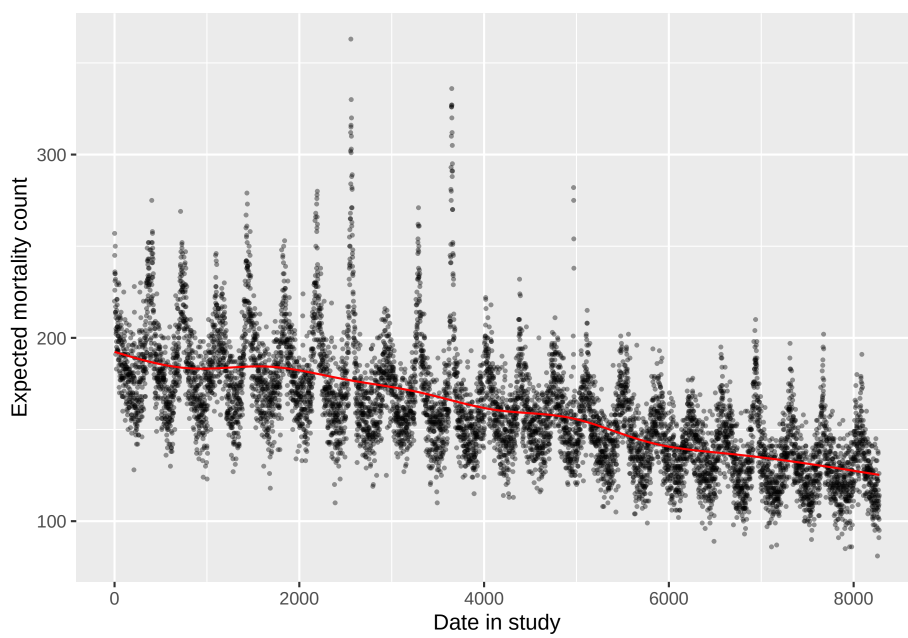
```
mod_time_nonlin %>%
  augment() %>%
  mutate(time = obs$time) %>%
  ggplot(aes(x = time)) +
  geom_point(aes(y = all), alpha = 0.4, size = 0.5) +
  geom_line(aes(y = exp(.fitted)), color = "red") +
  labs(x = "Date in study", y = "Expected mortality count")
```



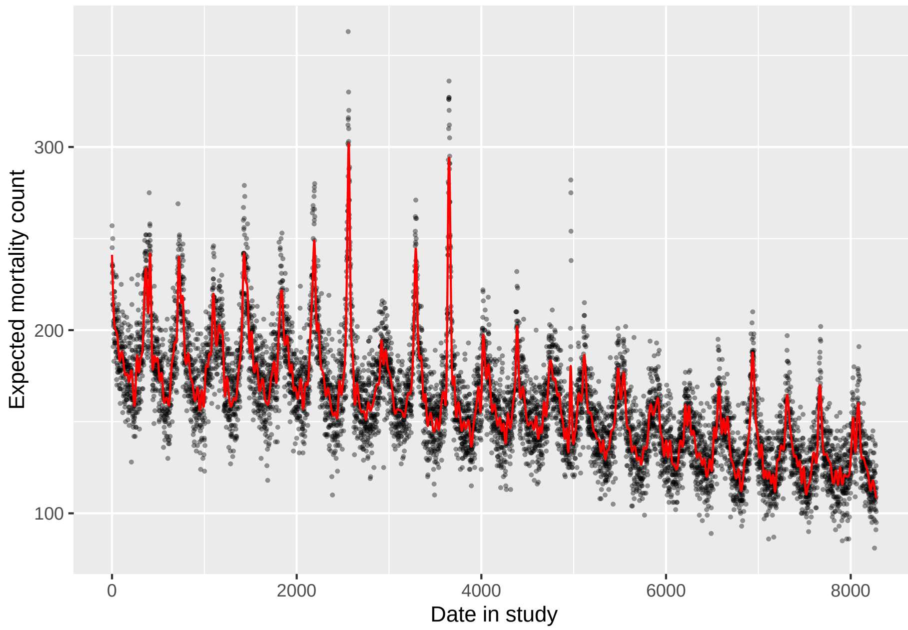
The non-linear term for time has allowed enough flexibility that the model now captures both long-term and seasonal trends in the data.

[More on how to pick a good d.f. for an env. epi. model like this]. In practice, researchers often using about 6–8 degrees of freedom per year of the study, in the case of year-round data. You can explore how changing the degrees of freedom changes the way the model fits to the observed data. As you use more degrees of freedom, the line will capture very short-term effects, and may start to interfere with the shorter-term associations between environmental exposures and health risk that you are trying to capture. Even in the example model we just fit, for example, it looks like the control for time may be capturing some patterns that were likely caused by heatwaves (the rare summer peaks, including one from the 1995 heatwave). Conversely, if too few degrees of freedom are used, the model will shift to look much more like the linear model, with inadequate control for seasonal patterns.

```r
# A model with many less d.f. for the time spline
mod_time_nonlin_lowdf <- glm(all ~ ns(time, df = 10),
                             data = obs, family = "quasipoisson")
mod_time_nonlin_lowdf %>%
  augment() %>%
  mutate(time = obs$time) %>%
  ggplot(aes(x = time)) +
  geom_point(aes(y = all), alpha = 0.4, size = 0.5) +
  geom_line(aes(y = exp(.fitted)), color = "red") +
  labs(x = "Date in study", y = "Expected mortality count")
```




```r
# A model with many more d.f. for the time spline
# (Takes a little while to run)
mod_time_nonlin_highdf <- glm(all ~ ns(time, df = 400),
                              data = obs, family = "quasipoisson")
mod_time_nonlin_highdf %>%
  augment() %>%
  mutate(time = obs$time) %>%
  ggplot(aes(x = time)) +
  geom_point(aes(y = all), alpha = 0.4, size = 0.5) +
  geom_line(aes(y = exp(.fitted)), color = "red") +
  labs(x = "Date in study", y = "Expected mortality count")
```



In all cases, when you fit a non-linear function of an explanatory variable, it will make the model summary results look much more complicated, e.g.:

```
mod_time_nonlin_lowdf %>%
  tidy()
```

```
## # A tibble: 11 x 5
##    term                  estimate std.error statistic   p.value
##    <chr>                    <dbl>     <dbl>     <dbl>     <dbl>
##  1 (Intercept)             5.26     0.00948    555.   0.
##  2 ns(time, df = 10)1    -0.0260    0.0119      -2.18 2.93e-  2
##  3 ns(time, df = 10)2    -0.0860    0.0155      -5.56 2.85e-  8
##  4 ns(time, df = 10)3    -0.114     0.0139      -8.15 4.01e- 16
##  5 ns(time, df = 10)4    -0.196     0.0151     -13.0  4.47e- 38
##  6 ns(time, df = 10)5    -0.187     0.0148     -12.6  2.80e- 36
##  7 ns(time, df = 10)6    -0.315     0.0154     -20.5  5.62e- 91
##  8 ns(time, df = 10)7    -0.337     0.0154     -21.9  1.95e-103
##  9 ns(time, df = 10)8    -0.358     0.0135     -26.5  1.56e-148
## 10 ns(time, df = 10)9    -0.467     0.0244     -19.2  4.49e- 80
## 11 ns(time, df = 10)10   -0.392     0.0126     -31.2  8.01e-202
```

You can see that there are multiple model coefficients for the variable fit using a spline function, one less than the number of degrees of freedom. These model coefficients are very hard to interpret on their own. When we are using the spline to *control* for a factor that might serve as a confounder of the association of interest, we typically won't need to try to interpret these model coefficients—

instead, we are interested in accounting for how this factor explains variability in the outcome, without needing to quantify the association as a key result. However, there are also cases where we want to use a spline to fit the association with the exposure that we are interested in. In this case, we will want to be able to interpret model coefficients from the spline. Later in this chapter, we will introduce the `dlnm` package, which includes functions to both fit and interpret natural cubic splines within GLMs for environmental epidemiology.

2. **Start from the last model created in the last chapter and add control for long-term and seasonal trends over the study period.**

The last model fit in the last chapter was the following, which fits for the association between a linear term of temperature and mortality risk, with control for day of week:

```
mod_ctrl_dow <- glm(all ~ tmean + factor(dow, ordered = FALSE),
                    data = obs, family = "quasipoisson")
```

To add control for long-term and seasonal trends, you can take the natural cubic spline function of temperature that you just fit and include it among the explanatory / independent variables from the model in the last chapter. If you want to control for only long-term trends, a linear term of the `time` column could work, as we discovered in the first part of this chapter's exercise. However, seasonal trends could certainly confound the association of interest. Mortality rates have a clear seasonal pattern, and temperature does as well, and these patterns create the potential for confounding when we look at how temperature and mortality risk are associated, beyond any seasonally-driven pathways.

```
mod_ctrl_dow_time <- glm(all ~ tmean + factor(dow, ordered = FALSE) +
                           ns(time, df = 158),
                         data = obs, family = "quasipoisson")
```

You can see the influence of this seasonal confounding if you look at the model results. When we look at the results from the model that did not control for long-term and seasonal trends, we get an estimate that mortality rates tend to be lower on days with higher temperature, with a negative term for `tmean`:

```
mod_ctrl_dow %>%
  tidy() %>%
  filter(term == "tmean")
```

```
## # A tibble: 1 x 5
##   term  estimate std.error statistic p.value
##   <chr>    <dbl>     <dbl>     <dbl>   <dbl>
## 1 tmean  -0.0148  0.000354     -41.7       0
```

Conversely, when we include control for long-term and seasonal trends, the estimated association between mortality rates and temperature is reversed, estimating increased mortality rates on days with higher temperature, *controlling* *for long-term and seasonal trends*:

```
mod_ctrl_dow_time %>%
  tidy() %>%
  filter(term == "tmean")
```

```
## # A tibble: 1 x 5
##   term  estimate std.error statistic  p.value
##   <chr>    <dbl>     <dbl>     <dbl>    <dbl>
## 1 tmean  0.00370  0.000395      9.36 1.02e-20
```

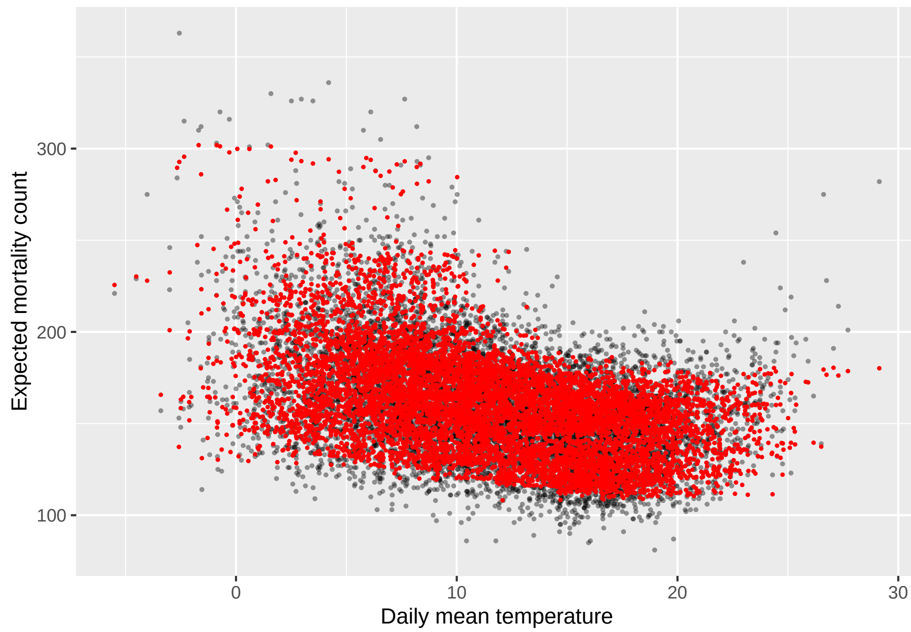
3. **Refine your model to fit for a non-linear, rather than linear, function of temperature in the model.**

You can use a spline in the same way to fit a non-linear function for the exposure of interest in the model (temperature). We'll start there. However, as mentioned earlier, it's a bit tricky to interpret the coefficients from the fit model—you no longer generate a single coefficient for the exposure of interest, but instead several related to the spline. Therefore, once we show how to fit using `ns` directly, we'll show how you can do the same thing using specialized functions in the `dlnm` package. This package includes a lot of nice functions for not only fitting an association using a non-linear term, but also for interpreting the results after the model is fit.

First, here is code that can be used to fit the model using `ns` directly, similarly to the approach we used to control for temporal patterns with a flexible function:

```
mod_ctrl_nl_temp <- glm(all ~ ns(tmean, 4) + factor(dow, ordered = FALSE) +
                          ns(time, df = 158),
                        data = obs, family = "quasipoisson")
```

```
mod_time_nonlin_highdf %>%
  augment() %>%
  mutate(tmean = obs$tmean) %>%
  ggplot(aes(x = tmean)) +
  geom_point(aes(y = all), alpha = 0.4, size = 0.5) +
  geom_point(aes(y = exp(.fitted)), color = "red",  size = 0.4) +
  labs(x = "Daily mean temperature", y = "Expected mortality count")
```



4.2 Cross-basis functions in GLMs

[Using a cross-basis to model an exposure's association with the outcome in two dimensions (dimensions of time and exposure level)]

4.3 Chapter vocabulary

Each class will start with a vocabulary quiz on a select number of the words from the chapter's vocabulary list. The vocabulary words for this chapter are:

Chapter 5

Natural experiments

The readings for this chapter are:

- Bernal et al. (2017) (on interrupted time series), with a correction to an equation in the paper at https://academic.oup.com/ije/article/49/4/1414/5900884. Example data and R code for the paper are available to download through a Supplemental Appendix.
- Barone-Adesi et al. (2011), the scientific paper highlighted as an example in the tutorial in the previous reading
- Bor et al. (2014) (on interrupted time series)
- Casey et al. (2018) (on difference-in-differences)
- Mendola (2018), an Invited Commentary on the previous reading

5.1 Interrupted time series

[Interrupted time series assessing effects of policy/intervention in specific point in time]

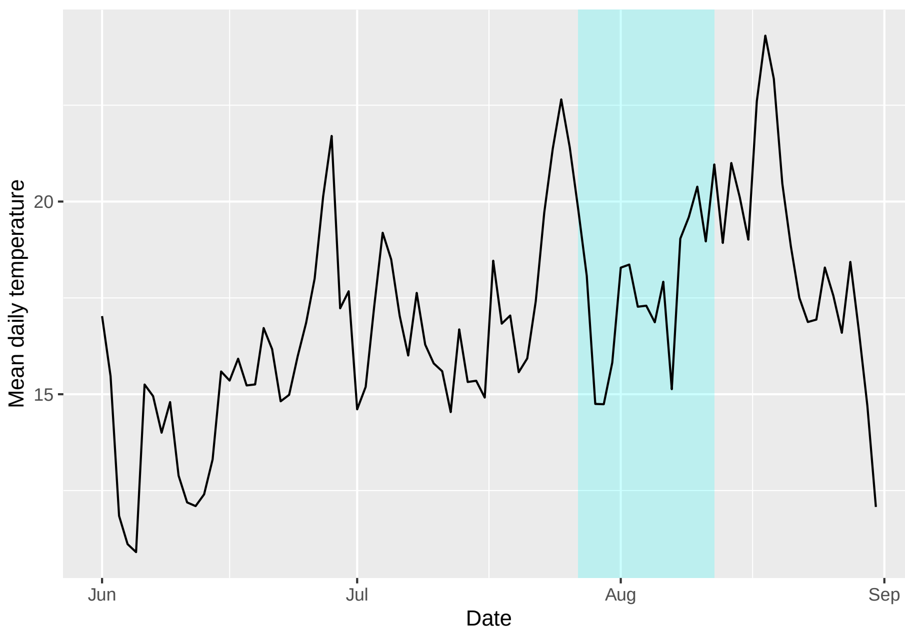
```r
# Load some packages that will likely be useful
library(tidyverse)
library(viridis)
library(lubridate)
library(broom)

# Load and clean the data
obs <- read_csv("data/lndn_obs.csv") %>%
  mutate(dow = wday(date, label = TRUE)) %>%
  mutate(time = as.numeric(date) - first(as.numeric(date)))
```

```r
london_summer_2012 <- obs %>%
  filter(ymd("2012-06-01") <= date & date <= ymd("2012-09-30"))
```

```
london_olympic_dates <- tibble(date = ymd(c("2012-07-27", "2012-08-12")))

ggplot() +
  geom_polygon(aes(x = ymd(c("2012-07-27", "2012-08-12",
                             "2012-08-12", "2012-07-27")),
                   y = c(Inf, Inf, -Inf, -Inf)), fill = "cyan", alpha = 0.2) +
  geom_line(data = london_summer_2012, aes(x = date, y = tmean)) +
  labs(x = "Date", y = "Mean daily temperature")
```



Example data from Bernal et al. (2017):

```
sicily <- read_csv("data/sicily.csv") %>%
  mutate(date = paste(year, month, "15"), # Use middle of the month for plotting
         date = ymd(date))
```

Identify dates of the smoking band:

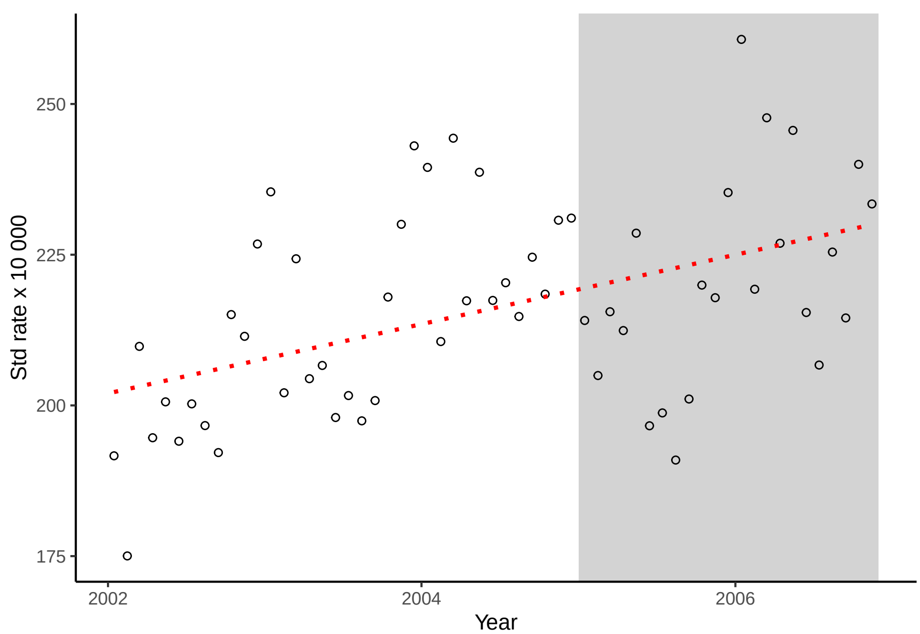
```
sicily %>%
  group_by(smokban) %>%
  slice(c(1, n()))
```

```
## # A tibble: 4 x 8
## # Groups:   smokban [2]
##    year month  aces  time smokban     pop  stdpop date
##   <dbl> <dbl> <dbl> <dbl>   <dbl>   <dbl>   <dbl> <date>
## 1  2002     1   728     1       0 364277. 379875. 2002-01-15
```

```
## 2  2004    12    886    36       0 364700. 383428. 2004-12-15
## 3  2005     1    831    37       1 364421. 388153. 2005-01-15
## 4  2006    11    912    59       1 363833. 390712. 2006-11-15
```

Recreate Figure 1 from Bernal et al. (2017):

```
ggplot() +
  geom_polygon(aes(x = ymd(c("2005-01-01", "2006-11-30",
                             "2006-11-30", "2005-01-01")),
               y = c(Inf, Inf, -Inf, -Inf)), fill = "lightgray") +
  geom_point(data = sicily,
             aes(x = date, y = 10000 * 10 * aces / stdpop), shape = 21) +
  geom_smooth(data = sicily,
              aes(x = date, y = 10000 * 10 * aces / stdpop), # Need the extra 10 to line up with
              method = "lm", se = FALSE, color = "red", linetype = 3) +
  labs(x = "Year", y = "Std rate x 10 000") +
  theme_classic()
```



5.2 Difference-in-differences

[Difference-in differences application for intervention introduced in one point in time]

Chapter 6

Risk assessment

[Predict expected heat-related mortality under a climate change scenario]

Chapter 7

Longitudinal cohort study designs

The readings for this chapter are

- Andersson et al. (2019)
- Wong et al. (1989)

The following are a series of instructional papers on survival analysis, that are meant as general background on how to fit survival analysis models.

- Clark et al. (2003)
- Bradburn et al. (2003a)
- Bradburn et al. (2003b)

7.1 Longitudinal cohort data

Example datasets are available online, but also made available to you on the course website. For the Framingham Heart Study the example data are available as the file "frmgham2.csv". It is saved in a csv format, and so they can be read into R using the `read_csv` function from the `readr` package (part of the tidyverse). You can use the following code to read in these data, assuming you have saved them in a "data" subdirectory of your current working directory:

```
library(tidyverse) # Loads all the tidyverse packages, including readr
fhs <- read_csv("data/frmgham2.csv")
fhs
```

```
## # A tibble: 11,627 x 39
##    RANDID   SEX TOTCHOL   AGE SYSBP DIABP CURSMOKE CIGPDAY   BMI DIABETES BPMEDS
```

```
##      <dbl> <dbl>   <dbl> <dbl> <dbl> <dbl>    <dbl>    <dbl> <dbl>    <dbl>  <dbl>
##  1   2448     1     195    39  106    70          0        0  27.0        0      0
##  2   2448     1     209    52  121    66          0        0  NA          0      0
##  3   6238     2     250    46  121    81          0        0  28.7        0      0
##  4   6238     2     260    52  105    69.5        0        0  29.4        0      0
##  5   6238     2     237    58  108    66          0        0  28.5        0      0
##  6   9428     1     245    48  128.   80          1       20  25.3        0      0
##  7   9428     1     283    54  141    89          1       30  25.3        0      0
##  8  10552     2     225    61  150    95          1       30  28.6        0      0
##  9  10552     2     232    67  183   109          1       20  30.2        0      0
## 10  11252     2     285    46  130    84          1       23  23.1        0      0
## # ... with 11,617 more rows, and 28 more variables: HEARTRTE <dbl>,
## #   GLUCOSE <dbl>, educ <dbl>, PREVCHD <dbl>, PREVAP <dbl>, PREVMI <dbl>,
## #   PREVSTRK <dbl>, PREVHYP <dbl>, TIME <dbl>, PERIOD <dbl>, HDLC <dbl>,
## #   LDLC <dbl>, DEATH <dbl>, ANGINA <dbl>, HOSPMI <dbl>, MI_FCHD <dbl>,
## #   ANYCHD <dbl>, STROKE <dbl>, CVD <dbl>, HYPERTEN <dbl>, TIMEAP <dbl>,
## #   TIMEMI <dbl>, TIMEMIFC <dbl>, TIMECHD <dbl>, TIMESTRK <dbl>, TIMECVD <dbl>,
## #   TIMEDTH <dbl>, TIMEHYP <dbl>
```

- One important difference compared to a time-series dataset is the `RANDID` variable. This is the unique identifier for unit for which we have repeated observations for over time. In this case the `RANDID` variable represents a unique identifier for each study participant, with multiple observations (rows) per participant over time.
- The `TIME` variable indicates the number of days that have ellapsed since beginning of follow-up of each observation. (`TIME=0` for the first observation of each participant).
- Number of observations varies between participants (typical)
- The time spacing between observations is not constant. This is because the repeated observations in the Framingham Heart Study are the result of follow-up exams happening 3 to 5 years apart. Many longitudinal cohorts will instead have observations over a fixed time interval (monthly, annual, biannual etc), resulting in a more balanced dataset.
- Observations are given for various risk factors, covariates and cardiovascular outcomes. Some will be invariant for each participant over time (`SEX`, `educ`), while others will vary with each exam.

From a data management perspective, we might want to change all the column names to be in lowercase, rather than uppercase. This will save our pinkies some work as we code with the data! You can make that change with the following code, using the `str_to_lower` function from the `stringr` package (part of the `tidyverse`):

```
fhs <- fhs %>%
  rename_all(.funs = str_to_lower)
fhs
```

```
## # A tibble: 11,627 x 39
##    randid   sex totchol   age sysbp diabp cursmoke cigpday   bmi diabetes bpmeds
##     <dbl> <dbl>   <dbl> <dbl> <dbl> <dbl>    <dbl>   <dbl> <dbl>    <dbl>  <dbl>
## 1    2448     1     195    39  106   70          0       0  27.0        0      0
## 2    2448     1     209    52  121   66          0       0  NA          0      0
## 3    6238     2     250    46  121   81          0       0  28.7        0      0
## 4    6238     2     260    52  105   69.5        0       0  29.4        0      0
## 5    6238     2     237    58  108   66          0       0  28.5        0      0
## 6    9428     1     245    48  128.  80          1      20  25.3        0      0
## 7    9428     1     283    54  141   89          1      30  25.3        0      0
## 8   10552     2     225    61  150   95          1      30  28.6        0      0
## 9   10552     2     232    67  183  109          1      20  30.2        0      0
## 10  11252     2     285    46  130   84          1      23  23.1        0      0
## # ... with 11,617 more rows, and 28 more variables: heartrte <dbl>,
## #   glucose <dbl>, educ <dbl>, prevchd <dbl>, prevap <dbl>, prevmi <dbl>,
## #   prevstrk <dbl>, prevhyp <dbl>, time <dbl>, period <dbl>, hdlc <dbl>,
## #   ldlc <dbl>, death <dbl>, angina <dbl>, hospmi <dbl>, mi_fchd <dbl>,
## #   anychd <dbl>, stroke <dbl>, cvd <dbl>, hyperten <dbl>, timeap <dbl>,
## #   timemi <dbl>, timemifc <dbl>, timechd <dbl>, timestrk <dbl>, timecvd <dbl>,
## #   timedth <dbl>, timehyp <dbl>
```

Applied exercise: Exploring longitudinal cohort data Read the example cohort data in R and explore it to answer the following questions:

1. What is the number of participants and number of observations in the `fhs` dataset?
2. Is there any missingness in the data?
3. How many participants die? What is the distribution of age at time of death?
4. What is the distribution of age at time of incident MI? Are there differences between males and females? Are there differences in smoking between males and females?
5. What is the distribution of BMI among MI cases and non-cases? How about between smokers and non-smokers

Based on this exploratory exercise in this section, talk about the potential for confounding when these data are analyzed to estimate the association between smoking and risk of incident MI.

Applied exercise: Example code

1. **What is the number of participants and the number of observations in the `fhs` dataset? (i.e what is the sample size and number of person-time observations)**

In the `fhs` dataset, the number of participants will be equal to the number of unique ID's (The `RANDID` variable which takes a unique value for each participant). We can extract this using the `unique` function nested within the `length` function

```
length(unique(fhs$randid))
```

```
## [1] 4434
```

If you'd like to use `tidyverse` tools to answer this question, you can do that, as well. The pipe operator (`%>%`) works on any type of object—it will take your current output and include it as the first parameter value for the function call you pipe into. If you want to perform operations on a column of a dataframe, you can use `pull` to extract it from the dataframe as a vector, and then pipe that into vector operations:

```
fhs %>%
  pull(randid) %>%
  unique() %>%
  length()
```

```
## [1] 4434
```

It's entirely a personal choice whether you use the `$` operator and "nesting" of function calls, versus `pull` and piping to do a series of function calls. You can see you get the same result, so it just comes down to the style that you will find easiest to understand when you look at your code later.

The number of person-time observations will actually be equal to the length of the dataset. The `dim` function gives us the length (number of rows) and width (number of columns) for a dataframe or any matrix like object in R.

```
dim(fhs)
```

```
## [1] 11627    39
```

We see that there is approximately an average of 2 to 3 observations per participants.

When you know there are repeated measurements, it can be helpful to explore how much variation there is in the number of observations per study subject. You could do that in this dataset with the following code:

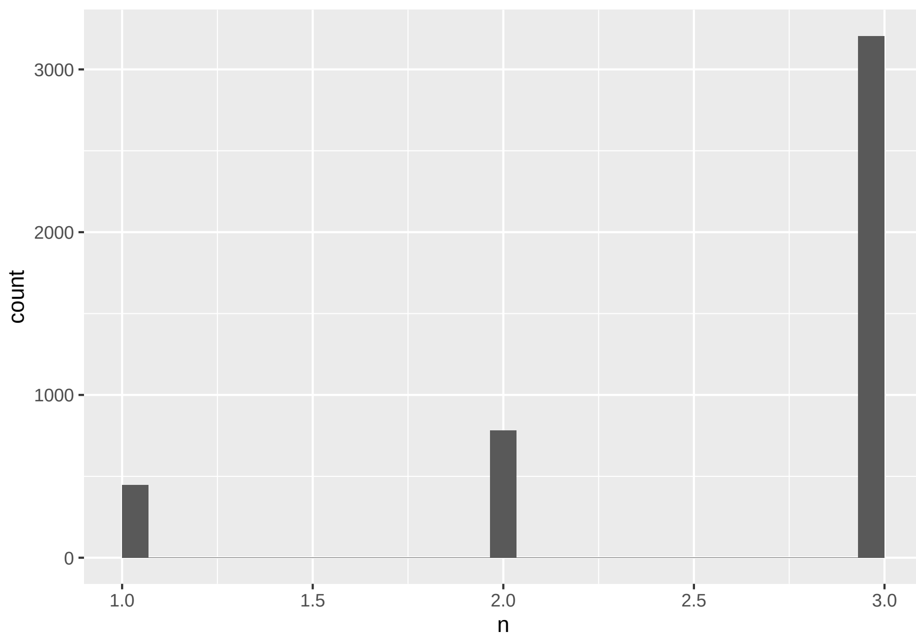
```
fhs %>%
  # Group by the study subject identifier and then count the rows for each
  group_by(randid) %>%
  count() %>%
  # Reorder the dataset so the subjects with the most observations come first
  arrange(desc(n)) %>%
  head()
```

```
## # A tibble: 6 x 2
## # Groups:   randid [6]
##   randid     n
##    <dbl> <int>
```

```
## 1   6238     3
## 2  11252     3
## 3  11263     3
## 4  12806     3
## 5  14367     3
## 6  16365     3
```

You can visualize this, as well. A histogram is one good choice:

```
fhs %>%
  # Group by the study subject identifier and then count the rows for each
  group_by(randid) %>%
  count() %>%
  ggplot(aes(x = n)) +
  geom_histogram()
```



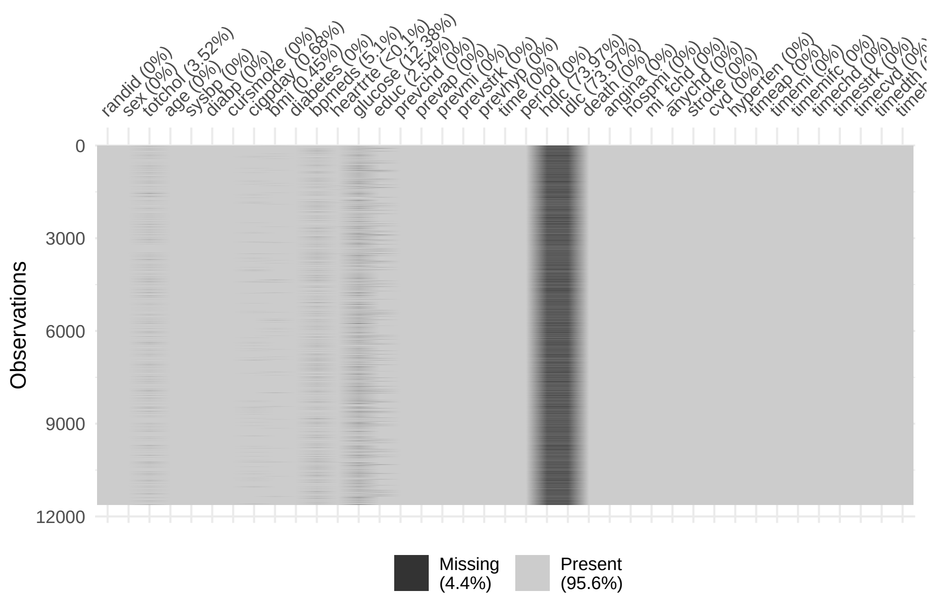
All study subjects have between one and three measurements. Most of the study subjects (over 3,000) have three measurements recorded in the dataset.

2. *Is there any missingness in the data?*

We can check for missingness in a number of ways. There are a couple of great packages, `visdat` and `naniar`, that include functions for investigating missingness in a dataset. If you don't have these installed, you can install them using `install.packages("naniar")` and `install.packages("visdat")`. The `naniar` package has a vignette with examples that is a nice starting point for working with both packages.

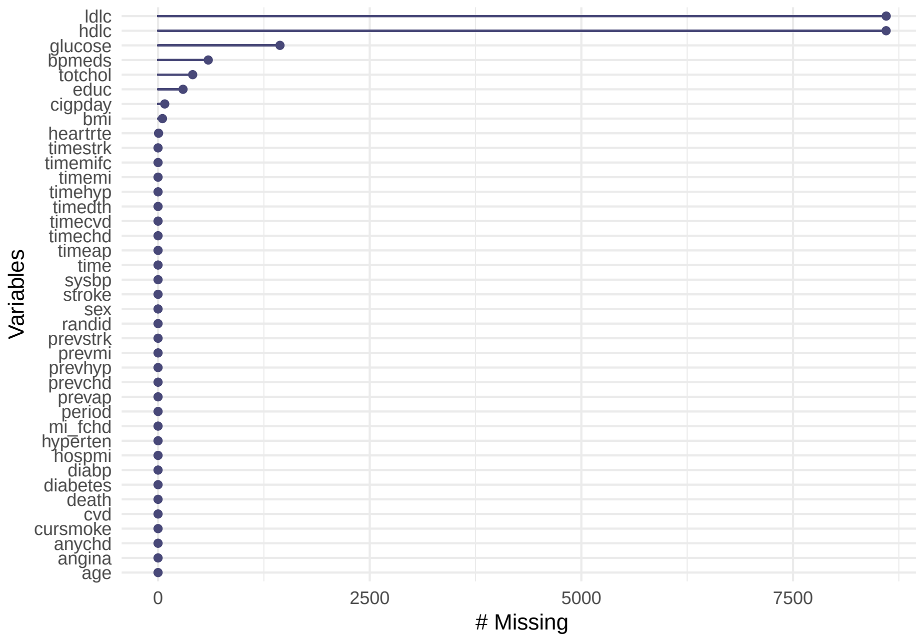
The `vis_miss` function shows missingness in a dataset in a way that lets you get a top-level snapshot:

```
library(visdat)
vis_miss(fhs)
```



Another was to visualize this is with `gg_miss_var`:

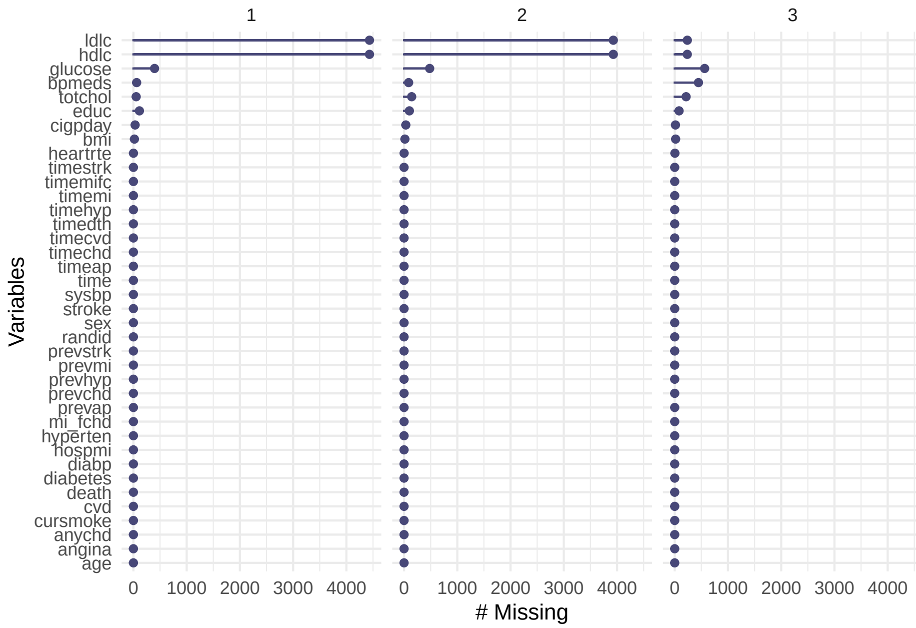
```
library(naniar)
gg_miss_var(fhs)
```



Many of the variables are available for all observations, with no missingness, including records of the subject's ID, measures of death, stroke, CVD, and other events, age, sex, and BMI. Some of the measured values from visits are missing occasionally, like the total cholesterol, and glucose. Other measures asked of the participants (number of cigarettes per day, education) are occasionally missing. Two of the variables—`hdlc` and `ldlc`—are missing more often than they are available.

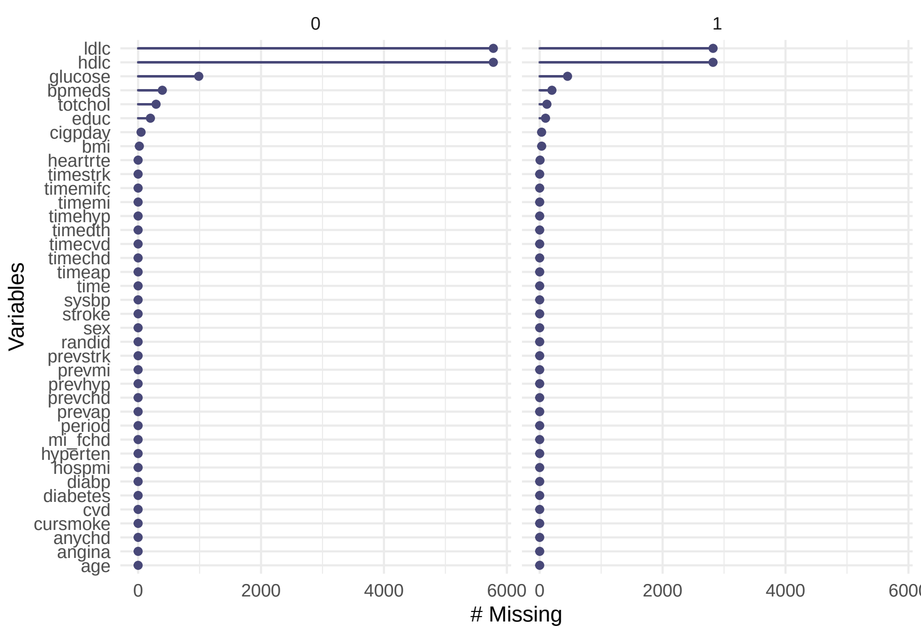
You can also do faceting with the `gg_miss_var` function. For example, you could see if missingness varies by the period of the observation:

```
gg_miss_var(fhs, facet = period)
```



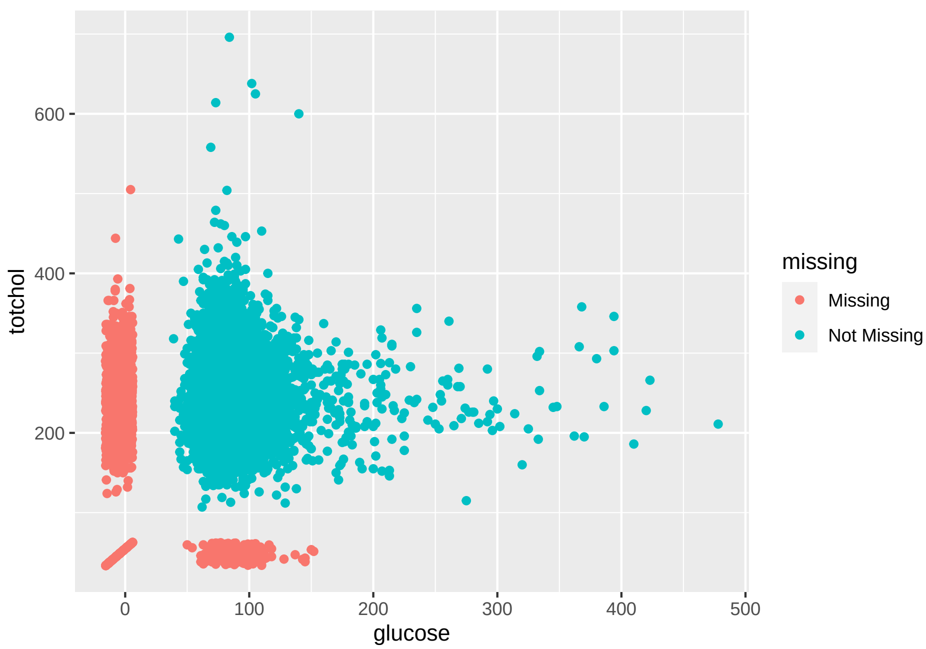
You may also want to check if missingness varies with whether an observation was associated with death of the study subject:

```
gg_miss_var(fhs, facet = death)
```



There are also functions in these packages that allow you to look at how missingness is related across variables. For example, both `glucose` and `totchol` are continuous variables, and both are occasionally missing. You can use the geom function `geom_miss_point` from the `nanair` package with a ggplot object to explore patterns of missingness among these two variables:

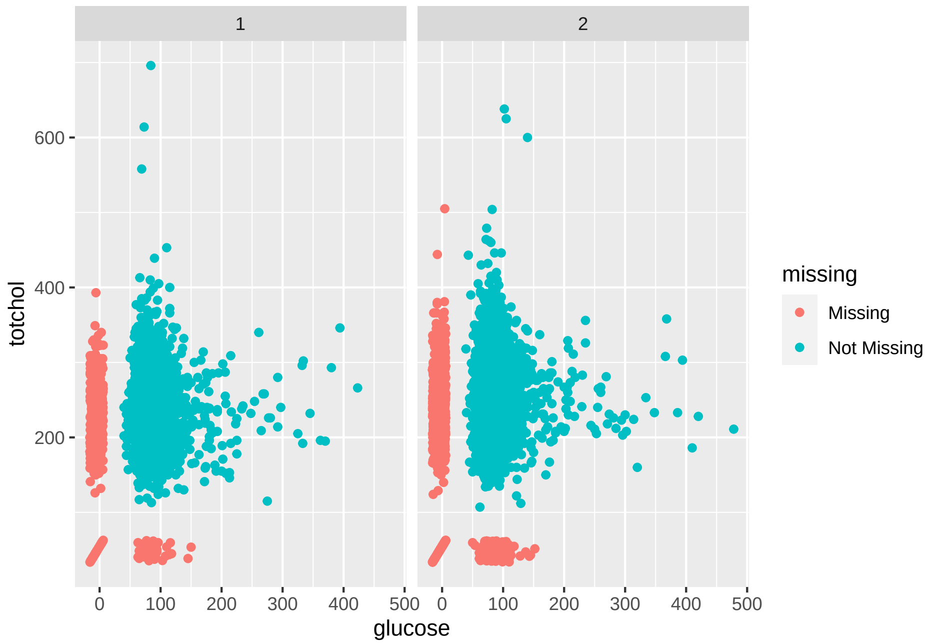
```
fhs %>%
  ggplot(aes(x = glucose, y = totchol)) +
  geom_miss_point()
```



The lower left corner shows the observations where both values are missing—it looks like there aren't too many. For observations with one missing but not the other (the points in red along the x- and y-axes), it looks like the distribution across the non-missing variable is pretty similar to that for observations with both measurements avaiable. In other words, `totchol` has a similar distribution among observations where `glucose` is available as observations where `glucose` is missing.

You can also do things like facet by sex to explore patterns at a finer level:

```
fhs %>%
  ggplot(aes(x = glucose, y = totchol)) +
  geom_miss_point() +
  facet_wrap(~ sex)
```



3. *How many participants die? What is the distribution of age at time of death?*

The `death` variable in the `fhs` data is an indicator for mortality if a participant died at any point during follow-up. It is time-invariant taking the value 1 if a participant died at any point or 0 if they were alive at their end of follow-up, so we have to be careful on how to extract the actual number of deaths.

If you arrange by the random ID and look at `period` and `death` for each subject, you can see that the `death` variable is the same for all periods for each subject:

```
fhs %>%
  arrange(randid) %>%
  select(randid, period, death)
```

```
## # A tibble: 11,627 x 3
##    randid period death
##     <dbl>  <dbl> <dbl>
##  1   2448      1     0
##  2   2448      3     0
##  3   6238      1     0
##  4   6238      2     0
##  5   6238      3     0
##  6   9428      1     0
##  7   9428      2     0
##  8  10552      1     1
##  9  10552      2     1
```

```
## 10  11252      1     0
## # ... with 11,617 more rows
```

We need to think some about this convention of recording the data when we count the deaths.

It is often useful to extract the first (and sometimes last) observation, in order to assess certain covariate statistics on the individual level. We can create a dataset including only the first (or last) observation per participant from the `fhs` data using `tidyverse` tools. The `group_by` functions groups data by unique values of designated variables (here `randid`) and the `slice` function selects rows as designated.

```
fhs_first <- fhs %>%
  group_by(randid) %>%
  slice(1L)%>%
  ungroup()
```

Alternatively you can use the `slice_head` function, which allows us to slice a designated number of rows beginning from the first observation. Because we are piping this in the `group_by` function, we will be slicing rows beginning from the first observation for each `randid`

```
fhs_first <- fhs %>%
  group_by(randid) %>%
  slice_head(n=1)%>%
ungroup()
```

We can similarly select the last observation for each participant

```
fhs_last <- fhs %>%
  group_by(randid) %>%
  slice(n())%>%
ungroup()
```

or using the `slice_tail` function

```
fhs_last <- fhs %>%
  group_by(randid) %>%
  slice_tail(n=1)%>%
ungroup()
```

In this dataset we can extract statistics on baseline covariates on the individual level, but also assess the number of participants with specific values, including `death=1`. For example, we can use the `sum` function in base R, which generates the sum of all values for a given vector. In this case since each death has the value of 1 the `sum` function will give as the number of deaths in the sample.

```
sum(fhs_first$death)
```

```
## [1] 1550
```

Conversely using `tidyverse` tools we can extract the number of observations with `death=1` using the `count` function

```
fhs_first %>%
count(death)
```

```
## # A tibble: 2 x 2
##   death     n
## * <dbl> <int>
## 1     0  2884
## 2     1  1550
```

Note that survival or time-to-event outcomes in longitudinal cohort data will often be time-varying. For example, a variable for mortality will take the value of zero until the person-time observation that represents the time interval that the outcome actually happens in. For outcomes such as mortality this will typically be the last observation. We will construct a variable like this in `fhs` below.

In order to estimate the distribution of age at death among those participants who died during follow-up we need to create a new age at death variable. The `age` variable in `fhs` represents the participants age at each visit. Typically a death would happen between visits so the last recorded value for `age` would be less than the age at death. We will use the `timedth` variable to help us determine the actual age at death. The value of `timedth` is the number of days from beginning of follow-up until death for those with `death=1`, while it is a fixed value of `timedth=8766` (the maximum duration of follow-up) for those with `death=0`.

We can create a new age at death variable for those with `death=1` using the `age` at baseline and `timedth` values

```
fhs_first<-fhs_first %>%
mutate(agedth=age+timedth/365.25)
```

We can then get summary statistics on this new variable

```
fhs_first %>%
summarize(min_agedth = min(agedth),
mean_agedth = mean(agedth),
max_agedth = max(agedth))
```

```
## # A tibble: 1 x 3
##   min_agedth mean_agedth max_agedth
##        <dbl>       <dbl>      <dbl>
## 1       38.4        70.5         93
```

We can also check on these values by groups of interest such as sex

```
fhs_first %>%
group_by(sex) %>%
summarize(min_agedth = min(agedth),
mean_agedth = mean(agedth),
max_agedth = max(agedth))
```

```
## # A tibble: 2 x 4
##     sex min_agedth mean_agedth max_agedth
## * <dbl>      <dbl>       <dbl>      <dbl>
## 1     1       41.6        69.5       91.1
## 2     2       38.4        71.3       93
```

4. *What is the distribution of age at time of incident MI? Are there differences between males and females? Are there differences in smoking between males and females?*

Similar to the question about death (all-cause mortality) we can look at disease incidence, for example myocardial infarction (MI). The `fhs` dataset has the `hospmi` variable as an indicator for any participant who had a hospitalization due to MI and `timemi` gives the number of days from beginning of follow up to the hospitalization due to MI. We can create an age at incident MI hospitalizaton in a similar fashion as the example for age at death.

```
fhs_first<-fhs_first %>%
mutate(agemi=age+timemi/365.25)
```

We can then get summary statistics on this new `agemi` variable

```
fhs_first %>%
summarize(min_agemi = min(agemi),
mean_agemi = mean(agemi),
max_agemi = max(agemi))
```

```
## # A tibble: 1 x 3
##   min_agemi mean_agemi max_agemi
##       <dbl>      <dbl>     <dbl>
## 1        37       69.7        93
```

And by sex

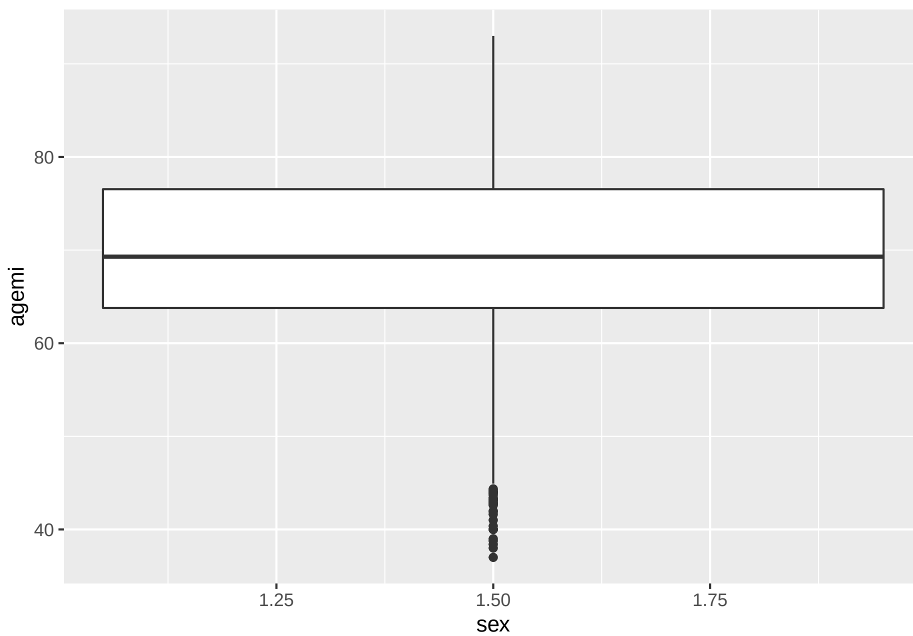
```
fhs_first %>%
group_by(sex)  %>%
summarize(min_agemi = min(agemi),
mean_agemi = mean(agemi),
max_agemi = max(agemi))
```

```
## # A tibble: 2 x 4
##     sex min_agemi mean_agemi max_agemi
## * <dbl>     <dbl>      <dbl>     <dbl>
```

```
## 1      1       37          68.2       91.1
## 2      2       38.4        70.9       93
```

We can see that the mean age at incident MI hospitalization among males and females is similar, but with males being somewhat younger on average at the time of incident MI. We can take a closer look at the distibution using boxplots:

```
fhs_first %>%
  # define the axes for the boxplot
  ggplot(aes(x = sex, y=agemi)) +
  geom_boxplot()
```



We see that R didn't return two separate boxplots by sex, but rather one centered between the two values of `sex=1` and `sex=2` which are the values for males and females respectively. This is an indicator that the sex variable is of class `numeric` and is treated as a continuous values rather than categorical. We can verify that this is in fact the case:

```
class(fhs_first$sex)
```

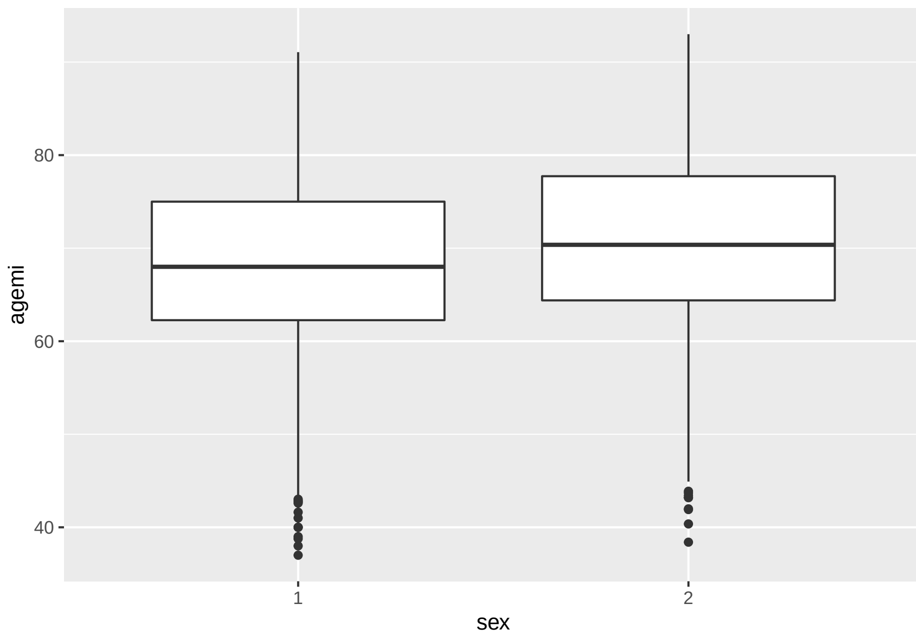
```
## [1] "numeric"
```

We can trasform the variable to one of class `factor` in order for it to be trated as a cateogrical variable

```
fhs_first<-fhs_first %>%
mutate(sex=as.factor(sex))
```

If we repeat the function for the boxplot now we get separate boxplots by sex

```
fhs_first %>%
  # define the axes for the boxplot
  ggplot(aes(x = sex, y=agemi)) +
  geom_boxplot()
```



We can once again see from the the boxplots that females tend to be a little older at incidence of MI.

5. *What is the distribution of BMI among MI cases and non-cases? How about between smokers and non-smokers*

Similar to the exercise above we can compare BMI distributions by MI case status.

7.2 Coding a survival analysis

[R package `survival`]

In the context of survival analysis what is modelled is time to an event (also referred to as survival time or failure time). This is a bit different than the models in the linear or `glm` family that model an outcome that may follow a gaussian (linear regression), binomial (logistic model) or Poisson distribution. Another difference is that the outcome (time to event) will not be determined in some participants, as they will not have experienced the event of interest during their follow-up. These participants are considered ‘censored’. Censoring can occur in three ways:

- the participant does not experience the event of interest before the study end
- the participant is lossed to follow-up before experiencing the event of interest
- the participant experiences a difference event that makes the event of interest impossible (for example if the event of interest is acute MI a participants that dies from a different cause is considered censored)

These are all types of right censoring and in simple survival analysis they are considered to be uninformative (typically not related to exposure). If the censoring is related to the exposure and the outcome then adjustment for censoring has to happen.

Let's assume that we are interested in all cause mortality as the event of interest let's denote T is time to death and $T \geq 0$. We define the survival function as $S(t) = Pr[T > t] = 1 - F(t)$, where the survival function $S(t)$ is the probability that a participant survives past time t ($Pr[T > t] = 1$). $F(t)$ is the Probability Density Function, (sometimes also denoted as the the Cumulative Incidence Function, $R(t)$) or the probability that that an individual will have a survival time less than or equal to t ($[Pr(T \leq t)]$)

Time to event t is bounded by $[0, \infty)$ and $S(t)$ is non-increasing as t becomes greater. At $t = 0$, $S(t) = 1$ and conversely as t approaches ∞, $S(t) = 0$. A property of the survival and probabilty density function is $S(t) = 1–F(t)$: the survival function and the probability density function (or cumulative incidence function ($R(t)$) sum to 1.

Another useful function is the hazard Function, $h(t)$, which is the instantaneous potential of experiencing an event at time t, conditional on having survived to that time ($h(t) = \frac{Pr[t<T\leq t+\Delta t|T>t]}{\Delta t} = \frac{f(t)}{S(t)}$). The cumulative Hazard Function, $H(t)$ is defined as the integral of the hazard function from time 0 to time t, which equals the area under the curve $h(t)$ between time 0 and time t ($H(t) = \int_0^t h(u)du$). If we know any of $S(t)$, $H(t)$ or $h(t)$, we can derive the rest based on the following relationships:

$h(t) = \frac{\partial log(S(t))}{\partial t}$

$H(t) = -log(S(t))$ and conversely $S(t) = exp(-H(t))$

The `survival` package in R allows us to fit these types of models, including a very popular model in survival analysis, the Cox proportional hazards model that was also applied in Wong et al. (1989). A very simple way to estimate survival is the non-parametric Kaplan-Meier estimator.

In R we would estimate Survival $S(t)$ with all-cause mortality representing failure as follows:

```
library(survival)
 S1=Surv(fhs_first$timedth,fhs_first$death)
 S1
```

```
##    [1] 8766+ 8766+ 8766+ 2956  8766+ 8766+ 8766+ 8766+ 8766+ 8766+ 8766+ 8766+
##   [13] 8766+ 5592  6411   146  8766+ 1442  8766+ 8766+ 8766+ 8766+ 6410  8766+
##   [25] 8766+  430  8766+ 8766+  168  8423  8766+ 8766+ 8766+ 1047  6948  1417
##   [37] 5839  8766+ 8766+ 6269  8766+ 8766+ 8766+ 8766+ 6524  8766+ 2697  8766+
##   [49] 5973  8766+ 1881  8312  3315  8766+ 8766+ 8766+ 8766+ 8766+ 8766+ 8766+
##   [61] 7102  8766+ 8766+ 5526  5276  4875  1620  5572  8406  8766+ 8766+ 8766+
##   [73] 7078  8766+ 8766+ 8766+ 8766+ 2749  8766+ 8766+ 8766+ 8766+ 5030  2365
##   [85] 8766+ 8766+ 5320  8766+ 7119  7493  8766+ 1833  8766+ 8766+ 8766+ 4514
##   [97] 8676  4365  7643  8766+ 8766+ 2017  3873  8766+ 6036  8766+ 8766+ 5181
##  [109] 8766+ 8766+ 5590  8766+ 1187  2013  8766+ 6246  8766+ 8766+ 7796  8766+
##  [121] 4605  7801  8766+ 8766+ 8766+ 8766+ 8766+ 6020  8766+ 4090  4568  8766+
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##  [157] 8766+ 1607  2138  8766+ 8766+ 8766+ 8766+ 8766+ 8766+ 8766+ 4753  1440
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##  [181] 8766+ 5272  8766+ 3914  8766+ 8766+ 8766+ 7607  8766+ 7166  4257  8766+
##  [193] 3888  8766+ 8766+ 2346  8766+ 8766+ 4238   709  8766+ 1547  8766+ 8766+
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##  [217] 8766+  234  8766+ 8436  8766+ 6410  8766+ 8766+ 8766+ 8766+ 8766+ 4563
##  [229] 8766+ 8766+ 8766+ 8766+ 8766+ 8766+ 8766+ 8766+ 1761  8766+ 3595  8766+
##  [241] 8766+ 8766+ 4728  8766+ 8766+ 8766+ 8766+ 8766+ 8766+ 1649  8766+ 8516
##  [253]  938  8766+ 5330  8766+ 8671  8766+ 2531  1169  6187  6735  8766+ 7571
##  [265] 8766+ 8766+ 5475  4200  8766+ 8766+ 8766+ 3716  7820  4564  8766+ 4580
##  [277] 8766+ 8766+ 8766+ 8766+ 8766+ 8766+ 2205  6949  3683  8766+ 8766+ 8766+
##  [289] 8766+ 3945  8766+ 8766+ 8766+ 8766+ 8766+ 8766+ 3450  8766+ 8766+ 8766+
##  [301] 8766+ 8766+ 8766+ 8766+ 5556  8766+   73  5189  8766+ 8766+ 8766+ 8766+
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##  [469] 5687  8766+ 8766+ 8766+ 7308  8766+ 7570  7050  8766+ 8766+ 8766+ 8766+
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```

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##  [493] 8413  8766+ 8766+ 8766+ 8766+ 4808  8766+ 8766+ 2424  8766+ 8766+ 5518
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##  [517] 8766+ 1517  8766+ 8766+ 3379  8766+ 8766+ 8766+ 8766+ 8766+ 3910  8766+
##  [529] 8766+ 8766+ 8766+ 8766+ 8766+ 8766+ 8766+ 7223  5167  8766+ 8766+ 5410
##  [541] 2707  8766+ 2462    58  1142  8766+ 8766+ 8766+ 6734  8766+ 8766+ 5437
##  [553] 8766+ 8766+ 8766+ 8766+ 8766+ 7303  6808  8766+ 8766+ 3405  8766+ 1920
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##  [637] 4145  8766+ 8766+ 8766+ 8766+ 8092  7771   992  8766+ 8766+ 8766+  612
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##  [733] 1370  8766+ 6984  5351  8766+ 8766+ 8766+ 8766+ 3434  4145  8766+ 8766+
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## [1177] 2285  8766+ 5229  8766+ 5272  8766+ 8766+ 5387  8766+ 4154  6184  5820 
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## [1249] 8766+ 8766+ 8766+ 8766+ 8766+ 8766+ 6418  8766+ 8766+ 6210  8766+ 8766+
## [1261] 8132  8766+ 8766+ 6824  8766+ 8766+ 8766+ 8766+ 6254  2666  2079  8766+
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## [1285]   26  8766+ 8766+ 8766+ 8766+ 8766+ 6316  8549  8766+ 8766+ 8766+ 6770 
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## [1801] 8766+ 7679  8766+ 5655  6007  2570  8766+ 8766+ 8766+ 8766+ 8766+ 6777
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## [1897] 8766+ 6804  7367  2243  7365  5789  8766+ 1023  3455  8766+ 8766+ 2634
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## [1945] 3211  4162  8766+ 5413  8766+ 7613   623  6952  4967  8766+ 8172  8766+
## [1957] 8753  8766+ 8766+ 8766+ 5139  8766+ 8766+ 8766+ 4894  2784  4293  5761
## [1969] 8766+ 8766+ 8766+ 8766+ 8766+ 8766+ 8766+ 2752  8766+ 8766+ 8240  8766+
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## [3217] 8505  8766+ 8766+ 8766+ 8766+ 4977  6006  8766+ 8766+ 2105  2235  7230 
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## [4381] 8766+  334  4357  8766+ 6691  1788   938  1626  8766+ 8766+ 7363  6990
## [4393] 8766+ 8766+ 8766+ 8766+ 5764  8766+ 8766+ 8766+ 2364  7923  6434  8766+
## [4405] 8766+ 8501  2312  8766+ 5538  8766+ 5894  8766+ 8766+ 1552  8766+ 8494
## [4417] 1911  8766+ 8766+ 8650  7362  4177  8766+ 6562  8766+ 8457   565  4300
## [4429] 7746  6433  6729  8766+ 8766+ 8766+
```

The numbers assigned to each individual is their censoring times, with each number with a plus sign indicating that the participant was censored at that times without developing the outcome (haven't failed/died), while those without the plus sign are the times at which participants developed the outcome (failure/death).

```
library(survminer) ##for plotting survival plots with ggplot2
```

```
## Loading required package: ggpubr
```

```
fit1<-survfit(Surv(timedth, death) ~ 1, data = fhs_first)
summary(fit1)
```

```
## Call: survfit(formula = Surv(timedth, death) ~ 1, data = fhs_first)
##
##  time n.risk n.event survival  std.err lower 95% CI upper 95% CI
##    26   4434       1    1.000 0.000226        0.999        1.000
##    34   4433       1    1.000 0.000319        0.999        1.000
##    40   4432       1    0.999 0.000390        0.999        1.000
##    45   4431       1    0.999 0.000451        0.998        1.000
##    46   4430       1    0.999 0.000504        0.998        1.000
##    53   4429       1    0.999 0.000552        0.998        1.000
##    58   4428       1    0.998 0.000596        0.997        1.000
##    73   4427       1    0.998 0.000637        0.997        0.999
##    87   4426       1    0.998 0.000676        0.997        0.999
##   126   4425       1    0.998 0.000712        0.996        0.999
##   133   4424       1    0.998 0.000747        0.996        0.999
##   145   4423       1    0.997 0.000780        0.996        0.999
##   146   4422       1    0.997 0.000812        0.995        0.999
##   163   4421       1    0.997 0.000843        0.995        0.998
##   168   4420       1    0.997 0.000872        0.995        0.998
##   174   4419       1    0.996 0.000900        0.995        0.998
##   178   4418       1    0.996 0.000928        0.994        0.998
##   182   4417       1    0.996 0.000955        0.994        0.998
##   184   4416       1    0.996 0.000981        0.994        0.998
##   234   4415       1    0.995 0.001006        0.994        0.997
##   266   4414       1    0.995 0.001031        0.993        0.997
##   267   4413       1    0.995 0.001055        0.993        0.997
##   282   4412       1    0.995 0.001079        0.993        0.997
```

```
##   287  4411       1    0.995 0.001102        0.992        0.997
##   305  4410       1    0.994 0.001124        0.992        0.997
##   307  4409       1    0.994 0.001147        0.992        0.996
##   310  4408       1    0.994 0.001168        0.992        0.996
##   327  4407       1    0.994 0.001190        0.991        0.996
##   331  4406       1    0.993 0.001211        0.991        0.996
##   334  4405       1    0.993 0.001231        0.991        0.996
##   339  4404       1    0.993 0.001251        0.991        0.995
##   367  4403       1    0.993 0.001271        0.990        0.995
##   378  4402       1    0.993 0.001291        0.990        0.995
##   385  4401       1    0.992 0.001310        0.990        0.995
##   415  4400       1    0.992 0.001329        0.990        0.995
##   424  4399       1    0.992 0.001348        0.989        0.995
##   429  4398       1    0.992 0.001366        0.989        0.994
##   430  4397       2    0.991 0.001402        0.988        0.994
##   442  4395       1    0.991 0.001420        0.988        0.994
##   498  4394       1    0.991 0.001437        0.988        0.994
##   526  4393       1    0.991 0.001455        0.988        0.993
##   537  4392       2    0.990 0.001489        0.987        0.993
##   544  4390       1    0.990 0.001505        0.987        0.993
##   564  4389       1    0.990 0.001522        0.987        0.993
##   565  4388       1    0.989 0.001538        0.986        0.992
##   572  4387       1    0.989 0.001554        0.986        0.992
##   584  4386       1    0.989 0.001570        0.986        0.992
##   593  4385       1    0.989 0.001586        0.986        0.992
##   607  4384       1    0.988 0.001601        0.985        0.992
##   612  4383       1    0.988 0.001617        0.985        0.991
##   623  4382       1    0.988 0.001632        0.985        0.991
##   647  4381       1    0.988 0.001647        0.985        0.991
##   672  4380       1    0.988 0.001662        0.984        0.991
##   693  4379       1    0.987 0.001677        0.984        0.991
##   700  4378       1    0.987 0.001692        0.984        0.990
##   709  4377       1    0.987 0.001706        0.984        0.990
##   717  4376       1    0.987 0.001721        0.983        0.990
##   753  4375       1    0.986 0.001735        0.983        0.990
##   756  4374       1    0.986 0.001749        0.983        0.990
##   764  4373       1    0.986 0.001763        0.983        0.989
##   771  4372       1    0.986 0.001777        0.982        0.989
##   788  4371       1    0.986 0.001791        0.982        0.989
##   803  4370       1    0.985 0.001805        0.982        0.989
##   806  4369       1    0.985 0.001819        0.982        0.989
##   815  4368       1    0.985 0.001832        0.981        0.988
##   822  4367       1    0.985 0.001845        0.981        0.988
##   827  4366       1    0.984 0.001859        0.981        0.988
##   828  4365       1    0.984 0.001872        0.981        0.988
##   832  4364       1    0.984 0.001885        0.980        0.988
```

```
##   854   4363         1     0.984 0.001898         0.980          0.987
##   858   4362         1     0.984 0.001911         0.980          0.987
##   869   4361         1     0.983 0.001924         0.980          0.987
##   885   4360         1     0.983 0.001937         0.979          0.987
##   887   4359         1     0.983 0.001949         0.979          0.987
##   889   4358         1     0.983 0.001962         0.979          0.986
##   935   4357         1     0.982 0.001974         0.979          0.986
##   938   4356         2     0.982 0.001999         0.978          0.986
##   945   4354         1     0.982 0.002011         0.978          0.986
##   946   4353         1     0.982 0.002023         0.978          0.985
##   987   4352         1     0.981 0.002035         0.977          0.985
##   992   4351         1     0.981 0.002047         0.977          0.985
##   996   4350         1     0.981 0.002059         0.977          0.985
##  1003   4349         1     0.981 0.002071         0.977          0.985
##  1023   4348         1     0.980 0.002083         0.976          0.984
##  1040   4347         1     0.980 0.002095         0.976          0.984
##  1047   4346         1     0.980 0.002106         0.976          0.984
##  1099   4345         1     0.980 0.002118         0.976          0.984
##  1100   4344         1     0.979 0.002129         0.975          0.984
##  1102   4343         1     0.979 0.002141         0.975          0.983
##  1103   4342         1     0.979 0.002152         0.975          0.983
##  1141   4341         1     0.979 0.002163         0.975          0.983
##  1142   4340         1     0.979 0.002175         0.974          0.983
##  1154   4339         1     0.978 0.002186         0.974          0.983
##  1168   4338         1     0.978 0.002197         0.974          0.982
##  1169   4337         1     0.978 0.002208         0.974          0.982
##  1175   4336         1     0.978 0.002219         0.973          0.982
##  1187   4335         1     0.977 0.002230         0.973          0.982
##  1197   4334         2     0.977 0.002251         0.973          0.981
##  1204   4332         1     0.977 0.002262         0.972          0.981
##  1214   4331         1     0.977 0.002273         0.972          0.981
##  1215   4330         1     0.976 0.002283         0.972          0.981
##  1221   4329         1     0.976 0.002294         0.972          0.981
##  1235   4328         1     0.976 0.002305         0.971          0.980
##  1240   4327         1     0.976 0.002315         0.971          0.980
##  1269   4326         1     0.975 0.002325         0.971          0.980
##  1273   4325         1     0.975 0.002336         0.971          0.980
##  1303   4324         1     0.975 0.002346         0.970          0.980
##  1305   4323         1     0.975 0.002356         0.970          0.979
##  1336   4322         1     0.975 0.002367         0.970          0.979
##  1350   4321         1     0.974 0.002377         0.970          0.979
##  1355   4320         1     0.974 0.002387         0.969          0.979
##  1368   4319         1     0.974 0.002397         0.969          0.979
##  1370   4318         1     0.974 0.002407         0.969          0.978
##  1377   4317         1     0.973 0.002417         0.969          0.978
##  1386   4316         1     0.973 0.002427         0.968          0.978
```

```
##  1395  4315      1   0.973 0.002437      0.968      0.978
##  1396  4314      1   0.973 0.002447      0.968      0.978
##  1400  4313      1   0.972 0.002457      0.968      0.977
##  1416  4312      1   0.972 0.002466      0.967      0.977
##  1417  4311      1   0.972 0.002476      0.967      0.977
##  1433  4310      1   0.972 0.002486      0.967      0.977
##  1440  4309      2   0.971 0.002505      0.966      0.976
##  1442  4307      1   0.971 0.002514      0.966      0.976
##  1443  4306      1   0.971 0.002524      0.966      0.976
##  1454  4305      1   0.971 0.002533      0.966      0.976
##  1462  4304      1   0.970 0.002543      0.965      0.975
##  1466  4303      1   0.970 0.002552      0.965      0.975
##  1490  4302      1   0.970 0.002562      0.965      0.975
##  1492  4301      1   0.970 0.002571      0.965      0.975
##  1506  4300      1   0.970 0.002580      0.965      0.975
##  1517  4299      1   0.969 0.002589      0.964      0.974
##  1547  4298      2   0.969 0.002608      0.964      0.974
##  1552  4296      1   0.969 0.002617      0.964      0.974
##  1563  4295      1   0.968 0.002626      0.963      0.974
##  1568  4294      1   0.968 0.002635      0.963      0.973
##  1575  4293      1   0.968 0.002644      0.963      0.973
##  1582  4292      1   0.968 0.002653      0.963      0.973
##  1587  4291      2   0.967 0.002671      0.962      0.973
##  1607  4289      2   0.967 0.002689      0.962      0.972
##  1620  4287      1   0.967 0.002698      0.961      0.972
##  1622  4286      1   0.966 0.002706      0.961      0.972
##  1626  4285      1   0.966 0.002715      0.961      0.972
##  1629  4284      1   0.966 0.002724      0.961      0.971
##  1632  4283      1   0.966 0.002732      0.960      0.971
##  1644  4282      2   0.965 0.002750      0.960      0.971
##  1649  4280      1   0.965 0.002758      0.960      0.970
##  1660  4279      1   0.965 0.002767      0.959      0.970
##  1686  4278      1   0.965 0.002775      0.959      0.970
##  1692  4277      1   0.964 0.002784      0.959      0.970
##  1710  4276      1   0.964 0.002792      0.959      0.970
##  1729  4275      1   0.964 0.002801      0.958      0.969
##  1740  4274      1   0.964 0.002809      0.958      0.969
##  1747  4273      1   0.963 0.002818      0.958      0.969
##  1748  4272      1   0.963 0.002826      0.958      0.969
##  1752  4271      1   0.963 0.002834      0.957      0.969
##  1755  4270      1   0.963 0.002843      0.957      0.968
##  1757  4269      1   0.963 0.002851      0.957      0.968
##  1761  4268      2   0.962 0.002867      0.957      0.968
##  1765  4266      1   0.962 0.002875      0.956      0.968
##  1770  4265      1   0.962 0.002884      0.956      0.967
##  1778  4264      1   0.961 0.002892      0.956      0.967
```

```
## 1781 4263 1 0.961 0.002900 0.956 0.967
## 1788 4262 1 0.961 0.002908 0.955 0.967
## 1792 4261 1 0.961 0.002916 0.955 0.966
## 1805 4260 1 0.961 0.002924 0.955 0.966
## 1815 4259 1 0.960 0.002932 0.955 0.966
## 1825 4258 1 0.960 0.002940 0.954 0.966
## 1833 4257 1 0.960 0.002948 0.954 0.966
## 1847 4256 1 0.960 0.002956 0.954 0.965
## 1848 4255 1 0.959 0.002964 0.954 0.965
## 1863 4254 1 0.959 0.002972 0.953 0.965
## 1879 4253 1 0.959 0.002979 0.953 0.965
## 1881 4252 1 0.959 0.002987 0.953 0.965
## 1883 4251 1 0.959 0.002995 0.953 0.964
## 1885 4250 1 0.958 0.003003 0.952 0.964
## 1886 4249 1 0.958 0.003011 0.952 0.964
## 1903 4248 1 0.958 0.003018 0.952 0.964
## 1904 4247 1 0.958 0.003026 0.952 0.964
## 1906 4246 1 0.957 0.003034 0.951 0.963
## 1911 4245 1 0.957 0.003041 0.951 0.963
## 1912 4244 1 0.957 0.003049 0.951 0.963
## 1920 4243 1 0.957 0.003057 0.951 0.963
## 1933 4242 1 0.956 0.003064 0.950 0.962
## 1936 4241 1 0.956 0.003072 0.950 0.962
## 1939 4240 1 0.956 0.003079 0.950 0.962
## 1942 4239 1 0.956 0.003087 0.950 0.962
## 1943 4238 1 0.956 0.003094 0.950 0.962
## 1947 4237 1 0.955 0.003102 0.949 0.961
## 1959 4236 1 0.955 0.003109 0.949 0.961
## 1984 4235 1 0.955 0.003117 0.949 0.961
## 1985 4234 1 0.955 0.003124 0.949 0.961
## 1986 4233 1 0.954 0.003132 0.948 0.961
## 1988 4232 1 0.954 0.003139 0.948 0.960
## 1989 4231 1 0.954 0.003146 0.948 0.960
## 2008 4230 1 0.954 0.003154 0.948 0.960
## 2013 4229 1 0.954 0.003161 0.947 0.960
## 2015 4228 1 0.953 0.003168 0.947 0.960
## 2017 4227 1 0.953 0.003175 0.947 0.959
## 2021 4226 1 0.953 0.003183 0.947 0.959
## 2029 4225 1 0.953 0.003190 0.946 0.959
## 2042 4224 1 0.952 0.003197 0.946 0.959
## 2046 4223 1 0.952 0.003204 0.946 0.958
## 2058 4222 1 0.952 0.003211 0.946 0.958
## 2079 4221 1 0.952 0.003219 0.945 0.958
## 2104 4220 1 0.952 0.003226 0.945 0.958
## 2105 4219 1 0.951 0.003233 0.945 0.958
## 2112 4218 1 0.951 0.003240 0.945 0.957
```

```
##   2116   4217       1    0.951 0.003247        0.944         0.957
##   2117   4216       1    0.951 0.003254        0.944         0.957
##   2122   4215       1    0.950 0.003261        0.944         0.957
##   2138   4214       1    0.950 0.003268        0.944         0.957
##   2141   4213       1    0.950 0.003275        0.944         0.956
##   2142   4212       1    0.950 0.003282        0.943         0.956
##   2143   4211       1    0.949 0.003289        0.943         0.956
##   2146   4210       1    0.949 0.003296        0.943         0.956
##   2148   4209       1    0.949 0.003303        0.943         0.956
##   2157   4208       1    0.949 0.003310        0.942         0.955
##   2159   4207       1    0.949 0.003317        0.942         0.955
##   2160   4206       1    0.948 0.003324        0.942         0.955
##   2192   4205       1    0.948 0.003330        0.942         0.955
##   2193   4204       1    0.948 0.003337        0.941         0.954
##   2194   4203       1    0.948 0.003344        0.941         0.954
##   2205   4202       1    0.947 0.003351        0.941         0.954
##   2218   4201       1    0.947 0.003358        0.941         0.954
##   2230   4200       1    0.947 0.003364        0.940         0.954
##   2235   4199       1    0.947 0.003371        0.940         0.953
##   2243   4198       1    0.947 0.003378        0.940         0.953
##   2247   4197       1    0.946 0.003385        0.940         0.953
##   2270   4196       1    0.946 0.003391        0.939         0.953
##   2285   4195       1    0.946 0.003398        0.939         0.953
##   2287   4194       1    0.946 0.003405        0.939         0.952
##   2289   4193       1    0.945 0.003411        0.939         0.952
##   2298   4192       1    0.945 0.003418        0.939         0.952
##   2311   4191       1    0.945 0.003425        0.938         0.952
##   2312   4190       1    0.945 0.003431        0.938         0.951
##   2329   4189       1    0.945 0.003438        0.938         0.951
##   2335   4188       1    0.944 0.003444        0.938         0.951
##   2345   4187       1    0.944 0.003451        0.937         0.951
##   2346   4186       1    0.944 0.003457        0.937         0.951
##   2348   4185       1    0.944 0.003464        0.937         0.950
##   2364   4184       2    0.943 0.003477        0.936         0.950
##   2365   4182       1    0.943 0.003483        0.936         0.950
##   2389   4181       1    0.943 0.003490        0.936         0.950
##   2391   4180       1    0.942 0.003496        0.936         0.949
##   2395   4179       1    0.942 0.003503        0.935         0.949
##   2397   4178       1    0.942 0.003509        0.935         0.949
##   2400   4177       1    0.942 0.003516        0.935         0.949
##   2406   4176       1    0.942 0.003522        0.935         0.949
##   2420   4175       1    0.941 0.003528        0.934         0.948
##   2424   4174       2    0.941 0.003541        0.934         0.948
##   2425   4172       1    0.941 0.003547        0.934         0.948
##   2434   4171       1    0.940 0.003554        0.934         0.947
##   2453   4170       1    0.940 0.003560        0.933         0.947
```

```
## 2457 4169 1 0.940 0.003566 0.933 0.947
## 2462 4168 1 0.940 0.003573 0.933 0.947
## 2465 4167 1 0.940 0.003579 0.933 0.947
## 2474 4166 1 0.939 0.003585 0.932 0.946
## 2478 4165 1 0.939 0.003591 0.932 0.946
## 2481 4164 1 0.939 0.003597 0.932 0.946
## 2488 4163 1 0.939 0.003604 0.932 0.946
## 2503 4162 1 0.938 0.003610 0.931 0.946
## 2520 4161 1 0.938 0.003616 0.931 0.945
## 2531 4160 1 0.938 0.003622 0.931 0.945
## 2540 4159 1 0.938 0.003628 0.931 0.945
## 2549 4158 1 0.938 0.003634 0.930 0.945
## 2550 4157 1 0.937 0.003641 0.930 0.944
## 2562 4156 1 0.937 0.003647 0.930 0.944
## 2567 4155 1 0.937 0.003653 0.930 0.944
## 2568 4154 1 0.937 0.003659 0.929 0.944
## 2570 4153 1 0.936 0.003665 0.929 0.944
## 2573 4152 1 0.936 0.003671 0.929 0.943
## 2580 4151 1 0.936 0.003677 0.929 0.943
## 2587 4150 1 0.936 0.003683 0.929 0.943
## 2589 4149 1 0.935 0.003689 0.928 0.943
## 2590 4148 1 0.935 0.003695 0.928 0.943
## 2601 4147 1 0.935 0.003701 0.928 0.942
## 2606 4146 1 0.935 0.003707 0.928 0.942
## 2609 4145 1 0.935 0.003713 0.927 0.942
## 2614 4144 1 0.934 0.003719 0.927 0.942
## 2618 4143 1 0.934 0.003725 0.927 0.941
## 2620 4142 1 0.934 0.003731 0.927 0.941
## 2634 4141 2 0.933 0.003743 0.926 0.941
## 2641 4139 1 0.933 0.003748 0.926 0.941
## 2666 4138 2 0.933 0.003760 0.925 0.940
## 2674 4136 1 0.933 0.003766 0.925 0.940
## 2677 4135 1 0.932 0.003772 0.925 0.940
## 2682 4134 1 0.932 0.003778 0.925 0.940
## 2697 4133 1 0.932 0.003783 0.925 0.939
## 2707 4132 1 0.932 0.003789 0.924 0.939
## 2708 4131 1 0.931 0.003795 0.924 0.939
## 2719 4130 1 0.931 0.003801 0.924 0.939
## 2720 4129 1 0.931 0.003807 0.924 0.938
## 2738 4128 1 0.931 0.003812 0.923 0.938
## 2749 4127 1 0.931 0.003818 0.923 0.938
## 2752 4126 1 0.930 0.003824 0.923 0.938
## 2759 4125 1 0.930 0.003830 0.923 0.938
## 2784 4124 1 0.930 0.003835 0.922 0.937
## 2796 4123 1 0.930 0.003841 0.922 0.937
## 2807 4122 2 0.929 0.003852 0.922 0.937
```

```
##   2812   4120        1     0.929 0.003858          0.921          0.937
##   2818   4119        1     0.929 0.003864          0.921          0.936
##   2826   4118        1     0.929 0.003869          0.921          0.936
##   2830   4117        1     0.928 0.003875          0.921          0.936
##   2841   4116        1     0.928 0.003880          0.920          0.936
##   2857   4115        1     0.928 0.003886          0.920          0.935
##   2864   4114        1     0.928 0.003892          0.920          0.935
##   2869   4113        1     0.927 0.003897          0.920          0.935
##   2891   4112        1     0.927 0.003903          0.920          0.935
##   2896   4111        1     0.927 0.003908          0.919          0.935
##   2937   4110        1     0.927 0.003914          0.919          0.934
##   2948   4109        1     0.926 0.003919          0.919          0.934
##   2956   4108        1     0.926 0.003925          0.919          0.934
##   2960   4107        1     0.926 0.003931          0.918          0.934
##   2964   4106        1     0.926 0.003936          0.918          0.934
##   2965   4105        1     0.926 0.003942          0.918          0.933
##   2971   4104        1     0.925 0.003947          0.918          0.933
##   2975   4103        1     0.925 0.003953          0.917          0.933
##   2980   4102        1     0.925 0.003958          0.917          0.933
##   2981   4101        1     0.925 0.003963          0.917          0.932
##   2983   4100        1     0.924 0.003969          0.917          0.932
##   2984   4099        1     0.924 0.003974          0.916          0.932
##   2990   4098        1     0.924 0.003980          0.916          0.932
##   2993   4097        1     0.924 0.003985          0.916          0.932
##   2995   4096        1     0.924 0.003991          0.916          0.931
##   3017   4095        1     0.923 0.003996          0.916          0.931
##   3025   4094        1     0.923 0.004001          0.915          0.931
##   3032   4093        1     0.923 0.004007          0.915          0.931
##   3065   4092        1     0.923 0.004012          0.915          0.931
##   3076   4091        1     0.922 0.004017          0.915          0.930
##   3077   4090        2     0.922 0.004028          0.914          0.930
##   3091   4088        1     0.922 0.004033          0.914          0.930
##   3109   4087        1     0.922 0.004039          0.914          0.929
##   3128   4086        1     0.921 0.004044          0.913          0.929
##   3129   4085        1     0.921 0.004049          0.913          0.929
##   3130   4084        2     0.921 0.004060          0.913          0.929
##   3132   4082        1     0.920 0.004065          0.912          0.928
##   3133   4081        1     0.920 0.004070          0.912          0.928
##   3147   4080        1     0.920 0.004076          0.912          0.928
##   3156   4079        1     0.920 0.004081          0.912          0.928
##   3161   4078        1     0.919 0.004086          0.912          0.928
##   3173   4077        1     0.919 0.004091          0.911          0.927
##   3176   4076        3     0.919 0.004107          0.911          0.927
##   3184   4073        1     0.918 0.004112          0.910          0.926
##   3208   4072        1     0.918 0.004117          0.910          0.926
##   3211   4071        1     0.918 0.004122          0.910          0.926
```

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## 3219   4070      1    0.918 0.004128       0.910       0.926
## 3247   4069      1    0.917 0.004133       0.909       0.926
## 3251   4068      1    0.917 0.004138       0.909       0.925
## 3253   4067      1    0.917 0.004143       0.909       0.925
## 3269   4066      1    0.917 0.004148       0.909       0.925
## 3272   4065      1    0.917 0.004153       0.908       0.925
## 3273   4064      1    0.916 0.004158       0.908       0.925
## 3282   4063      1    0.916 0.004163       0.908       0.924
## 3288   4062      1    0.916 0.004168       0.908       0.924
## 3295   4061      1    0.916 0.004174       0.908       0.924
## 3315   4060      1    0.915 0.004179       0.907       0.924
## 3337   4059      1    0.915 0.004184       0.907       0.923
## 3339   4058      1    0.915 0.004189       0.907       0.923
## 3348   4057      1    0.915 0.004194       0.907       0.923
## 3352   4056      1    0.915 0.004199       0.906       0.923
## 3356   4055      1    0.914 0.004204       0.906       0.923
## 3368   4054      1    0.914 0.004209       0.906       0.922
## 3379   4053      1    0.914 0.004214       0.906       0.922
## 3391   4052      1    0.914 0.004219       0.905       0.922
## 3394   4051      1    0.913 0.004224       0.905       0.922
## 3405   4050      1    0.913 0.004229       0.905       0.921
## 3406   4049      1    0.913 0.004234       0.905       0.921
## 3407   4048      1    0.913 0.004239       0.904       0.921
## 3413   4047      1    0.912 0.004244       0.904       0.921
## 3416   4046      1    0.912 0.004249       0.904       0.921
## 3429   4045      2    0.912 0.004258       0.904       0.920
## 3434   4043      1    0.912 0.004263       0.903       0.920
## 3450   4042      1    0.911 0.004268       0.903       0.920
## 3455   4041      1    0.911 0.004273       0.903       0.920
## 3459   4040      1    0.911 0.004278       0.903       0.919
## 3460   4039      1    0.911 0.004283       0.902       0.919
## 3463   4038      1    0.910 0.004288       0.902       0.919
## 3471   4037      1    0.910 0.004293       0.902       0.919
## 3488   4036      1    0.910 0.004297       0.902       0.918
## 3489   4035      1    0.910 0.004302       0.901       0.918
## 3490   4034      1    0.910 0.004307       0.901       0.918
## 3503   4033      1    0.909 0.004312       0.901       0.918
## 3510   4032      1    0.909 0.004317       0.901       0.918
## 3514   4031      1    0.909 0.004322       0.900       0.917
## 3518   4030      1    0.909 0.004326       0.900       0.917
## 3536   4029      1    0.908 0.004331       0.900       0.917
## 3538   4028      1    0.908 0.004336       0.900       0.917
## 3549   4027      1    0.908 0.004341       0.900       0.917
## 3550   4026      1    0.908 0.004346       0.899       0.916
## 3564   4025      1    0.908 0.004350       0.899       0.916
## 3565   4024      1    0.907 0.004355       0.899       0.916
```

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##  3568   4023       1    0.907 0.004360        0.899        0.916
##  3571   4022       1    0.907 0.004365        0.898        0.915
##  3573   4021       2    0.906 0.004374        0.898        0.915
##  3587   4019       2    0.906 0.004384        0.897        0.915
##  3591   4017       1    0.906 0.004388        0.897        0.914
##  3595   4016       1    0.906 0.004393        0.897        0.914
##  3600   4015       1    0.905 0.004398        0.897        0.914
##  3601   4014       1    0.905 0.004402        0.896        0.914
##  3607   4013       1    0.905 0.004407        0.896        0.914
##  3619   4012       1    0.905 0.004412        0.896        0.913
##  3622   4011       1    0.904 0.004416        0.896        0.913
##  3624   4010       1    0.904 0.004421        0.896        0.913
##  3625   4009       1    0.904 0.004426        0.895        0.913
##  3632   4008       1    0.904 0.004430        0.895        0.912
##  3640   4007       1    0.903 0.004435        0.895        0.912
##  3646   4006       1    0.903 0.004440        0.895        0.912
##  3655   4005       2    0.903 0.004449        0.894        0.912
##  3657   4003       1    0.903 0.004453        0.894        0.911
##  3660   4002       1    0.902 0.004458        0.894        0.911
##  3672   4001       1    0.902 0.004463        0.893        0.911
##  3683   4000       2    0.902 0.004472        0.893        0.910
##  3692   3998       1    0.901 0.004476        0.893        0.910
##  3694   3997       1    0.901 0.004481        0.892        0.910
##  3698   3996       1    0.901 0.004485        0.892        0.910
##  3704   3995       1    0.901 0.004490        0.892        0.910
##  3716   3994       1    0.901 0.004494        0.892        0.909
##  3721   3993       1    0.900 0.004499        0.892        0.909
##  3726   3992       1    0.900 0.004503        0.891        0.909
##  3728   3991       1    0.900 0.004508        0.891        0.909
##  3730   3990       1    0.900 0.004513        0.891        0.909
##  3731   3989       1    0.899 0.004517        0.891        0.908
##  3738   3988       1    0.899 0.004522        0.890        0.908
##  3752   3987       1    0.899 0.004526        0.890        0.908
##  3758   3986       1    0.899 0.004530        0.890        0.908
##  3760   3985       1    0.899 0.004535        0.890        0.907
##  3763   3984       1    0.898 0.004539        0.889        0.907
##  3765   3983       1    0.898 0.004544        0.889        0.907
##  3773   3982       1    0.898 0.004548        0.889        0.907
##  3774   3981       1    0.898 0.004553        0.889        0.907
##  3776   3980       2    0.897 0.004562        0.888        0.906
##  3777   3978       1    0.897 0.004566        0.888        0.906
##  3779   3977       1    0.897 0.004570        0.888        0.906
##  3789   3976       1    0.896 0.004575        0.888        0.905
##  3790   3975       1    0.896 0.004579        0.887        0.905
##  3796   3974       1    0.896 0.004584        0.887        0.905
##  3797   3973       1    0.896 0.004588        0.887        0.905
```

```
##  3802   3972       2   0.895 0.004597       0.886        0.904
##  3807   3970       1   0.895 0.004601       0.886        0.904
##  3833   3969       1   0.895 0.004606       0.886        0.904
##  3837   3968       1   0.895 0.004610       0.886        0.904
##  3840   3967       1   0.894 0.004614       0.885        0.904
##  3848   3966       1   0.894 0.004619       0.885        0.903
##  3851   3965       1   0.894 0.004623       0.885        0.903
##  3859   3964       1   0.894 0.004627       0.885        0.903
##  3873   3963       1   0.894 0.004632       0.885        0.903
##  3878   3962       1   0.893 0.004636       0.884        0.902
##  3882   3961       1   0.893 0.004640       0.884        0.902
##  3888   3960       2   0.893 0.004649       0.884        0.902
##  3893   3958       1   0.892 0.004653       0.883        0.902
##  3898   3957       2   0.892 0.004662       0.883        0.901
##  3910   3955       1   0.892 0.004666       0.883        0.901
##  3914   3954       1   0.892 0.004670       0.882        0.901
##  3932   3953       1   0.891 0.004675       0.882        0.901
##  3941   3952       1   0.891 0.004679       0.882        0.900
##  3944   3951       1   0.891 0.004683       0.882        0.900
##  3945   3950       2   0.890 0.004692       0.881        0.900
##  3953   3948       2   0.890 0.004700       0.881        0.899
##  3970   3946       1   0.890 0.004704       0.881        0.899
##  3973   3945       1   0.889 0.004708       0.880        0.899
##  3981   3944       1   0.889 0.004713       0.880        0.899
##  3998   3943       1   0.889 0.004717       0.880        0.898
##  3999   3942       1   0.889 0.004721       0.880        0.898
##  4011   3941       1   0.889 0.004725       0.879        0.898
##  4019   3940       1   0.888 0.004729       0.879        0.898
##  4024   3939       1   0.888 0.004734       0.879        0.897
##  4028   3938       1   0.888 0.004738       0.879        0.897
##  4034   3937       1   0.888 0.004742       0.878        0.897
##  4036   3936       1   0.887 0.004746       0.878        0.897
##  4041   3935       1   0.887 0.004750       0.878        0.897
##  4050   3934       1   0.887 0.004754       0.878        0.896
##  4051   3933       1   0.887 0.004758       0.878        0.896
##  4053   3932       1   0.887 0.004763       0.877        0.896
##  4060   3931       1   0.886 0.004767       0.877        0.896
##  4082   3930       2   0.886 0.004775       0.877        0.895
##  4090   3928       1   0.886 0.004779       0.876        0.895
##  4097   3927       1   0.885 0.004783       0.876        0.895
##  4102   3926       1   0.885 0.004787       0.876        0.895
##  4104   3925       1   0.885 0.004791       0.876        0.894
##  4118   3924       1   0.885 0.004795       0.875        0.894
##  4119   3923       1   0.885 0.004799       0.875        0.894
##  4127   3922       1   0.884 0.004804       0.875        0.894
##  4128   3921       1   0.884 0.004808       0.875        0.894
```

```
##   4142   3920       1    0.884 0.004812        0.874         0.893
##   4145   3919       2    0.883 0.004820        0.874         0.893
##   4146   3917       1    0.883 0.004824        0.874         0.893
##   4154   3916       2    0.883 0.004832        0.873         0.892
##   4158   3914       1    0.882 0.004836        0.873         0.892
##   4162   3913       1    0.882 0.004840        0.873         0.892
##   4168   3912       1    0.882 0.004844        0.873         0.892
##   4177   3911       1    0.882 0.004848        0.872         0.891
##   4181   3910       1    0.882 0.004852        0.872         0.891
##   4182   3909       1    0.881 0.004856        0.872         0.891
##   4183   3908       1    0.881 0.004860        0.872         0.891
##   4185   3907       1    0.881 0.004864        0.871         0.891
##   4200   3906       1    0.881 0.004868        0.871         0.890
##   4205   3905       1    0.880 0.004872        0.871         0.890
##   4235   3904       1    0.880 0.004876        0.871         0.890
##   4237   3903       1    0.880 0.004880        0.871         0.890
##   4238   3902       1    0.880 0.004884        0.870         0.889
##   4243   3901       1    0.880 0.004888        0.870         0.889
##   4245   3900       1    0.879 0.004892        0.870         0.889
##   4246   3899       1    0.879 0.004896        0.870         0.889
##   4249   3898       1    0.879 0.004900        0.869         0.889
##   4257   3897       1    0.879 0.004904        0.869         0.888
##   4262   3896       1    0.878 0.004907        0.869         0.888
##   4266   3895       1    0.878 0.004911        0.869         0.888
##   4270   3894       1    0.878 0.004915        0.868         0.888
##   4275   3893       1    0.878 0.004919        0.868         0.887
##   4276   3892       1    0.878 0.004923        0.868         0.887
##   4286   3891       1    0.877 0.004927        0.868         0.887
##   4293   3890       1    0.877 0.004931        0.867         0.887
##   4295   3889       1    0.877 0.004935        0.867         0.887
##   4300   3888       1    0.877 0.004939        0.867         0.886
##   4318   3887       1    0.876 0.004943        0.867         0.886
##   4319   3886       1    0.876 0.004946        0.867         0.886
##   4321   3885       1    0.876 0.004950        0.866         0.886
##   4324   3884       1    0.876 0.004954        0.866         0.885
##   4338   3883       1    0.876 0.004958        0.866         0.885
##   4341   3882       1    0.875 0.004962        0.866         0.885
##   4343   3881       1    0.875 0.004966        0.865         0.885
##   4351   3880       1    0.875 0.004970        0.865         0.885
##   4352   3879       1    0.875 0.004973        0.865         0.884
##   4356   3878       1    0.874 0.004977        0.865         0.884
##   4357   3877       1    0.874 0.004981        0.864         0.884
##   4359   3876       2    0.874 0.004989        0.864         0.884
##   4360   3874       1    0.873 0.004992        0.864         0.883
##   4365   3873       1    0.873 0.004996        0.864         0.883
##   4369   3872       1    0.873 0.005000        0.863         0.883
```

```
## 4378   3871       1    0.873 0.005004       0.863        0.883
## 4392   3870       1    0.873 0.005008       0.863        0.882
## 4396   3869       1    0.872 0.005011       0.863        0.882
## 4423   3868       1    0.872 0.005015       0.862        0.882
## 4441   3867       1    0.872 0.005019       0.862        0.882
## 4442   3866       2    0.871 0.005026       0.862        0.881
## 4444   3864       1    0.871 0.005030       0.861        0.881
## 4447   3863       1    0.871 0.005034       0.861        0.881
## 4452   3862       1    0.871 0.005038       0.861        0.881
## 4467   3861       1    0.871 0.005041       0.861        0.880
## 4470   3860       1    0.870 0.005045       0.860        0.880
## 4484   3859       2    0.870 0.005053       0.860        0.880
## 4485   3857       1    0.870 0.005056       0.860        0.880
## 4492   3856       1    0.869 0.005060       0.860        0.879
## 4494   3855       2    0.869 0.005068       0.859        0.879
## 4496   3853       1    0.869 0.005071       0.859        0.879
## 4500   3852       1    0.869 0.005075       0.859        0.879
## 4511   3851       1    0.868 0.005079       0.858        0.878
## 4513   3850       1    0.868 0.005082       0.858        0.878
## 4514   3849       1    0.868 0.005086       0.858        0.878
## 4516   3848       1    0.868 0.005090       0.858        0.878
## 4522   3847       1    0.867 0.005093       0.857        0.877
## 4537   3846       1    0.867 0.005097       0.857        0.877
## 4542   3845       1    0.867 0.005101       0.857        0.877
## 4554   3844       1    0.867 0.005104       0.857        0.877
## 4560   3843       2    0.866 0.005112       0.856        0.876
## 4561   3841       1    0.866 0.005115       0.856        0.876
## 4563   3840       1    0.866 0.005119       0.856        0.876
## 4564   3839       1    0.866 0.005123       0.856        0.876
## 4568   3838       1    0.865 0.005126       0.855        0.875
## 4576   3837       2    0.865 0.005133       0.855        0.875
## 4580   3835       1    0.865 0.005137       0.855        0.875
## 4585   3834       1    0.864 0.005141       0.854        0.875
## 4605   3833       1    0.864 0.005144       0.854        0.874
## 4616   3832       1    0.864 0.005148       0.854        0.874
## 4618   3831       1    0.864 0.005151       0.854        0.874
## 4635   3830       1    0.864 0.005155       0.854        0.874
## 4637   3829       1    0.863 0.005159       0.853        0.873
## 4643   3828       1    0.863 0.005162       0.853        0.873
## 4652   3827       1    0.863 0.005166       0.853        0.873
## 4653   3826       1    0.863 0.005169       0.853        0.873
## 4654   3825       1    0.862 0.005173       0.852        0.873
## 4659   3824       1    0.862 0.005176       0.852        0.872
## 4677   3823       1    0.862 0.005180       0.852        0.872
## 4683   3822       1    0.862 0.005184       0.852        0.872
## 4684   3821       1    0.862 0.005187       0.851        0.872
```

```
##  4685   3820         1     0.861 0.005191          0.851          0.872
##  4700   3819         1     0.861 0.005194          0.851          0.871
##  4705   3818         1     0.861 0.005198          0.851          0.871
##  4714   3817         1     0.861 0.005201          0.850          0.871
##  4719   3816         1     0.860 0.005205          0.850          0.871
##  4723   3815         1     0.860 0.005208          0.850          0.870
##  4725   3814         1     0.860 0.005212          0.850          0.870
##  4728   3813         1     0.860 0.005215          0.850          0.870
##  4729   3812         1     0.859 0.005219          0.849          0.870
##  4730   3811         1     0.859 0.005222          0.849          0.870
##  4753   3810         1     0.859 0.005226          0.849          0.869
##  4757   3809         1     0.859 0.005229          0.849          0.869
##  4758   3808         1     0.859 0.005233          0.848          0.869
##  4762   3807         1     0.858 0.005236          0.848          0.869
##  4763   3806         1     0.858 0.005240          0.848          0.868
##  4775   3805         1     0.858 0.005243          0.848          0.868
##  4776   3804         1     0.858 0.005247          0.847          0.868
##  4780   3803         1     0.857 0.005250          0.847          0.868
##  4788   3802         1     0.857 0.005254          0.847          0.868
##  4792   3801         1     0.857 0.005257          0.847          0.867
##  4793   3800         1     0.857 0.005261          0.847          0.867
##  4808   3799         1     0.857 0.005264          0.846          0.867
##  4817   3798         1     0.856 0.005267          0.846          0.867
##  4820   3797         1     0.856 0.005271          0.846          0.867
##  4844   3796         1     0.856 0.005274          0.846          0.866
##  4845   3795         1     0.856 0.005278          0.845          0.866
##  4854   3794         1     0.855 0.005281          0.845          0.866
##  4860   3793         1     0.855 0.005285          0.845          0.866
##  4867   3792         1     0.855 0.005288          0.845          0.865
##  4870   3791         1     0.855 0.005291          0.844          0.865
##  4873   3790         1     0.855 0.005295          0.844          0.865
##  4875   3789         1     0.854 0.005298          0.844          0.865
##  4878   3788         1     0.854 0.005302          0.844          0.865
##  4882   3787         1     0.854 0.005305          0.844          0.864
##  4887   3786         1     0.854 0.005308          0.843          0.864
##  4890   3785         1     0.853 0.005312          0.843          0.864
##  4894   3784         1     0.853 0.005315          0.843          0.864
##  4895   3783         1     0.853 0.005319          0.843          0.863
##  4896   3782         1     0.853 0.005322          0.842          0.863
##  4900   3781         1     0.853 0.005325          0.842          0.863
##  4903   3780         1     0.852 0.005329          0.842          0.863
##  4907   3779         2     0.852 0.005335          0.841          0.862
##  4915   3777         1     0.852 0.005339          0.841          0.862
##  4921   3776         1     0.851 0.005342          0.841          0.862
##  4924   3775         1     0.851 0.005345          0.841          0.862
##  4931   3774         1     0.851 0.005349          0.841          0.861
```

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##  4934   3773        1     0.851 0.005352        0.840          0.861
##  4936   3772        1     0.850 0.005355        0.840          0.861
##  4949   3771        1     0.850 0.005359        0.840          0.861
##  4961   3770        1     0.850 0.005362        0.840          0.861
##  4967   3769        1     0.850 0.005365        0.839          0.860
##  4969   3768        1     0.850 0.005369        0.839          0.860
##  4972   3767        1     0.849 0.005372        0.839          0.860
##  4975   3766        1     0.849 0.005375        0.839          0.860
##  4977   3765        1     0.849 0.005379        0.838          0.860
##  4984   3764        1     0.849 0.005382        0.838          0.859
##  4988   3763        1     0.848 0.005385        0.838          0.859
##  4995   3762        1     0.848 0.005388        0.838          0.859
##  4999   3761        1     0.848 0.005392        0.837          0.859
##  5000   3760        1     0.848 0.005395        0.837          0.858
##  5002   3759        1     0.848 0.005398        0.837          0.858
##  5007   3758        1     0.847 0.005402        0.837          0.858
##  5009   3757        1     0.847 0.005405        0.837          0.858
##  5010   3756        1     0.847 0.005408        0.836          0.858
##  5011   3755        1     0.847 0.005411        0.836          0.857
##  5017   3754        1     0.846 0.005415        0.836          0.857
##  5020   3753        1     0.846 0.005418        0.836          0.857
##  5024   3752        1     0.846 0.005421        0.835          0.857
##  5026   3751        1     0.846 0.005424        0.835          0.856
##  5030   3750        1     0.846 0.005428        0.835          0.856
##  5035   3749        1     0.845 0.005431        0.835          0.856
##  5040   3748        2     0.845 0.005437        0.834          0.856
##  5062   3746        1     0.845 0.005441        0.834          0.855
##  5065   3745        1     0.844 0.005444        0.834          0.855
##  5066   3744        1     0.844 0.005447        0.834          0.855
##  5071   3743        1     0.844 0.005450        0.833          0.855
##  5072   3742        1     0.844 0.005453        0.833          0.854
##  5081   3741        1     0.843 0.005457        0.833          0.854
##  5085   3740        1     0.843 0.005460        0.833          0.854
##  5088   3739        1     0.843 0.005463        0.832          0.854
##  5095   3738        1     0.843 0.005466        0.832          0.854
##  5098   3737        1     0.843 0.005469        0.832          0.853
##  5101   3736        1     0.842 0.005473        0.832          0.853
##  5119   3735        1     0.842 0.005476        0.831          0.853
##  5122   3734        1     0.842 0.005479        0.831          0.853
##  5123   3733        1     0.842 0.005482        0.831          0.852
##  5127   3732        1     0.841 0.005485        0.831          0.852
##  5128   3731        1     0.841 0.005488        0.831          0.852
##  5131   3730        1     0.841 0.005492        0.830          0.852
##  5136   3729        1     0.841 0.005495        0.830          0.852
##  5137   3728        1     0.841 0.005498        0.830          0.851
##  5139   3727        1     0.840 0.005501        0.830          0.851
```

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##   5145    3726        2     0.840 0.005507          0.829         0.851
##   5150    3724        1     0.840 0.005510          0.829         0.851
##   5154    3723        2     0.839 0.005517          0.828         0.850
##   5157    3721        1     0.839 0.005520          0.828         0.850
##   5159    3720        1     0.839 0.005523          0.828         0.850
##   5167    3719        1     0.839 0.005526          0.828         0.849
##   5169    3718        1     0.838 0.005529          0.828         0.849
##   5181    3717        1     0.838 0.005532          0.827         0.849
##   5183    3716        1     0.838 0.005535          0.827         0.849
##   5189    3715        1     0.838 0.005539          0.827         0.849
##   5194    3714        1     0.837 0.005542          0.827         0.848
##   5200    3713        1     0.837 0.005545          0.826         0.848
##   5206    3712        1     0.837 0.005548          0.826         0.848
##   5226    3711        1     0.837 0.005551          0.826         0.848
##   5229    3710        1     0.836 0.005554          0.826         0.847
##   5232    3709        1     0.836 0.005557          0.825         0.847
##   5245    3708        1     0.836 0.005560          0.825         0.847
##   5252    3707        3     0.835 0.005569          0.825         0.846
##   5263    3704        1     0.835 0.005572          0.824         0.846
##   5265    3703        1     0.835 0.005575          0.824         0.846
##   5269    3702        2     0.834 0.005582          0.824         0.845
##   5272    3700        2     0.834 0.005588          0.823         0.845
##   5276    3698        1     0.834 0.005591          0.823         0.845
##   5283    3697        1     0.834 0.005594          0.823         0.845
##   5296    3696        1     0.833 0.005597          0.822         0.844
##   5309    3695        1     0.833 0.005600          0.822         0.844
##   5313    3694        1     0.833 0.005603          0.822         0.844
##   5316    3693        1     0.833 0.005606          0.822         0.844
##   5320    3692        2     0.832 0.005612          0.821         0.843
##   5321    3690        1     0.832 0.005615          0.821         0.843
##   5322    3689        3     0.831 0.005624          0.820         0.842
##   5330    3686        1     0.831 0.005627          0.820         0.842
##   5337    3685        1     0.831 0.005630          0.820         0.842
##   5351    3684        2     0.830 0.005636          0.819         0.842
##   5353    3682        1     0.830 0.005639          0.819         0.841
##   5362    3681        1     0.830 0.005642          0.819         0.841
##   5375    3680        1     0.830 0.005645          0.819         0.841
##   5376    3679        1     0.829 0.005648          0.819         0.841
##   5380    3678        1     0.829 0.005651          0.818         0.840
##   5384    3677        2     0.829 0.005657          0.818         0.840
##   5387    3675        1     0.829 0.005660          0.818         0.840
##   5396    3674        1     0.828 0.005663          0.817         0.840
##   5399    3673        1     0.828 0.005665          0.817         0.839
##   5400    3672        1     0.828 0.005668          0.817         0.839
##   5410    3671        1     0.828 0.005671          0.817         0.839
##   5413    3670        2     0.827 0.005677          0.816         0.838
```

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##  5428   3668        1    0.827 0.005680        0.816          0.838
##  5437   3667        2    0.827 0.005686        0.815          0.838
##  5439   3665        2    0.826 0.005692        0.815          0.837
##  5444   3663        1    0.826 0.005695        0.815          0.837
##  5446   3662        1    0.826 0.005698        0.815          0.837
##  5448   3661        1    0.825 0.005701        0.814          0.837
##  5452   3660        1    0.825 0.005703        0.814          0.836
##  5458   3659        1    0.825 0.005706        0.814          0.836
##  5466   3658        1    0.825 0.005709        0.814          0.836
##  5475   3657        1    0.825 0.005712        0.813          0.836
##  5490   3656        1    0.824 0.005715        0.813          0.836
##  5496   3655        1    0.824 0.005718        0.813          0.835
##  5499   3654        2    0.824 0.005724        0.812          0.835
##  5515   3652        1    0.823 0.005727        0.812          0.835
##  5518   3651        1    0.823 0.005729        0.812          0.834
##  5526   3650        2    0.823 0.005735        0.812          0.834
##  5527   3648        1    0.823 0.005738        0.811          0.834
##  5530   3647        1    0.822 0.005741        0.811          0.834
##  5538   3646        2    0.822 0.005747        0.811          0.833
##  5542   3644        1    0.822 0.005749        0.810          0.833
##  5545   3643        1    0.821 0.005752        0.810          0.833
##  5553   3642        1    0.821 0.005755        0.810          0.833
##  5554   3641        1    0.821 0.005758        0.810          0.832
##  5556   3640        1    0.821 0.005761        0.809          0.832
##  5565   3639        1    0.820 0.005764        0.809          0.832
##  5569   3638        1    0.820 0.005766        0.809          0.832
##  5572   3637        1    0.820 0.005769        0.809          0.831
##  5579   3636        1    0.820 0.005772        0.809          0.831
##  5581   3635        2    0.819 0.005778        0.808          0.831
##  5589   3633        1    0.819 0.005781        0.808          0.831
##  5590   3632        1    0.819 0.005783        0.808          0.830
##  5591   3631        1    0.819 0.005786        0.807          0.830
##  5592   3630        1    0.818 0.005789        0.807          0.830
##  5597   3629        1    0.818 0.005792        0.807          0.830
##  5600   3628        2    0.818 0.005797        0.806          0.829
##  5604   3626        1    0.818 0.005800        0.806          0.829
##  5611   3625        1    0.817 0.005803        0.806          0.829
##  5616   3624        1    0.817 0.005806        0.806          0.829
##  5618   3623        1    0.817 0.005808        0.806          0.828
##  5619   3622        1    0.817 0.005811        0.805          0.828
##  5620   3621        1    0.816 0.005814        0.805          0.828
##  5621   3620        1    0.816 0.005817        0.805          0.828
##  5623   3619        1    0.816 0.005820        0.805          0.827
##  5629   3618        2    0.816 0.005825        0.804          0.827
##  5638   3616        1    0.815 0.005828        0.804          0.827
##  5641   3615        1    0.815 0.005831        0.804          0.827
```

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##  5644  3614       1    0.815 0.005833        0.803        0.826
##  5655  3613       2    0.814 0.005839        0.803        0.826
##  5660  3611       1    0.814 0.005841        0.803        0.826
##  5667  3610       1    0.814 0.005844        0.803        0.825
##  5674  3609       1    0.814 0.005847        0.802        0.825
##  5685  3608       1    0.813 0.005850        0.802        0.825
##  5687  3607       2    0.813 0.005855        0.802        0.825
##  5693  3605       1    0.813 0.005858        0.801        0.824
##  5702  3604       1    0.813 0.005861        0.801        0.824
##  5709  3603       1    0.812 0.005863        0.801        0.824
##  5714  3602       1    0.812 0.005866        0.801        0.824
##  5722  3601       2    0.812 0.005871        0.800        0.823
##  5727  3599       1    0.811 0.005874        0.800        0.823
##  5731  3598       1    0.811 0.005877        0.800        0.823
##  5732  3597       2    0.811 0.005882        0.799        0.822
##  5733  3595       1    0.811 0.005885        0.799        0.822
##  5740  3594       1    0.810 0.005888        0.799        0.822
##  5746  3593       1    0.810 0.005890        0.799        0.822
##  5755  3592       1    0.810 0.005893        0.798        0.822
##  5756  3591       1    0.810 0.005896        0.798        0.821
##  5761  3590       1    0.809 0.005898        0.798        0.821
##  5764  3589       2    0.809 0.005904        0.797        0.821
##  5769  3587       1    0.809 0.005906        0.797        0.820
##  5773  3586       1    0.809 0.005909        0.797        0.820
##  5775  3585       1    0.808 0.005912        0.797        0.820
##  5778  3584       1    0.808 0.005914        0.797        0.820
##  5786  3583       1    0.808 0.005917        0.796        0.820
##  5788  3582       1    0.808 0.005919        0.796        0.819
##  5789  3581       1    0.807 0.005922        0.796        0.819
##  5794  3580       1    0.807 0.005925        0.796        0.819
##  5806  3579       1    0.807 0.005927        0.795        0.819
##  5813  3578       1    0.807 0.005930        0.795        0.818
##  5816  3577       1    0.806 0.005933        0.795        0.818
##  5820  3576       1    0.806 0.005935        0.795        0.818
##  5839  3575       1    0.806 0.005938        0.794        0.818
##  5843  3574       2    0.806 0.005943        0.794        0.817
##  5861  3572       1    0.805 0.005946        0.794        0.817
##  5867  3571       1    0.805 0.005948        0.794        0.817
##  5870  3570       1    0.805 0.005951        0.793        0.817
##  5876  3569       1    0.805 0.005954        0.793        0.816
##  5878  3568       1    0.804 0.005956        0.793        0.816
##  5879  3567       1    0.804 0.005959        0.793        0.816
##  5883  3566       1    0.804 0.005961        0.792        0.816
##  5885  3565       1    0.804 0.005964        0.792        0.816
##  5888  3564       1    0.804 0.005967        0.792        0.815
##  5891  3563       1    0.803 0.005969        0.792        0.815
```

```
## 5894 3562 1 0.803 0.005972 0.791 0.815
## 5898 3561 1 0.803 0.005974 0.791 0.815
## 5899 3560 1 0.803 0.005977 0.791 0.814
## 5900 3559 1 0.802 0.005979 0.791 0.814
## 5901 3558 1 0.802 0.005982 0.791 0.814
## 5905 3557 1 0.802 0.005985 0.790 0.814
## 5906 3556 2 0.802 0.005990 0.790 0.813
## 5908 3554 1 0.801 0.005992 0.790 0.813
## 5911 3553 1 0.801 0.005995 0.789 0.813
## 5921 3552 1 0.801 0.005997 0.789 0.813
## 5930 3551 1 0.801 0.006000 0.789 0.812
## 5931 3550 2 0.800 0.006005 0.788 0.812
## 5936 3548 1 0.800 0.006008 0.788 0.812
## 5953 3547 1 0.800 0.006010 0.788 0.812
## 5954 3546 1 0.800 0.006013 0.788 0.811
## 5958 3545 1 0.799 0.006015 0.788 0.811
## 5962 3544 1 0.799 0.006018 0.787 0.811
## 5973 3543 1 0.799 0.006020 0.787 0.811
## 5977 3542 1 0.799 0.006023 0.787 0.810
## 5992 3541 1 0.798 0.006025 0.787 0.810
## 5997 3540 1 0.798 0.006028 0.786 0.810
## 6001 3539 2 0.798 0.006033 0.786 0.810
## 6002 3537 1 0.797 0.006035 0.786 0.809
## 6006 3536 1 0.797 0.006038 0.786 0.809
## 6007 3535 1 0.797 0.006040 0.785 0.809
## 6019 3534 1 0.797 0.006043 0.785 0.809
## 6020 3533 1 0.797 0.006045 0.785 0.809
## 6024 3532 1 0.796 0.006048 0.785 0.808
## 6026 3531 1 0.796 0.006050 0.784 0.808
## 6028 3530 1 0.796 0.006053 0.784 0.808
## 6029 3529 1 0.796 0.006055 0.784 0.808
## 6030 3528 1 0.795 0.006058 0.784 0.807
## 6034 3527 1 0.795 0.006060 0.783 0.807
## 6036 3526 1 0.795 0.006063 0.783 0.807
## 6049 3525 1 0.795 0.006065 0.783 0.807
## 6060 3524 1 0.795 0.006068 0.783 0.807
## 6063 3523 1 0.794 0.006070 0.783 0.806
## 6070 3522 1 0.794 0.006073 0.782 0.806
## 6078 3521 1 0.794 0.006075 0.782 0.806
## 6080 3520 1 0.794 0.006078 0.782 0.806
## 6084 3519 1 0.793 0.006080 0.782 0.805
## 6085 3518 1 0.793 0.006082 0.781 0.805
## 6092 3517 1 0.793 0.006085 0.781 0.805
## 6104 3516 1 0.793 0.006087 0.781 0.805
## 6124 3515 1 0.793 0.006090 0.781 0.805
## 6129 3514 1 0.792 0.006092 0.780 0.804
```

```
## 6130   3513        1    0.792 0.006095        0.780        0.804
## 6131   3512        1    0.792 0.006097        0.780        0.804
## 6132   3511        1    0.792 0.006100        0.780        0.804
## 6136   3510        1    0.791 0.006102        0.780        0.803
## 6144   3509        1    0.791 0.006104        0.779        0.803
## 6152   3508        1    0.791 0.006107        0.779        0.803
## 6155   3507        1    0.791 0.006109        0.779        0.803
## 6164   3506        1    0.790 0.006112        0.779        0.803
## 6170   3505        1    0.790 0.006114        0.778        0.802
## 6176   3504        1    0.790 0.006116        0.778        0.802
## 6180   3503        1    0.790 0.006119        0.778        0.802
## 6182   3502        1    0.790 0.006121        0.778        0.802
## 6183   3501        1    0.789 0.006124        0.777        0.801
## 6184   3500        1    0.789 0.006126        0.777        0.801
## 6187   3499        2    0.789 0.006131        0.777        0.801
## 6188   3497        1    0.788 0.006133        0.777        0.801
## 6190   3496        1    0.788 0.006136        0.776        0.800
## 6199   3495        1    0.788 0.006138        0.776        0.800
## 6201   3494        2    0.788 0.006143        0.776        0.800
## 6205   3492        1    0.787 0.006145        0.775        0.799
## 6209   3491        1    0.787 0.006148        0.775        0.799
## 6210   3490        1    0.787 0.006150        0.775        0.799
## 6212   3489        1    0.787 0.006152        0.775        0.799
## 6214   3488        1    0.786 0.006155        0.774        0.799
## 6224   3487        1    0.786 0.006157        0.774        0.798
## 6226   3486        1    0.786 0.006159        0.774        0.798
## 6227   3485        1    0.786 0.006162        0.774        0.798
## 6245   3484        1    0.786 0.006164        0.774        0.798
## 6246   3483        1    0.785 0.006167        0.773        0.797
## 6248   3482        1    0.785 0.006169        0.773        0.797
## 6254   3481        1    0.785 0.006171        0.773        0.797
## 6258   3480        1    0.785 0.006174        0.773        0.797
## 6260   3479        1    0.784 0.006176        0.772        0.797
## 6262   3478        1    0.784 0.006178        0.772        0.796
## 6269   3477        1    0.784 0.006181        0.772        0.796
## 6272   3476        1    0.784 0.006183        0.772        0.796
## 6274   3475        1    0.783 0.006185        0.771        0.796
## 6281   3474        1    0.783 0.006188        0.771        0.795
## 6283   3473        1    0.783 0.006190        0.771        0.795
## 6284   3472        1    0.783 0.006192        0.771        0.795
## 6290   3471        1    0.783 0.006195        0.771        0.795
## 6291   3470        1    0.782 0.006197        0.770        0.795
## 6295   3469        1    0.782 0.006199        0.770        0.794
## 6316   3468        1    0.782 0.006201        0.770        0.794
## 6320   3467        1    0.782 0.006204        0.770        0.794
## 6340   3466        1    0.781 0.006206        0.769        0.794
```

```
##  6343   3465         1    0.781 0.006208         0.769          0.793
##  6350   3464         1    0.781 0.006211         0.769          0.793
##  6353   3463         1    0.781 0.006213         0.769          0.793
##  6356   3462         1    0.781 0.006215         0.768          0.793
##  6367   3461         1    0.780 0.006218         0.768          0.793
##  6381   3460         1    0.780 0.006220         0.768          0.792
##  6385   3459         1    0.780 0.006222         0.768          0.792
##  6387   3458         1    0.780 0.006224         0.768          0.792
##  6389   3457         1    0.779 0.006227         0.767          0.792
##  6394   3456         1    0.779 0.006229         0.767          0.792
##  6404   3455         1    0.779 0.006231         0.767          0.791
##  6407   3454         1    0.779 0.006234         0.767          0.791
##  6410   3453         2    0.778 0.006238         0.766          0.791
##  6411   3451         2    0.778 0.006243         0.766          0.790
##  6412   3449         2    0.777 0.006247         0.765          0.790
##  6418   3447         1    0.777 0.006249         0.765          0.790
##  6423   3446         1    0.777 0.006252         0.765          0.789
##  6427   3445         1    0.777 0.006254         0.765          0.789
##  6433   3444         1    0.776 0.006256         0.764          0.789
##  6434   3443         2    0.776 0.006261         0.764          0.788
##  6437   3441         1    0.776 0.006263         0.764          0.788
##  6438   3440         1    0.776 0.006265         0.763          0.788
##  6449   3439         1    0.775 0.006267         0.763          0.788
##  6452   3438         1    0.775 0.006270         0.763          0.788
##  6455   3437         1    0.775 0.006272         0.763          0.787
##  6460   3436         1    0.775 0.006274         0.762          0.787
##  6464   3435         2    0.774 0.006279         0.762          0.787
##  6474   3433         1    0.774 0.006281         0.762          0.786
##  6495   3432         1    0.774 0.006283         0.762          0.786
##  6497   3431         1    0.774 0.006285         0.761          0.786
##  6502   3430         1    0.773 0.006287         0.761          0.786
##  6506   3429         1    0.773 0.006290         0.761          0.786
##  6511   3428         1    0.773 0.006292         0.761          0.785
##  6517   3427         1    0.773 0.006294         0.760          0.785
##  6518   3426         1    0.772 0.006296         0.760          0.785
##  6519   3425         1    0.772 0.006298         0.760          0.785
##  6524   3424         1    0.772 0.006301         0.760          0.784
##  6531   3423         3    0.771 0.006307         0.759          0.784
##  6532   3420         1    0.771 0.006309         0.759          0.784
##  6533   3419         1    0.771 0.006312         0.759          0.783
##  6538   3418         1    0.771 0.006314         0.758          0.783
##  6554   3417         1    0.770 0.006316         0.758          0.783
##  6558   3416         1    0.770 0.006318         0.758          0.783
##  6561   3415         2    0.770 0.006322         0.757          0.782
##  6562   3413         1    0.770 0.006325         0.757          0.782
##  6568   3412         1    0.769 0.006327         0.757          0.782
```

```
##  6572   3411       1    0.769 0.006329        0.757        0.782
##  6577   3410       1    0.769 0.006331        0.757        0.781
##  6583   3409       1    0.769 0.006333        0.756        0.781
##  6584   3408       1    0.768 0.006335        0.756        0.781
##  6585   3407       1    0.768 0.006338        0.756        0.781
##  6591   3406       1    0.768 0.006340        0.756        0.780
##  6598   3405       1    0.768 0.006342        0.755        0.780
##  6602   3404       1    0.767 0.006344        0.755        0.780
##  6604   3403       1    0.767 0.006346        0.755        0.780
##  6610   3402       1    0.767 0.006348        0.755        0.780
##  6615   3401       1    0.767 0.006350        0.754        0.779
##  6618   3400       1    0.767 0.006353        0.754        0.779
##  6621   3399       1    0.766 0.006355        0.754        0.779
##  6626   3398       1    0.766 0.006357        0.754        0.779
##  6630   3397       1    0.766 0.006359        0.754        0.778
##  6632   3396       1    0.766 0.006361        0.753        0.778
##  6633   3395       1    0.765 0.006363        0.753        0.778
##  6647   3394       1    0.765 0.006365        0.753        0.778
##  6655   3393       1    0.765 0.006367        0.753        0.778
##  6660   3392       1    0.765 0.006370        0.752        0.777
##  6670   3391       1    0.765 0.006372        0.752        0.777
##  6672   3390       1    0.764 0.006374        0.752        0.777
##  6678   3389       1    0.764 0.006376        0.752        0.777
##  6684   3388       1    0.764 0.006378        0.751        0.776
##  6687   3387       1    0.764 0.006380        0.751        0.776
##  6691   3386       1    0.763 0.006382        0.751        0.776
##  6692   3385       1    0.763 0.006384        0.751        0.776
##  6695   3384       1    0.763 0.006386        0.751        0.776
##  6700   3383       1    0.763 0.006389        0.750        0.775
##  6718   3382       1    0.763 0.006391        0.750        0.775
##  6719   3381       1    0.762 0.006393        0.750        0.775
##  6722   3380       1    0.762 0.006395        0.750        0.775
##  6729   3379       1    0.762 0.006397        0.749        0.774
##  6734   3378       1    0.762 0.006399        0.749        0.774
##  6735   3377       1    0.761 0.006401        0.749        0.774
##  6737   3376       2    0.761 0.006405        0.748        0.774
##  6746   3374       2    0.760 0.006409        0.748        0.773
##  6747   3372       1    0.760 0.006411        0.748        0.773
##  6755   3371       1    0.760 0.006413        0.748        0.773
##  6756   3370       1    0.760 0.006416        0.747        0.772
##  6757   3369       1    0.760 0.006418        0.747        0.772
##  6763   3368       1    0.759 0.006420        0.747        0.772
##  6769   3367       1    0.759 0.006422        0.747        0.772
##  6770   3366       1    0.759 0.006424        0.746        0.772
##  6777   3365       1    0.759 0.006426        0.746        0.771
##  6781   3364       1    0.758 0.006428        0.746        0.771
```

```
##  6798   3363        1    0.758 0.006430          0.746          0.771
##  6804   3362        1    0.758 0.006432          0.746          0.771
##  6808   3361        2    0.758 0.006436          0.745          0.770
##  6813   3359        1    0.757 0.006438          0.745          0.770
##  6817   3358        1    0.757 0.006440          0.745          0.770
##  6819   3357        1    0.757 0.006442          0.744          0.770
##  6824   3356        2    0.756 0.006446          0.744          0.769
##  6831   3354        1    0.756 0.006448          0.744          0.769
##  6832   3353        1    0.756 0.006450          0.743          0.769
##  6833   3352        1    0.756 0.006452          0.743          0.769
##  6846   3351        1    0.756 0.006454          0.743          0.768
##  6851   3350        1    0.755 0.006456          0.743          0.768
##  6876   3349        1    0.755 0.006458          0.743          0.768
##  6877   3348        1    0.755 0.006460          0.742          0.768
##  6893   3347        1    0.755 0.006462          0.742          0.767
##  6899   3346        1    0.754 0.006464          0.742          0.767
##  6900   3345        1    0.754 0.006466          0.742          0.767
##  6902   3344        1    0.754 0.006468          0.741          0.767
##  6910   3343        1    0.754 0.006470          0.741          0.767
##  6925   3342        1    0.753 0.006472          0.741          0.766
##  6926   3341        1    0.753 0.006474          0.741          0.766
##  6934   3340        1    0.753 0.006476          0.740          0.766
##  6937   3339        1    0.753 0.006478          0.740          0.766
##  6938   3338        1    0.753 0.006480          0.740          0.765
##  6940   3337        1    0.752 0.006482          0.740          0.765
##  6942   3336        1    0.752 0.006484          0.740          0.765
##  6944   3335        1    0.752 0.006486          0.739          0.765
##  6948   3334        1    0.752 0.006488          0.739          0.765
##  6949   3333        1    0.751 0.006490          0.739          0.764
##  6952   3332        1    0.751 0.006492          0.739          0.764
##  6954   3331        1    0.751 0.006494          0.738          0.764
##  6965   3330        1    0.751 0.006496          0.738          0.764
##  6968   3329        1    0.751 0.006498          0.738          0.763
##  6970   3328        1    0.750 0.006500          0.738          0.763
##  6973   3327        1    0.750 0.006502          0.737          0.763
##  6974   3326        1    0.750 0.006504          0.737          0.763
##  6975   3325        1    0.750 0.006506          0.737          0.763
##  6977   3324        1    0.749 0.006508          0.737          0.762
##  6984   3323        1    0.749 0.006510          0.737          0.762
##  6986   3322        1    0.749 0.006512          0.736          0.762
##  6990   3321        1    0.749 0.006514          0.736          0.762
##  6997   3320        1    0.749 0.006515          0.736          0.761
##  7005   3319        2    0.748 0.006519          0.735          0.761
##  7012   3317        1    0.748 0.006521          0.735          0.761
##  7014   3316        1    0.748 0.006523          0.735          0.761
##  7015   3315        1    0.747 0.006525          0.735          0.760
```

```
##   7019   3314       1    0.747 0.006527        0.734        0.760
##   7026   3313       1    0.747 0.006529        0.734        0.760
##   7035   3312       1    0.747 0.006531        0.734        0.760
##   7036   3311       1    0.747 0.006533        0.734        0.759
##   7038   3310       1    0.746 0.006535        0.734        0.759
##   7041   3309       1    0.746 0.006537        0.733        0.759
##   7045   3308       1    0.746 0.006539        0.733        0.759
##   7049   3307       1    0.746 0.006541        0.733        0.759
##   7050   3306       1    0.745 0.006542        0.733        0.758
##   7051   3305       2    0.745 0.006546        0.732        0.758
##   7052   3303       1    0.745 0.006548        0.732        0.758
##   7059   3302       1    0.744 0.006550        0.732        0.757
##   7064   3301       1    0.744 0.006552        0.732        0.757
##   7066   3300       2    0.744 0.006556        0.731        0.757
##   7070   3298       1    0.744 0.006558        0.731        0.757
##   7073   3297       1    0.743 0.006560        0.731        0.756
##   7074   3296       1    0.743 0.006561        0.730        0.756
##   7077   3295       1    0.743 0.006563        0.730        0.756
##   7078   3294       1    0.743 0.006565        0.730        0.756
##   7083   3293       1    0.742 0.006567        0.730        0.755
##   7086   3292       1    0.742 0.006569        0.729        0.755
##   7091   3291       1    0.742 0.006571        0.729        0.755
##   7092   3290       1    0.742 0.006573        0.729        0.755
##   7102   3289       1    0.742 0.006575        0.729        0.755
##   7104   3288       1    0.741 0.006576        0.729        0.754
##   7113   3287       1    0.741 0.006578        0.728        0.754
##   7115   3286       1    0.741 0.006580        0.728        0.754
##   7117   3285       1    0.741 0.006582        0.728        0.754
##   7118   3284       1    0.740 0.006584        0.728        0.753
##   7119   3283       1    0.740 0.006586        0.727        0.753
##   7135   3282       1    0.740 0.006588        0.727        0.753
##   7146   3281       1    0.740 0.006589        0.727        0.753
##   7151   3280       1    0.740 0.006591        0.727        0.753
##   7155   3279       1    0.739 0.006593        0.726        0.752
##   7157   3278       2    0.739 0.006597        0.726        0.752
##   7166   3276       1    0.739 0.006599        0.726        0.752
##   7176   3275       1    0.738 0.006600        0.726        0.751
##   7179   3274       1    0.738 0.006602        0.725        0.751
##   7183   3273       1    0.738 0.006604        0.725        0.751
##   7184   3272       1    0.738 0.006606        0.725        0.751
##   7192   3271       1    0.737 0.006608        0.725        0.751
##   7193   3270       1    0.737 0.006610        0.724        0.750
##   7210   3269       1    0.737 0.006611        0.724        0.750
##   7212   3268       1    0.737 0.006613        0.724        0.750
##   7216   3267       1    0.737 0.006615        0.724        0.750
##   7220   3266       1    0.736 0.006617        0.724        0.749
```

```
##  7223   3265        1    0.736 0.006619        0.723         0.749
##  7225   3264        2    0.736 0.006622        0.723         0.749
##  7230   3262        1    0.735 0.006624        0.723         0.749
##  7241   3261        1    0.735 0.006626        0.722         0.748
##  7246   3260        1    0.735 0.006628        0.722         0.748
##  7251   3259        1    0.735 0.006630        0.722         0.748
##  7256   3258        1    0.735 0.006631        0.722         0.748
##  7267   3257        2    0.734 0.006635        0.721         0.747
##  7269   3255        1    0.734 0.006637        0.721         0.747
##  7270   3254        1    0.734 0.006639        0.721         0.747
##  7283   3253        2    0.733 0.006642        0.720         0.746
##  7294   3251        2    0.733 0.006646        0.720         0.746
##  7303   3249        1    0.733 0.006647        0.720         0.746
##  7305   3248        1    0.732 0.006649        0.719         0.745
##  7306   3247        2    0.732 0.006653        0.719         0.745
##  7307   3245        2    0.731 0.006656        0.718         0.745
##  7308   3243        1    0.731 0.006658        0.718         0.744
##  7317   3242        1    0.731 0.006660        0.718         0.744
##  7322   3241        1    0.731 0.006662        0.718         0.744
##  7327   3240        1    0.730 0.006663        0.718         0.744
##  7328   3239        2    0.730 0.006667        0.717         0.743
##  7337   3237        1    0.730 0.006669        0.717         0.743
##  7340   3236        1    0.730 0.006670        0.717         0.743
##  7347   3235        1    0.729 0.006672        0.716         0.743
##  7348   3234        1    0.729 0.006674        0.716         0.742
##  7352   3233        1    0.729 0.006676        0.716         0.742
##  7357   3232        1    0.729 0.006677        0.716         0.742
##  7359   3231        1    0.728 0.006679        0.715         0.742
##  7360   3230        1    0.728 0.006681        0.715         0.741
##  7362   3229        1    0.728 0.006683        0.715         0.741
##  7363   3228        1    0.728 0.006684        0.715         0.741
##  7365   3227        1    0.728 0.006686        0.715         0.741
##  7367   3226        1    0.727 0.006688        0.714         0.741
##  7373   3225        1    0.727 0.006690        0.714         0.740
##  7378   3224        1    0.727 0.006691        0.714         0.740
##  7389   3223        1    0.727 0.006693        0.714         0.740
##  7395   3222        1    0.726 0.006695        0.713         0.740
##  7403   3221        1    0.726 0.006696        0.713         0.739
##  7406   3220        1    0.726 0.006698        0.713         0.739
##  7419   3219        1    0.726 0.006700        0.713         0.739
##  7428   3218        2    0.725 0.006703        0.712         0.739
##  7431   3216        1    0.725 0.006705        0.712         0.738
##  7436   3215        3    0.724 0.006710        0.711         0.738
##  7439   3212        1    0.724 0.006712        0.711         0.737
##  7447   3211        1    0.724 0.006714        0.711         0.737
##  7448   3210        2    0.724 0.006717        0.710         0.737
```

```
##  7455   3208        1   0.723 0.006719        0.710        0.737
##  7460   3207        1   0.723 0.006720        0.710        0.736
##  7469   3206        1   0.723 0.006722        0.710        0.736
##  7472   3205        1   0.723 0.006724        0.710        0.736
##  7483   3204        1   0.722 0.006725        0.709        0.736
##  7484   3203        1   0.722 0.006727        0.709        0.735
##  7493   3202        2   0.722 0.006730        0.709        0.735
##  7499   3200        1   0.721 0.006732        0.708        0.735
##  7504   3199        1   0.721 0.006734        0.708        0.735
##  7505   3198        1   0.721 0.006735        0.708        0.734
##  7506   3197        1   0.721 0.006737        0.708        0.734
##  7507   3196        1   0.721 0.006739        0.707        0.734
##  7514   3195        1   0.720 0.006740        0.707        0.734
##  7518   3194        1   0.720 0.006742        0.707        0.733
##  7519   3193        1   0.720 0.006744        0.707        0.733
##  7520   3192        1   0.720 0.006745        0.707        0.733
##  7537   3191        1   0.719 0.006747        0.706        0.733
##  7539   3190        1   0.719 0.006749        0.706        0.733
##  7541   3189        1   0.719 0.006750        0.706        0.732
##  7542   3188        1   0.719 0.006752        0.706        0.732
##  7543   3187        1   0.719 0.006754        0.705        0.732
##  7548   3186        1   0.718 0.006755        0.705        0.732
##  7552   3185        1   0.718 0.006757        0.705        0.731
##  7554   3184        1   0.718 0.006759        0.705        0.731
##  7557   3183        1   0.718 0.006760        0.705        0.731
##  7560   3182        1   0.717 0.006762        0.704        0.731
##  7563   3181        1   0.717 0.006763        0.704        0.731
##  7567   3180        1   0.717 0.006765        0.704        0.730
##  7569   3179        3   0.716 0.006770        0.703        0.730
##  7570   3176        1   0.716 0.006772        0.703        0.729
##  7571   3175        1   0.716 0.006773        0.703        0.729
##  7574   3174        1   0.716 0.006775        0.702        0.729
##  7576   3173        1   0.715 0.006776        0.702        0.729
##  7583   3172        1   0.715 0.006778        0.702        0.729
##  7587   3171        1   0.715 0.006780        0.702        0.728
##  7591   3170        1   0.715 0.006781        0.702        0.728
##  7592   3169        2   0.714 0.006785        0.701        0.728
##  7594   3167        1   0.714 0.006786        0.701        0.727
##  7600   3166        1   0.714 0.006788        0.701        0.727
##  7601   3165        1   0.714 0.006789        0.700        0.727
##  7607   3164        1   0.713 0.006791        0.700        0.727
##  7608   3163        1   0.713 0.006793        0.700        0.727
##  7609   3162        1   0.713 0.006794        0.700        0.726
##  7610   3161        1   0.713 0.006796        0.699        0.726
##  7611   3160        1   0.712 0.006797        0.699        0.726
##  7613   3159        1   0.712 0.006799        0.699        0.726
```

```
##  7618   3158       1    0.712 0.006800        0.699          0.725
##  7623   3157       2    0.712 0.006804        0.698          0.725
##  7624   3155       1    0.711 0.006805        0.698          0.725
##  7630   3154       2    0.711 0.006808        0.698          0.724
##  7632   3152       1    0.711 0.006810        0.697          0.724
##  7633   3151       1    0.710 0.006812        0.697          0.724
##  7634   3150       1    0.710 0.006813        0.697          0.724
##  7635   3149       1    0.710 0.006815        0.697          0.723
##  7643   3148       1    0.710 0.006816        0.697          0.723
##  7644   3147       1    0.710 0.006818        0.696          0.723
##  7649   3146       1    0.709 0.006819        0.696          0.723
##  7654   3145       1    0.709 0.006821        0.696          0.723
##  7661   3144       2    0.709 0.006824        0.695          0.722
##  7667   3142       2    0.708 0.006827        0.695          0.722
##  7668   3140       1    0.708 0.006829        0.695          0.721
##  7671   3139       1    0.708 0.006830        0.694          0.721
##  7679   3138       1    0.707 0.006832        0.694          0.721
##  7681   3137       1    0.707 0.006833        0.694          0.721
##  7684   3136       1    0.707 0.006835        0.694          0.721
##  7685   3135       1    0.707 0.006836        0.694          0.720
##  7689   3134       2    0.706 0.006839        0.693          0.720
##  7707   3132       1    0.706 0.006841        0.693          0.720
##  7708   3131       1    0.706 0.006843        0.693          0.719
##  7710   3130       2    0.705 0.006846        0.692          0.719
##  7711   3128       1    0.705 0.006847        0.692          0.719
##  7729   3127       1    0.705 0.006849        0.692          0.719
##  7738   3126       1    0.705 0.006850        0.691          0.718
##  7739   3125       1    0.705 0.006852        0.691          0.718
##  7746   3124       1    0.704 0.006853        0.691          0.718
##  7758   3123       1    0.704 0.006855        0.691          0.718
##  7766   3122       2    0.704 0.006858        0.690          0.717
##  7769   3120       1    0.703 0.006859        0.690          0.717
##  7771   3119       1    0.703 0.006861        0.690          0.717
##  7772   3118       1    0.703 0.006862        0.690          0.717
##  7774   3117       2    0.703 0.006865        0.689          0.716
##  7784   3115       1    0.702 0.006867        0.689          0.716
##  7793   3114       1    0.702 0.006868        0.689          0.716
##  7794   3113       1    0.702 0.006870        0.689          0.715
##  7795   3112       1    0.702 0.006871        0.688          0.715
##  7796   3111       1    0.701 0.006873        0.688          0.715
##  7799   3110       1    0.701 0.006874        0.688          0.715
##  7801   3109       1    0.701 0.006876        0.688          0.715
##  7803   3108       1    0.701 0.006877        0.687          0.714
##  7809   3107       1    0.700 0.006879        0.687          0.714
##  7818   3106       1    0.700 0.006880        0.687          0.714
##  7819   3105       1    0.700 0.006882        0.687          0.714
```

```
##   7820   3104       3    0.699 0.006886         0.686         0.713
##   7823   3101       1    0.699 0.006888         0.686         0.713
##   7826   3100       1    0.699 0.006889         0.686         0.713
##   7837   3099       1    0.699 0.006890         0.685         0.712
##   7840   3098       1    0.698 0.006892         0.685         0.712
##   7850   3097       1    0.698 0.006893         0.685         0.712
##   7851   3096       1    0.698 0.006895         0.685         0.712
##   7858   3095       1    0.698 0.006896         0.684         0.711
##   7866   3094       1    0.698 0.006898         0.684         0.711
##   7876   3093       1    0.697 0.006899         0.684         0.711
##   7884   3092       1    0.697 0.006901         0.684         0.711
##   7885   3091       1    0.697 0.006902         0.683         0.711
##   7887   3090       1    0.697 0.006904         0.683         0.710
##   7888   3089       1    0.696 0.006905         0.683         0.710
##   7889   3088       1    0.696 0.006907         0.683         0.710
##   7892   3087       1    0.696 0.006908         0.683         0.710
##   7895   3086       1    0.696 0.006909         0.682         0.709
##   7897   3085       1    0.696 0.006911         0.682         0.709
##   7899   3084       1    0.695 0.006912         0.682         0.709
##   7905   3083       1    0.695 0.006914         0.682         0.709
##   7921   3082       1    0.695 0.006915         0.681         0.709
##   7923   3081       1    0.695 0.006917         0.681         0.708
##   7935   3080       1    0.694 0.006918         0.681         0.708
##   7940   3079       1    0.694 0.006919         0.681         0.708
##   7945   3078       1    0.694 0.006921         0.681         0.708
##   7950   3077       1    0.694 0.006922         0.680         0.707
##   7951   3076       1    0.694 0.006924         0.680         0.707
##   7953   3075       1    0.693 0.006925         0.680         0.707
##   7963   3074       1    0.693 0.006927         0.680         0.707
##   7972   3073       1    0.693 0.006928         0.679         0.707
##   7974   3072       1    0.693 0.006929         0.679         0.706
##   7980   3071       1    0.692 0.006931         0.679         0.706
##   7985   3070       1    0.692 0.006932         0.679         0.706
##   7996   3069       1    0.692 0.006934         0.678         0.706
##   7998   3068       1    0.692 0.006935         0.678         0.705
##   8002   3067       1    0.691 0.006936         0.678         0.705
##   8007   3066       1    0.691 0.006938         0.678         0.705
##   8013   3065       1    0.691 0.006939         0.678         0.705
##   8016   3064       2    0.691 0.006942         0.677         0.704
##   8020   3062       2    0.690 0.006945         0.677         0.704
##   8031   3060       1    0.690 0.006946         0.676         0.704
##   8036   3059       1    0.690 0.006948         0.676         0.703
##   8046   3058       1    0.689 0.006949         0.676         0.703
##   8048   3057       1    0.689 0.006950         0.676         0.703
##   8050   3056       1    0.689 0.006952         0.676         0.703
##   8052   3055       1    0.689 0.006953         0.675         0.703
```

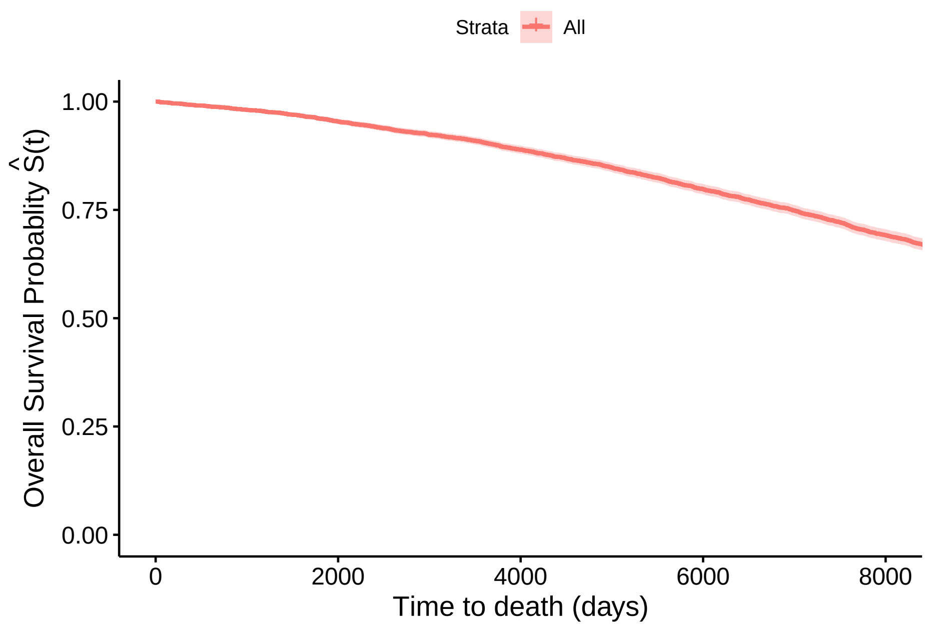
```
##  8054   3054        1     0.689 0.006955        0.675         0.702
##  8060   3053        2     0.688 0.006957        0.675         0.702
##  8064   3051        1     0.688 0.006959        0.674         0.702
##  8066   3050        1     0.688 0.006960        0.674         0.701
##  8078   3049        1     0.687 0.006961        0.674         0.701
##  8084   3048        1     0.687 0.006963        0.674         0.701
##  8092   3047        1     0.687 0.006964        0.673         0.701
##  8098   3046        1     0.687 0.006965        0.673         0.701
##  8101   3045        1     0.687 0.006967        0.673         0.700
##  8111   3044        1     0.686 0.006968        0.673         0.700
##  8119   3043        1     0.686 0.006970        0.673         0.700
##  8122   3042        1     0.686 0.006971        0.672         0.700
##  8128   3041        1     0.686 0.006972        0.672         0.699
##  8132   3040        1     0.685 0.006974        0.672         0.699
##  8133   3039        1     0.685 0.006975        0.672         0.699
##  8137   3038        1     0.685 0.006976        0.671         0.699
##  8141   3037        1     0.685 0.006978        0.671         0.699
##  8157   3036        1     0.684 0.006979        0.671         0.698
##  8158   3035        1     0.684 0.006980        0.671         0.698
##  8163   3034        1     0.684 0.006982        0.670         0.698
##  8164   3033        1     0.684 0.006983        0.670         0.698
##  8172   3032        2     0.683 0.006986        0.670         0.697
##  8173   3030        1     0.683 0.006987        0.670         0.697
##  8177   3029        1     0.683 0.006988        0.669         0.697
##  8187   3028        1     0.683 0.006990        0.669         0.697
##  8195   3027        1     0.682 0.006991        0.669         0.696
##  8212   3026        1     0.682 0.006992        0.669         0.696
##  8214   3025        1     0.682 0.006994        0.668         0.696
##  8215   3024        1     0.682 0.006995        0.668         0.696
##  8218   3023        1     0.682 0.006996        0.668         0.695
##  8220   3022        1     0.681 0.006998        0.668         0.695
##  8223   3021        1     0.681 0.006999        0.668         0.695
##  8233   3020        1     0.681 0.007000        0.667         0.695
##  8234   3019        1     0.681 0.007002        0.667         0.695
##  8238   3018        1     0.680 0.007003        0.667         0.694
##  8240   3017        1     0.680 0.007004        0.667         0.694
##  8241   3016        1     0.680 0.007006        0.666         0.694
##  8242   3015        1     0.680 0.007007        0.666         0.694
##  8244   3014        1     0.680 0.007008        0.666         0.693
##  8246   3013        1     0.679 0.007009        0.666         0.693
##  8263   3012        1     0.679 0.007011        0.665         0.693
##  8264   3011        1     0.679 0.007012        0.665         0.693
##  8266   3010        1     0.679 0.007013        0.665         0.693
##  8271   3009        1     0.678 0.007015        0.665         0.692
##  8273   3008        1     0.678 0.007016        0.665         0.692
##  8274   3007        2     0.678 0.007019        0.664         0.692
```

```
##  8275   3005        1    0.677 0.007020        0.664         0.691
##  8277   3004        1    0.677 0.007021        0.664         0.691
##  8281   3003        1    0.677 0.007022        0.663         0.691
##  8285   3002        3    0.676 0.007026        0.663         0.690
##  8291   2999        1    0.676 0.007027        0.663         0.690
##  8293   2998        1    0.676 0.007029        0.662         0.690
##  8295   2997        1    0.676 0.007030        0.662         0.690
##  8298   2996        1    0.675 0.007031        0.662         0.689
##  8305   2995        1    0.675 0.007033        0.662         0.689
##  8307   2994        1    0.675 0.007034        0.661         0.689
##  8310   2993        1    0.675 0.007035        0.661         0.689
##  8312   2992        1    0.675 0.007036        0.661         0.688
##  8317   2991        1    0.674 0.007038        0.661         0.688
##  8319   2990        1    0.674 0.007039        0.660         0.688
##  8321   2989        1    0.674 0.007040        0.660         0.688
##  8332   2988        1    0.674 0.007041        0.660         0.688
##  8335   2987        1    0.673 0.007043        0.660         0.687
##  8337   2986        1    0.673 0.007044        0.660         0.687
##  8344   2985        1    0.673 0.007045        0.659         0.687
##  8349   2984        1    0.673 0.007046        0.659         0.687
##  8357   2983        2    0.672 0.007049        0.659         0.686
##  8361   2981        1    0.672 0.007050        0.658         0.686
##  8370   2980        1    0.672 0.007051        0.658         0.686
##  8371   2979        1    0.672 0.007053        0.658         0.686
##  8374   2978        1    0.671 0.007054        0.658         0.685
##  8386   2977        1    0.671 0.007055        0.657         0.685
##  8392   2976        1    0.671 0.007056        0.657         0.685
##  8401   2975        1    0.671 0.007058        0.657         0.685
##  8402   2974        1    0.671 0.007059        0.657         0.684
##  8404   2973        2    0.670 0.007061        0.656         0.684
##  8406   2971        1    0.670 0.007062        0.656         0.684
##  8411   2970        1    0.670 0.007064        0.656         0.684
##  8413   2969        1    0.669 0.007065        0.656         0.683
##  8415   2968        1    0.669 0.007066        0.655         0.683
##  8417   2967        1    0.669 0.007067        0.655         0.683
##  8423   2966        1    0.669 0.007069        0.655         0.683
##  8436   2965        1    0.668 0.007070        0.655         0.682
##  8451   2964        1    0.668 0.007071        0.655         0.682
##  8452   2963        1    0.668 0.007072        0.654         0.682
##  8454   2962        1    0.668 0.007073        0.654         0.682
##  8457   2961        1    0.668 0.007075        0.654         0.682
##  8469   2960        2    0.667 0.007077        0.653         0.681
##  8470   2958        1    0.667 0.007078        0.653         0.681
##  8471   2957        1    0.667 0.007079        0.653         0.681
##  8490   2956        1    0.666 0.007081        0.653         0.680
##  8494   2955        1    0.666 0.007082        0.652         0.680
```

```
## 8498   2954        1    0.666 0.007083      0.652        0.680
## 8501   2953        1    0.666 0.007084      0.652        0.680
## 8505   2952        1    0.666 0.007085      0.652        0.680
## 8507   2951        1    0.665 0.007087      0.652        0.679
## 8511   2950        1    0.665 0.007088      0.651        0.679
## 8513   2949        3    0.664 0.007091      0.651        0.678
## 8516   2946        1    0.664 0.007092      0.650        0.678
## 8518   2945        1    0.664 0.007094      0.650        0.678
## 8519   2944        1    0.664 0.007095      0.650        0.678
## 8525   2943        1    0.664 0.007096      0.650        0.678
## 8529   2942        1    0.663 0.007097      0.650        0.677
## 8530   2941        1    0.663 0.007098      0.649        0.677
## 8538   2940        1    0.663 0.007099      0.649        0.677
## 8543   2939        1    0.663 0.007101      0.649        0.677
## 8546   2938        1    0.662 0.007102      0.649        0.676
## 8549   2937        1    0.662 0.007103      0.648        0.676
## 8550   2936        1    0.662 0.007104      0.648        0.676
## 8556   2935        1    0.662 0.007105      0.648        0.676
## 8576   2934        1    0.661 0.007106      0.648        0.676
## 8577   2933        1    0.661 0.007108      0.647        0.675
## 8589   2932        1    0.661 0.007109      0.647        0.675
## 8595   2931        2    0.661 0.007111      0.647        0.675
## 8608   2929        1    0.660 0.007112      0.647        0.674
## 8610   2928        1    0.660 0.007113      0.646        0.674
## 8613   2927        1    0.660 0.007114      0.646        0.674
## 8618   2926        1    0.660 0.007116      0.646        0.674
## 8622   2925        1    0.659 0.007117      0.646        0.674
## 8625   2924        1    0.659 0.007118      0.645        0.673
## 8627   2923        2    0.659 0.007120      0.645        0.673
## 8630   2921        1    0.659 0.007121      0.645        0.673
## 8631   2920        1    0.658 0.007122      0.645        0.672
## 8640   2919        1    0.658 0.007124      0.644        0.672
## 8648   2918        1    0.658 0.007125      0.644        0.672
## 8650   2917        2    0.657 0.007127      0.644        0.672
## 8656   2915        1    0.657 0.007128      0.643        0.671
## 8657   2914        1    0.657 0.007129      0.643        0.671
## 8664   2913        1    0.657 0.007130      0.643        0.671
## 8669   2912        1    0.657 0.007131      0.643        0.671
## 8671   2911        1    0.656 0.007133      0.642        0.670
## 8674   2910        1    0.656 0.007134      0.642        0.670
## 8676   2909        2    0.656 0.007136      0.642        0.670
## 8683   2907        1    0.655 0.007137      0.642        0.670
## 8690   2906        2    0.655 0.007139      0.641        0.669
## 8697   2904        1    0.655 0.007140      0.641        0.669
## 8700   2903        1    0.654 0.007141      0.641        0.669
## 8702   2902        1    0.654 0.007143      0.640        0.668
```

```
## 8705   2901        1    0.654 0.007144        0.640         0.668
## 8707   2900        1    0.654 0.007145        0.640         0.668
## 8708   2899        1    0.654 0.007146        0.640         0.668
## 8717   2898        1    0.653 0.007147        0.640         0.668
## 8722   2897        1    0.653 0.007148        0.639         0.667
## 8723   2896        1    0.653 0.007149        0.639         0.667
## 8726   2895        1    0.653 0.007150        0.639         0.667
## 8727   2894        2    0.652 0.007152        0.638         0.666
## 8734   2892        1    0.652 0.007153        0.638         0.666
## 8738   2891        1    0.652 0.007154        0.638         0.666
## 8741   2890        1    0.652 0.007156        0.638         0.666
## 8744   2889        2    0.651 0.007158        0.637         0.665
## 8747   2887        1    0.651 0.007159        0.637         0.665
## 8753   2886        1    0.651 0.007160        0.637         0.665
## 8759   2885        1    0.650 0.007161        0.637         0.665
```

```
fit1 %>%
ggsurvplot(xlab="Time to death (days)",ylab=expression(paste('Overall Survival Probabli
```



We can see that as follow-up time increases survival decreases rather monotinacally over time, or in other words the number of people who have died increases. Survival $\hat{S}(t)$ drops to about 0.65 at the end of follow-up, or in other words about 35% of participants have died, which is what is expected as we already know that 1550 of 4434 participants have died.

We can repeat this estimation with a different time-scale of interest. Other that follow-up times we may also be interested in Survival and failure (mortality) with respect to age. We repeat the same code only changing the first argument in the `Surv` function, substituting time of death with respect to follow-up time with age at death.

```
fit2<-survfit(Surv(agedth, death) ~ 1, data = fhs_first)
summary(fit2)
```

```
## Call: survfit(formula = Surv(agedth, death) ~ 1, data = fhs_first)
##
##  time n.risk n.event survival  std.err lower 95% CI upper 95% CI
##  38.4   4434       1   0.9998 0.000226       0.9993        1.000
##  40.4   4433       1   0.9995 0.000319       0.9989        1.000
##  41.6   4432       1   0.9993 0.000390       0.9986        1.000
##  41.9   4431       1   0.9991 0.000451       0.9982        1.000
##  42.6   4430       1   0.9989 0.000504       0.9979        1.000
##  43.0   4429       1   0.9986 0.000552       0.9976        1.000
##  43.2   4428       1   0.9984 0.000596       0.9973        1.000
##  43.2   4427       1   0.9982 0.000637       0.9969        0.999
##  43.7   4426       1   0.9980 0.000676       0.9966        0.999
##  43.9   4425       1   0.9977 0.000712       0.9963        0.999
##  44.2   4424       1   0.9975 0.000747       0.9961        0.999
##  44.3   4423       1   0.9973 0.000780       0.9958        0.999
##  44.9   4422       1   0.9971 0.000812       0.9955        0.999
##  45.4   4421       1   0.9968 0.000843       0.9952        0.998
##  45.5   4420       1   0.9966 0.000872       0.9949        0.998
##  45.5   4419       1   0.9964 0.000900       0.9946        0.998
##  45.6   4418       1   0.9962 0.000928       0.9943        0.998
##  46.1   4417       1   0.9959 0.000955       0.9941        0.998
##  46.6   4416       1   0.9957 0.000981       0.9938        0.998
##  46.8   4415       1   0.9955 0.001006       0.9935        0.997
##  47.0   4414       1   0.9953 0.001031       0.9932        0.997
##  47.2   4413       1   0.9950 0.001055       0.9930        0.997
##  47.4   4412       1   0.9948 0.001079       0.9927        0.997
##  47.5   4411       1   0.9946 0.001102       0.9924        0.997
##  47.5   4410       1   0.9944 0.001124       0.9922        0.997
##  47.7   4409       1   0.9941 0.001147       0.9919        0.996
##  47.9   4408       1   0.9939 0.001168       0.9916        0.996
##  48.2   4407       1   0.9937 0.001190       0.9914        0.996
##  48.3   4406       1   0.9935 0.001211       0.9911        0.996
##  48.3   4405       1   0.9932 0.001231       0.9908        0.996
##  48.6   4404       1   0.9930 0.001251       0.9906        0.995
##  48.6   4403       1   0.9928 0.001271       0.9903        0.995
##  48.7   4402       1   0.9926 0.001291       0.9900        0.995
##  48.9   4401       1   0.9923 0.001310       0.9898        0.995
##  49.0   4400       1   0.9921 0.001329       0.9895        0.995
##  49.0   4399       1   0.9919 0.001348       0.9892        0.995
```

```
##  49.1   4398        1    0.9917 0.001366        0.9890          0.994
##  49.2   4397        1    0.9914 0.001384        0.9887          0.994
##  49.3   4396        1    0.9912 0.001402        0.9885          0.994
##  49.3   4395        1    0.9910 0.001420        0.9882          0.994
##  49.4   4394        1    0.9908 0.001437        0.9879          0.994
##  49.4   4393        1    0.9905 0.001455        0.9877          0.993
##  49.4   4392        1    0.9903 0.001472        0.9874          0.993
##  49.6   4391        1    0.9901 0.001489        0.9872          0.993
##  49.6   4390        1    0.9899 0.001505        0.9869          0.993
##  49.7   4389        1    0.9896 0.001522        0.9866          0.993
##  49.8   4388        1    0.9894 0.001538        0.9864          0.992
##  49.8   4387        1    0.9892 0.001554        0.9861          0.992
##  49.8   4386        1    0.9889 0.001570        0.9859          0.992
##  49.9   4385        1    0.9887 0.001586        0.9856          0.992
##  49.9   4384        1    0.9885 0.001601        0.9854          0.992
##  49.9   4383        1    0.9883 0.001617        0.9851          0.991
##  49.9   4382        1    0.9880 0.001632        0.9849          0.991
##  50.1   4381        1    0.9878 0.001647        0.9846          0.991
##  50.1   4380        1    0.9876 0.001662        0.9843          0.991
##  50.2   4379        1    0.9874 0.001677        0.9841          0.991
##  50.3   4378        2    0.9869 0.001706        0.9836          0.990
##  50.3   4376        1    0.9867 0.001721        0.9833          0.990
##  50.4   4375        1    0.9865 0.001735        0.9831          0.990
##  50.4   4374        1    0.9862 0.001749        0.9828          0.990
##  50.7   4373        1    0.9860 0.001763        0.9826          0.989
##  50.8   4372        1    0.9858 0.001777        0.9823          0.989
##  50.9   4371        1    0.9856 0.001791        0.9821          0.989
##  51.1   4370        1    0.9853 0.001805        0.9818          0.989
##  51.2   4369        1    0.9851 0.001819        0.9816          0.989
##  51.2   4368        1    0.9849 0.001832        0.9813          0.988
##  51.2   4367        1    0.9847 0.001845        0.9811          0.988
##  51.2   4366        1    0.9844 0.001859        0.9808          0.988
##  51.3   4365        1    0.9842 0.001872        0.9806          0.988
##  51.3   4364        1    0.9840 0.001885        0.9803          0.988
##  51.3   4363        1    0.9838 0.001898        0.9800          0.987
##  51.3   4362        1    0.9835 0.001911        0.9798          0.987
##  51.4   4361        1    0.9833 0.001924        0.9795          0.987
##  51.4   4360        1    0.9831 0.001937        0.9793          0.987
##  51.4   4359        1    0.9829 0.001949        0.9790          0.987
##  51.5   4358        1    0.9826 0.001962        0.9788          0.986
##  51.5   4357        1    0.9824 0.001974        0.9785          0.986
##  51.5   4356        1    0.9822 0.001987        0.9783          0.986
##  51.7   4355        1    0.9820 0.001999        0.9780          0.986
##  51.8   4354        1    0.9817 0.002011        0.9778          0.986
##  51.8   4353        1    0.9815 0.002023        0.9775          0.985
##  51.8   4352        1    0.9813 0.002035        0.9773          0.985
```

```
## 51.9 4351 1 0.9811 0.002047 0.9771 0.985
## 52.0 4350 1 0.9808 0.002059 0.9768 0.985
## 52.1 4349 1 0.9806 0.002071 0.9766 0.985
## 52.1 4348 1 0.9804 0.002083 0.9763 0.984
## 52.2 4347 1 0.9802 0.002095 0.9761 0.984
## 52.2 4346 1 0.9799 0.002106 0.9758 0.984
## 52.3 4345 1 0.9797 0.002118 0.9756 0.984
## 52.3 4344 1 0.9795 0.002129 0.9753 0.984
## 52.3 4343 1 0.9793 0.002141 0.9751 0.983
## 52.4 4342 1 0.9790 0.002152 0.9748 0.983
## 52.4 4341 1 0.9788 0.002163 0.9746 0.983
## 52.5 4340 1 0.9786 0.002175 0.9743 0.983
## 52.7 4339 1 0.9783 0.002186 0.9741 0.983
## 52.7 4338 1 0.9781 0.002197 0.9738 0.982
## 52.8 4337 1 0.9779 0.002208 0.9736 0.982
## 52.8 4336 1 0.9777 0.002219 0.9733 0.982
## 52.9 4335 1 0.9774 0.002230 0.9731 0.982
## 53.0 4334 1 0.9772 0.002241 0.9728 0.982
## 53.1 4333 1 0.9770 0.002251 0.9726 0.981
## 53.1 4332 1 0.9768 0.002262 0.9723 0.981
## 53.2 4331 1 0.9765 0.002273 0.9721 0.981
## 53.2 4330 1 0.9763 0.002283 0.9719 0.981
## 53.2 4329 1 0.9761 0.002294 0.9716 0.981
## 53.3 4328 1 0.9759 0.002305 0.9714 0.980
## 53.3 4327 1 0.9756 0.002315 0.9711 0.980
## 53.3 4326 1 0.9754 0.002325 0.9709 0.980
## 53.4 4325 1 0.9752 0.002336 0.9706 0.980
## 53.5 4324 1 0.9750 0.002346 0.9704 0.980
## 53.5 4323 1 0.9747 0.002356 0.9701 0.979
## 53.6 4322 1 0.9745 0.002367 0.9699 0.979
## 53.6 4321 1 0.9743 0.002377 0.9696 0.979
## 53.6 4320 1 0.9741 0.002387 0.9694 0.979
## 53.7 4319 1 0.9738 0.002397 0.9692 0.979
## 53.8 4318 1 0.9736 0.002407 0.9689 0.978
## 53.8 4317 1 0.9734 0.002417 0.9687 0.978
## 53.8 4316 1 0.9732 0.002427 0.9684 0.978
## 53.8 4315 1 0.9729 0.002437 0.9682 0.978
## 53.9 4314 1 0.9727 0.002447 0.9679 0.978
## 53.9 4313 1 0.9725 0.002457 0.9677 0.977
## 53.9 4312 1 0.9723 0.002466 0.9674 0.977
## 54.0 4311 1 0.9720 0.002476 0.9672 0.977
## 54.0 4310 1 0.9718 0.002486 0.9669 0.977
## 54.1 4309 1 0.9716 0.002495 0.9667 0.976
## 54.2 4308 1 0.9714 0.002505 0.9665 0.976
## 54.2 4307 1 0.9711 0.002514 0.9662 0.976
## 54.2 4306 1 0.9709 0.002524 0.9660 0.976
```

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##   54.2   4305        1    0.9707 0.002533        0.9657        0.976
##   54.3   4304        1    0.9705 0.002543        0.9655        0.975
##   54.3   4303        1    0.9702 0.002552        0.9652        0.975
##   54.3   4302        1    0.9700 0.002562        0.9650        0.975
##   54.4   4301        1    0.9698 0.002571        0.9648        0.975
##   54.4   4300        1    0.9696 0.002580        0.9645        0.975
##   54.4   4299        1    0.9693 0.002589        0.9643        0.974
##   54.4   4298        1    0.9691 0.002599        0.9640        0.974
##   54.4   4297        1    0.9689 0.002608        0.9638        0.974
##   54.5   4296        1    0.9687 0.002617        0.9635        0.974
##   54.5   4295        1    0.9684 0.002626        0.9633        0.974
##   54.6   4294        1    0.9682 0.002635        0.9630        0.973
##   54.6   4293        1    0.9680 0.002644        0.9628        0.973
##   54.6   4292        1    0.9677 0.002653        0.9626        0.973
##   54.6   4291        1    0.9675 0.002662        0.9623        0.973
##   54.7   4290        1    0.9673 0.002671        0.9621        0.973
##   54.7   4289        1    0.9671 0.002680        0.9618        0.972
##   54.7   4288        1    0.9668 0.002689        0.9616        0.972
##   54.8   4287        1    0.9666 0.002698        0.9613        0.972
##   54.9   4286        1    0.9664 0.002706        0.9611        0.972
##   54.9   4285        1    0.9662 0.002715        0.9609        0.972
##   55.0   4284        1    0.9659 0.002724        0.9606        0.971
##   55.1   4283        1    0.9657 0.002732        0.9604        0.971
##   55.1   4282        1    0.9655 0.002741        0.9601        0.971
##   55.1   4281        1    0.9653 0.002750        0.9599        0.971
##   55.1   4280        1    0.9650 0.002758        0.9597        0.970
##   55.1   4279        1    0.9648 0.002767        0.9594        0.970
##   55.2   4278        1    0.9646 0.002775        0.9592        0.970
##   55.2   4277        1    0.9644 0.002784        0.9589        0.970
##   55.2   4276        2    0.9639 0.002801        0.9584        0.969
##   55.3   4274        1    0.9637 0.002809        0.9582        0.969
##   55.3   4273        1    0.9635 0.002818        0.9580        0.969
##   55.3   4272        1    0.9632 0.002826        0.9577        0.969
##   55.3   4271        1    0.9630 0.002834        0.9575        0.969
##   55.3   4270        1    0.9628 0.002843        0.9572        0.968
##   55.4   4269        1    0.9626 0.002851        0.9570        0.968
##   55.4   4268        1    0.9623 0.002859        0.9567        0.968
##   55.4   4267        1    0.9621 0.002867        0.9565        0.968
##   55.5   4266        1    0.9619 0.002875        0.9563        0.968
##   55.5   4265        1    0.9617 0.002884        0.9560        0.967
##   55.6   4264        1    0.9614 0.002892        0.9558        0.967
##   55.7   4263        1    0.9612 0.002900        0.9555        0.967
##   55.7   4262        1    0.9610 0.002908        0.9553        0.967
##   55.7   4261        1    0.9608 0.002916        0.9551        0.966
##   55.7   4260        1    0.9605 0.002924        0.9548        0.966
##   55.8   4259        1    0.9603 0.002932        0.9546        0.966
```

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##   55.8   4258        1   0.9601 0.002940        0.9543          0.966
##   55.8   4257        1   0.9599 0.002948        0.9541          0.966
##   55.8   4256        1   0.9596 0.002956        0.9539          0.965
##   55.9   4255        1   0.9594 0.002964        0.9536          0.965
##   55.9   4254        1   0.9592 0.002972        0.9534          0.965
##   56.0   4253        1   0.9590 0.002979        0.9531          0.965
##   56.0   4252        1   0.9587 0.002987        0.9529          0.965
##   56.0   4251        1   0.9585 0.002995        0.9527          0.964
##   56.0   4250        1   0.9583 0.003003        0.9524          0.964
##   56.0   4248        1   0.9581 0.003011        0.9522          0.964
##   56.1   4247        1   0.9578 0.003018        0.9519          0.964
##   56.1   4246        1   0.9576 0.003026        0.9517          0.964
##   56.1   4245        1   0.9574 0.003034        0.9514          0.963
##   56.1   4244        1   0.9571 0.003041        0.9512          0.963
##   56.2   4243        1   0.9569 0.003049        0.9510          0.963
##   56.3   4242        1   0.9567 0.003057        0.9507          0.963
##   56.3   4241        1   0.9565 0.003064        0.9505          0.962
##   56.4   4240        1   0.9562 0.003072        0.9502          0.962
##   56.4   4239        1   0.9560 0.003079        0.9500          0.962
##   56.6   4238        1   0.9558 0.003087        0.9498          0.962
##   56.6   4237        1   0.9556 0.003094        0.9495          0.962
##   56.6   4236        1   0.9553 0.003102        0.9493          0.961
##   56.6   4235        1   0.9551 0.003109        0.9490          0.961
##   56.6   4234        1   0.9549 0.003117        0.9488          0.961
##   56.7   4233        1   0.9547 0.003124        0.9486          0.961
##   56.7   4232        1   0.9544 0.003132        0.9483          0.961
##   56.8   4231        1   0.9542 0.003139        0.9481          0.960
##   56.8   4230        1   0.9540 0.003146        0.9478          0.960
##   56.9   4229        1   0.9538 0.003154        0.9476          0.960
##   56.9   4228        1   0.9535 0.003161        0.9474          0.960
##   56.9   4227        1   0.9533 0.003168        0.9471          0.960
##   56.9   4226        1   0.9531 0.003176        0.9469          0.959
##   56.9   4225        1   0.9529 0.003183        0.9466          0.959
##   57.0   4224        1   0.9526 0.003190        0.9464          0.959
##   57.0   4223        1   0.9524 0.003197        0.9462          0.959
##   57.1   4217        1   0.9522 0.003204        0.9459          0.958
##   57.1   4216        1   0.9520 0.003212        0.9457          0.958
##   57.2   4215        1   0.9517 0.003219        0.9454          0.958
##   57.2   4214        1   0.9515 0.003226        0.9452          0.958
##   57.3   4213        1   0.9513 0.003233        0.9450          0.958
##   57.3   4212        1   0.9511 0.003240        0.9447          0.957
##   57.4   4211        1   0.9508 0.003247        0.9445          0.957
##   57.4   4210        1   0.9506 0.003254        0.9442          0.957
##   57.4   4209        1   0.9504 0.003261        0.9440          0.957
##   57.5   4208        1   0.9502 0.003268        0.9438          0.957
##   57.5   4207        1   0.9499 0.003275        0.9435          0.956
```

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##   57.6    4206         1    0.9497 0.003282          0.9433          0.956
##   57.6    4205         1    0.9495 0.003289          0.9431          0.956
##   57.6    4204         1    0.9492 0.003296          0.9428          0.956
##   57.6    4203         1    0.9490 0.003303          0.9426          0.956
##   57.6    4202         1    0.9488 0.003310          0.9423          0.955
##   57.6    4201         1    0.9486 0.003317          0.9421          0.955
##   57.6    4200         1    0.9483 0.003324          0.9419          0.955
##   57.7    4199         1    0.9481 0.003331          0.9416          0.955
##   57.7    4198         1    0.9479 0.003338          0.9414          0.954
##   57.7    4197         1    0.9477 0.003345          0.9411          0.954
##   57.7    4196         1    0.9474 0.003351          0.9409          0.954
##   57.8    4195         1    0.9472 0.003358          0.9407          0.954
##   57.9    4194         1    0.9470 0.003365          0.9404          0.954
##   57.9    4193         1    0.9468 0.003372          0.9402          0.953
##   57.9    4192         1    0.9465 0.003379          0.9399          0.953
##   58.0    4175         1    0.9463 0.003385          0.9397          0.953
##   58.1    4174         1    0.9461 0.003392          0.9395          0.953
##   58.2    4173         1    0.9459 0.003399          0.9392          0.953
##   58.2    4172         1    0.9456 0.003406          0.9390          0.952
##   58.3    4171         1    0.9454 0.003412          0.9387          0.952
##   58.3    4170         1    0.9452 0.003419          0.9385          0.952
##   58.3    4169         2    0.9447 0.003432          0.9380          0.951
##   58.3    4167         1    0.9445 0.003439          0.9378          0.951
##   58.4    4166         1    0.9443 0.003446          0.9375          0.951
##   58.5    4165         1    0.9440 0.003452          0.9373          0.951
##   58.5    4164         1    0.9438 0.003459          0.9371          0.951
##   58.5    4163         1    0.9436 0.003465          0.9368          0.950
##   58.5    4162         1    0.9434 0.003472          0.9366          0.950
##   58.6    4161         1    0.9431 0.003479          0.9363          0.950
##   58.6    4160         1    0.9429 0.003485          0.9361          0.950
##   58.6    4159         1    0.9427 0.003492          0.9359          0.950
##   58.6    4158         1    0.9425 0.003498          0.9356          0.949
##   58.6    4157         1    0.9422 0.003505          0.9354          0.949
##   58.7    4156         1    0.9420 0.003511          0.9351          0.949
##   58.7    4155         1    0.9418 0.003518          0.9349          0.949
##   58.8    4154         1    0.9416 0.003524          0.9347          0.948
##   58.8    4153         1    0.9413 0.003531          0.9344          0.948
##   58.8    4152         1    0.9411 0.003537          0.9342          0.948
##   58.8    4151         1    0.9409 0.003543          0.9340          0.948
##   58.8    4150         1    0.9406 0.003550          0.9337          0.948
##   58.8    4149         1    0.9404 0.003556          0.9335          0.947
##   58.8    4148         1    0.9402 0.003563          0.9332          0.947
##   58.8    4147         1    0.9400 0.003569          0.9330          0.947
##   59.0    4146         1    0.9397 0.003575          0.9328          0.947
##   59.0    4106         1    0.9395 0.003582          0.9325          0.947
##   59.1    4105         1    0.9393 0.003588          0.9323          0.946
```

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##  59.1   4104        1   0.9391 0.003594         0.9320            0.946
##  59.1   4103        1   0.9388 0.003601         0.9318            0.946
##  59.1   4102        1   0.9386 0.003607         0.9316            0.946
##  59.1   4101        1   0.9384 0.003614         0.9313            0.945
##  59.1   4100        1   0.9381 0.003620         0.9311            0.945
##  59.2   4099        1   0.9379 0.003626         0.9308            0.945
##  59.2   4098        1   0.9377 0.003633         0.9306            0.945
##  59.2   4097        1   0.9374 0.003639         0.9303            0.945
##  59.3   4096        1   0.9372 0.003645         0.9301            0.944
##  59.3   4095        1   0.9370 0.003652         0.9299            0.944
##  59.3   4094        1   0.9368 0.003658         0.9296            0.944
##  59.3   4093        1   0.9365 0.003664         0.9294            0.944
##  59.3   4092        1   0.9363 0.003670         0.9291            0.944
##  59.4   4091        1   0.9361 0.003677         0.9289            0.943
##  59.4   4090        1   0.9358 0.003683         0.9287            0.943
##  59.4   4089        1   0.9356 0.003689         0.9284            0.943
##  59.5   4088        1   0.9354 0.003695         0.9282            0.943
##  59.5   4087        1   0.9352 0.003701         0.9279            0.942
##  59.5   4086        1   0.9349 0.003708         0.9277            0.942
##  59.6   4085        1   0.9347 0.003714         0.9275            0.942
##  59.7   4084        1   0.9345 0.003720         0.9272            0.942
##  59.7   4083        1   0.9342 0.003726         0.9270            0.942
##  59.7   4082        1   0.9340 0.003732         0.9267            0.941
##  59.7   4081        1   0.9338 0.003738         0.9265            0.941
##  59.8   4080        1   0.9336 0.003744         0.9262            0.941
##  59.8   4079        1   0.9333 0.003750         0.9260            0.941
##  59.8   4078        1   0.9331 0.003756         0.9258            0.940
##  59.9   4077        1   0.9329 0.003762         0.9255            0.940
##  60.0   4000        1   0.9326 0.003769         0.9253            0.940
##  60.1   3999        1   0.9324 0.003775         0.9250            0.940
##  60.1   3998        1   0.9322 0.003781         0.9248            0.940
##  60.2   3997        1   0.9319 0.003787         0.9245            0.939
##  60.2   3996        1   0.9317 0.003794         0.9243            0.939
##  60.2   3995        1   0.9315 0.003800         0.9241            0.939
##  60.2   3994        1   0.9312 0.003806         0.9238            0.939
##  60.3   3993        1   0.9310 0.003812         0.9236            0.939
##  60.3   3992        1   0.9308 0.003818         0.9233            0.938
##  60.3   3991        1   0.9305 0.003825         0.9231            0.938
##  60.3   3990        1   0.9303 0.003831         0.9228            0.938
##  60.4   3989        1   0.9301 0.003837         0.9226            0.938
##  60.4   3988        1   0.9298 0.003843         0.9223            0.937
##  60.4   3987        1   0.9296 0.003849         0.9221            0.937
##  60.5   3986        2   0.9291 0.003861         0.9216            0.937
##  60.5   3984        1   0.9289 0.003867         0.9214            0.937
##  60.5   3983        1   0.9287 0.003873         0.9211            0.936
##  60.5   3982        1   0.9284 0.003879         0.9209            0.936
```

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##   60.6   3981       1   0.9282 0.003885      0.9206        0.936
##   60.6   3980       1   0.9280 0.003892      0.9204        0.936
##   60.7   3979       1   0.9277 0.003898      0.9201        0.935
##   60.7   3978       1   0.9275 0.003904      0.9199        0.935
##   60.7   3977       1   0.9273 0.003909      0.9196        0.935
##   60.7   3976       1   0.9270 0.003915      0.9194        0.935
##   60.8   3975       1   0.9268 0.003921      0.9192        0.935
##   60.8   3974       1   0.9266 0.003927      0.9189        0.934
##   60.8   3973       1   0.9263 0.003933      0.9187        0.934
##   60.8   3972       1   0.9261 0.003939      0.9184        0.934
##   60.8   3971       1   0.9259 0.003945      0.9182        0.934
##   60.8   3970       1   0.9256 0.003951      0.9179        0.933
##   60.9   3969       1   0.9254 0.003957      0.9177        0.933
##   60.9   3968       1   0.9252 0.003963      0.9174        0.933
##   60.9   3967       1   0.9249 0.003969      0.9172        0.933
##   60.9   3966       1   0.9247 0.003974      0.9170        0.933
##   60.9   3965       1   0.9245 0.003980      0.9167        0.932
##   61.0   3964       1   0.9242 0.003986      0.9165        0.932
##   61.0   3963       1   0.9240 0.003992      0.9162        0.932
##   61.0   3962       1   0.9238 0.003998      0.9160        0.932
##   61.0   3874       1   0.9235 0.004004      0.9157        0.931
##   61.0   3873       1   0.9233 0.004010      0.9155        0.931
##   61.0   3872       1   0.9231 0.004016      0.9152        0.931
##   61.1   3871       1   0.9228 0.004022      0.9150        0.931
##   61.1   3870       1   0.9226 0.004028      0.9147        0.931
##   61.1   3869       1   0.9223 0.004034      0.9145        0.930
##   61.1   3868       1   0.9221 0.004040      0.9142        0.930
##   61.2   3867       1   0.9219 0.004046      0.9140        0.930
##   61.2   3866       1   0.9216 0.004052      0.9137        0.930
##   61.2   3865       1   0.9214 0.004058      0.9135        0.929
##   61.2   3864       1   0.9212 0.004064      0.9132        0.929
##   61.2   3863       1   0.9209 0.004070      0.9130        0.929
##   61.2   3862       1   0.9207 0.004076      0.9127        0.929
##   61.2   3861       1   0.9204 0.004082      0.9125        0.928
##   61.3   3860       1   0.9202 0.004088      0.9122        0.928
##   61.4   3859       1   0.9200 0.004093      0.9120        0.928
##   61.4   3858       1   0.9197 0.004099      0.9117        0.928
##   61.4   3857       1   0.9195 0.004105      0.9115        0.928
##   61.5   3856       1   0.9192 0.004111      0.9112        0.927
##   61.5   3855       1   0.9190 0.004117      0.9110        0.927
##   61.5   3854       1   0.9188 0.004123      0.9107        0.927
##   61.6   3853       1   0.9185 0.004129      0.9105        0.927
##   61.6   3852       1   0.9183 0.004134      0.9102        0.926
##   61.6   3851       1   0.9181 0.004140      0.9100        0.926
##   61.6   3850       1   0.9178 0.004146      0.9097        0.926
##   61.6   3849       1   0.9176 0.004152      0.9095        0.926
```

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## 61.6 3848 1 0.9173 0.004157 0.9092 0.926
## 61.6 3847 1 0.9171 0.004163 0.9090 0.925
## 61.6 3846 1 0.9169 0.004169 0.9087 0.925
## 61.6 3845 1 0.9166 0.004175 0.9085 0.925
## 61.7 3844 1 0.9164 0.004180 0.9082 0.925
## 61.7 3843 1 0.9161 0.004186 0.9080 0.924
## 61.7 3842 1 0.9159 0.004192 0.9077 0.924
## 61.7 3841 1 0.9157 0.004197 0.9075 0.924
## 61.8 3840 1 0.9154 0.004203 0.9072 0.924
## 61.8 3839 1 0.9152 0.004209 0.9070 0.923
## 61.8 3838 1 0.9150 0.004214 0.9067 0.923
## 61.8 3837 1 0.9147 0.004220 0.9065 0.923
## 61.8 3836 1 0.9145 0.004226 0.9062 0.923
## 61.8 3835 1 0.9142 0.004231 0.9060 0.923
## 61.9 3834 1 0.9140 0.004237 0.9057 0.922
## 61.9 3833 1 0.9138 0.004243 0.9055 0.922
## 61.9 3832 1 0.9135 0.004248 0.9052 0.922
## 61.9 3831 1 0.9133 0.004254 0.9050 0.922
## 61.9 3830 1 0.9130 0.004259 0.9047 0.921
## 61.9 3829 1 0.9128 0.004265 0.9045 0.921
## 62.0 3828 1 0.9126 0.004270 0.9042 0.921
## 62.0 3827 1 0.9123 0.004276 0.9040 0.921
## 62.0 3699 1 0.9121 0.004282 0.9037 0.921
## 62.0 3698 1 0.9118 0.004288 0.9035 0.920
## 62.1 3697 1 0.9116 0.004294 0.9032 0.920
## 62.1 3696 1 0.9113 0.004300 0.9030 0.920
## 62.1 3695 2 0.9109 0.004311 0.9024 0.919
## 62.1 3693 1 0.9106 0.004317 0.9022 0.919
## 62.2 3692 1 0.9104 0.004323 0.9019 0.919
## 62.3 3691 1 0.9101 0.004329 0.9017 0.919
## 62.3 3690 1 0.9099 0.004335 0.9014 0.918
## 62.3 3689 1 0.9096 0.004341 0.9011 0.918
## 62.3 3688 1 0.9094 0.004347 0.9009 0.918
## 62.3 3687 1 0.9091 0.004352 0.9006 0.918
## 62.3 3686 1 0.9089 0.004358 0.9004 0.917
## 62.3 3685 1 0.9086 0.004364 0.9001 0.917
## 62.3 3684 1 0.9084 0.004370 0.8999 0.917
## 62.3 3683 1 0.9081 0.004376 0.8996 0.917
## 62.3 3682 1 0.9079 0.004381 0.8993 0.917
## 62.4 3681 1 0.9076 0.004387 0.8991 0.916
## 62.4 3680 1 0.9074 0.004393 0.8988 0.916
## 62.4 3679 2 0.9069 0.004404 0.8983 0.916
## 62.4 3677 1 0.9067 0.004410 0.8981 0.915
## 62.4 3676 1 0.9064 0.004416 0.8978 0.915
## 62.4 3675 1 0.9062 0.004421 0.8975 0.915
## 62.5 3674 1 0.9059 0.004427 0.8973 0.915
```

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##   62.5   3673        1   0.9057 0.004433         0.8970         0.914
##   62.5   3672        1   0.9054 0.004438         0.8968         0.914
##   62.5   3671        1   0.9052 0.004444         0.8965         0.914
##   62.5   3670        1   0.9049 0.004450         0.8963         0.914
##   62.5   3669        1   0.9047 0.004455         0.8960         0.913
##   62.5   3668        1   0.9044 0.004461         0.8957         0.913
##   62.6   3667        1   0.9042 0.004466         0.8955         0.913
##   62.6   3666        1   0.9039 0.004472         0.8952         0.913
##   62.6   3665        1   0.9037 0.004478         0.8950         0.913
##   62.6   3664        1   0.9035 0.004483         0.8947         0.912
##   62.6   3663        1   0.9032 0.004489         0.8945         0.912
##   62.6   3662        1   0.9030 0.004494         0.8942         0.912
##   62.6   3661        1   0.9027 0.004500         0.8939         0.912
##   62.7   3660        1   0.9025 0.004505         0.8937         0.911
##   62.7   3659        1   0.9022 0.004511         0.8934         0.911
##   62.7   3658        1   0.9020 0.004516         0.8932         0.911
##   62.8   3657        1   0.9017 0.004522         0.8929         0.911
##   62.8   3656        1   0.9015 0.004527         0.8926         0.910
##   62.8   3655        1   0.9012 0.004533         0.8924         0.910
##   62.8   3654        1   0.9010 0.004538         0.8921         0.910
##   62.8   3653        1   0.9007 0.004544         0.8919         0.910
##   62.8   3652        1   0.9005 0.004549         0.8916         0.909
##   62.8   3651        1   0.9002 0.004555         0.8914         0.909
##   62.9   3650        1   0.9000 0.004560         0.8911         0.909
##   62.9   3649        1   0.8998 0.004565         0.8908         0.909
##   62.9   3648        1   0.8995 0.004571         0.8906         0.909
##   62.9   3647        1   0.8993 0.004576         0.8903         0.908
##   62.9   3646        1   0.8990 0.004582         0.8901         0.908
##   62.9   3645        1   0.8988 0.004587         0.8898         0.908
##   63.0   3644        1   0.8985 0.004592         0.8896         0.908
##   63.0   3643        1   0.8983 0.004598         0.8893         0.907
##   63.0   3493        1   0.8980 0.004604         0.8890         0.907
##   63.1   3492        1   0.8978 0.004609         0.8888         0.907
##   63.1   3491        1   0.8975 0.004615         0.8885         0.907
##   63.1   3490        1   0.8972 0.004621         0.8882         0.906
##   63.1   3489        1   0.8970 0.004627         0.8880         0.906
##   63.2   3488        1   0.8967 0.004633         0.8877         0.906
##   63.2   3487        1   0.8965 0.004639         0.8874         0.906
##   63.2   3486        1   0.8962 0.004644         0.8872         0.905
##   63.2   3485        1   0.8960 0.004650         0.8869         0.905
##   63.3   3484        1   0.8957 0.004656         0.8866         0.905
##   63.3   3483        1   0.8954 0.004662         0.8864         0.905
##   63.3   3482        1   0.8952 0.004667         0.8861         0.904
##   63.3   3481        1   0.8949 0.004673         0.8858         0.904
##   63.4   3480        1   0.8947 0.004679         0.8855         0.904
##   63.4   3479        1   0.8944 0.004685         0.8853         0.904
```

```
##  63.4   3478        1   0.8942 0.004690        0.8850            0.903
##  63.4   3477        1   0.8939 0.004696        0.8847            0.903
##  63.4   3476        1   0.8936 0.004702        0.8845            0.903
##  63.4   3475        1   0.8934 0.004707        0.8842            0.903
##  63.5   3474        1   0.8931 0.004713        0.8839            0.902
##  63.5   3473        1   0.8929 0.004719        0.8837            0.902
##  63.5   3472        1   0.8926 0.004724        0.8834            0.902
##  63.5   3471        1   0.8924 0.004730        0.8831            0.902
##  63.5   3470        1   0.8921 0.004736        0.8829            0.901
##  63.5   3469        1   0.8918 0.004741        0.8826            0.901
##  63.6   3468        1   0.8916 0.004747        0.8823            0.901
##  63.6   3467        1   0.8913 0.004752        0.8821            0.901
##  63.6   3466        1   0.8911 0.004758        0.8818            0.900
##  63.7   3465        1   0.8908 0.004763        0.8815            0.900
##  63.7   3464        1   0.8906 0.004769        0.8813            0.900
##  63.7   3463        1   0.8903 0.004775        0.8810            0.900
##  63.8   3462        1   0.8900 0.004780        0.8807            0.899
##  63.8   3461        1   0.8898 0.004786        0.8805            0.899
##  63.9   3460        1   0.8895 0.004791        0.8802            0.899
##  63.9   3459        1   0.8893 0.004797        0.8799            0.899
##  63.9   3458        1   0.8890 0.004802        0.8797            0.898
##  64.0   3457        1   0.8888 0.004808        0.8794            0.898
##  64.0   3294        1   0.8885 0.004814        0.8791            0.898
##  64.0   3293        1   0.8882 0.004820        0.8788            0.898
##  64.0   3292        1   0.8879 0.004826        0.8785            0.897
##  64.0   3291        1   0.8877 0.004832        0.8783            0.897
##  64.1   3290        1   0.8874 0.004838        0.8780            0.897
##  64.1   3289        1   0.8871 0.004844        0.8777            0.897
##  64.2   3288        1   0.8869 0.004850        0.8774            0.896
##  64.2   3287        1   0.8866 0.004856        0.8771            0.896
##  64.2   3286        1   0.8863 0.004862        0.8769            0.896
##  64.2   3285        1   0.8861 0.004868        0.8766            0.896
##  64.3   3284        1   0.8858 0.004874        0.8763            0.895
##  64.3   3283        1   0.8855 0.004880        0.8760            0.895
##  64.3   3282        1   0.8852 0.004886        0.8757            0.895
##  64.3   3281        1   0.8850 0.004892        0.8754            0.895
##  64.3   3280        1   0.8847 0.004898        0.8752            0.894
##  64.3   3279        1   0.8844 0.004904        0.8749            0.894
##  64.3   3278        1   0.8842 0.004910        0.8746            0.894
##  64.3   3277        1   0.8839 0.004916        0.8743            0.894
##  64.3   3276        1   0.8836 0.004922        0.8740            0.893
##  64.4   3275        2   0.8831 0.004933        0.8735            0.893
##  64.4   3273        2   0.8826 0.004945        0.8729            0.892
##  64.4   3271        1   0.8823 0.004951        0.8726            0.892
##  64.4   3270        1   0.8820 0.004957        0.8723            0.892
##  64.4   3269        1   0.8817 0.004963        0.8721            0.892
```

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##   64.5   3268        1   0.8815 0.004969        0.8718          0.891
##   64.5   3267        1   0.8812 0.004974        0.8715          0.891
##   64.5   3266        1   0.8809 0.004980        0.8712          0.891
##   64.6   3265        1   0.8807 0.004986        0.8709          0.890
##   64.6   3264        1   0.8804 0.004992        0.8707          0.890
##   64.6   3263        1   0.8801 0.004997        0.8704          0.890
##   64.6   3262        1   0.8799 0.005003        0.8701          0.890
##   64.6   3261        1   0.8796 0.005009        0.8698          0.889
##   64.7   3260        1   0.8793 0.005015        0.8695          0.889
##   64.7   3259        1   0.8790 0.005020        0.8693          0.889
##   64.7   3258        1   0.8788 0.005026        0.8690          0.889
##   64.7   3257        1   0.8785 0.005032        0.8687          0.888
##   64.7   3256        1   0.8782 0.005037        0.8684          0.888
##   64.7   3255        1   0.8780 0.005043        0.8681          0.888
##   64.7   3254        1   0.8777 0.005049        0.8679          0.888
##   64.8   3253        1   0.8774 0.005054        0.8676          0.887
##   64.8   3252        1   0.8772 0.005060        0.8673          0.887
##   64.8   3251        1   0.8769 0.005066        0.8670          0.887
##   64.8   3250        1   0.8766 0.005071        0.8667          0.887
##   64.9   3249        1   0.8763 0.005077        0.8665          0.886
##   65.0   3248        1   0.8761 0.005083        0.8662          0.886
##   65.0   3095        1   0.8758 0.005089        0.8659          0.886
##   65.0   3094        1   0.8755 0.005095        0.8656          0.886
##   65.0   3093        1   0.8752 0.005101        0.8653          0.885
##   65.1   3092        1   0.8749 0.005107        0.8650          0.885
##   65.1   3091        1   0.8747 0.005114        0.8647          0.885
##   65.1   3090        1   0.8744 0.005120        0.8644          0.884
##   65.2   3089        1   0.8741 0.005126        0.8641          0.884
##   65.2   3088        1   0.8738 0.005132        0.8638          0.884
##   65.2   3087        1   0.8735 0.005138        0.8635          0.884
##   65.2   3086        1   0.8732 0.005144        0.8632          0.883
##   65.2   3085        1   0.8730 0.005150        0.8629          0.883
##   65.2   3084        1   0.8727 0.005157        0.8626          0.883
##   65.3   3083        1   0.8724 0.005163        0.8623          0.883
##   65.3   3082        1   0.8721 0.005169        0.8620          0.882
##   65.3   3081        1   0.8718 0.005175        0.8617          0.882
##   65.3   3080        1   0.8715 0.005181        0.8615          0.882
##   65.3   3079        1   0.8713 0.005187        0.8612          0.881
##   65.3   3078        1   0.8710 0.005193        0.8609          0.881
##   65.4   3077        1   0.8707 0.005199        0.8606          0.881
##   65.4   3076        1   0.8704 0.005205        0.8603          0.881
##   65.4   3075        1   0.8701 0.005211        0.8600          0.880
##   65.4   3074        2   0.8696 0.005223        0.8594          0.880
##   65.4   3072        1   0.8693 0.005229        0.8591          0.880
##   65.4   3071        1   0.8690 0.005235        0.8588          0.879
##   65.4   3070        1   0.8687 0.005241        0.8585          0.879
```

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##   65.4   3069       1   0.8684 0.005247       0.8582          0.879
##   65.5   3068       1   0.8682 0.005253       0.8579          0.879
##   65.5   3067       1   0.8679 0.005259       0.8576          0.878
##   65.5   3066       1   0.8676 0.005264       0.8573          0.878
##   65.6   3065       1   0.8673 0.005270       0.8570          0.878
##   65.6   3064       1   0.8670 0.005276       0.8567          0.877
##   65.6   3063       1   0.8667 0.005282       0.8564          0.877
##   65.6   3062       1   0.8665 0.005288       0.8561          0.877
##   65.6   3061       1   0.8662 0.005294       0.8559          0.877
##   65.6   3060       1   0.8659 0.005300       0.8556          0.876
##   65.6   3059       1   0.8656 0.005305       0.8553          0.876
##   65.6   3058       1   0.8653 0.005311       0.8550          0.876
##   65.6   3057       1   0.8650 0.005317       0.8547          0.876
##   65.6   3056       1   0.8648 0.005323       0.8544          0.875
##   65.6   3055       1   0.8645 0.005329       0.8541          0.875
##   65.7   3054       1   0.8642 0.005334       0.8538          0.875
##   65.7   3053       1   0.8639 0.005340       0.8535          0.874
##   65.7   3052       1   0.8636 0.005346       0.8532          0.874
##   65.7   3051       1   0.8633 0.005352       0.8529          0.874
##   65.7   3050       1   0.8631 0.005357       0.8526          0.874
##   65.8   3049       1   0.8628 0.005363       0.8523          0.873
##   65.8   3048       1   0.8625 0.005369       0.8520          0.873
##   65.8   3047       1   0.8622 0.005374       0.8517          0.873
##   65.8   3046       1   0.8619 0.005380       0.8514          0.873
##   65.8   3045       1   0.8616 0.005386       0.8511          0.872
##   65.8   3044       1   0.8614 0.005391       0.8509          0.872
##   65.8   3043       1   0.8611 0.005397       0.8506          0.872
##   65.9   3042       1   0.8608 0.005403       0.8503          0.871
##   65.9   3041       1   0.8605 0.005408       0.8500          0.871
##   65.9   3040       1   0.8602 0.005414       0.8497          0.871
##   65.9   3039       1   0.8599 0.005420       0.8494          0.871
##   65.9   3038       1   0.8597 0.005425       0.8491          0.870
##   65.9   3037       1   0.8594 0.005431       0.8488          0.870
##   65.9   3036       1   0.8591 0.005436       0.8485          0.870
##   66.0   3035       1   0.8588 0.005442       0.8482          0.870
##   66.0   3034       1   0.8585 0.005448       0.8479          0.869
##   66.0   3033       1   0.8582 0.005453       0.8476          0.869
##   66.0   3032       1   0.8580 0.005459       0.8473          0.869
##   66.0   3031       1   0.8577 0.005464       0.8470          0.868
##   66.0   2877       1   0.8574 0.005470       0.8467          0.868
##   66.0   2876       1   0.8571 0.005477       0.8464          0.868
##   66.0   2875       1   0.8568 0.005483       0.8461          0.868
##   66.0   2874       1   0.8565 0.005489       0.8458          0.867
##   66.0   2873       1   0.8562 0.005495       0.8455          0.867
##   66.0   2872       1   0.8559 0.005501       0.8452          0.867
##   66.1   2871       1   0.8556 0.005507       0.8449          0.866
```

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##   66.1    2870          1    0.8553 0.005514         0.8446          0.866
##   66.2    2869          1    0.8550 0.005520         0.8442          0.866
##   66.2    2868          1    0.8547 0.005526         0.8439          0.866
##   66.2    2867          1    0.8544 0.005532         0.8436          0.865
##   66.2    2866          1    0.8541 0.005538         0.8433          0.865
##   66.2    2865          1    0.8538 0.005544         0.8430          0.865
##   66.3    2864          1    0.8535 0.005550         0.8427          0.864
##   66.4    2863          1    0.8532 0.005556         0.8424          0.864
##   66.4    2862          1    0.8529 0.005562         0.8421          0.864
##   66.4    2861          1    0.8526 0.005568         0.8418          0.864
##   66.5    2860          1    0.8523 0.005574         0.8415          0.863
##   66.5    2859          1    0.8520 0.005580         0.8411          0.863
##   66.5    2858          1    0.8517 0.005586         0.8408          0.863
##   66.5    2857          1    0.8514 0.005592         0.8405          0.862
##   66.5    2856          1    0.8511 0.005598         0.8402          0.862
##   66.6    2855          1    0.8508 0.005604         0.8399          0.862
##   66.6    2854          1    0.8505 0.005610         0.8396          0.862
##   66.6    2853          1    0.8502 0.005616         0.8393          0.861
##   66.6    2852          1    0.8499 0.005622         0.8390          0.861
##   66.6    2851          1    0.8496 0.005628         0.8387          0.861
##   66.6    2850          1    0.8493 0.005634         0.8384          0.860
##   66.7    2849          1    0.8490 0.005640         0.8380          0.860
##   66.7    2848          1    0.8487 0.005646         0.8377          0.860
##   66.7    2847          1    0.8484 0.005652         0.8374          0.860
##   66.7    2846          1    0.8481 0.005658         0.8371          0.859
##   66.8    2845          1    0.8478 0.005663         0.8368          0.859
##   66.8    2844          1    0.8475 0.005669         0.8365          0.859
##   66.8    2843          1    0.8472 0.005675         0.8362          0.858
##   66.8    2842          1    0.8469 0.005681         0.8359          0.858
##   66.9    2841          1    0.8466 0.005687         0.8356          0.858
##   66.9    2840          1    0.8463 0.005693         0.8353          0.858
##   67.0    2839          1    0.8461 0.005698         0.8350          0.857
##   67.0    2838          1    0.8458 0.005704         0.8346          0.857
##   67.0    2705          1    0.8454 0.005711         0.8343          0.857
##   67.0    2704          1    0.8451 0.005717         0.8340          0.856
##   67.0    2703          1    0.8448 0.005724         0.8337          0.856
##   67.1    2702          1    0.8445 0.005730         0.8333          0.856
##   67.1    2701          1    0.8442 0.005736         0.8330          0.856
##   67.1    2700          1    0.8439 0.005743         0.8327          0.855
##   67.2    2699          1    0.8436 0.005749         0.8324          0.855
##   67.2    2698          1    0.8433 0.005755         0.8320          0.855
##   67.2    2697          1    0.8429 0.005762         0.8317          0.854
##   67.2    2696          1    0.8426 0.005768         0.8314          0.854
##   67.3    2695          1    0.8423 0.005774         0.8311          0.854
##   67.3    2694          1    0.8420 0.005781         0.8307          0.853
##   67.3    2693          1    0.8417 0.005787         0.8304          0.853
```

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##   67.4   2692        1   0.8414 0.005793        0.8301           0.853
##   67.4   2691        1   0.8411 0.005800        0.8298           0.853
##   67.4   2690        1   0.8407 0.005806        0.8294           0.852
##   67.4   2689        1   0.8404 0.005812        0.8291           0.852
##   67.4   2688        1   0.8401 0.005818        0.8288           0.852
##   67.4   2687        1   0.8398 0.005825        0.8285           0.851
##   67.4   2686        1   0.8395 0.005831        0.8281           0.851
##   67.5   2685        1   0.8392 0.005837        0.8278           0.851
##   67.5   2684        1   0.8389 0.005843        0.8275           0.850
##   67.5   2683        1   0.8386 0.005849        0.8272           0.850
##   67.5   2682        1   0.8382 0.005856        0.8268           0.850
##   67.5   2681        1   0.8379 0.005862        0.8265           0.850
##   67.6   2680        1   0.8376 0.005868        0.8262           0.849
##   67.6   2679        1   0.8373 0.005874        0.8259           0.849
##   67.6   2678        1   0.8370 0.005880        0.8256           0.849
##   67.6   2677        1   0.8367 0.005886        0.8252           0.848
##   67.6   2676        1   0.8364 0.005892        0.8249           0.848
##   67.6   2675        1   0.8361 0.005898        0.8246           0.848
##   67.6   2674        1   0.8357 0.005905        0.8243           0.847
##   67.6   2673        1   0.8354 0.005911        0.8239           0.847
##   67.7   2672        1   0.8351 0.005917        0.8236           0.847
##   67.7   2671        1   0.8348 0.005923        0.8233           0.846
##   67.7   2670        1   0.8345 0.005929        0.8230           0.846
##   67.7   2669        1   0.8342 0.005935        0.8226           0.846
##   67.7   2668        1   0.8339 0.005941        0.8223           0.846
##   67.7   2667        1   0.8336 0.005947        0.8220           0.845
##   67.8   2666        1   0.8332 0.005953        0.8217           0.845
##   67.8   2665        1   0.8329 0.005959        0.8213           0.845
##   67.9   2664        1   0.8326 0.005965        0.8210           0.844
##   67.9   2663        1   0.8323 0.005971        0.8207           0.844
##   67.9   2662        1   0.8320 0.005977        0.8204           0.844
##   67.9   2661        1   0.8317 0.005982        0.8200           0.843
##   67.9   2660        1   0.8314 0.005988        0.8197           0.843
##   67.9   2659        1   0.8311 0.005994        0.8194           0.843
##   67.9   2658        1   0.8307 0.006000        0.8191           0.843
##   67.9   2657        1   0.8304 0.006006        0.8187           0.842
##   68.0   2656        1   0.8301 0.006012        0.8184           0.842
##   68.0   2655        1   0.8298 0.006018        0.8181           0.842
##   68.0   2530        1   0.8295 0.006024        0.8178           0.841
##   68.0   2529        1   0.8292 0.006031        0.8174           0.841
##   68.0   2528        1   0.8288 0.006037        0.8171           0.841
##   68.1   2527        1   0.8285 0.006044        0.8167           0.840
##   68.1   2526        1   0.8282 0.006050        0.8164           0.840
##   68.1   2525        1   0.8278 0.006057        0.8161           0.840
##   68.1   2524        1   0.8275 0.006063        0.8157           0.839
##   68.1   2523        1   0.8272 0.006070        0.8154           0.839
```

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##   68.1    2522        1    0.8269 0.006076        0.8150         0.839
##   68.1    2521        1    0.8265 0.006083        0.8147         0.839
##   68.1    2520        1    0.8262 0.006089        0.8143         0.838
##   68.1    2519        1    0.8259 0.006096        0.8140         0.838
##   68.1    2518        1    0.8255 0.006102        0.8137         0.838
##   68.2    2517        1    0.8252 0.006108        0.8133         0.837
##   68.2    2516        1    0.8249 0.006115        0.8130         0.837
##   68.2    2515        1    0.8246 0.006121        0.8126         0.837
##   68.2    2514        1    0.8242 0.006127        0.8123         0.836
##   68.2    2513        1    0.8239 0.006134        0.8120         0.836
##   68.2    2512        1    0.8236 0.006140        0.8116         0.836
##   68.3    2511        1    0.8232 0.006146        0.8113         0.835
##   68.3    2510        1    0.8229 0.006153        0.8109         0.835
##   68.4    2509        1    0.8226 0.006159        0.8106         0.835
##   68.4    2508        1    0.8223 0.006165        0.8103         0.834
##   68.4    2507        1    0.8219 0.006172        0.8099         0.834
##   68.4    2506        1    0.8216 0.006178        0.8096         0.834
##   68.4    2505        1    0.8213 0.006184        0.8092         0.833
##   68.5    2504        1    0.8210 0.006190        0.8089         0.833
##   68.6    2503        1    0.8206 0.006196        0.8086         0.833
##   68.6    2502        1    0.8203 0.006203        0.8082         0.833
##   68.6    2501        1    0.8200 0.006209        0.8079         0.832
##   68.6    2500        1    0.8196 0.006215        0.8075         0.832
##   68.6    2499        1    0.8193 0.006221        0.8072         0.832
##   68.6    2498        1    0.8190 0.006227        0.8069         0.831
##   68.7    2497        1    0.8187 0.006233        0.8065         0.831
##   68.7    2496        1    0.8183 0.006240        0.8062         0.831
##   68.7    2495        1    0.8180 0.006246        0.8058         0.830
##   68.7    2494        1    0.8177 0.006252        0.8055         0.830
##   68.8    2493        1    0.8173 0.006258        0.8052         0.830
##   68.8    2492        1    0.8170 0.006264        0.8048         0.829
##   68.8    2491        1    0.8167 0.006270        0.8045         0.829
##   68.8    2490        1    0.8164 0.006276        0.8042         0.829
##   68.9    2489        1    0.8160 0.006282        0.8038         0.828
##   68.9    2488        1    0.8157 0.006288        0.8035         0.828
##   68.9    2487        1    0.8154 0.006294        0.8031         0.828
##   68.9    2486        2    0.8147 0.006306        0.8025         0.827
##   69.0    2484        1    0.8144 0.006312        0.8021         0.827
##   69.0    2483        1    0.8141 0.006318        0.8018         0.827
##   69.0    2358        1    0.8137 0.006325        0.8014         0.826
##   69.0    2357        1    0.8134 0.006332        0.8011         0.826
##   69.0    2356        1    0.8130 0.006338        0.8007         0.826
##   69.0    2355        1    0.8127 0.006345        0.8003         0.825
##   69.1    2354        1    0.8123 0.006352        0.8000         0.825
##   69.1    2353        1    0.8120 0.006358        0.7996         0.825
##   69.1    2352        1    0.8116 0.006365        0.7993         0.824
```

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##  69.1   2351        1   0.8113 0.006372        0.7989           0.824
##  69.1   2350        1   0.8110 0.006378        0.7986           0.824
##  69.2   2349        1   0.8106 0.006385        0.7982           0.823
##  69.2   2348        1   0.8103 0.006392        0.7978           0.823
##  69.2   2347        1   0.8099 0.006398        0.7975           0.823
##  69.2   2346        1   0.8096 0.006405        0.7971           0.822
##  69.2   2345        1   0.8092 0.006411        0.7968           0.822
##  69.2   2344        1   0.8089 0.006418        0.7964           0.822
##  69.2   2343        1   0.8085 0.006424        0.7960           0.821
##  69.2   2342        1   0.8082 0.006431        0.7957           0.821
##  69.2   2341        1   0.8078 0.006437        0.7953           0.821
##  69.3   2340        1   0.8075 0.006444        0.7950           0.820
##  69.3   2339        1   0.8072 0.006450        0.7946           0.820
##  69.3   2338        1   0.8068 0.006457        0.7943           0.820
##  69.3   2337        1   0.8065 0.006463        0.7939           0.819
##  69.3   2336        1   0.8061 0.006470        0.7935           0.819
##  69.3   2335        1   0.8058 0.006476        0.7932           0.819
##  69.3   2334        1   0.8054 0.006483        0.7928           0.818
##  69.3   2333        1   0.8051 0.006489        0.7925           0.818
##  69.3   2332        1   0.8047 0.006495        0.7921           0.818
##  69.4   2331        1   0.8044 0.006502        0.7918           0.817
##  69.4   2330        1   0.8041 0.006508        0.7914           0.817
##  69.4   2329        1   0.8037 0.006515        0.7910           0.817
##  69.5   2328        1   0.8034 0.006521        0.7907           0.816
##  69.5   2327        1   0.8030 0.006527        0.7903           0.816
##  69.5   2326        1   0.8027 0.006534        0.7900           0.816
##  69.5   2325        1   0.8023 0.006540        0.7896           0.815
##  69.5   2324        1   0.8020 0.006546        0.7893           0.815
##  69.5   2323        1   0.8016 0.006552        0.7889           0.815
##  69.5   2322        1   0.8013 0.006559        0.7885           0.814
##  69.5   2321        1   0.8009 0.006565        0.7882           0.814
##  69.5   2320        1   0.8006 0.006571        0.7878           0.814
##  69.5   2319        1   0.8003 0.006577        0.7875           0.813
##  69.6   2318        1   0.7999 0.006584        0.7871           0.813
##  69.6   2317        1   0.7996 0.006590        0.7868           0.813
##  69.7   2316        1   0.7992 0.006596        0.7864           0.812
##  69.7   2315        1   0.7989 0.006602        0.7860           0.812
##  69.7   2314        1   0.7985 0.006608        0.7857           0.812
##  69.7   2313        1   0.7982 0.006615        0.7853           0.811
##  69.7   2312        1   0.7978 0.006621        0.7850           0.811
##  69.8   2311        1   0.7975 0.006627        0.7846           0.811
##  69.8   2310        1   0.7971 0.006633        0.7843           0.810
##  69.8   2309        1   0.7968 0.006639        0.7839           0.810
##  69.8   2308        1   0.7965 0.006645        0.7835           0.810
##  69.8   2307        1   0.7961 0.006651        0.7832           0.809
##  69.8   2306        1   0.7958 0.006657        0.7828           0.809
```

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##   69.8   2305        1   0.7954 0.006663        0.7825         0.809
##   69.8   2304        1   0.7951 0.006669        0.7821         0.808
##   69.8   2303        1   0.7947 0.006675        0.7818         0.808
##   69.8   2302        1   0.7944 0.006681        0.7814         0.808
##   69.8   2301        1   0.7940 0.006687        0.7810         0.807
##   69.8   2300        1   0.7937 0.006693        0.7807         0.807
##   69.9   2299        1   0.7933 0.006699        0.7803         0.807
##   69.9   2298        1   0.7930 0.006705        0.7800         0.806
##   69.9   2297        1   0.7927 0.006711        0.7796         0.806
##   70.0   2296        2   0.7920 0.006723        0.7789         0.805
##   70.0   2145        1   0.7916 0.006730        0.7785         0.805
##   70.0   2144        1   0.7912 0.006737        0.7781         0.805
##   70.1   2143        1   0.7909 0.006744        0.7778         0.804
##   70.1   2142        1   0.7905 0.006751        0.7774         0.804
##   70.1   2141        1   0.7901 0.006758        0.7770         0.803
##   70.1   2140        1   0.7898 0.006765        0.7766         0.803
##   70.2   2139        1   0.7894 0.006772        0.7762         0.803
##   70.2   2138        1   0.7890 0.006779        0.7758         0.802
##   70.2   2137        1   0.7886 0.006786        0.7755         0.802
##   70.2   2136        1   0.7883 0.006793        0.7751         0.802
##   70.3   2135        1   0.7879 0.006799        0.7747         0.801
##   70.3   2134        1   0.7875 0.006806        0.7743         0.801
##   70.4   2133        1   0.7872 0.006813        0.7739         0.801
##   70.4   2132        1   0.7868 0.006820        0.7735         0.800
##   70.4   2131        1   0.7864 0.006827        0.7732         0.800
##   70.4   2130        1   0.7861 0.006833        0.7728         0.800
##   70.5   2129        1   0.7857 0.006840        0.7724         0.799
##   70.5   2128        1   0.7853 0.006847        0.7720         0.799
##   70.5   2127        1   0.7850 0.006854        0.7716         0.799
##   70.5   2126        1   0.7846 0.006860        0.7713         0.798
##   70.5   2125        1   0.7842 0.006867        0.7709         0.798
##   70.5   2124        1   0.7838 0.006874        0.7705         0.797
##   70.5   2123        1   0.7835 0.006880        0.7701         0.797
##   70.5   2122        1   0.7831 0.006887        0.7697         0.797
##   70.6   2121        1   0.7827 0.006894        0.7693         0.796
##   70.7   2120        1   0.7824 0.006900        0.7690         0.796
##   70.7   2119        1   0.7820 0.006907        0.7686         0.796
##   70.7   2118        1   0.7816 0.006914        0.7682         0.795
##   70.7   2117        1   0.7813 0.006920        0.7678         0.795
##   70.7   2116        1   0.7809 0.006927        0.7674         0.795
##   70.7   2115        1   0.7805 0.006933        0.7671         0.794
##   70.7   2114        1   0.7802 0.006940        0.7667         0.794
##   70.8   2113        1   0.7798 0.006946        0.7663         0.794
##   70.8   2112        1   0.7794 0.006953        0.7659         0.793
##   70.8   2111        1   0.7790 0.006959        0.7655         0.793
##   70.8   2110        1   0.7787 0.006966        0.7651         0.792
```

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##  70.8   2109        1   0.7783 0.006972        0.7648          0.792
##  70.8   2108        1   0.7779 0.006979        0.7644          0.792
##  70.9   2107        1   0.7776 0.006985        0.7640          0.791
##  70.9   2106        1   0.7772 0.006992        0.7636          0.791
##  70.9   2105        1   0.7768 0.006998        0.7632          0.791
##  70.9   2104        1   0.7765 0.007004        0.7629          0.790
##  70.9   2103        1   0.7761 0.007011        0.7625          0.790
##  71.0   2004        1   0.7757 0.007018        0.7621          0.790
##  71.0   2003        1   0.7753 0.007025        0.7617          0.789
##  71.0   2002        1   0.7749 0.007032        0.7613          0.789
##  71.1   2001        1   0.7745 0.007040        0.7609          0.788
##  71.1   2000        1   0.7742 0.007047        0.7605          0.788
##  71.1   1999        1   0.7738 0.007054        0.7601          0.788
##  71.1   1998        2   0.7730 0.007068        0.7593          0.787
##  71.1   1996        1   0.7726 0.007075        0.7589          0.787
##  71.2   1995        1   0.7722 0.007082        0.7585          0.786
##  71.2   1994        2   0.7714 0.007096        0.7577          0.785
##  71.3   1992        1   0.7711 0.007103        0.7573          0.785
##  71.3   1991        1   0.7707 0.007110        0.7569          0.785
##  71.3   1990        1   0.7703 0.007117        0.7565          0.784
##  71.3   1989        1   0.7699 0.007124        0.7561          0.784
##  71.3   1988        1   0.7695 0.007131        0.7557          0.784
##  71.3   1987        1   0.7691 0.007138        0.7553          0.783
##  71.4   1986        1   0.7687 0.007145        0.7549          0.783
##  71.4   1985        1   0.7683 0.007152        0.7545          0.782
##  71.4   1984        1   0.7680 0.007159        0.7541          0.782
##  71.4   1983        1   0.7676 0.007165        0.7537          0.782
##  71.4   1982        1   0.7672 0.007172        0.7533          0.781
##  71.4   1981        1   0.7668 0.007179        0.7529          0.781
##  71.5   1980        1   0.7664 0.007186        0.7525          0.781
##  71.5   1979        1   0.7660 0.007193        0.7521          0.780
##  71.5   1978        1   0.7656 0.007199        0.7517          0.780
##  71.5   1977        1   0.7652 0.007206        0.7513          0.780
##  71.5   1976        1   0.7649 0.007213        0.7509          0.779
##  71.5   1975        1   0.7645 0.007220        0.7505          0.779
##  71.6   1974        1   0.7641 0.007226        0.7501          0.778
##  71.6   1973        1   0.7637 0.007233        0.7497          0.778
##  71.7   1972        1   0.7633 0.007240        0.7493          0.778
##  71.7   1971        1   0.7629 0.007246        0.7489          0.777
##  71.7   1970        1   0.7625 0.007253        0.7485          0.777
##  71.7   1969        1   0.7622 0.007260        0.7481          0.777
##  71.7   1968        1   0.7618 0.007266        0.7477          0.776
##  71.7   1967        1   0.7614 0.007273        0.7473          0.776
##  71.7   1966        1   0.7610 0.007280        0.7469          0.775
##  71.7   1965        1   0.7606 0.007286        0.7465          0.775
##  71.7   1964        1   0.7602 0.007293        0.7461          0.775
```

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## 71.8 1963 1 0.7598 0.007299 0.7457 0.774
## 71.8 1962 1 0.7594 0.007306 0.7453 0.774
## 71.8 1961 1 0.7591 0.007312 0.7449 0.774
## 71.8 1960 1 0.7587 0.007319 0.7445 0.773
## 71.8 1959 1 0.7583 0.007325 0.7441 0.773
## 71.8 1958 1 0.7579 0.007332 0.7437 0.772
## 71.9 1957 1 0.7575 0.007338 0.7433 0.772
## 71.9 1956 1 0.7571 0.007345 0.7429 0.772
## 71.9 1955 1 0.7567 0.007351 0.7425 0.771
## 71.9 1954 1 0.7563 0.007358 0.7421 0.771
## 71.9 1953 2 0.7556 0.007371 0.7413 0.770
## 71.9 1951 1 0.7552 0.007377 0.7409 0.770
## 71.9 1950 1 0.7548 0.007383 0.7405 0.769
## 71.9 1949 1 0.7544 0.007390 0.7401 0.769
## 71.9 1948 1 0.7540 0.007396 0.7397 0.769
## 72.0 1947 1 0.7536 0.007402 0.7393 0.768
## 72.0 1946 1 0.7532 0.007409 0.7389 0.768
## 72.0 1945 1 0.7529 0.007415 0.7385 0.768
## 72.0 1811 1 0.7524 0.007423 0.7380 0.767
## 72.0 1810 1 0.7520 0.007430 0.7376 0.767
## 72.0 1809 1 0.7516 0.007438 0.7372 0.766
## 72.0 1808 1 0.7512 0.007445 0.7367 0.766
## 72.0 1807 1 0.7508 0.007453 0.7363 0.766
## 72.1 1806 1 0.7504 0.007460 0.7359 0.765
## 72.1 1805 2 0.7495 0.007475 0.7350 0.764
## 72.1 1803 1 0.7491 0.007482 0.7346 0.764
## 72.1 1802 1 0.7487 0.007490 0.7342 0.764
## 72.1 1801 1 0.7483 0.007497 0.7337 0.763
## 72.1 1800 1 0.7479 0.007504 0.7333 0.763
## 72.2 1799 1 0.7475 0.007512 0.7329 0.762
## 72.2 1798 1 0.7470 0.007519 0.7324 0.762
## 72.3 1797 1 0.7466 0.007526 0.7320 0.762
## 72.3 1796 1 0.7462 0.007534 0.7316 0.761
## 72.3 1795 1 0.7458 0.007541 0.7312 0.761
## 72.3 1794 1 0.7454 0.007548 0.7307 0.760
## 72.3 1793 1 0.7450 0.007555 0.7303 0.760
## 72.3 1792 1 0.7445 0.007563 0.7299 0.760
## 72.3 1791 1 0.7441 0.007570 0.7294 0.759
## 72.4 1790 1 0.7437 0.007577 0.7290 0.759
## 72.4 1789 1 0.7433 0.007584 0.7286 0.758
## 72.4 1788 1 0.7429 0.007591 0.7281 0.758
## 72.4 1787 1 0.7425 0.007598 0.7277 0.758
## 72.4 1786 1 0.7420 0.007606 0.7273 0.757
## 72.4 1785 1 0.7416 0.007613 0.7269 0.757
## 72.4 1784 1 0.7412 0.007620 0.7264 0.756
## 72.5 1783 1 0.7408 0.007627 0.7260 0.756
```

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##   72.5   1782        1   0.7404 0.007634        0.7256          0.755
##   72.6   1781        1   0.7400 0.007641        0.7251          0.755
##   72.6   1780        1   0.7396 0.007648        0.7247          0.755
##   72.6   1779        1   0.7391 0.007655        0.7243          0.754
##   72.6   1778        1   0.7387 0.007662        0.7239          0.754
##   72.6   1777        1   0.7383 0.007669        0.7234          0.753
##   72.6   1776        1   0.7379 0.007676        0.7230          0.753
##   72.6   1775        1   0.7375 0.007683        0.7226          0.753
##   72.6   1774        1   0.7371 0.007690        0.7221          0.752
##   72.7   1773        1   0.7366 0.007696        0.7217          0.752
##   72.7   1772        1   0.7362 0.007703        0.7213          0.751
##   72.7   1771        1   0.7358 0.007710        0.7209          0.751
##   72.7   1770        1   0.7354 0.007717        0.7204          0.751
##   72.7   1769        2   0.7346 0.007731        0.7196          0.750
##   72.7   1767        1   0.7341 0.007737        0.7191          0.749
##   72.7   1766        1   0.7337 0.007744        0.7187          0.749
##   72.7   1765        1   0.7333 0.007751        0.7183          0.749
##   72.8   1764        1   0.7329 0.007758        0.7179          0.748
##   72.8   1763        1   0.7325 0.007764        0.7174          0.748
##   72.8   1762        1   0.7321 0.007771        0.7170          0.747
##   72.8   1761        1   0.7317 0.007778        0.7166          0.747
##   72.8   1760        1   0.7312 0.007785        0.7161          0.747
##   72.9   1759        1   0.7308 0.007791        0.7157          0.746
##   72.9   1758        2   0.7300 0.007804        0.7149          0.745
##   72.9   1756        1   0.7296 0.007811        0.7144          0.745
##   72.9   1755        1   0.7292 0.007818        0.7140          0.745
##   72.9   1754        1   0.7287 0.007824        0.7136          0.744
##   72.9   1753        1   0.7283 0.007831        0.7131          0.744
##   73.0   1752        1   0.7279 0.007837        0.7127          0.743
##   73.0   1751        2   0.7271 0.007850        0.7119          0.743
##   73.0   1648        1   0.7266 0.007858        0.7114          0.742
##   73.0   1647        1   0.7262 0.007866        0.7109          0.742
##   73.1   1646        1   0.7258 0.007873        0.7105          0.741
##   73.1   1645        1   0.7253 0.007881        0.7100          0.741
##   73.1   1644        1   0.7249 0.007888        0.7096          0.741
##   73.1   1643        1   0.7244 0.007896        0.7091          0.740
##   73.1   1642        1   0.7240 0.007903        0.7087          0.740
##   73.1   1641        1   0.7236 0.007911        0.7082          0.739
##   73.1   1640        1   0.7231 0.007918        0.7078          0.739
##   73.2   1639        1   0.7227 0.007926        0.7073          0.738
##   73.2   1638        2   0.7218 0.007941        0.7064          0.738
##   73.2   1636        1   0.7213 0.007948        0.7059          0.737
##   73.2   1635        1   0.7209 0.007955        0.7055          0.737
##   73.2   1634        1   0.7205 0.007963        0.7050          0.736
##   73.3   1633        1   0.7200 0.007970        0.7046          0.736
##   73.3   1632        1   0.7196 0.007977        0.7041          0.735
```

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##   73.3   1631        1   0.7191 0.007985        0.7037          0.735
##   73.3   1630        2   0.7183 0.007999        0.7027          0.734
##   73.3   1628        1   0.7178 0.008007        0.7023          0.734
##   73.3   1627        1   0.7174 0.008014        0.7018          0.733
##   73.3   1626        1   0.7169 0.008021        0.7014          0.733
##   73.3   1625        1   0.7165 0.008028        0.7009          0.732
##   73.3   1624        1   0.7161 0.008035        0.7005          0.732
##   73.3   1623        1   0.7156 0.008042        0.7000          0.732
##   73.4   1622        1   0.7152 0.008050        0.6996          0.731
##   73.4   1621        2   0.7143 0.008064        0.6987          0.730
##   73.4   1619        1   0.7138 0.008071        0.6982          0.730
##   73.4   1618        1   0.7134 0.008078        0.6977          0.729
##   73.4   1617        1   0.7130 0.008085        0.6973          0.729
##   73.4   1616        1   0.7125 0.008092        0.6968          0.729
##   73.5   1615        1   0.7121 0.008099        0.6964          0.728
##   73.5   1614        1   0.7116 0.008106        0.6959          0.728
##   73.5   1613        1   0.7112 0.008113        0.6955          0.727
##   73.5   1612        1   0.7108 0.008120        0.6950          0.727
##   73.6   1611        1   0.7103 0.008127        0.6946          0.726
##   73.6   1610        2   0.7094 0.008141        0.6937          0.726
##   73.6   1608        1   0.7090 0.008148        0.6932          0.725
##   73.6   1607        1   0.7086 0.008154        0.6927          0.725
##   73.6   1606        1   0.7081 0.008161        0.6923          0.724
##   73.6   1605        1   0.7077 0.008168        0.6918          0.724
##   73.7   1604        1   0.7072 0.008175        0.6914          0.723
##   73.7   1603        1   0.7068 0.008182        0.6909          0.723
##   73.7   1602        1   0.7063 0.008189        0.6905          0.723
##   73.7   1601        1   0.7059 0.008195        0.6900          0.722
##   73.7   1600        1   0.7055 0.008202        0.6896          0.722
##   73.7   1599        1   0.7050 0.008209        0.6891          0.721
##   73.7   1598        1   0.7046 0.008216        0.6887          0.721
##   73.7   1597        1   0.7041 0.008222        0.6882          0.720
##   73.8   1596        1   0.7037 0.008229        0.6878          0.720
##   73.8   1595        1   0.7033 0.008236        0.6873          0.720
##   73.8   1594        1   0.7028 0.008242        0.6868          0.719
##   73.8   1593        1   0.7024 0.008249        0.6864          0.719
##   73.8   1592        1   0.7019 0.008255        0.6859          0.718
##   73.8   1591        1   0.7015 0.008262        0.6855          0.718
##   73.9   1590        1   0.7011 0.008269        0.6850          0.717
##   73.9   1589        1   0.7006 0.008275        0.6846          0.717
##   73.9   1588        1   0.7002 0.008282        0.6841          0.717
##   74.0   1587        1   0.6997 0.008288        0.6837          0.716
##   74.0   1586        1   0.6993 0.008295        0.6832          0.716
##   74.0   1488        1   0.6988 0.008302        0.6827          0.715
##   74.0   1487        1   0.6983 0.008310        0.6822          0.715
##   74.1   1486        1   0.6979 0.008318        0.6818          0.714
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##   74.1   1485       1   0.6974 0.008325       0.6813         0.714
##   74.1   1484       1   0.6969 0.008333       0.6808         0.713
##   74.1   1483       1   0.6965 0.008341       0.6803         0.713
##   74.1   1482       1   0.6960 0.008348       0.6798         0.713
##   74.2   1481       1   0.6955 0.008356       0.6793         0.712
##   74.2   1480       1   0.6951 0.008363       0.6789         0.712
##   74.2   1479       1   0.6946 0.008371       0.6784         0.711
##   74.2   1478       2   0.6936 0.008386       0.6774         0.710
##   74.2   1476       1   0.6932 0.008394       0.6769         0.710
##   74.2   1475       1   0.6927 0.008401       0.6764         0.709
##   74.2   1474       1   0.6922 0.008408       0.6760         0.709
##   74.3   1473       1   0.6918 0.008416       0.6755         0.708
##   74.3   1472       1   0.6913 0.008423       0.6750         0.708
##   74.3   1471       1   0.6908 0.008431       0.6745         0.708
##   74.4   1470       1   0.6904 0.008438       0.6740         0.707
##   74.4   1469       1   0.6899 0.008445       0.6735         0.707
##   74.4   1468       1   0.6894 0.008453       0.6730         0.706
##   74.4   1467       1   0.6889 0.008460       0.6726         0.706
##   74.4   1466       1   0.6885 0.008467       0.6721         0.705
##   74.5   1465       1   0.6880 0.008474       0.6716         0.705
##   74.5   1464       1   0.6875 0.008482       0.6711         0.704
##   74.5   1463       1   0.6871 0.008489       0.6706         0.704
##   74.5   1462       1   0.6866 0.008496       0.6701         0.703
##   74.5   1461       1   0.6861 0.008503       0.6697         0.703
##   74.5   1460       1   0.6857 0.008510       0.6692         0.703
##   74.6   1459       1   0.6852 0.008518       0.6687         0.702
##   74.6   1458       1   0.6847 0.008525       0.6682         0.702
##   74.7   1457       1   0.6842 0.008532       0.6677         0.701
##   74.7   1456       1   0.6838 0.008539       0.6672         0.701
##   74.7   1455       1   0.6833 0.008546       0.6668         0.700
##   74.8   1454       1   0.6828 0.008553       0.6663         0.700
##   74.8   1453       1   0.6824 0.008560       0.6658         0.699
##   74.8   1452       1   0.6819 0.008567       0.6653         0.699
##   74.8   1451       1   0.6814 0.008574       0.6648         0.698
##   74.8   1450       1   0.6810 0.008581       0.6643         0.698
##   74.8   1449       1   0.6805 0.008588       0.6639         0.698
##   74.8   1448       1   0.6800 0.008595       0.6634         0.697
##   74.8   1447       1   0.6795 0.008602       0.6629         0.697
##   74.8   1446       1   0.6791 0.008608       0.6624         0.696
##   74.9   1445       1   0.6786 0.008615       0.6619         0.696
##   74.9   1444       1   0.6781 0.008622       0.6614         0.695
##   74.9   1443       1   0.6777 0.008629       0.6610         0.695
##   74.9   1442       1   0.6772 0.008636       0.6605         0.694
##   74.9   1441       1   0.6767 0.008643       0.6600         0.694
##   75.0   1440       1   0.6763 0.008649       0.6595         0.693
##   75.0   1439       1   0.6758 0.008656       0.6590         0.693
```

```
##   75.0    1333         1    0.6753 0.008664        0.6585          0.692
##   75.0    1332         1    0.6748 0.008673        0.6580          0.692
##   75.0    1331         1    0.6743 0.008681        0.6575          0.691
##   75.1    1330         1    0.6738 0.008689        0.6569          0.691
##   75.1    1329         1    0.6733 0.008698        0.6564          0.691
##   75.1    1328         1    0.6727 0.008706        0.6559          0.690
##   75.1    1327         1    0.6722 0.008714        0.6554          0.690
##   75.1    1326         1    0.6717 0.008722        0.6549          0.689
##   75.1    1325         1    0.6712 0.008730        0.6543          0.689
##   75.2    1324         1    0.6707 0.008738        0.6538          0.688
##   75.2    1323         1    0.6702 0.008746        0.6533          0.688
##   75.3    1322         1    0.6697 0.008754        0.6528          0.687
##   75.4    1321         1    0.6692 0.008763        0.6522          0.687
##   75.4    1320         1    0.6687 0.008771        0.6517          0.686
##   75.5    1319         1    0.6682 0.008779        0.6512          0.686
##   75.5    1318         1    0.6677 0.008787        0.6507          0.685
##   75.5    1317         1    0.6672 0.008794        0.6502          0.685
##   75.5    1316         1    0.6667 0.008802        0.6496          0.684
##   75.5    1315         1    0.6662 0.008810        0.6491          0.684
##   75.5    1314         1    0.6656 0.008818        0.6486          0.683
##   75.5    1313         1    0.6651 0.008826        0.6481          0.683
##   75.5    1312         1    0.6646 0.008834        0.6475          0.682
##   75.6    1311         1    0.6641 0.008842        0.6470          0.682
##   75.6    1310         1    0.6636 0.008849        0.6465          0.681
##   75.6    1309         1    0.6631 0.008857        0.6460          0.681
##   75.7    1308         1    0.6626 0.008865        0.6455          0.680
##   75.7    1307         1    0.6621 0.008873        0.6449          0.680
##   75.7    1306         1    0.6616 0.008880        0.6444          0.679
##   75.7    1305         1    0.6611 0.008888        0.6439          0.679
##   75.7    1304         1    0.6606 0.008896        0.6434          0.678
##   75.7    1303         1    0.6601 0.008903        0.6429          0.678
##   75.7    1302         1    0.6596 0.008911        0.6423          0.677
##   75.7    1301         1    0.6591 0.008918        0.6418          0.677
##   75.7    1300         1    0.6586 0.008926        0.6413          0.676
##   75.8    1299         1    0.6580 0.008933        0.6408          0.676
##   75.8    1298         1    0.6575 0.008941        0.6402          0.675
##   75.9    1297         1    0.6570 0.008948        0.6397          0.675
##   75.9    1296         2    0.6560 0.008963        0.6387          0.674
##   75.9    1294         2    0.6550 0.008978        0.6376          0.673
##   75.9    1292         1    0.6545 0.008985        0.6371          0.672
##   75.9    1291         1    0.6540 0.008993        0.6366          0.672
##   75.9    1290         1    0.6535 0.009000        0.6361          0.671
##   75.9    1289         1    0.6530 0.009007        0.6356          0.671
##   75.9    1288         1    0.6525 0.009014        0.6350          0.670
##   75.9    1287         1    0.6520 0.009022        0.6345          0.670
##   76.0    1286         1    0.6515 0.009029        0.6340          0.669
```

```
## 76.0 1285 1 0.6509 0.009036 0.6335 0.669
## 76.0 1284 1 0.6504 0.009043 0.6330 0.668
## 76.0 1187 2 0.6493 0.009061 0.6318 0.667
## 76.0 1185 1 0.6488 0.009070 0.6313 0.667
## 76.0 1184 1 0.6482 0.009079 0.6307 0.666
## 76.0 1183 1 0.6477 0.009088 0.6301 0.666
## 76.1 1182 1 0.6472 0.009097 0.6296 0.665
## 76.1 1181 1 0.6466 0.009105 0.6290 0.665
## 76.1 1180 1 0.6461 0.009114 0.6284 0.664
## 76.1 1179 1 0.6455 0.009123 0.6279 0.664
## 76.2 1178 1 0.6450 0.009132 0.6273 0.663
## 76.2 1177 1 0.6444 0.009140 0.6267 0.663
## 76.2 1176 1 0.6439 0.009149 0.6262 0.662
## 76.2 1175 1 0.6433 0.009158 0.6256 0.662
## 76.2 1174 1 0.6428 0.009166 0.6251 0.661
## 76.2 1173 1 0.6422 0.009175 0.6245 0.660
## 76.3 1172 1 0.6417 0.009183 0.6239 0.660
## 76.3 1171 1 0.6411 0.009192 0.6234 0.659
## 76.3 1170 1 0.6406 0.009200 0.6228 0.659
## 76.3 1169 1 0.6400 0.009209 0.6222 0.658
## 76.3 1168 1 0.6395 0.009217 0.6217 0.658
## 76.3 1167 1 0.6389 0.009225 0.6211 0.657
## 76.3 1166 1 0.6384 0.009234 0.6205 0.657
## 76.4 1165 1 0.6378 0.009242 0.6200 0.656
## 76.4 1164 1 0.6373 0.009250 0.6194 0.656
## 76.4 1163 1 0.6367 0.009259 0.6189 0.655
## 76.5 1162 1 0.6362 0.009267 0.6183 0.655
## 76.5 1161 1 0.6356 0.009275 0.6177 0.654
## 76.5 1160 1 0.6351 0.009283 0.6172 0.654
## 76.5 1159 1 0.6345 0.009291 0.6166 0.653
## 76.6 1158 1 0.6340 0.009299 0.6160 0.652
## 76.6 1157 1 0.6335 0.009308 0.6155 0.652
## 76.6 1156 1 0.6329 0.009316 0.6149 0.651
## 76.6 1155 1 0.6324 0.009324 0.6143 0.651
## 76.6 1154 1 0.6318 0.009332 0.6138 0.650
## 76.6 1153 1 0.6313 0.009340 0.6132 0.650
## 76.6 1152 1 0.6307 0.009348 0.6127 0.649
## 76.7 1151 1 0.6302 0.009356 0.6121 0.649
## 76.7 1150 1 0.6296 0.009363 0.6115 0.648
## 76.7 1149 1 0.6291 0.009371 0.6110 0.648
## 76.7 1148 1 0.6285 0.009379 0.6104 0.647
## 76.7 1147 1 0.6280 0.009387 0.6098 0.647
## 76.8 1146 1 0.6274 0.009395 0.6093 0.646
## 76.8 1145 1 0.6269 0.009403 0.6087 0.646
## 76.8 1144 1 0.6263 0.009410 0.6082 0.645
## 76.8 1143 1 0.6258 0.009418 0.6076 0.645
```

```
##  76.8   1142        1   0.6252 0.009426        0.6070          0.644
##  76.9   1141        1   0.6247 0.009433        0.6065          0.643
##  76.9   1140        1   0.6241 0.009441        0.6059          0.643
##  76.9   1139        1   0.6236 0.009449        0.6053          0.642
##  76.9   1138        1   0.6230 0.009456        0.6048          0.642
##  76.9   1137        1   0.6225 0.009464        0.6042          0.641
##  76.9   1136        1   0.6219 0.009471        0.6037          0.641
##  76.9   1135        1   0.6214 0.009479        0.6031          0.640
##  77.0   1134        1   0.6209 0.009486        0.6025          0.640
##  77.0   1133        1   0.6203 0.009494        0.6020          0.639
##  77.0   1036        1   0.6197 0.009503        0.6014          0.639
##  77.0   1035        1   0.6191 0.009513        0.6007          0.638
##  77.0   1034        1   0.6185 0.009523        0.6001          0.637
##  77.0   1033        1   0.6179 0.009532        0.5995          0.637
##  77.0   1032        1   0.6173 0.009542        0.5989          0.636
##  77.0   1031        2   0.6161 0.009561        0.5977          0.635
##  77.1   1029        1   0.6155 0.009570        0.5970          0.635
##  77.1   1028        2   0.6143 0.009589        0.5958          0.633
##  77.1   1026        1   0.6137 0.009598        0.5952          0.633
##  77.1   1025        1   0.6131 0.009607        0.5946          0.632
##  77.1   1024        1   0.6125 0.009617        0.5940          0.632
##  77.2   1023        1   0.6119 0.009626        0.5933          0.631
##  77.2   1022        1   0.6113 0.009635        0.5927          0.631
##  77.2   1021        2   0.6101 0.009653        0.5915          0.629
##  77.2   1019        1   0.6095 0.009662        0.5909          0.629
##  77.2   1018        1   0.6089 0.009672        0.5903          0.628
##  77.3   1017        1   0.6083 0.009681        0.5896          0.628
##  77.3   1016        1   0.6077 0.009690        0.5890          0.627
##  77.3   1015        1   0.6071 0.009698        0.5884          0.626
##  77.4   1014        1   0.6065 0.009707        0.5878          0.626
##  77.4   1013        1   0.6059 0.009716        0.5872          0.625
##  77.4   1012        1   0.6053 0.009725        0.5866          0.625
##  77.4   1011        1   0.6047 0.009734        0.5860          0.624
##  77.4   1010        1   0.6041 0.009743        0.5853          0.624
##  77.4   1009        1   0.6035 0.009751        0.5847          0.623
##  77.5   1008        1   0.6029 0.009760        0.5841          0.622
##  77.6   1007        1   0.6023 0.009769        0.5835          0.622
##  77.6   1006        1   0.6017 0.009777        0.5829          0.621
##  77.6   1005        1   0.6011 0.009786        0.5823          0.621
##  77.6   1004        1   0.6005 0.009794        0.5817          0.620
##  77.6   1003        1   0.5999 0.009803        0.5810          0.619
##  77.6   1002        1   0.5993 0.009811        0.5804          0.619
##  77.6   1001        1   0.5987 0.009820        0.5798          0.618
##  77.7   1000        1   0.5981 0.009828        0.5792          0.618
##  77.7    999        1   0.5975 0.009837        0.5786          0.617
##  77.7    998        1   0.5970 0.009845        0.5780          0.617
```

```
## 77.7 997 1 0.5964 0.009853 0.5773 0.616
## 77.7 996 1 0.5958 0.009862 0.5767 0.615
## 77.8 995 1 0.5952 0.009870 0.5761 0.615
## 77.8 994 1 0.5946 0.009878 0.5755 0.614
## 77.8 993 2 0.5934 0.009894 0.5743 0.613
## 77.8 991 1 0.5928 0.009903 0.5737 0.612
## 77.8 990 1 0.5922 0.009911 0.5731 0.612
## 77.8 989 1 0.5916 0.009919 0.5724 0.611
## 77.8 988 1 0.5910 0.009927 0.5718 0.611
## 77.9 987 1 0.5904 0.009935 0.5712 0.610
## 77.9 986 1 0.5898 0.009943 0.5706 0.610
## 77.9 985 1 0.5892 0.009951 0.5700 0.609
## 77.9 984 1 0.5886 0.009958 0.5694 0.608
## 77.9 983 1 0.5880 0.009966 0.5688 0.608
## 77.9 982 1 0.5874 0.009974 0.5681 0.607
## 78.0 981 1 0.5868 0.009982 0.5675 0.607
## 78.0 893 1 0.5861 0.009992 0.5669 0.606
## 78.0 892 1 0.5855 0.010003 0.5662 0.605
## 78.0 891 1 0.5848 0.010013 0.5655 0.605
## 78.0 890 1 0.5841 0.010023 0.5648 0.604
## 78.1 889 1 0.5835 0.010034 0.5641 0.603
## 78.1 888 1 0.5828 0.010044 0.5635 0.603
## 78.1 887 1 0.5822 0.010054 0.5628 0.602
## 78.1 886 1 0.5815 0.010064 0.5621 0.602
## 78.1 885 1 0.5809 0.010074 0.5614 0.601
## 78.1 884 1 0.5802 0.010084 0.5608 0.600
## 78.2 883 1 0.5795 0.010094 0.5601 0.600
## 78.2 882 1 0.5789 0.010104 0.5594 0.599
## 78.2 881 1 0.5782 0.010114 0.5587 0.598
## 78.2 880 1 0.5776 0.010124 0.5581 0.598
## 78.2 879 1 0.5769 0.010133 0.5574 0.597
## 78.2 878 1 0.5763 0.010143 0.5567 0.596
## 78.3 877 1 0.5756 0.010153 0.5560 0.596
## 78.3 876 1 0.5749 0.010163 0.5554 0.595
## 78.3 875 1 0.5743 0.010172 0.5547 0.595
## 78.3 874 1 0.5736 0.010182 0.5540 0.594
## 78.3 873 1 0.5730 0.010191 0.5533 0.593
## 78.3 872 1 0.5723 0.010201 0.5527 0.593
## 78.3 871 1 0.5717 0.010210 0.5520 0.592
## 78.4 870 1 0.5710 0.010219 0.5513 0.591
## 78.4 869 1 0.5703 0.010229 0.5506 0.591
## 78.4 868 1 0.5697 0.010238 0.5500 0.590
## 78.4 867 1 0.5690 0.010247 0.5493 0.589
## 78.4 866 1 0.5684 0.010257 0.5486 0.589
## 78.4 865 1 0.5677 0.010266 0.5479 0.588
## 78.4 864 1 0.5671 0.010275 0.5473 0.588
```

```
##   78.4     863        1    0.5664 0.010284         0.5466           0.587
##   78.4     862        1    0.5657 0.010293         0.5459           0.586
##   78.4     861        1    0.5651 0.010302         0.5453           0.586
##   78.4     860        1    0.5644 0.010311         0.5446           0.585
##   78.4     859        1    0.5638 0.010320         0.5439           0.584
##   78.4     858        1    0.5631 0.010329         0.5432           0.584
##   78.5     857        1    0.5625 0.010338         0.5426           0.583
##   78.5     856        1    0.5618 0.010346         0.5419           0.582
##   78.5     855        1    0.5611 0.010355         0.5412           0.582
##   78.5     854        1    0.5605 0.010364         0.5405           0.581
##   78.5     853        1    0.5598 0.010372         0.5399           0.581
##   78.5     852        1    0.5592 0.010381         0.5392           0.580
##   78.6     851        1    0.5585 0.010390         0.5385           0.579
##   78.6     850        1    0.5579 0.010398         0.5378           0.579
##   78.6     849        1    0.5572 0.010407         0.5372           0.578
##   78.6     848        1    0.5565 0.010415         0.5365           0.577
##   78.7     847        1    0.5559 0.010424         0.5358           0.577
##   78.7     846        1    0.5552 0.010432         0.5352           0.576
##   78.7     845        1    0.5546 0.010440         0.5345           0.575
##   78.7     844        1    0.5539 0.010449         0.5338           0.575
##   78.7     843        1    0.5533 0.010457         0.5331           0.574
##   78.8     842        1    0.5526 0.010465         0.5325           0.574
##   78.8     841        1    0.5519 0.010473         0.5318           0.573
##   78.8     840        1    0.5513 0.010481         0.5311           0.572
##   78.9     839        1    0.5506 0.010489         0.5305           0.572
##   78.9     838        1    0.5500 0.010497         0.5298           0.571
##   78.9     837        1    0.5493 0.010505         0.5291           0.570
##   78.9     836        1    0.5487 0.010513         0.5284           0.570
##   78.9     835        1    0.5480 0.010521         0.5278           0.569
##   78.9     834        1    0.5473 0.010529         0.5271           0.568
##   78.9     833        1    0.5467 0.010537         0.5264           0.568
##   79.0     832        1    0.5460 0.010545         0.5258           0.567
##   79.0     741        1    0.5453 0.010556         0.5250           0.566
##   79.0     740        1    0.5446 0.010568         0.5242           0.566
##   79.0     739        1    0.5438 0.010579         0.5235           0.565
##   79.1     738        1    0.5431 0.010590         0.5227           0.564
##   79.1     737        1    0.5423 0.010602         0.5220           0.564
##   79.1     736        1    0.5416 0.010613         0.5212           0.563
##   79.1     735        1    0.5409 0.010624         0.5204           0.562
##   79.1     734        1    0.5401 0.010635         0.5197           0.561
##   79.1     733        1    0.5394 0.010646         0.5189           0.561
##   79.2     732        1    0.5387 0.010657         0.5182           0.560
##   79.3     731        1    0.5379 0.010668         0.5174           0.559
##   79.3     730        1    0.5372 0.010679         0.5167           0.559
##   79.3     729        1    0.5365 0.010689         0.5159           0.558
##   79.3     728        1    0.5357 0.010700         0.5152           0.557
```

```
##  79.3    727         1    0.5350 0.010711        0.5144          0.556
##  79.4    726         1    0.5342 0.010721        0.5136          0.556
##  79.4    725         1    0.5335 0.010732        0.5129          0.555
##  79.5    724         1    0.5328 0.010742        0.5121          0.554
##  79.5    723         1    0.5320 0.010753        0.5114          0.554
##  79.5    722         1    0.5313 0.010763        0.5106          0.553
##  79.6    721         1    0.5306 0.010773        0.5099          0.552
##  79.6    720         1    0.5298 0.010783        0.5091          0.551
##  79.6    719         1    0.5291 0.010793        0.5083          0.551
##  79.6    718         1    0.5283 0.010804        0.5076          0.550
##  79.7    717         1    0.5276 0.010814        0.5068          0.549
##  79.7    716         1    0.5269 0.010824        0.5061          0.549
##  79.8    715         1    0.5261 0.010833        0.5053          0.548
##  79.8    714         1    0.5254 0.010843        0.5046          0.547
##  79.8    713         1    0.5247 0.010853        0.5038          0.546
##  79.9    712         1    0.5239 0.010863        0.5031          0.546
##  79.9    711         1    0.5232 0.010873        0.5023          0.545
##  79.9    710         1    0.5225 0.010882        0.5016          0.544
##  80.0    709         1    0.5217 0.010892        0.5008          0.544
##  80.0    639         1    0.5209 0.010905        0.5000          0.543
##  80.0    638         1    0.5201 0.010919        0.4991          0.542
##  80.0    637         1    0.5193 0.010932        0.4983          0.541
##  80.1    636         1    0.5185 0.010945        0.4974          0.540
##  80.1    635         1    0.5176 0.010958        0.4966          0.540
##  80.1    634         1    0.5168 0.010972        0.4958          0.539
##  80.2    633         1    0.5160 0.010985        0.4949          0.538
##  80.2    632         1    0.5152 0.010998        0.4941          0.537
##  80.3    631         1    0.5144 0.011010        0.4932          0.536
##  80.3    630         1    0.5136 0.011023        0.4924          0.536
##  80.3    629         1    0.5127 0.011036        0.4916          0.535
##  80.4    628         1    0.5119 0.011048        0.4907          0.534
##  80.4    627         1    0.5111 0.011061        0.4899          0.533
##  80.4    626         1    0.5103 0.011073        0.4890          0.532
##  80.4    625         1    0.5095 0.011086        0.4882          0.532
##  80.4    624         1    0.5087 0.011098        0.4874          0.531
##  80.5    623         1    0.5078 0.011110        0.4865          0.530
##  80.5    622         1    0.5070 0.011122        0.4857          0.529
##  80.5    621         1    0.5062 0.011134        0.4848          0.529
##  80.5    620         1    0.5054 0.011146        0.4840          0.528
##  80.6    619         1    0.5046 0.011158        0.4832          0.527
##  80.7    618         1    0.5038 0.011170        0.4823          0.526
##  80.7    617         1    0.5029 0.011181        0.4815          0.525
##  80.7    616         2    0.5013 0.011205        0.4798          0.524
##  80.7    614         1    0.5005 0.011216        0.4790          0.523
##  80.7    613         1    0.4997 0.011227        0.4781          0.522
##  80.8    612         1    0.4989 0.011239        0.4773          0.521
```

```
##   80.8    611       1   0.4980 0.011250       0.4765        0.521
##   80.8    610       1   0.4972 0.011261       0.4756        0.520
##   80.9    609       1   0.4964 0.011272       0.4748        0.519
##   80.9    608       1   0.4956 0.011283       0.4740        0.518
##   80.9    607       1   0.4948 0.011294       0.4731        0.517
##   81.0    606       1   0.4940 0.011305       0.4723        0.517
##   81.0    605       1   0.4931 0.011316       0.4715        0.516
##   81.1    540       1   0.4922 0.011332       0.4705        0.515
##   81.1    539       1   0.4913 0.011347       0.4696        0.514
##   81.2    538       1   0.4904 0.011363       0.4686        0.513
##   81.2    537       1   0.4895 0.011378       0.4677        0.512
##   81.2    536       1   0.4886 0.011394       0.4667        0.511
##   81.2    535       1   0.4877 0.011409       0.4658        0.511
##   81.2    534       1   0.4867 0.011424       0.4649        0.510
##   81.2    533       1   0.4858 0.011439       0.4639        0.509
##   81.3    532       1   0.4849 0.011454       0.4630        0.508
##   81.3    531       1   0.4840 0.011469       0.4620        0.507
##   81.3    530       1   0.4831 0.011483       0.4611        0.506
##   81.4    529       1   0.4822 0.011498       0.4602        0.505
##   81.4    528       1   0.4813 0.011512       0.4592        0.504
##   81.4    527       1   0.4804 0.011527       0.4583        0.503
##   81.4    526       1   0.4794 0.011541       0.4573        0.503
##   81.5    525       1   0.4785 0.011555       0.4564        0.502
##   81.5    524       1   0.4776 0.011569       0.4555        0.501
##   81.5    523       1   0.4767 0.011583       0.4545        0.500
##   81.5    522       1   0.4758 0.011597       0.4536        0.499
##   81.6    521       1   0.4749 0.011610       0.4527        0.498
##   81.6    520       1   0.4740 0.011624       0.4517        0.497
##   81.6    519       1   0.4730 0.011637       0.4508        0.496
##   81.7    518       1   0.4721 0.011650       0.4498        0.496
##   81.7    517       1   0.4712 0.011664       0.4489        0.495
##   81.7    516       1   0.4703 0.011677       0.4480        0.494
##   81.8    515       1   0.4694 0.011690       0.4470        0.493
##   81.8    514       1   0.4685 0.011703       0.4461        0.492
##   81.8    513       1   0.4676 0.011715       0.4452        0.491
##   81.8    512       1   0.4667 0.011728       0.4442        0.490
##   81.8    511       1   0.4657 0.011741       0.4433        0.489
##   81.8    510       1   0.4648 0.011753       0.4424        0.488
##   81.9    509       1   0.4639 0.011765       0.4414        0.488
##   81.9    508       1   0.4630 0.011778       0.4405        0.487
##   81.9    507       1   0.4621 0.011790       0.4396        0.486
##   81.9    506       1   0.4612 0.011802       0.4386        0.485
##   82.0    505       1   0.4603 0.011814       0.4377        0.484
##   82.0    504       1   0.4594 0.011825       0.4367        0.483
##   82.0    447       1   0.4583 0.011844       0.4357        0.482
##   82.1    446       1   0.4573 0.011862       0.4346        0.481
```

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##  82.1    445       1   0.4563 0.011879        0.4336          0.480
##  82.1    444       1   0.4552 0.011897        0.4325          0.479
##  82.1    443       1   0.4542 0.011914        0.4315          0.478
##  82.1    442       1   0.4532 0.011932        0.4304          0.477
##  82.2    441       1   0.4522 0.011949        0.4293          0.476
##  82.2    440       1   0.4511 0.011966        0.4283          0.475
##  82.2    439       1   0.4501 0.011982        0.4272          0.474
##  82.2    438       1   0.4491 0.011999        0.4262          0.473
##  82.2    437       1   0.4480 0.012016        0.4251          0.472
##  82.3    436       1   0.4470 0.012032        0.4240          0.471
##  82.3    435       1   0.4460 0.012048        0.4230          0.470
##  82.3    434       1   0.4450 0.012064        0.4219          0.469
##  82.3    433       1   0.4439 0.012080        0.4209          0.468
##  82.3    432       1   0.4429 0.012096        0.4198          0.467
##  82.3    431       1   0.4419 0.012111        0.4188          0.466
##  82.4    430       1   0.4409 0.012126        0.4177          0.465
##  82.4    429       1   0.4398 0.012142        0.4167          0.464
##  82.4    428       1   0.4388 0.012157        0.4156          0.463
##  82.4    427       1   0.4378 0.012171        0.4146          0.462
##  82.4    426       1   0.4367 0.012186        0.4135          0.461
##  82.4    425       1   0.4357 0.012201        0.4124          0.460
##  82.5    424       1   0.4347 0.012215        0.4114          0.459
##  82.5    423       1   0.4337 0.012230        0.4103          0.458
##  82.5    422       1   0.4326 0.012244        0.4093          0.457
##  82.5    421       1   0.4316 0.012258        0.4082          0.456
##  82.6    420       1   0.4306 0.012271        0.4072          0.455
##  82.6    419       1   0.4295 0.012285        0.4061          0.454
##  82.7    418       1   0.4285 0.012299        0.4051          0.453
##  82.7    417       1   0.4275 0.012312        0.4040          0.452
##  82.7    416       1   0.4265 0.012325        0.4030          0.451
##  82.7    415       2   0.4244 0.012351        0.4009          0.449
##  82.7    413       1   0.4234 0.012364        0.3998          0.448
##  82.8    412       1   0.4224 0.012377        0.3988          0.447
##  82.8    411       1   0.4213 0.012389        0.3977          0.446
##  82.8    410       1   0.4203 0.012401        0.3967          0.445
##  82.9    409       1   0.4193 0.012414        0.3956          0.444
##  82.9    408       1   0.4182 0.012426        0.3946          0.443
##  82.9    407       1   0.4172 0.012437        0.3935          0.442
##  83.0    342       1   0.4160 0.012461        0.3923          0.441
##  83.0    341       1   0.4148 0.012484        0.3910          0.440
##  83.1    340       1   0.4136 0.012507        0.3898          0.439
##  83.1    339       1   0.4123 0.012529        0.3885          0.438
##  83.1    338       1   0.4111 0.012551        0.3872          0.436
##  83.2    337       1   0.4099 0.012573        0.3860          0.435
##  83.2    336       1   0.4087 0.012595        0.3847          0.434
##  83.2    335       1   0.4075 0.012616        0.3835          0.433
```
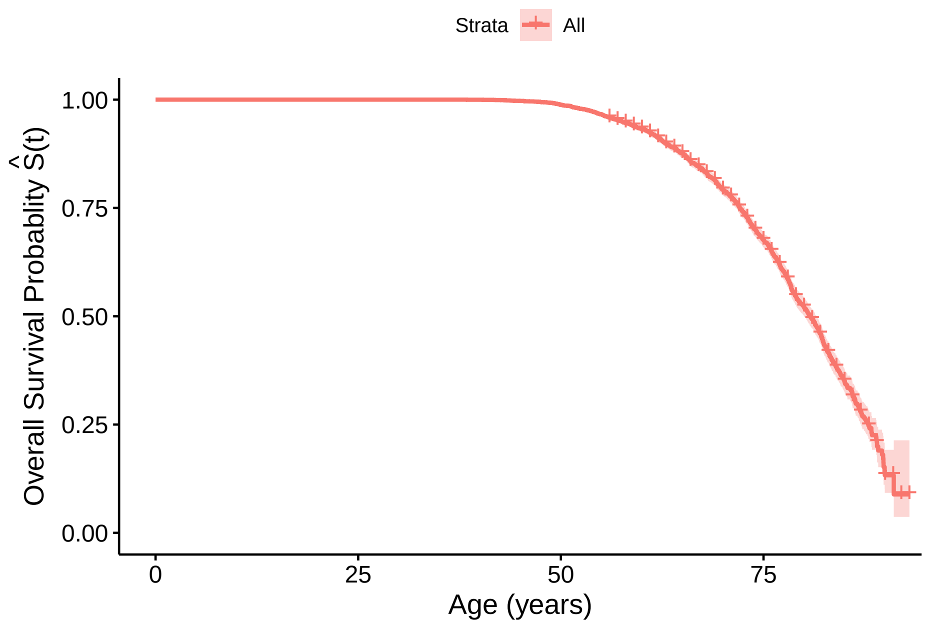

```
## 83.2 334 1 0.4062 0.012637 0.3822 0.432
## 83.3 333 1 0.4050 0.012658 0.3810 0.431
## 83.3 332 1 0.4038 0.012678 0.3797 0.429
## 83.4 331 1 0.4026 0.012699 0.3784 0.428
## 83.4 330 1 0.4014 0.012719 0.3772 0.427
## 83.4 329 1 0.4001 0.012738 0.3759 0.426
## 83.4 328 1 0.3989 0.012758 0.3747 0.425
## 83.4 327 1 0.3977 0.012777 0.3734 0.424
## 83.5 326 1 0.3965 0.012796 0.3722 0.422
## 83.6 325 1 0.3953 0.012815 0.3709 0.421
## 83.6 324 1 0.3940 0.012833 0.3697 0.420
## 83.6 323 1 0.3928 0.012851 0.3684 0.419
## 83.6 322 1 0.3916 0.012869 0.3672 0.418
## 83.7 321 1 0.3904 0.012887 0.3659 0.416
## 83.7 320 1 0.3892 0.012904 0.3647 0.415
## 83.8 319 1 0.3879 0.012921 0.3634 0.414
## 83.9 318 1 0.3867 0.012938 0.3622 0.413
## 83.9 317 1 0.3855 0.012954 0.3609 0.412
## 83.9 316 1 0.3843 0.012971 0.3597 0.411
## 84.0 315 1 0.3831 0.012987 0.3584 0.409
## 84.0 260 1 0.3816 0.013020 0.3569 0.408
## 84.0 259 1 0.3801 0.013053 0.3554 0.407
## 84.1 258 1 0.3786 0.013085 0.3538 0.405
## 84.1 257 1 0.3772 0.013117 0.3523 0.404
## 84.2 256 1 0.3757 0.013148 0.3508 0.402
## 84.3 255 1 0.3742 0.013179 0.3493 0.401
## 84.3 254 1 0.3727 0.013209 0.3477 0.400
## 84.3 253 1 0.3713 0.013239 0.3462 0.398
## 84.4 252 1 0.3698 0.013268 0.3447 0.397
## 84.4 251 1 0.3683 0.013297 0.3432 0.395
## 84.5 250 1 0.3669 0.013325 0.3416 0.394
## 84.5 249 1 0.3654 0.013353 0.3401 0.393
## 84.5 248 1 0.3639 0.013380 0.3386 0.391
## 84.6 247 1 0.3624 0.013407 0.3371 0.390
## 84.7 246 1 0.3610 0.013433 0.3356 0.388
## 84.7 245 1 0.3595 0.013458 0.3341 0.387
## 84.8 244 1 0.3580 0.013484 0.3325 0.385
## 84.8 243 1 0.3565 0.013508 0.3310 0.384
## 84.9 242 1 0.3551 0.013533 0.3295 0.383
## 84.9 241 1 0.3536 0.013557 0.3280 0.381
## 84.9 240 1 0.3521 0.013580 0.3265 0.380
## 85.0 239 1 0.3506 0.013603 0.3250 0.378
## 85.0 194 1 0.3488 0.013652 0.3231 0.377
## 85.0 193 1 0.3470 0.013701 0.3212 0.375
## 85.0 192 1 0.3452 0.013748 0.3193 0.373
## 85.1 191 1 0.3434 0.013794 0.3174 0.372
```

```
## 85.2    190        1   0.3416 0.013840        0.3155          0.370
## 85.3    189        1   0.3398 0.013884        0.3137          0.368
## 85.3    188        1   0.3380 0.013927        0.3118          0.366
## 85.3    187        1   0.3362 0.013970        0.3099          0.365
## 85.4    186        1   0.3344 0.014011        0.3080          0.363
## 85.7    185        1   0.3326 0.014051        0.3061          0.361
## 85.7    184        1   0.3308 0.014091        0.3043          0.360
## 85.8    183        1   0.3290 0.014129        0.3024          0.358
## 85.8    182        1   0.3272 0.014167        0.3005          0.356
## 85.9    181        1   0.3253 0.014203        0.2987          0.354
## 85.9    180        1   0.3235 0.014239        0.2968          0.353
## 85.9    179        1   0.3217 0.014273        0.2949          0.351
## 85.9    178        1   0.3199 0.014307        0.2931          0.349
## 86.0    177        1   0.3181 0.014340        0.2912          0.347
## 86.0    176        1   0.3163 0.014372        0.2894          0.346
## 86.0    175        1   0.3145 0.014403        0.2875          0.344
## 86.2    134        1   0.3122 0.014486        0.2850          0.342
## 86.2    133        1   0.3098 0.014566        0.2825          0.340
## 86.3    132        1   0.3075 0.014643        0.2801          0.338
## 86.3    131        2   0.3028 0.014791        0.2751          0.333
## 86.4    129        1   0.3004 0.014861        0.2727          0.331
## 86.4    128        1   0.2981 0.014929        0.2702          0.329
## 86.6    127        1   0.2957 0.014995        0.2677          0.327
## 86.6    126        1   0.2934 0.015059        0.2653          0.324
## 86.7    125        1   0.2910 0.015120        0.2629          0.322
## 86.8    124        1   0.2887 0.015179        0.2604          0.320
## 86.8    123        1   0.2863 0.015236        0.2580          0.318
## 86.9    122        1   0.2840 0.015291        0.2555          0.316
## 86.9    121        1   0.2816 0.015344        0.2531          0.313
## 87.0    120        1   0.2793 0.015394        0.2507          0.311
## 87.1     79        1   0.2758 0.015600        0.2468          0.308
## 87.1     78        1   0.2722 0.015796        0.2430          0.305
## 87.2     77        1   0.2687 0.015981        0.2391          0.302
## 87.4     76        1   0.2652 0.016157        0.2353          0.299
## 87.5     75        1   0.2616 0.016324        0.2315          0.296
## 87.6     74        1   0.2581 0.016482        0.2277          0.292
## 87.8     73        1   0.2545 0.016631        0.2240          0.289
## 87.9     72        1   0.2510 0.016771        0.2202          0.286
## 87.9     71        1   0.2475 0.016904        0.2165          0.283
## 88.1     45        1   0.2420 0.017400        0.2102          0.279
## 88.3     44        1   0.2365 0.017852        0.2040          0.274
## 88.3     43        1   0.2310 0.018264        0.1978          0.270
## 88.4     42        1   0.2255 0.018639        0.1918          0.265
## 88.9     41        1   0.2200 0.018979        0.1858          0.261
## 88.9     40        1   0.2145 0.019284        0.1798          0.256
## 89.0     39        1   0.2090 0.019558        0.1740          0.251
```

```
##   89.0      22        1    0.1995 0.020849       0.1625         0.245
##   89.1      21        1    0.1900 0.021913       0.1515         0.238
##   89.6      20        1    0.1805 0.022784       0.1409         0.231
##   89.8      19        1    0.1710 0.023481       0.1306         0.224
##   89.8      18        1    0.1615 0.024022       0.1206         0.216
##   89.8      17        1    0.1520 0.024414       0.1109         0.208
##   89.9      16        1    0.1425 0.024667       0.1015         0.200
##   90.0      15        1    0.1330 0.024784       0.0923         0.192
##   91.1       3        1    0.0887 0.039787       0.0368         0.214
```

```
fit2 %>%
ggsurvplot(xlab="Age (years)",ylab=expression(paste('Overall Survival Probablity ', ha
```



We see that the shape of this survival curve is different, with virtually no one dying until they reach their 40s, and then a sharper drop in survival as age increases.

The Cox proportional hazards model in a simple form has this form

$log(\lambda(t|X)) = log(\lambda_0(t)) + \beta_1 \times X$

where $\lambda(t)$ represent the hazard at time t, $\lambda_0(t)$ is the baseline hazard at time t, and β_1 is the log hazard for those with $X = 1$ compared to $X = 0$. The baseline hazard $\lambda_0(t)$ is similar to the intercept term in a linear model or glm and is the value of the hazard when all covariates equal 0. However, unlike the intercept term in a linear model or glm, $\lambda_0(t)$ is not estimated by the model. The above model can also be writen as

$\lambda(t|X) = \lambda_0(t) \times e^{\beta_1 \times X}$

e^{β_1} is the hazard ratio comparing those hose with $X = 1$ and $X = 0$

Using the `fhs` data we will fit a simple Cox proportianal hazard for the effect of smoking on the hazard for MI.

Note: Variables of interest to continue with: for mixed models, `sysbp`, `diabp`, `totchol` compared to `cigpday`, `bmi` smoking or not for long. analysis, `timemi` and `timestrk` and `hyperten`, exposure: `cigpday`, `sysbp`, `diabp`, `bmi`

7.3 Handling complexity

7.3.1 Multi-level exposure

7.3.2 Recurrent outcome

7.3.3 Time-varying coeffificents

7.3.4 Using survey results

[e.g., NHANES]

Chapter 8

Some approaches for confounding

8.1 Inverse probability weighting

8.2 Propensity scores

[Modeling for weights/propensity scores, involves machine learning]

Chapter 9

Mixed models

[Using a mixed modeling framework to help analyze repeated measures]

Chapter 10

Instrumental variables

Chapter 11

Causal inference

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