

# Statistics 305/605: Introduction to Biostatistical Methods for Health Sciences

R Demo for Chapter 18, part 2: Inference in Simple Linear  
Regression

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# Load the Data and Fit the Regression Model

- ▶ Load the data on low-birthweight babies:

```
uu <- url("http://people.stat.sfu.ca/~jgraham/Teaching/S305_17/Data/lbwt.csv")  
lbwt <- read.csv(uu)
```

- ▶ Fit the regression model and print out the fitted regression coefficients:

```
lfit <- lm(headcirc ~ gestage, data=lbwt)  
coefficients(lfit)
```

```
## (Intercept)      gestage  
##    3.9142641    0.7800532
```

- ▶ The regression parameters are estimated by  $\hat{\alpha} = 3.91$  (intercept) and  $\hat{\beta} = 0.78$  (gestage).

## Testing Example

- For the low-birthweight data, the model summary includes the p-value from the tests of  $H_0 : \beta = 0$  vs.  $H_a : \beta \neq 0$

```
summary(lfit)
```

```
##  
## Call:  
## lm(formula = headcirc ~ gestage, data = lbwt)  
##  
## Residuals:  
##      Min       1Q   Median       3Q      Max   
## -3.5358 -0.8760 -0.1458  0.9041  6.9041   
##  
## Coefficients:  
##              Estimate Std. Error t value Pr(>|t|)      
## (Intercept)  3.91426    1.82915   2.14   0.0348 *      
## gestage      0.78005    0.06307  12.37  <2e-16 ***   
## ---  
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1  
##  
## Residual standard error: 1.59 on 98 degrees of freedom  
## Multiple R-squared:  0.6095, Adjusted R-squared:  0.6055   
## F-statistic: 152.9 on 1 and 98 DF,  p-value: < 2.2e-16
```

- ▶ We're interested specifically in the `coefficients` component of the summary.
- ▶ Can extract the `coefficients` component with the `$` operator.

```
summary(lfit)$coefficients
```

```
##              Estimate Std. Error  t value    Pr(>|t|)
## (Intercept) 3.9142641 1.82914689   2.13994 3.48424e-02
## gestage     0.7800532 0.06307441  12.36719 1.00121e-21
```

- ▶ The test statistic value is about 12.37 and the p-value is tiny.
- ▶ Strong statistical evidence for an association between gestational age and head circumference.

# Software Notes

- ▶ The output of the `summary()` function includes a lot of components that we are not yet ready for.
  - ▶ However `summary(lfit)$coefficients` extracts just the coefficients table.
- ▶ Statistics related to a particular coefficient are in the row of the table labelled by the name of the explanatory variable.
  - ▶ E.G., Below the summaries related to the slope of the regression line are in the row labelled `gestage`.

```
summary(lfit)$coefficients
```

```
##           Estimate Std. Error  t value    Pr(>|t|)
## (Intercept) 3.9142641 1.82914689   2.13994 3.48424e-02
## gestage      0.7800532 0.06307441  12.36719 1.00121e-21
```

## CI Example

- ▶ We can use the `confint()` function in R to extract a confidence interval.

```
confint(lfit,conf.level=0.95)
```

```
##                2.5 %    97.5 %  
## (Intercept) 0.2843817 7.5441466  
## gestage     0.6548841 0.9052223
```

- ▶ The 95% CI for  $\beta$  is about (0.65, 0.91).
- ▶ Interpret: “With 95% confidence, we estimate that a one-week increase in gestational age is associated with an increase in head circumference of between 0.65 to 0.91 cm.”

## CI's at Observed Values of Explanatory Variable

- ▶ Use the `predict()` function to get predictions and confidence intervals for each observed value of the explanatory variable.
- ▶ Default coverage probability or level for the CI is  $C = 0.95$

```
lpred <- predict(lfit,interval="confidence")  
head(lpred)
```

```
##           fit          lwr          upr  
## 1 26.53581 26.21989 26.85172  
## 2 28.09591 27.68437 28.50745  
## 3 29.65602 29.05247 30.25956  
## 4 28.09591 27.68437 28.50745  
## 5 27.31586 26.97102 27.66070  
## 6 23.41559 22.83534 23.99584
```

- ▶ In a given row, 1st entry is fitted value  $\hat{y}$ , 2nd entry is lower bound of CI and last entry is upper bound of CI.
- ▶ Attach `lpred` to the corresponding values for  $y$  (`headcirc`) and  $x$  (`gestage`), to create a new R object called `lbwtFits`

...

```
lbwtFits <- data.frame(headcirc=lbwt$headcirc,gestage=lbwt$gestage,lpred)
head(lbwtFits)
```

##	headcirc	gestage	fit	lwr	upr
## 1	27	29	26.53581	26.21989	26.85172
## 2	29	31	28.09591	27.68437	28.50745
## 3	30	33	29.65602	29.05247	30.25956
## 4	28	31	28.09591	27.68437	28.50745
## 5	29	30	27.31586	26.97102	27.66070
## 6	23	25	23.41559	22.83534	23.99584

- ▶ The values of the response,  $y$ , are in the column `headcirc`.
- ▶ The values of the explanatory variable,  $x$ , are in the column `gestage`.
- ▶ The fitted values  $\hat{y}$  are in the column `fit`.
- ▶ The lower limits of the CIs are in the column `lwr` and the upper limits are in the column `upr`.



## 90% CIs at New Values of Explanatory Variable

- ▶ Suppose that we want 90% CI's at new values of the explanatory variable, such as gestage of 25.5 and 30.5 weeks.
- ▶ Create a dataset with the new values of the explanatory variables and pass this to `predict()`.
- ▶ Specify the level of the confidence interval with the `level` argument.

```
newdat <- data.frame(gestage = c(25.5,30.5))  
predict(lfit,newdata = newdat, interval="confidence", level=.90)
```

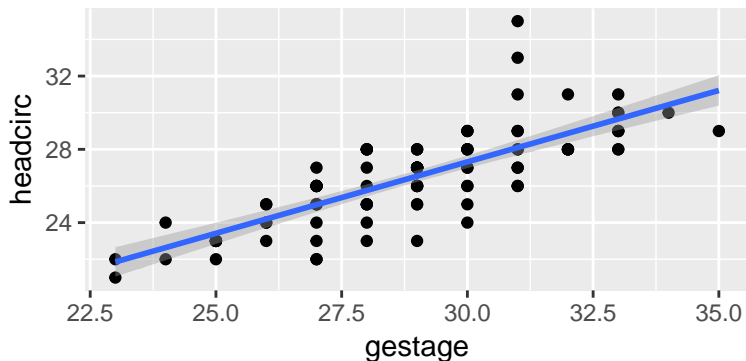
```
##           fit      lwr      upr  
## 1 23.80562 23.36311 24.24813  
## 2 27.70589 27.39254 28.01923
```

- ▶ The fitted values  $\hat{y}$  of `headcirc` for gestages of 25.5 and 30.5 are in the column `fit` and are about 23.8 and 27.7, respectively.
- ▶ The lower limits of the 90% CIs are in the column `lwr` and the upper limits are in the column `upr`.

## Adding CIs to a Scatterplot

- By default, pointwise 95% CIs around the fitted regression line are added by `ggplot() + geom_smooth(method="lm")`

```
library(ggplot2)
ggplot(lbwt, aes(x=gestage,y=headcirc)) +
  geom_point() +
  geom_smooth(method="lm")
```



- ▶ To change the default and add, e.g., pointwise 99% CIs around the fitted regression line, use the argument `level` in `geom_smooth()`:
  - ▶ `geom_smooth(method="lm", level=.99)` for 99% CIs.

```
library(ggplot2)
ggplot(lbwt, aes(x=gestage,y=headcirc)) +
  geom_point() +
  geom_smooth(method="lm", level=.99)
```

