Biost 518 / Biost 515
Applied Biostatistics II / Biostatistics II

Midterm Examination
February 13, 2015

Name: ____

Instructions: This exam is closed book, closed notes. You have 50 minutes. You may not use any device that is capable of accessing the internet.

Please provide concise answers to all questions. Rambling answers touching on topics not directly relevant to the question will tend to count against you. Nearly telegraphic writing style is permissible.

NOTE: When you need to make calculations, always use at least four significant digits in your intermediate calculations, and report at least three significant digits. (Example: 1.045 and 0.0001234 and 1234000 each have four significant digits.)

If you come to a problem that you believe cannot be answered without making additional assumptions, clearly state the reasonable assumptions that you make, and proceed.

Please adhere to and sign the following pledge. Should you be unable to truthfully sign the pledge for any reason, turn in your paper unsigned and discuss the circumstances with the instructor.

PLEDGE:
On my honor, I have neither given nor received unauthorized aid on this examination:

Signed:____

Problems 2 - 7 deal with data from an observational study of lung function and smoking in children. The appendices contain results from selected analyses:

Appendix A : Plots of simulated data (7 scenarios) **(problem 1)**
Appendix B : Description of the variables and descriptive statistics **(all problems 2- 7)**
Appendix C : Regression analyses of height by age **(problems 3 and 4)**
Appendix D : Regression analyses of smoking and sex **(problem 5)**
Appendix E : Regression analyses of smoking, age, and sex **(problem 6)**
Appendix F : Regression analysis of log transformed FEV by smoking, age, and height **(problem 7)**

1. (10 points) **Appendix A** displays 7 scatterplots labeled A - G. In the blanks below, list the plots in order according to lowest (most negative) to highest (most positive) correlation. (In all cases, the scale for the x and y axes are the same.)

Most…………………………………………………………………………………Most
Neg Pos

______ ______ ______ ______ ______ ______ ______

2. **Appendix B** presents descriptive statistics, including a scatterplot of child height versus age (the first of the three scatterplots presented).
   a. (10 points) What observations do you make from the scatterplot regarding the association between height and age?

   b. (5 points) Is there evidence from this plot that sex modifies the height - sex association? **Briefly** explain your reasoning.

   c. (5 points) Does sex confound the description of the height – sex association in the population? **Briefly** explain your reasoning.

3. Suppose we are interested in any association between height and age in pre-pubescent children. **Appendix C** contains the results of linear regression analyses exploring this question among the subjects who are 10 years old or younger..

    a. (5 points) Based on the regression model, what is the best estimate for the mean height in subjects who are 5 years old? (**In this and all problems, whenever the precision of the analysis reports will allow, use at least four significant digits in your calculations, and provide at least three significant digits in your answer, or you will receive no credit.)**

    b. (5 points) Based on the regression model, what is the best estimate for the mean height in subjects who are 6 years old?

    c. (5 points) Based on the regression model, what is the best estimate for the mean height in subjects who are 10 years old?

    d. (5 points) Based on the regression model, what is the best estimate for the difference in mean height between 6 year old subjects and 5 year old subjects?

    e. (5 points) Based on the regression model, what is the best estimate for the difference in mean height between 10 year old subjects and 5 year old subjects?

f. (5 points) Which regression analysis presented in Appendix B would you have chosen *a priori* to make statistical inference about any associations between mean height and age? Why? (A very brief answer should suffice here.)

g. (5 points) Using the regression analysis you identified in part (f), provide a 95% confidence interval for the difference in mean height between two populations who differ in age by 5 years. (Just the numbers, no interpretation necessary here.)

h. (5 points) Provide an interpretation for the intercept in the regression model. What scientific use would you make of this estimate?

i. (5 points) Provide an interpretation for the slope in the regression model. What scientific use would you make of this estimate?

j. (5 points) Is there evidence that there is an association between mean height and age? State your evidence.

k. (5 points) Is there evidence that there is a statistically significant correlation between height and age? State your evidence.

l. (5 points) Can you provide an estimate of the correlation between height and age in this sample? If so, do so. If not, explain why not.

m. (5 points) Based on the regression model, what is the best estimate for the average standard deviation of height within a group that is homogeneous with respect to age?

4. Again using the scatterplot of height versus age in **Appendix A**, answer the following questions.

   a. (5 points) From that plot, comment on the reliability of your estimates of age group specific means in parts (a) through (c) of problem 1.

   b. (5 points) From this plot, comment on the reliability of your answers to the statistical inference you provided in parts (g), (i), and (j) of problem 1.

c. (5 points) From this plot, comment on the reliability of your answers to part (m) of problem 1.

d. (5 points) From this plot, comment on why the difference between the precision of the confidence intervals for the two analyses might have been anticipated.

5. (15 points) Now suppose we are interested in investigating any association between self reported smoking and sex. **Appendix D** contains three regression analyses addressing this question**.**

   a. Using **Model D1**, provide estimates of the probability and odds that boys would report as smokers, and the probability and odds that girls would report as smokers. (I want four numbers: the probability and odds estimates for each sex.)

   b. Using **Model D2**, provide estimates of the probability and odds that boys would report as smokers, and the probability and odds that girls would report as smokers. (I want four numbers: the probability and odds estimates for each sex.)

c. Using **Model D3**, provide estimates of the probability and odds that boys would report as smokers, and the probability and odds that girls would report as smokers. (I want four numbers: the probability and odds estimates for each sex.)

6. **Appendix E** presents regression analyses investigating any association between self reported smoking and age and sex.. Use the results of **Appendices B** and **E** to answer the following questions.

    a. (5 points) Do the results of the available analyses suggest that sex modifies any association between smoking and age? Clearly explain your reasoning.

    b. (5 points) Do the results of the available analyses suggest that sex confounds any association between smoking and age? Clearly explain your reasoning.

    c. (Bonus: 15 points) **As briefly as you can do so while demonstrating your understanding of the scientific interpretation of the models,** describe the correspondences between the estimates and inference obtained in Models E2 and E3 as compared to the estimates and inference in Model E5, and explain how they differ from Models E1 and E4.

7. **Appendix F** presents results of regression analyses exploring an association between FEV and self-reported smoking, potentially adjusted for age and/or height.

   a. (15 points) Provide full inference (methods and results) for the analysis represented by **Model F1**. (You may be brief, but make sure you include the relevant parts.)

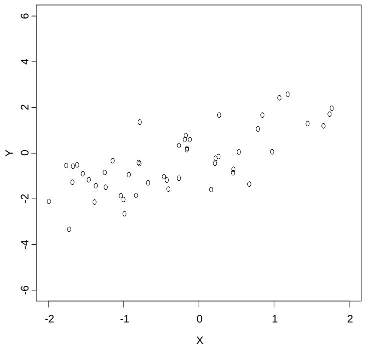
   b. (15 points) Provide brief interpretations of each of the four regression parameters in the regression in **Model F4**. (You do not need to report or interpret the CI, but your answer should include the number and what it means.)

c. (15 points) Although we would truly choose one of the models before looking at the data, it is still instructive to consider the differences between them as they might relate to confounding and precision. Discuss how any confounding and precision might affect the differences between the conclusions you might reach when using **Models F1, F2, F3, and F4.** Be sure to justify your reasoning (in a word or two)

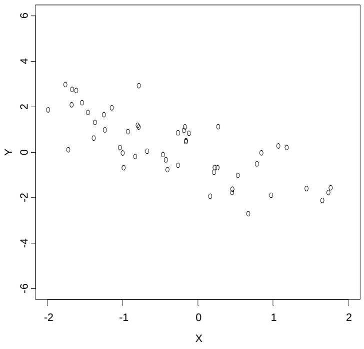
<u>APPENDIX A</u>: Simulated scatterplots.

Below are 7 scatterplots labeled A - G. In all cases, the scale for the x and y axes are the same.

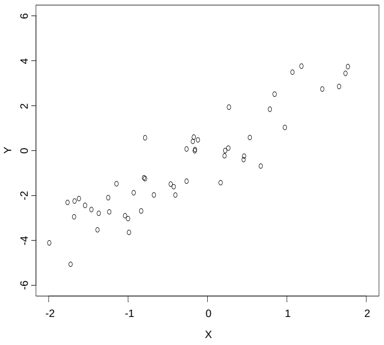
Plot A



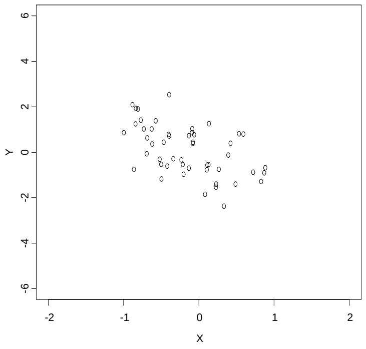
Plot B



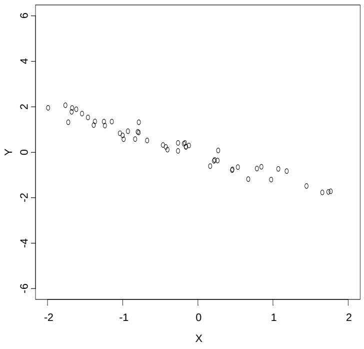
Plot C



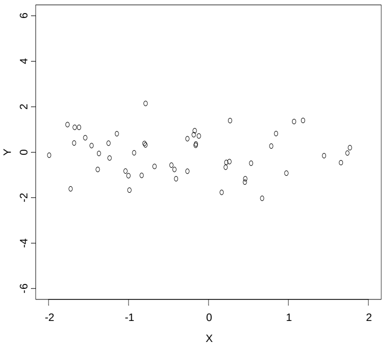
Plot D



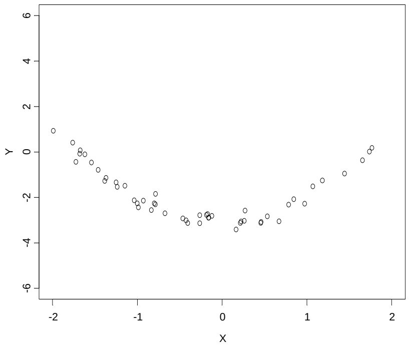
Plot E



Plot F



Plot G



<u>APPENDIX B</u>: Description of variables and descriptive statistics

These data come from an observational study of lung function in a sample of **N= 654** healthy children. Of particular interest is how lung function might vary with respect to self-reported smoking behavior.

age: Age in years of the subject at the time of study enrolment
female: Indicator that the subject is male (**0**= male, **1**= female)
height: Height in age of the subject at the time of study enrolment.
smoker: Indicator that the subject self-reports as a smoker (**0**= nonsmoker, **1**= smoker)
fev: Forced expiratory volume (FEV) in liters/sec (FEV= the volume of air that can be expired in 1 second with maximal effort.

The following table presents cross tabulation of the children's self reported smoking behavior by sex. The table contains counts, as well as percentage calculated both by row and column.

```
. tabulate smoker female, row col

+-------------------+
| Key               |
|-------------------|
|     frequency     |
|  row percentage   |
| column percentage |
+-------------------+

           |        female
    smoker |         0          1 |     Total
-----------+----------------------+----------
         0 |       310        279 |       589
           |     52.63      47.37 |    100.00
           |     92.26      87.74 |     90.06
-----------+----------------------+----------
         1 |        26         39 |        65
           |     40.00      60.00 |    100.00
           |      7.74      12.26 |      9.94
-----------+----------------------+----------
     Total |       336        318 |       654
           |     51.38      48.62 |    100.00
           |    100.00     100.00 |    100.00
```

APPENDIX B (cont.): **Description of variables and descriptive statistics**

The following tables present descriptive statistics for the above variables within strata defined by subject sex, self-reported smoking behavior, and for the entire sample. There is no missing data for any variable. Descriptive statistics include the sample size (N), sample mean, standard deviation (sd), minimum (min), 25th percentile (p25), median (p50), 75th percentile (p75) and maximum (max).:

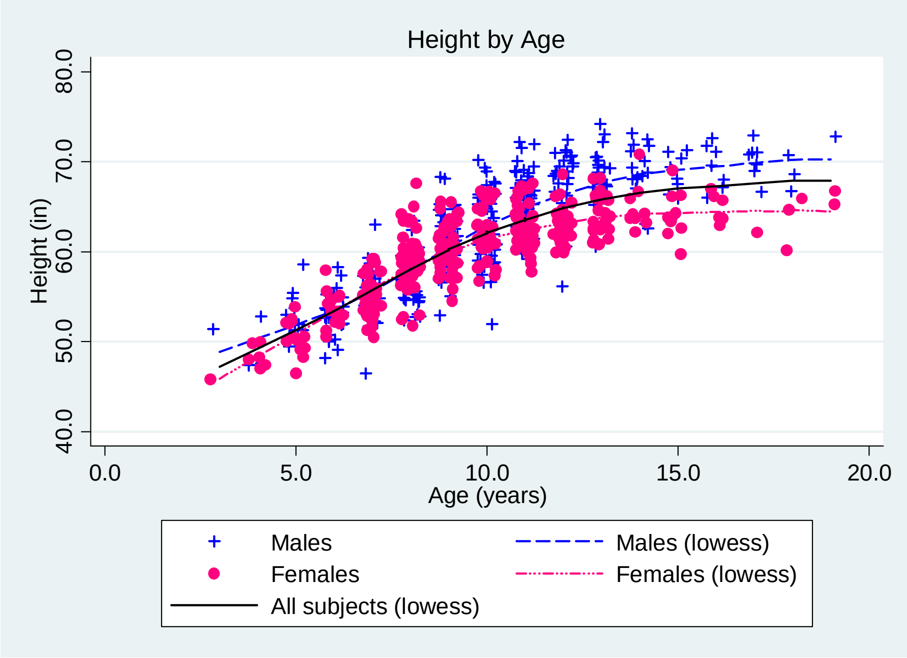
```
. tabstat age height fev, by(female) stat(n mean sd min q max) col(stat) long

female vrbl |       N   mean    sd     min       p25       p50       p75       max
------------+---------------------------------------------------------------------
0       age |     336  10.01   2.976     3         8        10        12        19
     height |     336  62.03   6.33     47        57        62      67.5        74
        fev |     336  2.812   1.004   .796     2.007     2.606     3.540     5.793
------------+---------------------------------------------------------------------
1       age |     318  9.843   2.933     3         8        10        12        19
     height |     318  60.21   4.792    46      57.5        61      63.5        71
        fev |     318  2.451   .6457   .791     1.947     2.486     2.993     3.835
------------+---------------------------------------------------------------------
Total   age |     654  9.931   2.954     3         8        10        12        19
     height |     654  61.14   5.704    46        57      61.5      65.5        74
        fev |     654  2.637   .8671   .791     1.979     2.548    3.12       5.793
----------------------------------------------------------------------------------
```

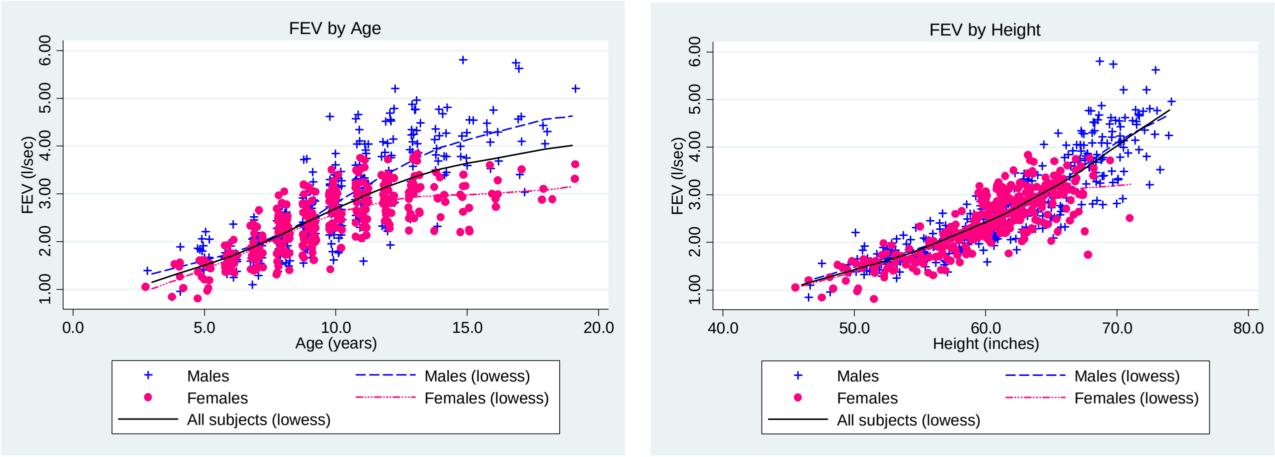
```
. tabstat age height fev, by(smoker) stat(n mean sd min q max) col(stat) long

smoker vrbl |       N   mean    sd     min       p25       p50       p75       max
------------+---------------------------------------------------------------------
0       age |     589  9.535  2.741      3         8         9        11        19
     height |     589  60.61  5.672     46        57        61      64.5        74
        fev |     589  2.566  .8505    .791      1.92     2.465     3.048     5.793
------------+---------------------------------------------------------------------
1       age |      65  13.52  2.339      9        12        13        15        19
     height |      65  65.95  3.193     58      63.5        66        68        72
        fev |      65  3.277  .7500   1.694     2.795     3.169     3.751     4.872
------------+---------------------------------------------------------------------
Total   age |     654  9.931   2.954     3         8        10        12        19
     height |     654  61.14   5.704    46        57      61.5      65.5        74
        fev |     654  2.637   .8671   .791     1.979     2.548    3.12       5.793
----------------------------------------------------------------------------------
```

<u>APPENDIX B (cont.)</u>:
Scatterplot of height versus age within sex strata (with superimposed lowess smooths by sex and overall).



Scatterplots of FEV versus age (left panel) and height (right panel) within sex strata (with superimposed lowess smooths by sex and overall).



APPENDIX C: Linear regression analyses of height by age in children who are 10 years old or younger.

```
######## MODEL C1

. regress height age if age <= 10

      Source |       SS       df       MS              Number of obs =     390
-------------+------------------------------           F(  1,   388) =  650.69
       Model |  5556.01834     1  5556.01834           Prob > F      =  0.0000
    Residual |  3313.00025   388  8.53866044           R-squared     =  0.6265
-------------+------------------------------           Adj R-squared =  0.6255
       Total |  8869.01859   389  22.7995336           Root MSE      =  2.9221

------------------------------------------------------------------------------
      height |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         age |   2.282997    .089499    25.51   0.000     2.107033    2.458961
       _cons |   39.82337   .7306722    54.50   0.000      38.3868    41.25995
------------------------------------------------------------------------------
```

```
######## MODEL C2

. regress height age if age <= 10, robust

Linear regression                                      Number of obs =     390
                                                       F(  1,   388) =  761.73
                                                       Prob > F      =  0.0000
                                                       R-squared     =  0.6265
                                                       Root MSE      =  2.9221

------------------------------------------------------------------------------
             |               Robust
      height |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         age |   2.282997   .0827192    27.60   0.000     2.120363    2.445631
       _cons |   39.82337   .6410044    62.13   0.000      38.5631    41.08365
------------------------------------------------------------------------------
```

<u>APPENDIX D</u>: Regression analyses of self reported smoking behavior score by sex.

```
######## MODEL D1
. regress smoker female, robust

Linear regression                                      Number of obs =     654
                                                       F(  1,   652) =    3.71
                                                       Prob > F      =  0.0546
                                                       R-squared     =  0.0057
                                                       Root MSE      =  .29878
             |               Robust
      smoker |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
      female |   .0452606   .0235061     1.93   0.055    -.0008962    .0914173
       _cons |    .077381    .014599     5.30   0.000     .0487142    .1060477
------------------------------------------------------------------------------
```

```
######## MODEL D2
. poisson smoker female, robust

Poisson regression                                Number of obs   =        654
                                                  Wald chi2(1)    =       3.65
                                                  Prob > chi2     =     0.0560
Log pseudolikelihood = -213.37548                 Pseudo R2       =     0.0079
             |               Robust
      smoker |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
      female |   .4605249   .2409782     1.91   0.056    -.0117838    .9328336
       _cons |  -2.559015   .1885197   -13.57   0.000    -2.928507   -2.189523
------------------------------------------------------------------------------
```

```
######## MODEL D3
. logit smoker female

Logistic regression                               Number of obs   =        654
                                                  LR chi2(1)      =       3.75
                                                  Prob > chi2     =     0.0527
Log likelihood = -209.84678                       Pseudo R2       =     0.0089
      smoker |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
      female |   .5108256   .2662942     1.92   0.055    -.0111014    1.032753
       _cons |  -2.478476   .2041748   -12.14   0.000    -2.878651     -2.0783
------------------------------------------------------------------------------
```

```
. logistic smoker female

Logistic regression                               Number of obs   =        654
                                                  LR chi2(1)      =       3.75
                                                  Prob > chi2     =     0.0527
Log likelihood = -209.84678                       Pseudo R2       =     0.0089
      smoker | Odds Ratio   Std. Err.      z    P>|z|     [95% Conf. Interval]
      female |   1.666667   .4438236     1.92   0.055       .98896    2.808787
       _cons |    .083871   .0171243   -12.14   0.000     .0562105    .1251427
------------------------------------------------------------------------------
```

APPENDIX E: Regression analyses of self reported smoking behavior by age and sex.

```
######## MODEL E1 : FEMALES

. logistic smoker age

Logistic regression                               Number of obs   =        654
                                                  LR chi2(1)      =     104.88
                                                  Prob > chi2     =     0.0000
Log likelihood = -159.28248                       Pseudo R2       =     0.2477
      smoker | Odds Ratio   Std. Err.      z    P>|z|     [95% Conf. Interval]
         age |   1.621967   .0894154     8.77   0.000     1.455852    1.807036
       _cons |   .0004334   .0003072   -10.92   0.000      .000108    .0017389
------------------------------------------------------------------------------

######## MODEL E2 : MALES

. logistic smoker age if female==0

Logistic regression                               Number of obs   =        336
                                                  LR chi2(1)      =      46.77
                                                  Prob > chi2     =     0.0000
Log likelihood = -68.118663                       Pseudo R2       =     0.2555
      smoker | Odds Ratio   Std. Err.      z    P>|z|     [95% Conf. Interval]
         age |   1.629525   .1337891     5.95   0.000     1.387314    1.914024
       _cons |   .0002709   .0002982    -7.46   0.000     .0000313    .0023434
------------------------------------------------------------------------------

######## MODEL E3 : FEMALES
. logistic smoker age if female==1

Logistic regression                               Number of obs   =        318
                                                  LR chi2(1)      =      61.29
                                                  Prob > chi2     =     0.0000
Log likelihood = -87.699186                       Pseudo R2       =     0.2590
      smoker | Odds Ratio   Std. Err.      z    P>|z|     [95% Conf. Interval]
         age |   1.669165    .132741     6.44   0.000     1.428259    1.950704
       _cons |   .0004415   .0004361    -7.82   0.000     .0000637    .0030605
------------------------------------------------------------------------------

######## MODEL E4 : Adjusted for sex
. logistic smoker age female

Logistic regression                               Number of obs   =        654
                                                  LR chi2(2)      =     111.77
                                                  Prob > chi2     =     0.0000
Log likelihood = -155.83995                       Pseudo R2       =     0.2639
      smoker | Odds Ratio   Std. Err.      z    P>|z|     [95% Conf. Interval]
         age |   1.650156   .0941799     8.78   0.000     1.475516    1.845465
      female |   2.209876   .6810666     2.57   0.010     1.207909     4.04298
       _cons |   .0002296   .0001804   -10.66   0.000     .0000492    .0010711
------------------------------------------------------------------------------
```

APPENDIX E: Regression analyses of self reported smoking behavior by age and sex. (cont'd)

```
######## MODEL E5 : Adjusted for sex and a multiplicative age-sex interaction

. g ageF= age*female
. logistic smoker age female ageF

Logistic regression                               Number of obs   =        654
                                                  LR chi2(3)      =     111.81
                                                  Prob > chi2     =     0.0000
Log likelihood = -155.81785                       Pseudo R2       =     0.2641
      smoker | Odds Ratio   Std. Err.      z    P>|z|     [95% Conf. Interval]
         age |   1.629525   .1337891     5.95   0.000     1.387314    1.914024
      female |   1.629672   2.410434     0.33   0.741     .0897626    29.58727
        ageF |   1.024326   .1170837     0.21   0.833     .8187345    1.281543
       _cons |   .0002709   .0002982    -7.46   0.000     .0000313    .0023434
------------------------------------------------------------------------------


. logit smoker age female ageF


Logistic regression                               Number of obs   =        654
                                                  LR chi2(3)      =     111.81
                                                  Prob > chi2     =     0.0000
Log likelihood = -155.81785                       Pseudo R2       =     0.2641
      smoker |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
         age |   .4882888   .0821031     5.95   0.000     .3273696     .649208
      female |   .4883787   1.479091     0.33   0.741    -2.410587    3.387344
        ageF |   .0240346   .1143032     0.21   0.833    -.1999955    .2480647
       _cons |   -8.21374   1.100836    -7.46   0.000    -10.37134   -6.056142
----------------------------------------------------------------------------------
```

APPENDIX F: Regression analyses of FEV by self-reported smoking behavior, age, and height among children ages 9 and older. In all cases, the response variable is a logarithmic transformation of FEV, and regression coefficients are exponentiated:

```
. g logfev= log(fev)


######## MODEL F1 : Unadjusted

. regress logfev smoker if age >= 9, robust eform("exp(Beta)")

Linear regression                                      Number of obs =     439
                                                       F(  1,   437) =   10.45
                                                       Prob > F      =  0.0013
                                                       R-squared     =  0.0212
                                                       Root MSE      =  .24765

------------------------------------------------------------------------------
             |               Robust
      logfev |  exp(Beta)   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      smoker |   1.107722   .0350638     3.23   0.001     1.040907    1.178825
       _cons |   2.881095   .0372627    81.82   0.000     2.808782     2.95527
------------------------------------------------------------------------------

######## MODEL F2 : Adjusted for age

. regress logfev smoker age if age >= 9, robust eform("exp(Beta)")

Linear regression                                      Number of obs =     439
                                                       F(  2,   436) =   82.28
                                                       Prob > F      =  0.0000
                                                       R-squared     =  0.3012
                                                       Root MSE      =  .20949

------------------------------------------------------------------------------
             |               Robust
      logfev |  exp(Beta)   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      smoker |   .9499466   .0326613    -1.49   0.136     .8878744    1.016358
         age |   1.065661   .0054776    12.37   0.000      1.05495    1.076482
       _cons |   1.421648   .0817463     6.12   0.000     1.269728    1.591744
------------------------------------------------------------------------------
```

APPENDIX F: (cont'd)

```
######## MODEL F3 : Adjusted for height

. regress logfev smoker height if age >= 9, robust eform("exp(Beta)")

Linear regression                                      Number of obs =     439
                                                       F(  2,   436) =  378.04
                                                       Prob > F      =  0.0000
                                                       R-squared     =  0.6458
                                                       Root MSE      =  .14914

------------------------------------------------------------------------------
             |               Robust
      logfev |  exp(Beta)   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      smoker |   .9865713   .0228252    -0.58   0.559     .9427149    1.032468
      height |   1.051825    .001985    26.77   0.000     1.047931    1.055734
       _cons |   .1155044   .0138017   -18.06   0.000     .0913281    .1460807
------------------------------------------------------------------------------

######## MODEL F4 : Adjusted for age, height

. regress logfev smoker age height if age >= 9, robust eform("exp(Beta)")

Linear regression                                      Number of obs =     439
                                                       F(  3,   435) =  278.58
                                                       Prob > F      =  0.0000
                                                       R-squared     =  0.6695
                                                       Root MSE      =  .14424

------------------------------------------------------------------------------
             |               Robust
      logfev |  exp(Beta)   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      smoker |   .9492467   .0229181    -2.16   0.032     .9052547    .9953766
         age |   1.021596   .0035316     6.18   0.000     1.014679    1.028561
      height |   1.045851   .0021099    22.22   0.000     1.041713    1.050006
       _cons |   .1309207   .0153144   -17.38   0.000     .1040306    .1647613
------------------------------------------------------------------------------
```