

# Homework 7

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Consider the ChickWeight data in R. The body weights of the chicks were measured at birth (i.e., time=0) and every second day thereafter until day 20. They were also measured on day 21. There were four groups of chicks on different protein diets.

Categorize weight as a binary variable, with Weight Group = 1 (or Low), if weight > 215 mg, and 0, Otherwise.

## Problem 1

Consider comparing Diet Levels 1 and 4 on Day 21.

(a). Determine whether there is association between Diet and Weight, using logistic regression, without adjusting for Birth Weight. Interpret what the estimated parameters denote.

Construct a logistic regression model with adjusting for Birth Weight with Weight for Diet group 1 and 4 on day 21. Restructure the data as categorical data type. The response and explanatory variable is like:

$$\text{Weight}_i = \begin{cases} 1 & \text{Weight} > 215 \\ 0 & \text{Weight} \leq 215 \end{cases} \quad \text{Group}_i = \begin{cases} 1 & \text{Diet} = 1 \\ 0 & \text{Diet} = 4 \end{cases}$$

Then the result is as follows:

Logistic Regression without adjust result

Call:

```
glm(formula = Weight ~ Group, family = "binomial", data = sub_day21)
```

Deviance Residuals:

Min	1Q	Median	3Q	Max
-1.2735	-0.6444	-0.6444	1.0842	1.8297

Coefficients:

	Estimate	Std. Error	z value	Pr(> z )
(Intercept)	0.2231	0.6708	0.333	0.7394
Group	-1.6895	0.9275	-1.822	0.0685 .

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Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for binomial family taken to be 1)

Null deviance: 31.343 on 24 degrees of freedom  
Residual deviance: 27.808 on 23 degrees of freedom  
AIC: 31.808

Number of Fisher Scoring iterations: 4

The model is:

$$\text{logit}(p) = 0.2231 - 1.6895 * \text{Group}$$

So for Diet group 1, the model is:

$$\text{logit}(p) = 0.2231 - 1.6895$$

And for Diet group 4, the model is:

$$\text{logit}(p) = 0.2231$$

There are two parameters here, intercept  $\beta_0$ , and coefficient  $\beta_1$  on Diet group.

- $\beta_0$  denotes the log odds ratio of Weight > 215 for Diet group 4, i.e., the odds ratio of Weight > 215 for Diet group 4 is  $e^{0.2231}$ .
- $\beta_1$  denotes the log odds ratio of Weight > 215 for Diet group 1 relative to Diet Group 4, i.e., odds ratio of Weight > 215 for Diet group 1 relative to Diet Group 4 is  $e^{-1.6895}$ , and also the odds ratio of Weight > 215 for Diet group 1 is  $e^{-1.4664}$ .

Since p-value for the intercept and Group are both p-value > 0.05, so we don't reject the null, i.e., there are no significant association between Diet Group 1 and 4 and Categorical Weight without adjusting for BirthWeight.

**(b). Repeat (a) adjusting for Birth Weight. Interpret what the estimated parameters denote.**

Construct a logistic regression model without adjusting for Birth Weight with Weight for Diet group 1 and 4 on day 21. Restructure the data as categorical data type. The response and explanatory variable is like:

$$\text{Weight}_i = \begin{cases} 1 & \text{Weight} > 215 \\ 0 & \text{Weight} \leq 215 \end{cases} \quad \text{Group}_i = \begin{cases} 1 & \text{Diet} = 1 \\ 0 & \text{Diet} = 4 \end{cases}$$

Then the result is as follows:

Logistic Regression with adjust result

Call:

```
glm(formula = Weight ~ Group + BirthWeight, family = "binomial",
    data = sub_day21)
```

Deviance Residuals:

Min	1Q	Median	3Q	Max
-1.3159	-0.7680	-0.4050	0.6028	1.6956

Coefficients:

	Estimate	Std. Error	z value	Pr(> z )
(Intercept)	57.2079	31.1175	1.838	0.0660 .
Group	-1.2935	1.0467	-1.236	0.2165
BirthWeight	-1.3899	0.7567	-1.837	0.0662 .

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Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for binomial family taken to be 1)

Null deviance: 31.343 on 24 degrees of freedom  
 Residual deviance: 22.856 on 22 degrees of freedom  
 AIC: 28.856

Number of Fisher Scoring iterations: 5

The model is:

$$\text{logit}(p) = 57.2079 - 1.2935 * \text{Group} - 1.3899 * \text{BirthWeight}$$

So for Diet group 1 the model is:

$$\text{logit}(p) = 57.2079 - 1.2935 - 1.3899 * \text{BirthWeight}$$

And for Diet group 4 the model is:

$$\text{logit}(p) = 57.2079 - 1.3899 * \text{BirthWeight}$$

There are three parameters here, intercept  $\beta_0$ , and coefficient  $\beta_1$  on Diet group, and coefficient  $\beta_2$  on BirthWeight.

- $\beta_0$  denotes when BirthWeight is given 0, the log odds ratio of Weight > 215 for Diet group 4, i.e., when BirthWeight=0(which is not realistic), the odds ratio of Weight > 215 for Diet group 4 is  $e^{57.2079}$ , and the odds ratio of Weight > 215 for Diet group 4 when given BirthWeight =  $x$  is  $e^{57.2079-1.3899x}$ .
- $\beta_1$  denotes the log odds ratio of Weight > 215 for Diet group 1 relative to Diet Group 4 when given BirthWeight = 0(which is not realistic), i.e., when BirthWeight = 0 odds ratio of Weight > 215 for Diet group 1 relative to Diet Group 4 is  $e^{-1.3899}$ , and odds ratio of Weight > 215 for Diet group 1 when given BirthWeight =  $x$  is  $e^{55.9144-1.3899x}$
- $\beta_2$  denotes under same Diet Group, the change in log odds for Weight > 215 when the BirthWeight is different, i.e., under same Diet Group, 1 unit change in BirthWeight will cause the odds for Weight > 215 in day 21 change  $e^{-1.3899}$ .

Since p-value for the intercept, Group and BirthWeight are all p-value > 0.05, so we don't reject the null, i.e., there are no significant association between Diet Group 1 and 4 and Categorical Weight with adjusting for BirthWeight.

## Problem 2

**Repeat 1 for all 4 Diet Levels.**

**(a). Without adjusting for BirthWeight.**

Construct a logistic regression model without adjusting for Birth Weight with Weight for Diet group 1 and 4 on day 21. Restructure the data as categorical data type. The response and explanatory variable is like:

$$\text{Weight}_i = \begin{cases} 1 & \text{Weight} > 215 \\ 0 & \text{Weight} \leq 215 \end{cases}$$

$$\text{Group1}_i = \begin{cases} 1 & \text{Diet} = 1 \\ 0 & \text{Diet} \neq 1 \end{cases}$$

$$\text{Group2}_i = \begin{cases} 1 & \text{Diet} = 2 \\ 0 & \text{Diet} \neq 2 \end{cases}$$

$$\text{Group3}_i = \begin{cases} 1 & \text{Diet} = 3 \\ 0 & \text{Diet} \neq 3 \end{cases}$$

Then the result is as follows:

Logistic Regression without adjust result

```
Call:
glm(formula = Weight ~ Group1 + Group2 + Group3, family = "binomial",
    data = sub_day21_all)
```

Deviance Residuals:

Min	1Q	Median	3Q	Max
-1.7941	-0.6444	-0.6444	1.0842	1.8297

Coefficients:

	Estimate	Std. Error	z value	Pr(> z )
(Intercept)	0.2231	0.6708	0.333	0.7394
Group1	-1.6895	0.9275	-1.822	0.0685 .
Group2	-0.2231	0.9220	-0.242	0.8088
Group3	1.1632	1.0368	1.122	0.2619

---

Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for binomial family taken to be 1)

Null deviance: 62.183 on 44 degrees of freedom  
 Residual deviance: 51.679 on 41 degrees of freedom  
 AIC: 59.679

Number of Fisher Scoring iterations: 4

The model is:

$$\text{logit}(p) = 0.2231 - 1.6895 * \text{Group1} - 0.2231 * \text{Group2} + 1.1632 * \text{Group3}$$

So for Diet group 1, the model is:

$$\text{logit}(p) = 0.2231 - 1.6895 = -1.4664$$

And for Diet group 2, the model is:

$$\text{logit}(p) = 0.2231 - 0.2231 = 0$$

And for Diet group 3, the model is:

$$\text{logit}(p) = 0.2231 + 1.1632 = 1.3863$$

And for Diet group 4, the model is:

$$\text{logit}(p) = 0.2231$$

There are four parameters here, intercept  $\beta_0$ , and coefficient  $\beta_1$  on Diet group1, coefficient  $\beta_2$  on Diet group2, coefficient  $\beta_3$  on Diet group3.

- $\beta_0$  denotes the log odds ratio of Weight > 215 for Diet group 4, i.e., the odds ratio of Weight > 215 for Diet group 4 is  $e^{0.2231}$ .
- $\beta_1$  denotes the log odds ratio of Weight > 215 for Diet group 1 relative to Diet Group 4, i.e., odds ratio of Weight > 215 for Diet group 1 relative to Diet Group 4 is  $e^{-1.6895}$ , and odds ratio of Weight > 215 for Diet group 1 is  $e^{-1.4664}$ .
- $\beta_2$  denotes the log odds ratio of Weight > 215 for Diet group 2 relative to Diet Group 4, i.e., odds ratio of Weight > 215 for Diet group 2 relative to Diet Group 4 is  $e^{-0.2231}$ , and odds ratio of Weight > 215 for Diet group 2 is  $e^0 = 1$ .

- $\beta_3$  denotes the log odds ratio of Weight > 215 for Diet group 3 relative to Diet Group 4, i.e., odds ratio of Weight > 215 for Diet group 3 relative to Diet Group 4 is  $e^{1.1632}$ , and odds ratio of Weight > 215 for Diet group 3 is  $e^{1.3863}$ .

Since p-value for the intercept, Group1, Group2, Group3 are all p-value > 0.05, so we don't reject the null, i.e., there are no significant association between Diet Group from 1 to 4 and Categorical Weight without adjusting for BirthWeight.

**(b). With adjusting for BirthWeight.**

Construct a logistic regression model without adjusting for Birth Weight with Weight for Diet group 1 and 4 on day 21. Restructure the data as categorical data type. The response and explanatory variable is like:

$$\text{Weight}_i = \begin{cases} 1 & \text{Weight} > 215 \\ 0 & \text{Weight} \leq 215 \end{cases} \quad \text{Group2}_i = \begin{cases} 1 & \text{Diet} = 2 \\ 0 & \text{Diet} \neq 2 \end{cases}$$

$$\text{Group1}_i = \begin{cases} 1 & \text{Diet} = 1 \\ 0 & \text{Diet} \neq 1 \end{cases} \quad \text{Group3}_i = \begin{cases} 1 & \text{Diet} = 3 \\ 0 & \text{Diet} \neq 3 \end{cases}$$

Then the result is as follows:

Logistic Regression with adjust result

Call:

```
glm(formula = Weight ~ Group1 + Group2 + Group3 + BirthWeight,
    family = "binomial", data = sub_day21_all)
```

Deviance Residuals:

Min	1Q	Median	3Q	Max
-2.3302	-0.7262	-0.4018	0.8540	1.7100

Coefficients:

	Estimate	Std. Error	z value	Pr(> z )
(Intercept)	26.3751	14.6987	1.794	0.0728 .
Group1	-1.3805	0.9641	-1.432	0.1522
Group2	-0.3800	0.9932	-0.383	0.7020
Group3	1.1864	1.0707	1.108	0.2678
BirthWeight	-0.6389	0.3582	-1.784	0.0745 .

---

Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for binomial family taken to be 1)

Null deviance: 62.183 on 44 degrees of freedom  
 Residual deviance: 48.021 on 40 degrees of freedom  
 AIC: 58.021

Number of Fisher Scoring iterations: 4

The model is:

$$\text{logit}(p) = 26.3751 - 1.3805 * \text{Group1} - 0.3800 * \text{Group2} + 1.1864 * \text{Group3} - 0.6389 * \text{BirthWeight}$$

So for Diet group 1 the model is:

$$\text{logit}(p) = 26.3751 - 1.3805 - 0.6389 * \text{BirthWeight}$$

And for Diet group 2 the model is:

$$\text{logit}(p) = 26.3751 - 0.3800 - 0.6389 * \text{BirthWeight}$$

And for Diet group 3 the model is:

$$\text{logit}(p) = 26.3751 + 1.1864 - 0.6389 * \text{BirthWeight}$$

And for Diet group 4 the model is:

$$\text{logit}(p) = 26.3751 - 0.6389 * \text{BirthWeight}$$

There are five parameters here, intercept  $\beta_0$ , and coefficient  $\beta_1$  on Diet group1, coefficient  $\beta_2$  on Diet group2, coefficient  $\beta_3$  on Diet group3, and coefficient  $\beta_4$  on BirthWeight.

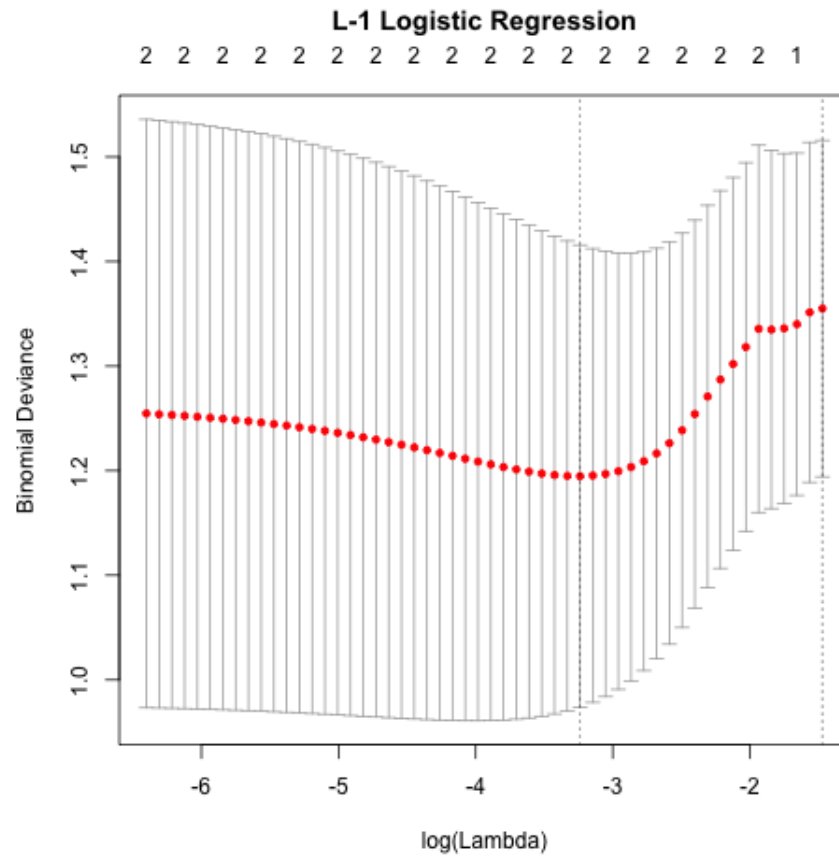
- $\beta_0$  denotes the log odds ratio of Weight > 215 for Diet group 4 under given BirthWeight=0(which is not realistic), i.e., the odds ratio of Weight > 215 for Diet group 4 when BirthWeight=0 is  $e^{26.3751}$ , and the odds ratio of Weight > 215 for Diet group 4 under given BirthWeight =  $x$  is  $e^{26.3751-0.6389x}$ .
- $\beta_1$  denotes the log odds ratio of Weight > 215 for Diet group 1 relative to Diet Group 4, under given BirthWeight=0(which is not realistic), i.e., when BirthWeight=0, odds ratio of Weight > 215 for Diet group 1 relative to Diet Group 4 is  $e^{-1.3805}$ , and under given BirthWeight =  $x$  odds ratio of Weight > 215 for Diet group 1 relative to Diet Group 4 is  $e^{-1.3805-0.6389x}$ .
- $\beta_2$  denotes the log odds ratio of Weight > 215 for Diet group 2 relative to Diet Group 4, under given BirthWeight=0(which is not realistic), i.e., when BirthWeight=0, odds ratio of Weight > 215 for Diet group 2 relative to Diet Group 4 is  $e^{1.1864}$ , and under given BirthWeight =  $x$  odds ratio of Weight > 215 for Diet group 2 relative to Diet Group 4 is  $e^{1.1864-0.6389x}$ .
- $\beta_3$  denotes the log odds ratio of Weight > 215 for Diet group 3 relative to Diet Group 4, under given BirthWeight=0(which is not realistic), i.e., when BirthWeight=0, odds ratio of Weight > 215 for Diet group 2 relative to Diet Group 4 is  $e^{1.1864}$ , and under given BirthWeight =  $x$  odds ratio of Weight > 215 for Diet group 3 relative to Diet Group 4 is  $e^{1.1864-0.6389x}$ .
- $\beta_4$  denotes under same Diet Group, the change in log odds for Weight > 215 when the BirthWeight is changing, i.e., under same Diet Group, 1 unit change in BirthWeight will cause the odds for Weight > 215 in day 21 change  $e^{-0.6389}$ .

Since p-value for the intercept, Group1, Group2, Group3 and BirthWeight are all p-value > 0.05, so we don't reject the null, i.e., there are no significant association between Diet Group from 1 to 4 and Categorical Weight with adjusting for BirthWeight.

## Problem 3

**Repeat 1 using the L-1 regularized logistic regression.**

We should use BirthWeight and Group for L-1 logistic regression. The cross validation plot of choosing best gamma is as follows:



Then, choose the best lambda,  $\lambda = 0.03921473$ , and get the model with the best lambda. The coefficients are as follows:

Coefficients of L-1 Logistic Regression

3 x 1 sparse Matrix of class "dgCMatrix"

```

      1
(Intercept) 39.9300576
BirthWeight -0.9754835
Group       -0.8577307

```

So, the final model is:

$$\text{logit}(p) = 39.9300576 - 0.9754835 * \text{BirthWeight} - 0.8577307 * \text{Group}$$

**R Code:**

```

rm(list=ls())
data("ChickWeight")

#Categorize weight as Weight
ChickWeight$Weight<-rep(0,dim(ChickWeight)[1])
ChickWeight$Weight[ChickWeight$weight>215]<-1

#logistic regression with Diet and Weight on day 21 without adjust for Birth Weight
sub_day21<-subset(ChickWeight,Diet %in% c(1,4) & Time==21)
sub_day21$Group<-rep(0,dim(sub_day21)[1])
sub_day21$Group[sub_day21$Diet==1]<-1
log_day21<-glm(Weight~Group,family="binomial",data=sub_day21)

sink(' /Users/raymond/Drive/STAT W4201/HW7/log_day21.txt')
summary(log_day21)
sink()

BirthWeight<-subset(ChickWeight,select=c(weight,Chick),Time==0)
names(BirthWeight)[names(BirthWeight)=="weight"]<- "BirthWeight"
sub_day21<-merge(sub_day21,BirthWeight,by.y = "Chick")

#logistic regression with Diet and Weight on day 21 with adjust for Birth Weight
log_day21_adjust<-glm(Weight~Group+BirthWeight,family="binomial",data=sub_day21)

sink(' /Users/raymond/Drive/STAT W4201/HW7/log_day21_adjust.txt')
summary(log_day21_adjust)
sink()

#all groups
sub_day21_all<-subset(ChickWeight,Time==21)
sub_day21_all$Group1<-rep(0,dim(sub_day21_all)[1])
sub_day21_all$Group1[sub_day21_all$Diet==1]<-1
sub_day21_all$Group2<-rep(0,dim(sub_day21_all)[1])
sub_day21_all$Group2[sub_day21_all$Diet==2]<-1
sub_day21_all$Group3<-rep(0,dim(sub_day21_all)[1])
sub_day21_all$Group3[sub_day21_all$Diet==3]<-1
log_day21_all<-glm(Weight~Group1+Group2+Group3,family="binomial",data=sub_day21_all)
sink(' /Users/raymond/Drive/STAT W4201/HW7/log_day21_all.txt')
summary(log_day21_all)
sink()

#logistic regression with Diet and Weight on day 21 with adjust for Birth Weight
sub_day21_all<-merge(sub_day21_all,BirthWeight,by.y = "Chick")
log_day21_all_adjust<-glm(Weight~Group1+Group2+Group3+BirthWeight,family="binomial",data=sub_day21_all)
sink(' /Users/raymond/Drive/STAT W4201/HW7/log_day21_all_adjust.txt')
summary(log_day21_all_adjust)
sink()

#L-1 regularized logistic regression with Diet and Weight on day 21 with adjust for Birth Weight
library(glmnet)
data<-as.matrix(subset(sub_day21,select = c("BirthWeight","Group")))
colnames(data)<-c("BirthWeight","Group")
l1log_day21<-glmnet(data,sub_day21$Weight,family="binomial")
cv_l1log_day21<-cv.glmnet(data,sub_day21$Weight,family="binomial")

png(filename = "/Users/raymond/Drive/STAT W4201/HW7/cv_l1log.png")
plot(cv_l1log_day21)
title(main = "L-1 Logistic Regression", line = 2.5)
dev.off()

lambda<-cv_l1log_day21$lambda.min
model<-cv_l1log_day21$glmnet.fit

coeff<-coef(model,lambda)
sink(' /Users/raymond/Drive/STAT W4201/HW7/coefficient.txt')
coeff

```



`sink()`