IPS9 in R: Looking at Data – Relations (Chapter 2)

Margaret Chien and Nicholas Horton (nhorton@amherst.edu)

July 19, 2018

Introduction and background

These documents are intended to help describe how to undertake analyses introduced as examples in the Ninth Edition of *Introduction to the Practice of Statistics* (2017) by Moore, McCabe, and Craig.

More information about the book can be found here. The data used in these documents can be found under Data Sets in the Student Site. This file as well as the associated R Markdown reproducible analysis source file used to create it can be found at https://nhorton.people.amherst.edu/ips9/.

This work leverages initiatives undertaken by Project MOSAIC (http://www.mosaic-web.org), an NSF-funded effort to improve the teaching of statistics, calculus, science and computing in the undergraduate curriculum. In particular, we utilize the `mosaic` package, which was written to simplify the use of R for introductory statistics courses. A short summary of the R needed to teach introductory statistics can be found in the mosaic package vignettes (http://cran.r-project.org/web/packages/mosaic). A paper describing the mosaic approach was published in the *R Journal*: https://journal.r-project.org/archive/2017/RJ-2017-024.

Chapter 2: Looking at Data – Relationships

This file replicates the analyses from 2: Looking at Data – Relationships.

First, load the packages that will be needed for this document:

```
library(mosaic)
library(readr)
```

Section 2.1: Relationships

Section 2.2: Scatterplots

Example 2.8: Laundry detergents

```
Laundry <- read_csv("https://nhorton.people.amherst.edu/ips9/data/chapter02/EG02-008LAUNDRY.csv")
```

```
## Parsed with column specification:
## cols(
##   Price = col_integer(),
##   Rating = col_integer(),
##   Type = col_character()
## )
```

```
# 2.10: Examine the spreadsheet
str(Laundry)
```

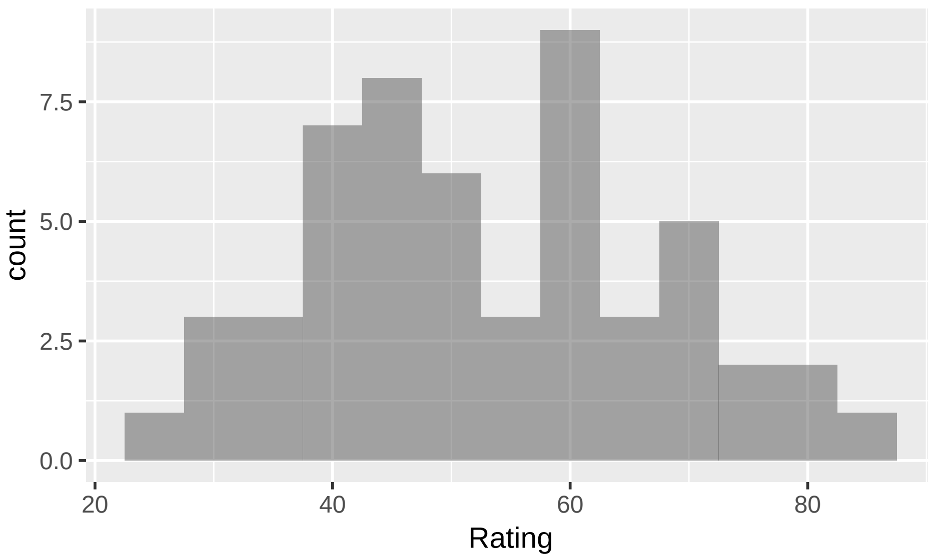
```
## Classes 'tbl_df', 'tbl' and 'data.frame':    53 obs. of  3 variables:
##  $ Price : int  14 14 14 12 10 8 56 14 18 13 ...
##  $ Rating: int  60 58 60 53 57 41 51 29 44 65 ...
##  $ Type  : chr  "Liquid" "Liquid" "Liquid" "Liquid" ...
##  - attr(*, "spec")=List of 2
```

```
##    ..$ cols    :List of 3
##    .. ..$ Price : list()
##    .. .. ..- attr(*, "class")= chr  "collector_integer" "collector"
##    .. ..$ Rating: list()
##    .. .. ..- attr(*, "class")= chr  "collector_integer" "collector"
##    .. ..$ Type  : list()
##    .. .. ..- attr(*, "class")= chr  "collector_character" "collector"
##    ..$ default: list()
##    .. ..- attr(*, "class")= chr  "collector_guess" "collector"
##    ..- attr(*, "class")= chr "col_spec"
```

```
favstats(~ Rating, data = Laundry)
```

```
##  min Q1 median Q3 max     mean       sd  n missing
##   25 42     51 61  85 53.01887 14.25387 53       0
```

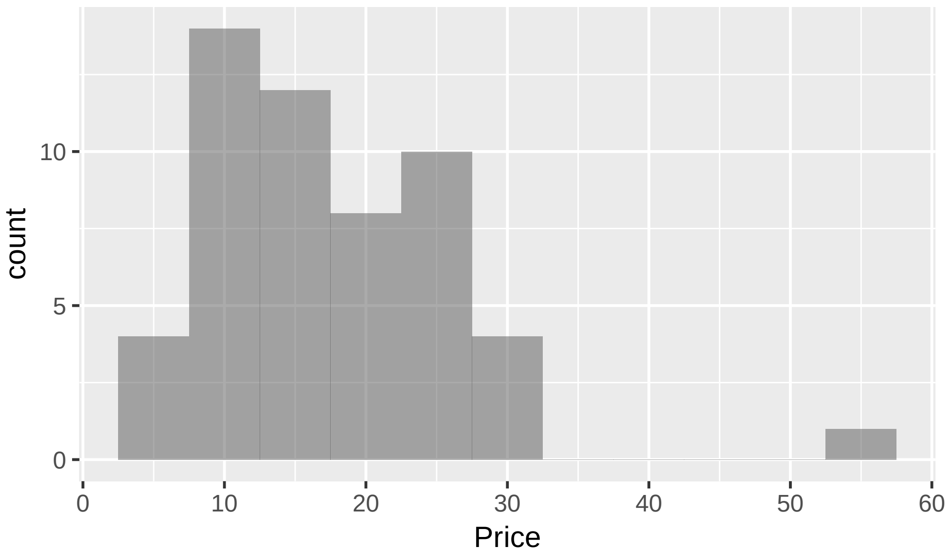
```
gf_histogram(~ Rating, data = Laundry, binwidth = 5)
```




```
favstats(~ Price, data = Laundry)
```

```
##  min Q1 median Q3 max     mean       sd  n missing
##    5 12     14 24  56 17.37736 8.838783 53       0
```

```
gf_histogram(~ Price, data = Laundry, binwidth = 5)
```

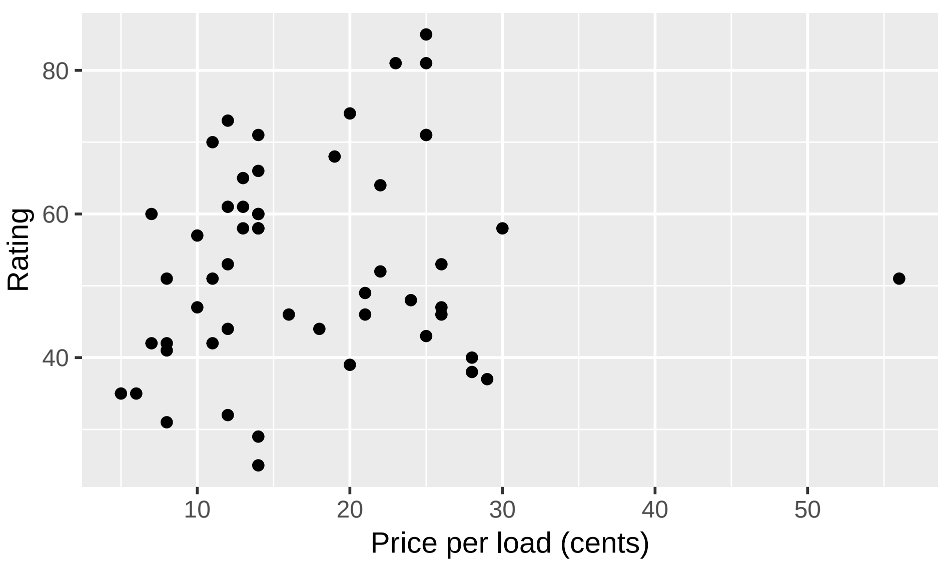


Example 2.9: Laundry detergents

```
Laundry <- read_csv("https://nhorton.people.amherst.edu/ips9/data/chapter02/EG02-009LAUNDRY.csv")
```

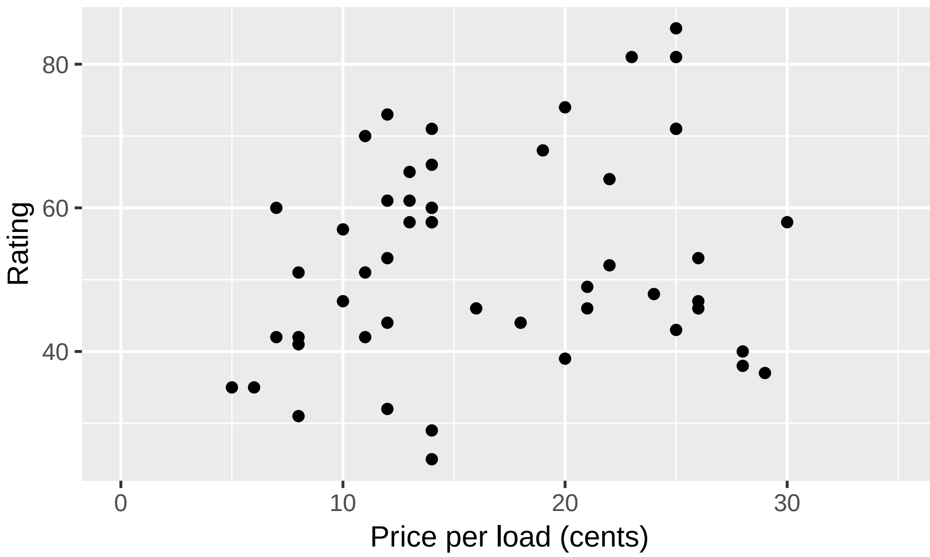
```
## Parsed with column specification:
## cols(
##   Price = col_integer(),
##   Rating = col_integer(),
##   Type = col_character()
## )
```

```
# Figure 2.1, page 86
gf_point(Rating ~ Price, data = Laundry, xlab = "Price per load (cents)")
```



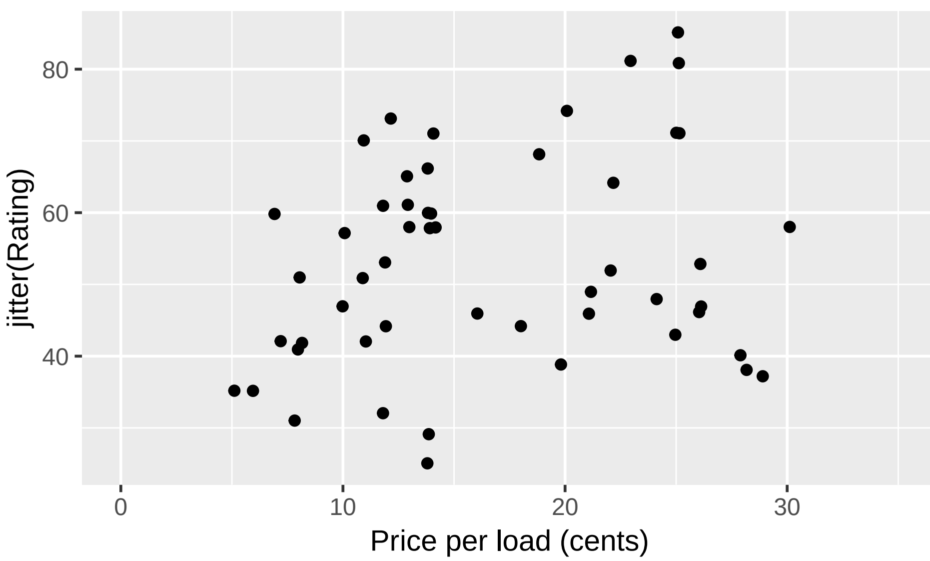

```
# Figure 2.2
gf_point(Rating ~ Price, data = Laundry, xlab = "Price per load (cents)") +
  xlim(0, 35)
```

```
## Warning: Removed 1 rows containing missing values (geom_point).
```




```
# 2.12: Make a scatterplot
gf_point(jitter(Rating) ~ jitter(Price), data = Laundry, xlab = "Price per load (cents)") +
  xlim(0, 35)
```

```
## Warning: Removed 1 rows containing missing values (geom_point).
```

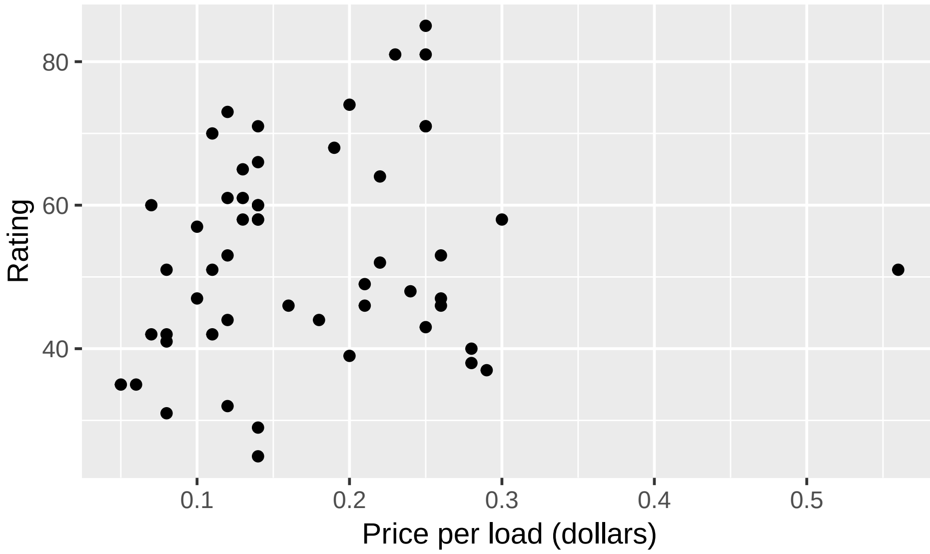


We can use `jitter()` to add some noise into the plot to show overlapped points.

```
# 2.13: Change the units
Laundry2 <- Laundry %>%
  mutate(Price = Price/100)
favstats(~ Price, data = Laundry2)
```

```
##   min   Q1 median   Q3  max      mean         sd  n missing
##  0.05 0.12   0.14 0.24 0.56 0.1737736 0.08838783 53       0
```

```r
gf_point(Rating ~ Price, data = Laundry2, xlab = "Price per load (dollars)")
```

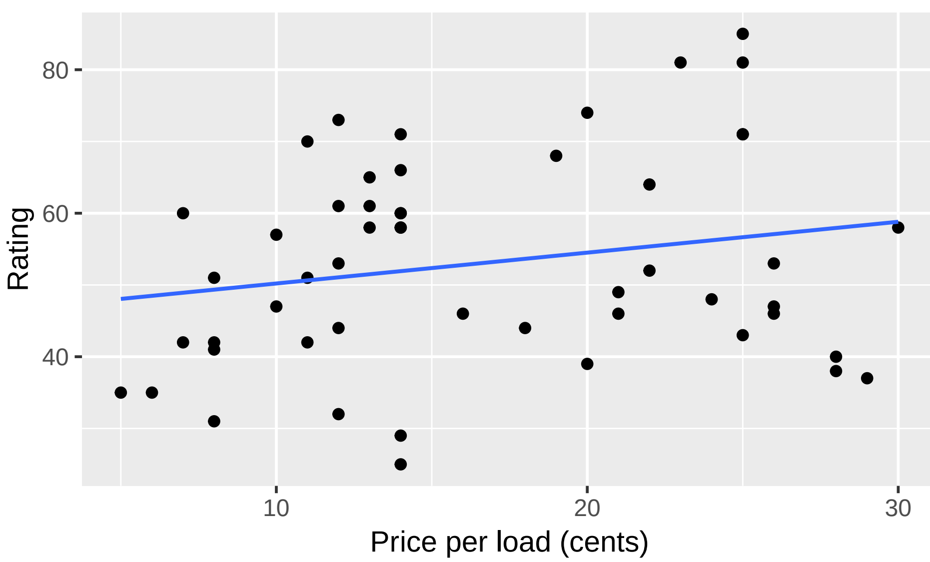


Example 2.10: Scatterplot with a straight line

```r
Laundry <- read_csv("https://nhorton.people.amherst.edu/ips9/data/chapter02/EG02-010LAUND.csv")
```

```
## Parsed with column specification:
## cols(
##   Price = col_integer(),
##   Rating = col_integer(),
##   Type = col_character()
## )
```

```r
gf_point(Rating ~ Price, data = Laundry, xlab = "Price per load (cents)") %>%
  gf_lm()
```



Example 2.11: Education spending and population: Benchmarking

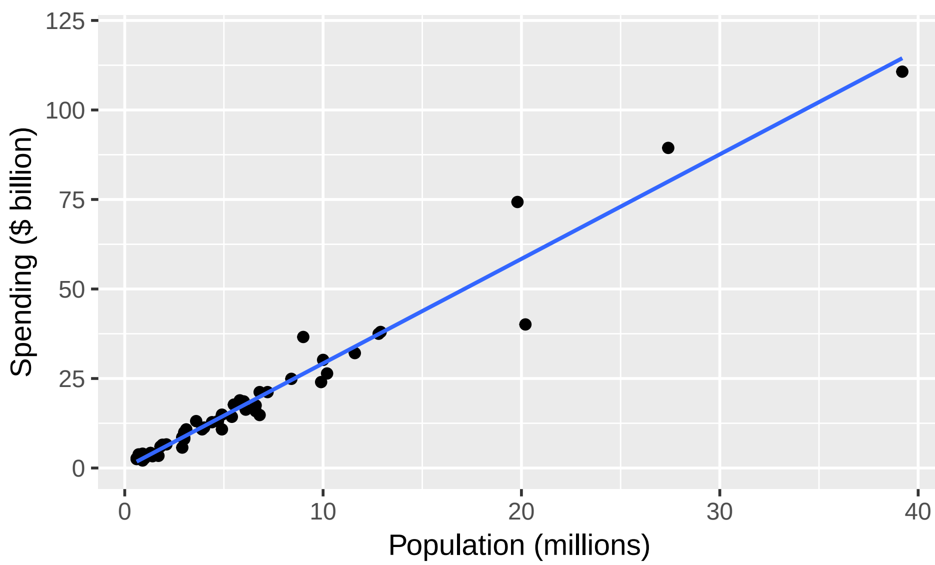
```r
EduSpending <- read_csv("https://nhorton.people.amherst.edu/ips9/data/chapter02/EG02-011EDSPEND.csv")
```

```
## Parsed with column specification:
## cols(
##   State = col_character(),
##   Spending = col_double(),
##   Population = col_double()
## )
```

```r
head(EduSpending)
```

```
## # A tibble: 6 x 3
##   State      Spending Population
##   <chr>         <dbl>      <dbl>
## 1 Alabama        14.9        4.9
## 2 Alaska          3.8        0.7
## 3 Arizona        14.8        6.8
## 4 Arkansas        8.5        3
## 5 California    111.        39.2
## 6 Colorado       14.3        5.4
```

```r
# Figure 2.5, page 90
gf_point(Spending ~ Population, data = EduSpending) %>%
  gf_lm() %>%
  gf_labs(x = "Population (millions)", y = "Spending ($ billion)")
```



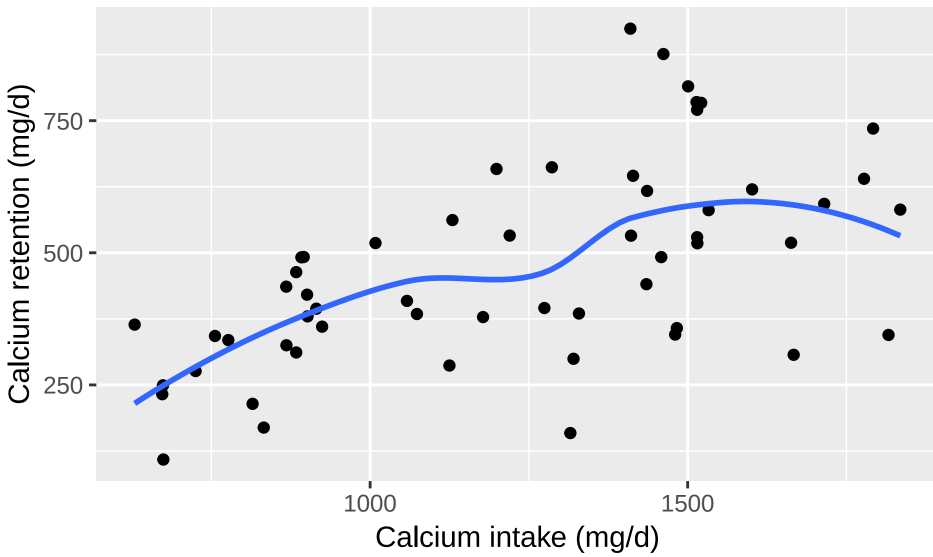
Example 2.12: Calcium retention

```r
Calcium <- read_csv("https://nhorton.people.amherst.edu/ips9/data/chapter02/EG02-012CALCIUM.csv")
```

```
## Parsed with column specification:
## cols(
##   CaIntake = col_double(),
##   CaRetention = col_double(),
##   LogRet = col_double()
## )
```

```r
# Figure 2.6
gf_point(CaRetention~ CaIntake, data = Calcium) %>%
  gf_smooth() %>%
  gf_labs(x = "Calcium intake (mg/d)", y = "Calcium retention (mg/d)")
```

```
## `geom_smooth()` using method = 'loess' and formula 'y ~ x'
```

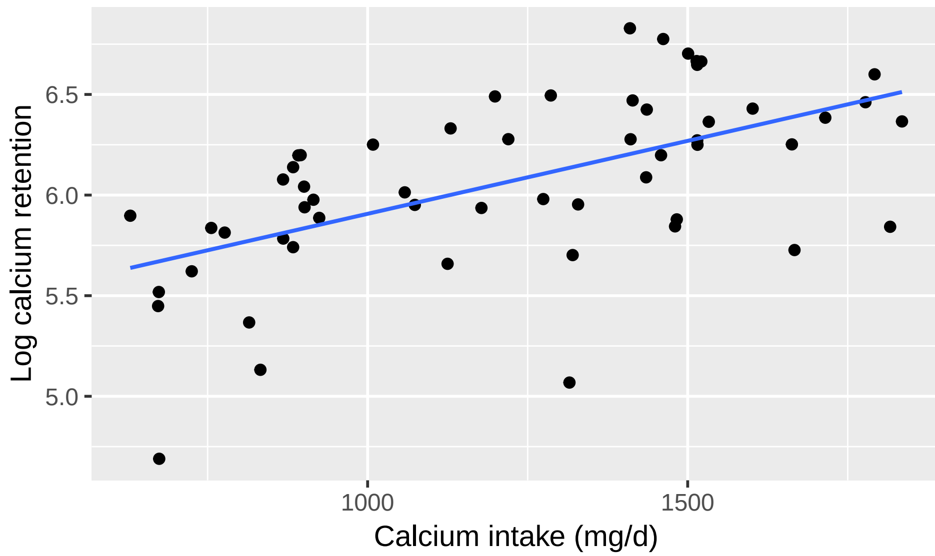


Example 2.13: Calcium retention with logarithms

```r
Calcium <- read_csv("https://nhorton.people.amherst.edu/ips9/data/chapter02/EG02-013CALCIUM.csv")
```

```
## Parsed with column specification:
## cols(
##   CaIntake = col_double(),
##   CaRetention = col_double(),
##   LogRet = col_double()
## )
```

```r
# Figure 2.7, page 91
gf_point(LogRet ~ CaIntake, data = Calcium) %>%
  gf_lm() %>%
  gf_labs(x = "Calcium intake (mg/d)", y = "Log calcium retention")
```

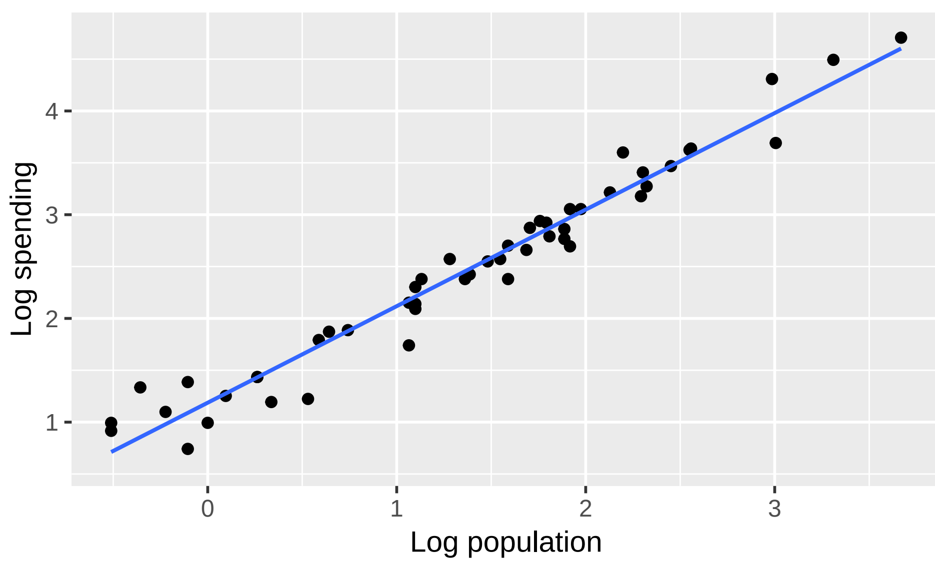


Example 2.14: Education spending and population with logarithms

```
EduSpending <- read_csv("https://nhorton.people.amherst.edu/ips9/data/chapter02/EG02-014EDSPEND.csv")
```

```
## Parsed with column specification:
## cols(
##   State = col_character(),
##   Spending = col_double(),
##   Population = col_double()
## )
```

```
# Figure 2.8, page 92
EduSpending %>%
  mutate(LogPop = log(Population), LogSpend = log(Spending)) %>%
  gf_point(LogSpend ~ LogPop) %>%
  gf_lm() %>%
  gf_labs(x = "Log population", y = "Log spending")
```

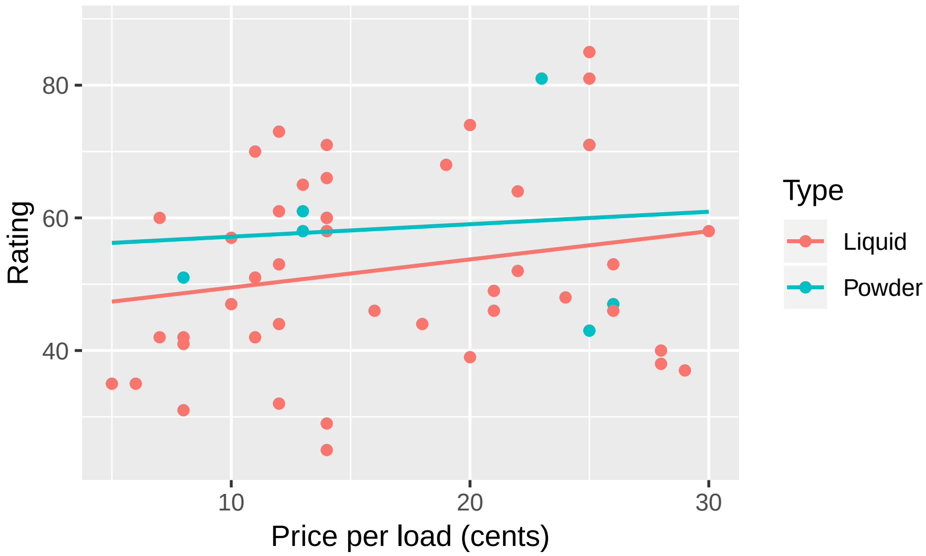


Example 2.15: Rating versus price and type of laundry detergent

```
Laundry <- read_csv("https://nhorton.people.amherst.edu/ips9/data/chapter02/EG02-015LAUND.csv")
```

```
## Parsed with column specification:
## cols(
##   Price = col_integer(),
##   Rating = col_integer(),
##   Type = col_character()
## )
```

```
# Figure 2.9, page 93
gf_point(Rating ~ Price, color = ~ Type, data = Laundry, xlab = "Price per load (cents)") %>%
  gf_lm()
```



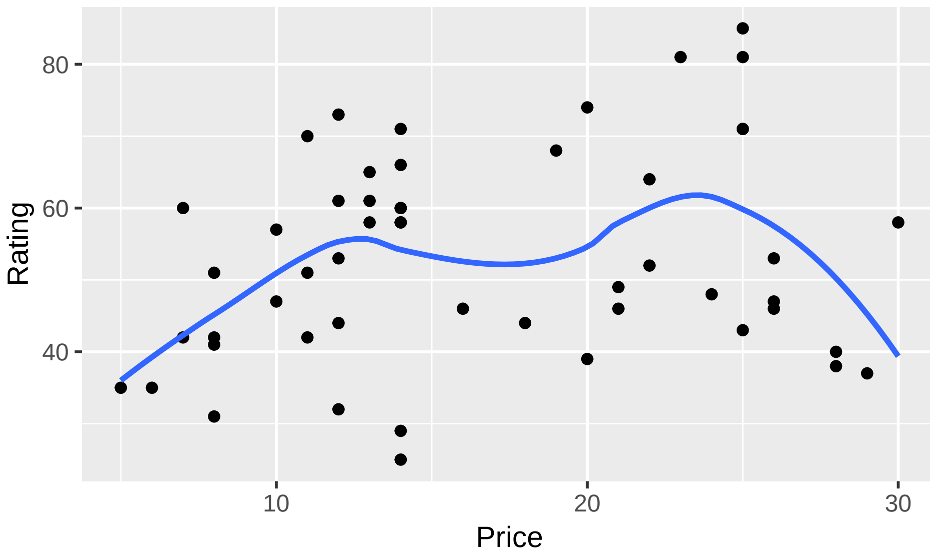
Example 2.16: Laundry rating versus price with a smooth fit

```
Laundry <- read_csv("https://nhorton.people.amherst.edu/ips9/data/chapter02/EG02-016LAUND.csv")
```

```
## Parsed with column specification:
## cols(
##   Price = col_integer(),
##   Rating = col_integer(),
##   Type = col_character()
## )
```

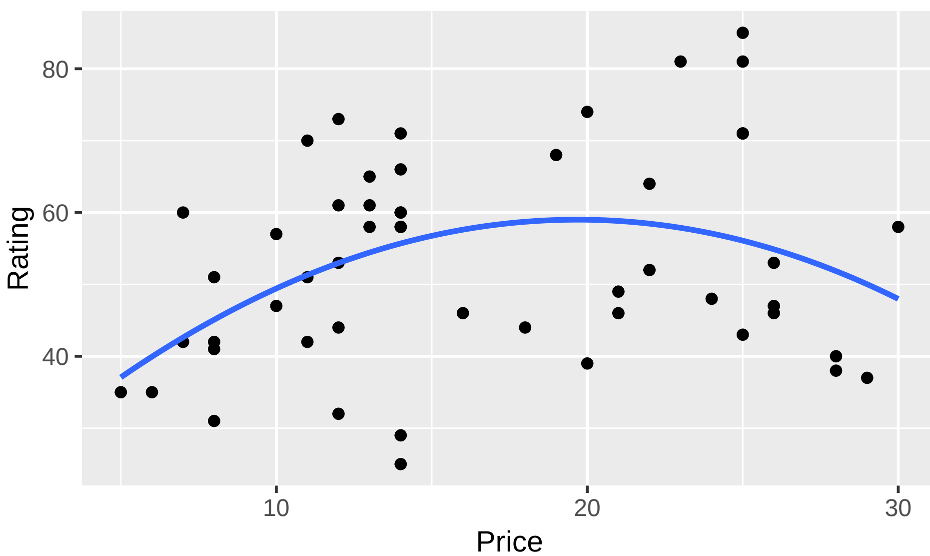
```
# Figure 2.10, page 94-95
gf_point(Rating ~ Price, data = Laundry) %>%
  gf_smooth(span = .5)
```

```
## `geom_smooth()` using method = 'loess' and formula 'y ~ x'
```




```r
gf_point(Rating ~ Price, data = Laundry) %>%
  gf_smooth(span = 5)
```

```
## `geom_smooth()` using method = 'loess' and formula 'y ~ x'
```



Example 2.17: A smooth fit for education spending and population with logs

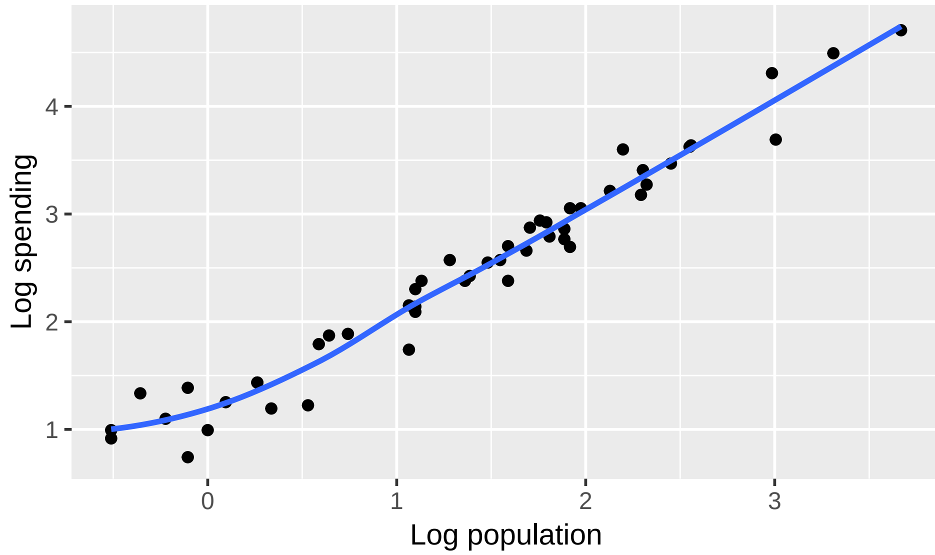
```r
EduSpending <- read_csv("https://nhorton.people.amherst.edu/ips9/data/chapter02/EG02-017EDSPEND.csv")
```

```
## Parsed with column specification:
## cols(
##   State = col_character(),
##   Spending = col_double(),
##   Population = col_double()
## )
```

```r
# Figure 2.8, page 92
EduSpending %>%
  mutate(LogPop = log(Population), LogSpend = log(Spending)) %>%
```

```
  gf_point(LogSpend ~ LogPop) %>%
  gf_smooth() %>%
  gf_labs(x = "Log population", y = "Log spending")
```

```
## `geom_smooth()` using method = 'loess' and formula 'y ~ x'
```



Section 2.3: Correlation

Use Your Knowledge: Laundry detergents

```
# page 102
cor(Rating ~ Price, data = Laundry)
```

```
## [1] 0.2109681
```

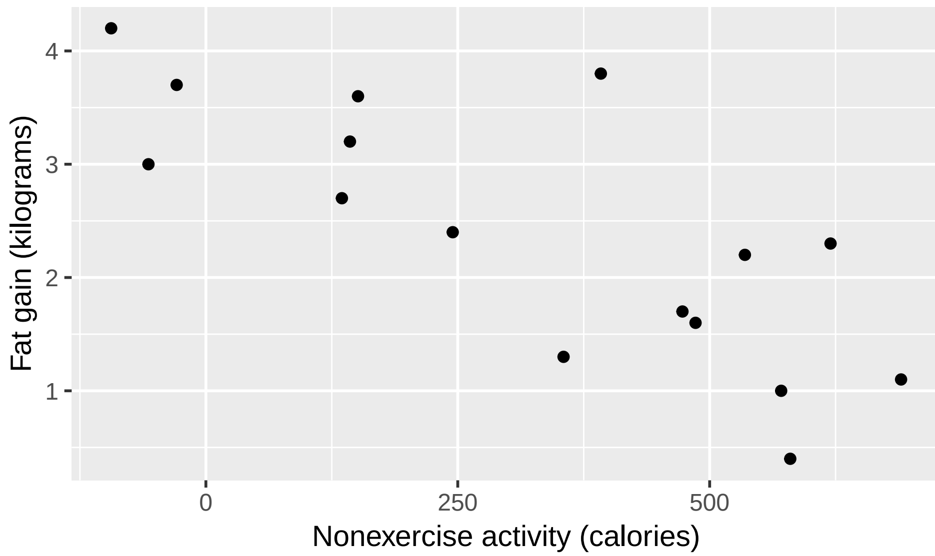
Section 2.4: Least Squares Regression

Example 2.19: Fidgeting and fat gain

```
Fidgeting <- read_csv("https://nhorton.people.amherst.edu/ips9/data/chapter02/EG02-019FIDGET.csv")
```

```
## Parsed with column specification:
## cols(
##   NEA = col_integer(),
##   Fat = col_double(),
##   Resid = col_double()
## )
```

```
# Figure 2.16, page 108
gf_point(Fat ~ NEA, data = Fidgeting) %>%
  gf_labs(x = "Nonexercise activity (calories)", y = "Fat gain (kilograms)")
```

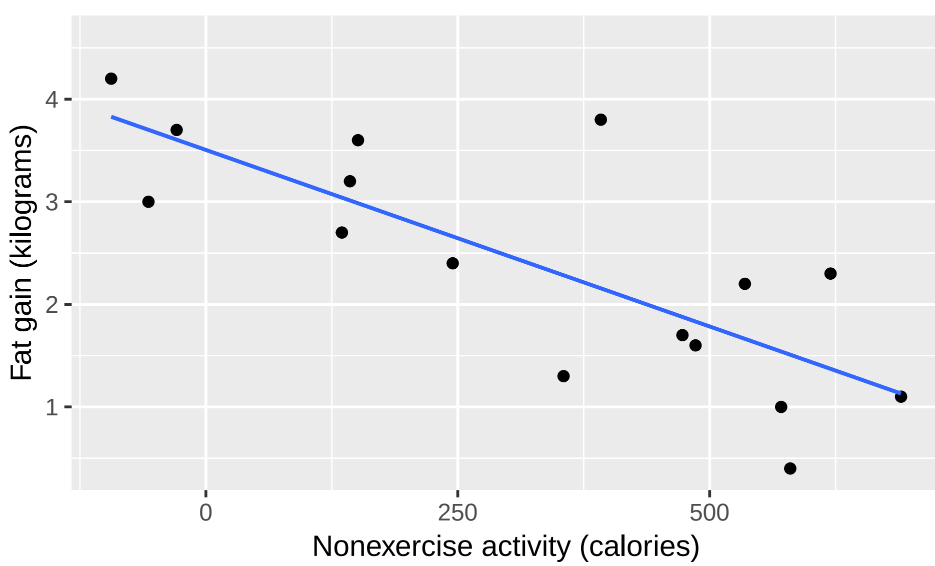


Example 2.20: Regression line for fat gain

```
Fidgeting <- read_csv("https://nhorton.people.amherst.edu/ips9/data/chapter02/EG02-020FIDGET.csv")
```

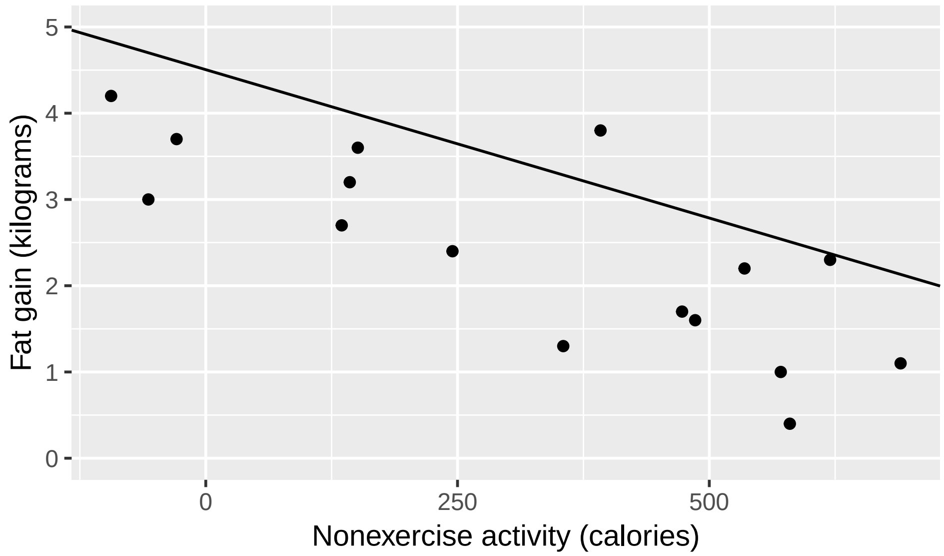
```
## Parsed with column specification:
## cols(
##   NEA = col_integer(),
##   Fat = col_double(),
##   Resid = col_double()
## )
```

```
# Figure 2.17, page 109
gf_point(Fat ~ NEA, data = Fidgeting) %>%
  gf_lm() %>%
  gf_labs(x = "Nonexercise activity (calories)", y = "Fat gain (kilograms)")
```




```
# Use Your Knowledge 2.61: Plot the line
gf_point(Fat ~ NEA, data = Fidgeting) %>%
```

```r
  gf_abline(slope = -.00344, intercept = 4.505) %>%
  gf_labs(x = "Nonexercise activity (calories)", y = "Fat gain (kilograms)") +
  ylim(0, 5)
```



Example 2.21: Prediction for fat gain

```r
fatlm <- lm(Fat ~ NEA, data = Fidgeting)
fatfun <- makeFun(fatlm)
fatfun(NEA = 400)
```

```
##        1
## 2.128528
```

Example 2.24: Regression

```r
# page 113
msummary(fatlm)
```

```
##                Estimate Std. Error t value Pr(>|t|)
## (Intercept)   3.5051229  0.3036164  11.545 1.53e-08 ***
## NEA          -0.0034415  0.0007414  -4.642 0.000381 ***
##
## Residual standard error: 0.7399 on 14 degrees of freedom
## Multiple R-squared:  0.6061, Adjusted R-squared:  0.578
## F-statistic: 21.55 on 1 and 14 DF,  p-value: 0.000381
```

Example 2.25: Fidgeting and fat gain

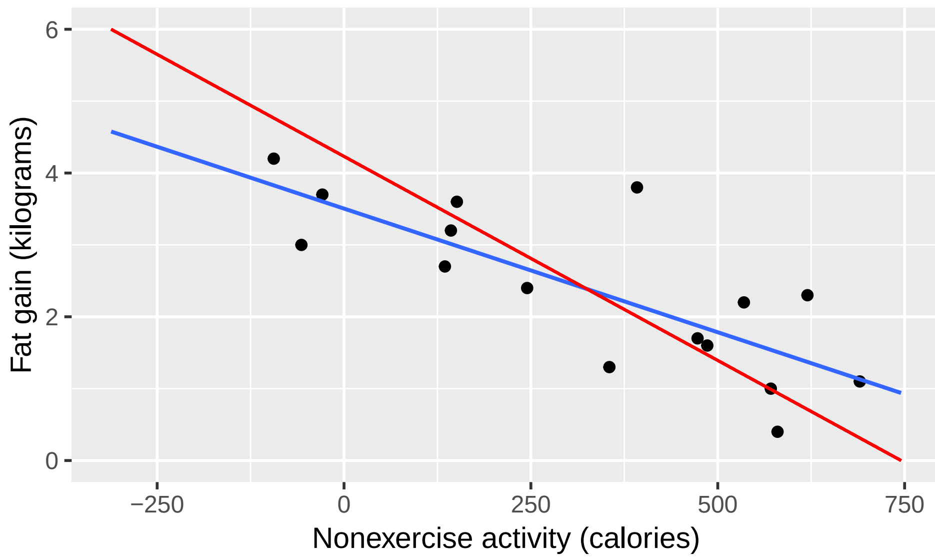
```r
# XX NH Issue with plot and ranges
NEAlm <- lm(NEA ~ Fat, data = Fidgeting) # using fat gain to predict nonexercise activity
NEAfun <- makeFun(NEAlm)
NEAfun(Fat = 6) # (-311.5197, 6)
```

```
##         1
## -311.5197
```

```r
NEAfun(Fat = 0) # (745.2604, 0)
```

```
##        1
## 745.2604
```

```r
# point 1
# Figure 2.20, page 115
gf_point(Fat ~ NEA, data = Fidgeting) %>%
  gf_lm() %>%
  #gf_fun(NEAlm, color = "red") +
  gf_segment(6 + 0 ~ -311.5197 + 745.2604, color = "red") %>%
  gf_labs(x = "Nonexercise activity (calories)", y = "Fat gain (kilograms)") +
  ylim(0, 6)
```



Section 2.5: Cautions about Correlation and Regression

Example 2.26: Residuals for fat gain

```r
fatlm
```

```
##
## Call:
## lm(formula = Fat ~ NEA, data = Fidgeting)
##
## Coefficients:
## (Intercept)          NEA
##    3.505123    -0.003441
```

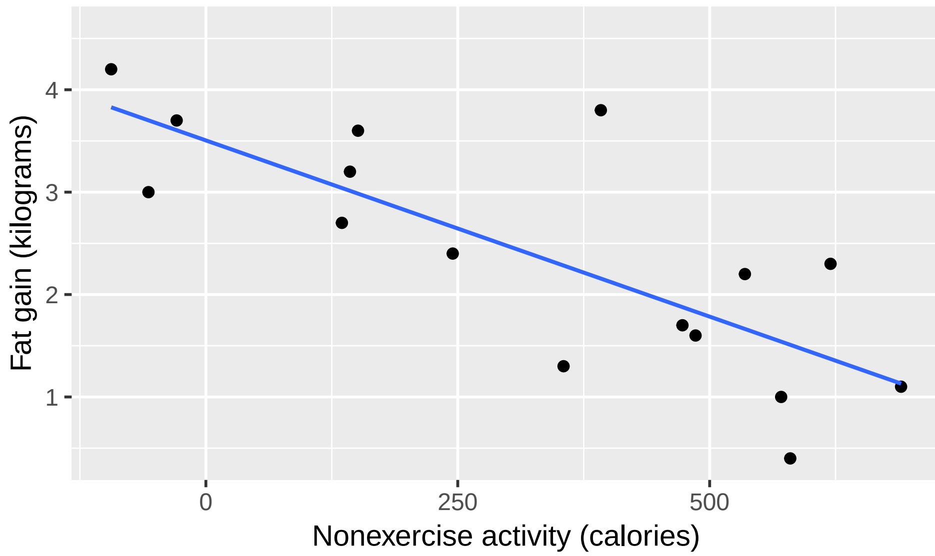
```r
fatfun(NEA = 135)
```

```
##        1
## 3.040522
```

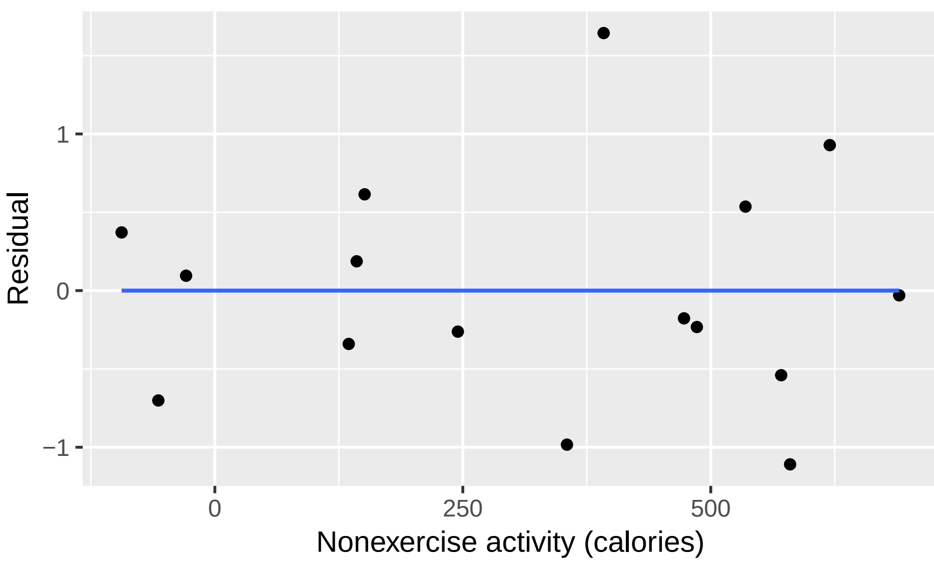
```r
2.7 - fatfun(NEA = 135)
```

```
##          1
## -0.3405222
```

```r
# Figure 2.23, page 124
gf_point(Fat ~ NEA, data = Fidgeting) %>%
  gf_lm() %>%
  gf_labs(x = "Nonexercise activity (calories)", y = "Fat gain (kilograms)")
```




```r
gf_point(resid(fatlm) ~ NEA, data = Fidgeting) %>%
  gf_lm() %>%
  gf_labs(x = "Nonexercise activity (calories)", y = "Residual")
```



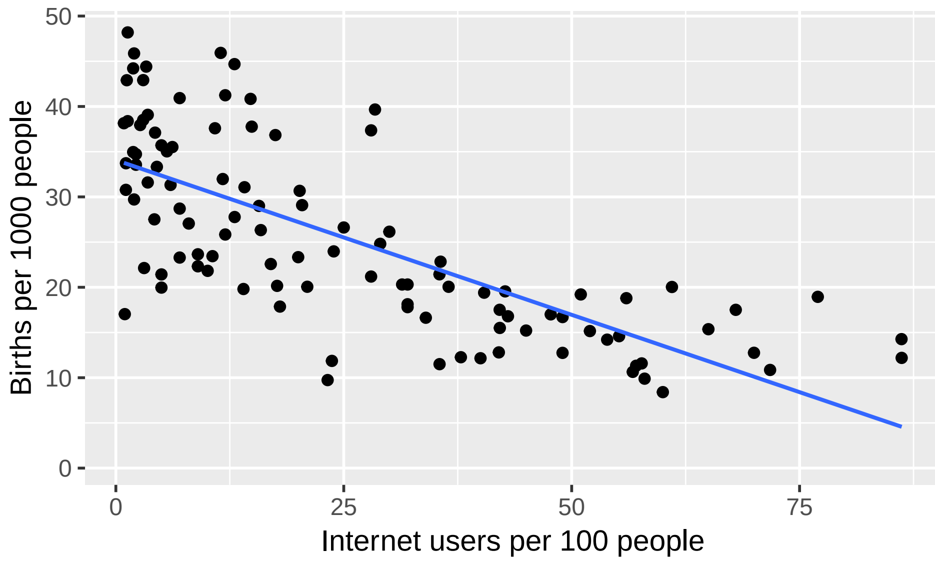
Example 2.27: Patterns in birthrate and Internet user residuals

```r
IntBirth <- read_csv("https://nhorton.people.amherst.edu/ips9/data/chapter02/EG02-027INBIRTH.csv")
```

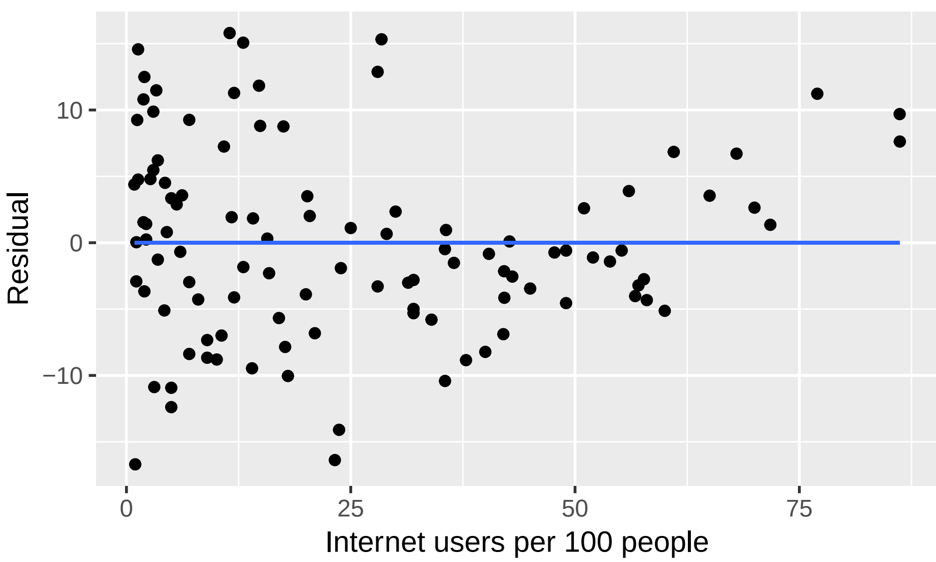
```
## Parsed with column specification:
## cols(
##   Country_Name = col_character(),
##   CountryCode = col_character(),
##   BirthRate2011 = col_double(),
```

```
##   UsersPreviousYear = col_double(),
##   Users = col_double(),
##   LogBirth = col_double(),
##   LogUsers = col_double()
## )
```

```
intbirthlm <- lm(BirthRate2011 ~ Users, data = IntBirth)
# Figure 2.24, page 126
gf_point(BirthRate2011 ~ Users, data = IntBirth) %>%
  gf_lm() %>%
  gf_labs(x = "Internet users per 100 people", y = "Births per 1000 people")
```




```
gf_point(resid(intbirthlm) ~ Users, data = IntBirth) %>%
  gf_lm() %>%
  gf_labs(x = "Internet users per 100 people", y = "Residual")
```

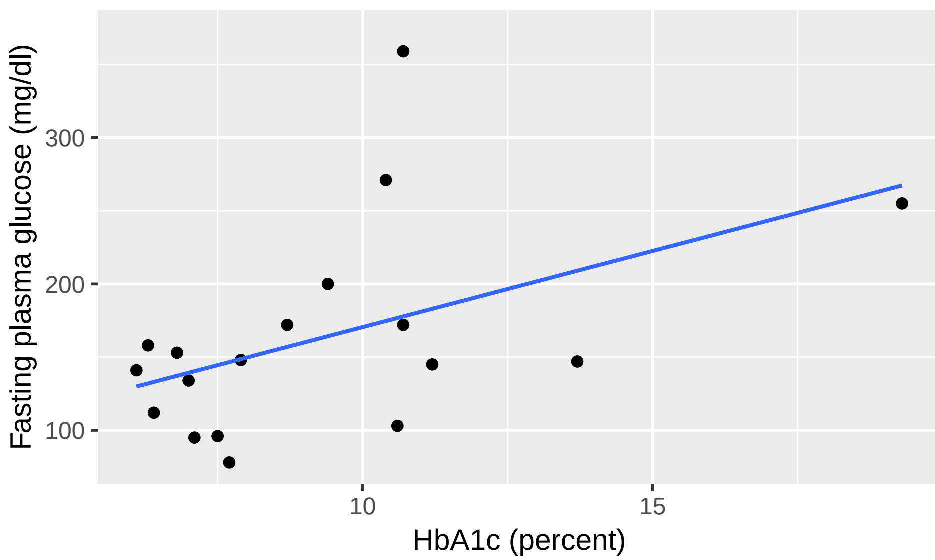


Example 2.28: Diabetes and blood sugar

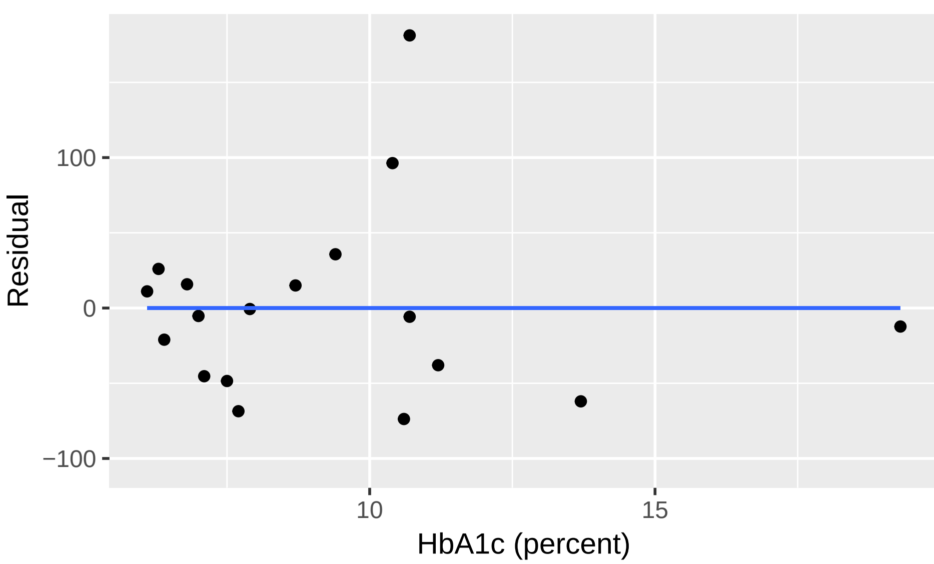
```r
Diabetes <- read_csv("https://nhorton.people.amherst.edu/ips9/data/chapter02/EG02-028HBA1C.csv")
```

```
## Parsed with column specification:
## cols(
##   Subject = col_integer(),
##   HbA1c_percent = col_double(),
##   FPG_mg_ml = col_integer()
## )
```

```r
diabeteslm <- lm(FPG_mg_ml ~ HbA1c_percent, data = Diabetes)
# Figure 2.25, page 127
gf_point(FPG_mg_ml ~ HbA1c_percent, data = Diabetes) %>%
  gf_lm() %>%
  gf_labs(x = "HbA1c (percent)", y = "Fasting plasma glucose (mg/dl)")
```



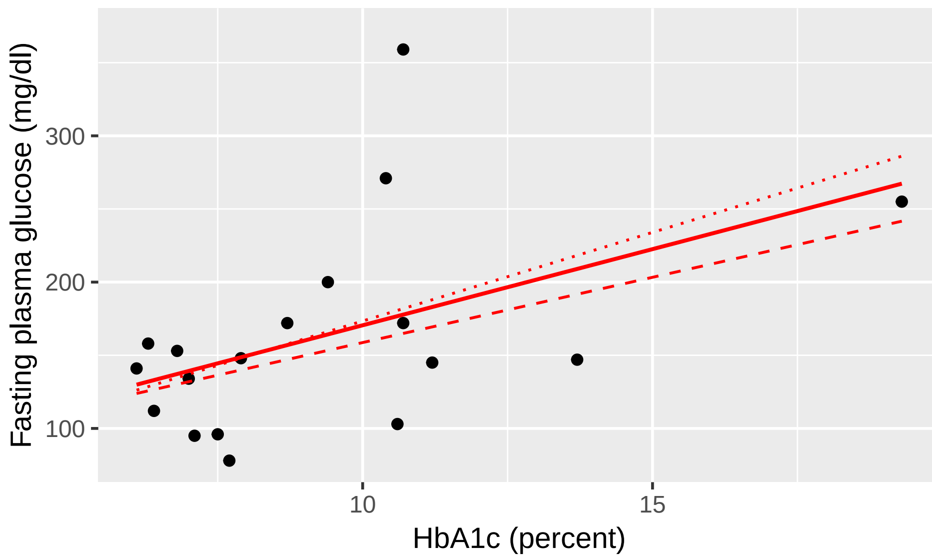

```r
gf_point(resid(diabeteslm) ~ HbA1c_percent, data = Diabetes) %>%
  gf_lm() %>%
  gf_labs(x = "HbA1c (percent)", y = "Residual")
```



Example 2.29: Influential observations

```
without15lm <- lm(FPG_mg_ml ~ HbA1c_percent, data = filter(Diabetes, FPG_mg_ml <= 300)) # model without
without18lm <- lm(FPG_mg_ml ~ HbA1c_percent, data = filter(Diabetes, HbA1c_percent <= 18)) # model with

# Figure 2.26, page 129
gf_point(FPG_mg_ml ~ HbA1c_percent, data = Diabetes) %>%
  gf_lm(color = "red") %>%
  gf_fun(without15lm, linetype = 2, color = "red") %>%
  gf_fun(without18lm, linetype = 3, color = "red") %>%
  gf_labs(x = "HbA1c (percent)", y = "Fasting plasma glucose (mg/dl)")
```



Section 2.6: Data Analysis from Two Way Tables

Example 2.33: Is the calcium intake adequate?

```
Calcium <- read_csv("https://nhorton.people.amherst.edu/ips9/data/chapter02/EG02-033IOM.csv")
```

```
## Parsed with column specification:
## cols(
##   Age = col_character(),
##   Met = col_character(),
##   Count = col_integer()
## )
```

```
Calcium # I forget how to change the data set so that it looks like the table on page 137
```

```
## # A tibble: 4 x 3
##   Age      Met   Count
##   <chr>    <chr> <int>
## 1 A05to10  No      194
## 2 A05to10  Yes     861
## 3 A11to13  No      557
## 4 A11to13  Yes     417
```

Example 2.34: Add the margins to the table

```r
# margin = TRUE
Calcium %>%
  group_by(Age) %>%
  summarise(sum(Count)) # column totals
```

```
## # A tibble: 2 x 2
##   Age     `sum(Count)`
##   <chr>          <int>
## 1 A05to10         1055
## 2 A11to13          974
```

```r
Calcium %>%
  group_by(Met) %>%
  summarise(sum(Count)) # row totals
```

```
## # A tibble: 2 x 2
##   Met   `sum(Count)`
##   <chr>        <int>
## 1 No             751
## 2 Yes           1278
```

```r
Calcium %>%
  summarise(sum(Count)) # overall total
```

```
## # A tibble: 1 x 1
##   `sum(Count)`
##          <int>
## 1         2029
```

Example 2.35: The joint distribution

```r
Calcium %>%
  mutate(proportion = Count/sum(Count)) %>%
  select(Age, Met, proportion)
```

```
## # A tibble: 4 x 3
##   Age     Met   proportion
##   <chr>   <chr>      <dbl>
## 1 A05to10 No        0.0956
## 2 A05to10 Yes       0.424
## 3 A11to13 No        0.275
## 4 A11to13 Yes       0.206
```

Example 2.36: The marginal distribution of age

```r
Calcium %>%
  group_by(Age) %>%
  summarise(count = sum(Count)) %>%
  mutate(proportion = count/sum(count)) %>%
  select(Age, proportion)
```

```
## # A tibble: 2 x 2
##   Age     proportion
##   <chr>        <dbl>
## 1 A05to10      0.520
## 2 A11to13      0.480
```

Example 2.37: The marginal distribution of "met requirement"

```
Calcium %>%
  group_by(Met) %>%
  summarise(count = sum(Count)) %>%
  mutate(proportion = count/sum(count)) %>%
  select(Met, proportion)
```

```
## # A tibble: 2 x 2
##   Met   proportion
##   <chr>      <dbl>
## 1 No         0.370
## 2 Yes        0.630
```

Example 2.39: Conditional distribution of "met requirement" for children aged 5 to 10

```
# page 141
Calcium %>%
  filter(Age == "A05to10") %>%
  mutate(percent = Count/sum(Count)) %>%
  select(Met, percent)
```

```
## # A tibble: 2 x 2
##   Met   percent
##   <chr>   <dbl>
## 1 No      0.184
## 2 Yes     0.816
```

```
# use your knowledge 2.118: a conditional distribution
Calcium %>%
  filter(Age == "A11to13") %>%
  mutate(percent = Count/sum(Count)) %>%
  select(Met, percent)
```

```
## # A tibble: 2 x 2
##   Met   percent
##   <chr>   <dbl>
## 1 No      0.572
## 2 Yes     0.428
```

Example 2.40: Software output

```
# Use vcd for a mosaicplot?
```

Example 2.41: Which customer service representative is better?

```
CustomerService <- read_csv("https://nhorton.people.amherst.edu/ips9/data/chapter02/EG02-041CUSTSER.csv
```

```
## Warning: Missing column names filled in: 'X4' [4], 'X9' [9]
```

```
## Warning: Duplicated column names deduplicated: 'Rep' => 'Rep_1' [5],
## 'GoalMet' => 'GoalMet_1' [6], 'Count' => 'Count_1' [8], 'Rep' =>
## 'Rep_2' [10], 'GoalMet' => 'GoalMet_2' [11], 'Week' => 'Week_1' [12],
## 'Count' => 'Count_2' [13]
```

```
## Parsed with column specification:
```

```
## cols(
##   Rep = col_character(),
##   GoalMet = col_character(),
##   Count = col_integer(),
##   X4 = col_character(),
##   Rep_1 = col_character(),
##   GoalMet_1 = col_character(),
##   Week = col_integer(),
##   Count_1 = col_integer(),
##   X9 = col_character(),
##   Rep_2 = col_character(),
##   GoalMet_2 = col_character(),
##   Week_1 = col_integer(),
##   Count_2 = col_integer()
## )
```

```r
CustomerService %>%
  select(Rep, GoalMet, Count)
```

```
## # A tibble: 4 x 3
##   Rep    GoalMet Count
##   <chr>  <chr>   <int>
## 1 Alexis Yes       172
## 2 Alexis No         28
## 3 Peyton Yes       118
## 4 Peyton No         82
```

```r
CustomerService %>%
  select(Rep, GoalMet, Count) %>%
  group_by(Rep) %>%
  summarise(total = sum(Count))
```

```
## # A tibble: 2 x 2
##   Rep    total
##   <chr>  <int>
## 1 Alexis   200
## 2 Peyton   200
```

Example 2.42: Look at the data more carefully

```r
CustomerService %>%
  select(Rep, GoalMet_1, Count_1, GoalMet_2, Count_2)
```

```
## # A tibble: 4 x 5
##   Rep    GoalMet_1 Count_1 GoalMet_2 Count_2
##   <chr>  <chr>       <int> <chr>       <int>
## 1 Alexis Yes           162 Yes            10
## 2 Alexis No             18 No             10
## 3 Peyton Yes            19 Yes            99
## 4 Peyton No              1 No             81
```

```r
# not sure how to deal with the structure of the table
```

Section 2.7: The Question of Causation