Analysis of Covariance (ANCOVA) Example
Sex and Depression with Physical Impairment as a Covariate

This example illustrates the equivalence of the regression and ANCOVA approaches to investigating whether sex differences in depression still exist after taking into account differences in physical functioning (activities of daily living or ADLs). Because the approaches are statistically equivalent, there would never be any need to do both analyses. Also, I used a hierarchical regression here to illustrate the change after adding the covariate but there is absolutely no need to use hierarchical entry.[1]

SPSS Syntax
ANCOVA[2]

```
*the EMMEANS normally produces estimated (i.e., observed) means but adding the WITH statement and the
covariate name and MEAN gives adjusted means.
GLM w1cesd9 BY w1sex WITH w1adldif
/EMMEANS=TABLES(w1sex) with (w1adldif=mean).
```

Between-Subjects Factors

		Value Label	N
A1-sex of R	.00	male	345
	1.00	female	561

Tests of Between-Subjects Effects

Dependent Variable: 9-item CES-D

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	3449.219[a]	2	1724.610	81.348	<.001
Intercept	4653.014	1	4653.014	219.479	<.001
w1adldif	3325.773	1	3325.773	156.874	<.001
w1sex	10.426	1	10.426	.492	.483
Error	19143.882	903	21.200		
Total	46195.953	906			
Corrected Total	22593.102	905			

a. R Squared = .153 (Adjusted R Squared = .151)

Estimated Marginal Means

A1-sex of R

Dependent Variable: w1cesd9 9-item CES-D

			95% Confidence Interval	
A1-sex of R	Mean	Std. Error	Lower Bound	Upper Bound
.00 male	4.966 [a]	.249	4.477	5.455
1.00 female	5.189 [a]	.195	4.806	5.572

a. Covariates appearing in the model are evaluated at the following values: w1adldif Total ADL difficulty (mean) = .6043.

Regression

```
*center w1adldiff.
*aggregate command finds the mean of the sample which can be used in the subsequent computation.
aggregate  /madldif=MEAN(w1adldif).
compute cw1adldif=w1adldif - madldif.
*use a descriptives to check if centered.

regression vars=w1cesd9 w1sex cw1adldif
    /descriptives=mean stdev n sig corr
    /statistics=anova r coeff ses cha
    /dependent=w1cesd9
    /method=enter w1sex /enter cw1adldif.
```

[1] These data come from the Later Life Study of Social Exchanges (LLSSE) Sorkin, D. H., & Rook, K. S. (2004). Interpersonal control strivings and vulnerability to negative social exchanges in later life. *Psychology and Aging, 19*(4), 555–564. https://10.1037/0882-7974.19.4.555. Newsom, J. T., Rook, K. S., Nishishiba, M., Sorkin, D. H., & Mahan, T. L. (2005). Understanding the relative importance of positive and negative social exchanges: Examining specific domains and appraisals. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences, 60*(6), P304-P312.
[2] GLM does not print the regression coefficient, so you could use MANOVA to obtain it.

```
manova w1cesd9 by w1sex(0,1) with w1adldif
  /print=signif(efsize)
  /design.
```

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.074[a]	.005	.004	4.98556	.005	4.966	1	904	.026
2	.391[b]	.153	.151	4.60438	.147	156.874	1	903	.000

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	123.446	1	123.446	4.966	.026[b]
	Residual	22469.655	904	24.856		
	Total	22593.102	905			
2	Regression	3449.219	2	1724.610	81.348	.000[c]
	Residual	19143.882	903	21.200		
	Total	22593.102	905			

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients		t	Sig.
		B	Std. Error	Beta	Std. Error		
1	(Constant)	4.633	.268			17.262	.000
	w1sex A1-sex of R	.760	.341	.074	.033	2.229	.026
2	(Constant)	4.984	.249			19.980	.000
	w1sex A1-sex of R	.223	.318	.022	.031	.701	.483
	cw1adldif	3.135	.250	.387	.031	12.525	.000

a. Dependent Variable: w1cesd9 9-item CES-D

R Code

ANCOVA

```
> library(car)
> ancova_model <- aov(w1cesd9 ~ w1sex + w1adldif, data=d)
> Anova(ancova_model, type="III")
Anova Table (Type III tests)

Response: w1cesd9
             Sum Sq  Df  F value               Pr(>F)
(Intercept)  2597.8   1 122.5377 <0.0000000000000002 ***
w1sex          10.4   1   0.4918               0.4833
w1adldif     3325.8   1 156.8738 <0.0000000000000002 ***
Residuals   19143.9 903
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
>
> #adjusted means
> library(emmeans)
> marginal = emmeans(ancova_model, ~ w1sex)
> summary(marginal)
 w1sex emmean    SE  df lower.CL upper.CL
     0   4.97 0.249 903     4.48     5.46
     1   5.19 0.195 903     4.81     5.57

Confidence level used: 0.95
```

Regression

```
> #listwise deletion to make sure each regression model has same n
> d = d[complete.cases(d[,c("w1sex","w1cesd9","w1adldif")]),]
> #always check to make sure this worked
> #summary(d)

> #listwise deletion to make sure each regression model has same n when centering
> d = d[complete.cases(d[,c("w1sex","w1cesd9","w1adldif")]),]
> #center (create deviation scores of) the covariate first
> d$cadldif <- scale(d$w1adldif, center = TRUE, scale = FALSE)
> #always check to make sure this worked
> #summary(d)
>
> #hierarchical regression using base R function lm
> model1 = lm(w1cesd9~w1sex, data=d)
> model2 = lm(w1cesd9~w1sex + cadldif, data=d)
> summary(model1)

Call:
lm(formula = w1cesd9 ~ w1sex, data = d)

Residuals:
```

```
   Min     1Q Median     3Q    Max
-5.394 -3.633 -1.394  2.367 20.606
Coefficients:
            Estimate Std. Error t value            Pr(>|t|)
(Intercept)   4.6334     0.2684  17.262 <0.0000000000000002
w1sex         0.7602     0.3411   2.229              0.0261

Residual standard error: 4.986 on 904 degrees of freedom
Multiple R-squared:  0.005464,	Adjusted R-squared:  0.004364
F-statistic: 4.966 on 1 and 904 DF,  p-value: 0.02609

> summary(model2)

Call:
lm(formula = w1cesd9 ~ w1sex + cadldif, data = d)

Residuals:
    Min      1Q  Median      3Q     Max
-11.446  -3.072  -1.021   1.869  21.719

Coefficients:
            Estimate Std. Error t value            Pr(>|t|)
(Intercept)   4.9660     0.2493  19.919 <0.0000000000000002
w1sex         0.2230     0.3179   0.701               0.483
cadldif       3.1350     0.2503  12.525 <0.0000000000000002

Residual standard error: 4.604 on 903 degrees of freedom
Multiple R-squared:  0.1527,	Adjusted R-squared:  0.1508
F-statistic: 81.35 on 2 and 903 DF,  p-value: < 0.00000000000000022

> # test change in R-sq for adding cadldif, if desired
> #manually compute change in R-sq for adding cadldif, if desired
> deltr2 = summary(model2)$r.squared - summary(model1)$r.squared
> deltr2
[1] 0.147203

> #test R-sq for significance
> anova(model1,model2)
Analysis of Variance Table

Model 1: w1cesd9 ~ w1sex
Model 2: w1cesd9 ~ w1sex + cadldif
  Res.Df   RSS Df Sum of Sq      F                Pr(>F)
1    904 22470
2    903 19144  1    3325.8 156.87 < 0.00000000000000022
```

Write-up

I illustrate a write-up of both methods here, but there would never be a reason to do a regression analysis and an ANCOVA to test the same hypothesis.

ANCOVA Results

An analysis of covariance (ANCOVA) was conducted to test for mean differences between men and women on depression after controlling for physical impairment. Descriptive statistics indicated that women had higher depression scores than men, with M = 5.394 and M = 4.633, respectively. The results for the ANCOVA, however, indicated that there was no gender difference once physical impairment was controlled for, $F(1,903) = .49$, $p = .48$. The adjusted means indicated a small difference between male (M = 4.97) and female (M = 5.19) depression scores once physical impairment was taken into account. The covariate, physical impairment, was significantly related to depression, however, B = 3.135, 95% CI[2.64,3.62], SE = .250, $\beta = .387$, $p < .001$. Both independent variables together accounted for approximately 15% of the variance in depression, $R^2 = .153$, $F(2,903) = 81.35$, $p < .001$.

Regression Results

A multiple regression model was tested to examine whether gender was related to depression after controlling for physical impairment. Although previous analyses showed that gender had a significant association with depression without controlling for other factors, gender was no longer significant once physical functioning was included in the model, B = .223, SE = .318, $\beta = .022$, $p = .48$. The unstandardized coefficient indicated that women had a mean depression score that was only .223 points higher than the mean depression score for men. Physical impairment was a significant predictor of depression, however, B = 3.135, 95% CI[2.64,3.62], SE = .250, $\beta = .387$, $p < .001$, indicating that depression scores were approximately three points higher for each unit increase of the physical impairment scale. The standardized coefficient suggested that this was a moderate effect. Approximately 15% of the variance in depression was accounted for by both predictors considered together, $R^2 = .153$, $F(2,903) = 81.35$, $p < .001$.