Name ______Hongqian Qin________

EDUC 880 Midterm
Fall 2019

Complete the analyses requested below. Please construct and turn in along with your exam the items in **boldface**. Answer all questions. Include any code and output you think necessary for me to understand what you did.

1. (10 pts) I would like you to run a *2 group x 4 time* repeated measures ANOVA on the dependent variable husbands' marital adjustment (`HMADJ1, HMADJ2, HMADJ3, HMADJ4`), where a high score is better. Use the seven error structures that we discussed in class. Assume equal spacing of the repeated measures. Make sure to pick the best error structure. **Table** the AIC and BIC for each error structure you try. The data are in the file, famdata1.nomiss.dat. The data can be read by the SAS program, madjust.midterm.sas. For R the data with header are in the file, famdata1.midterm.forR.dat.

	AIC	BIC
Compound Symmetry	2698.8	2704.2
Autoregressive	2689.1	2694.5
Toeplitz	2684.4	2695.2
Unstructured	2687.0	2714.0
Heterogeneous Compound Symmetry	2699.7	2713.2
Heterogeneous Autoregressive	2691.6	2705.1
Heterogeneous Toeplitz	2686.5	2705.4

Toeplitz has the smallest AIC , and Autogressive has the smallest BIC. They are very similar. Because for the model with fewer parameters we prefer BIC, in this question, we choose Autogressive (AR(1)) as the best error structure

A. **Table the ANOVA** results for the omnibus tests for the model with the best error structure. **Table the parameters** from the error structure. **Table the means** (main effects and interaction means).

Based on the model with Autoregressive error structure, we get the table of ANOVA:

Type 3 Tests of Fixed Effects				
Effect	Num DF	Den DF	F Value	Pr > F
GRP	1	108	0.04	0.8390
time0	3	324	20.81	<.0001
GRP*time0	3	324	0.10	0.9589

Parameter estimate(s):

Covariance Parameter Estimates		
Cov Parm	Subject	Estimate
AR(1)	ID	0.6642
Residual		42.0999

Means :

Least Squares Means							
Effect	GRP	time0	Estimate	Standard Error	DF	t Value	Pr > |t|
GRP	1		17.9615	0.6468	108	27.77	<.0001
GRP	2		17.7556	0.7774	108	22.84	<.0001
time0		0	19.7128	0.6291	324	31.33	<.0001
time0		1	16.2444	0.6291	324	25.82	<.0001
time0		2	16.4838	0.6291	324	26.20	<.0001
time0		3	18.9932	0.6291	324	30.19	<.0001
GRP*time0	1	0	19.6923	0.8048	324	24.47	<.0001
GRP*time0	1	1	16.4000	0.8048	324	20.38	<.0001
GRP*time0	1	2	16.5231	0.8048	324	20.53	<.0001
GRP*time0	1	3	19.2308	0.8048	324	23.90	<.0001
GRP*time0	2	0	19.7333	0.9672	324	20.40	<.0001
GRP*time0	2	1	16.0889	0.9672	324	16.63	<.0001
GRP*time0	2	2	16.4444	0.9672	324	17.00	<.0001
GRP*time0	2	3	18.7556	0.9672	324	19.39	<.0001

B. What do you conclude regarding differences among the means based on the above table? Which effects are significant? Which would you follow up?

Only Time effect is significant. The other main effect group and the interaction between the two main effects are not significant in this problem. Therefore, I will follow up the time effect.

C. Depending on the results of the omnibus tests, use followup contrasts to better describe how the means are different.

For your contrasts I would like you to use polynomial contrast coefficients for the 4 occasion time effect in your followup contrasts:

	Time 1	Time 2	Time 3	Time 4
Linear	-3	-1	1	3
Quadratic	1	-1	-1	1
Cubic	-1	3	-3	1

Remember that you can apply these coefficients to the time effect regardless of whether you follow up a main effect for time or an interaction effect including time.
Table the contrast results.

Contrasts				
Label	**Num DF**	**Den DF**	**F Value**	**Pr > F**
linear	1	324	0.58	0.4472
quadratic	1	324	60.46	<.0001
cubic	1	324	1.09	0.2969

What do you conclude?
We conclude that the Time Effect fits the quadratic relationship, which means if we increase the time, the means will be decreased until a certain point. And after that, the time effect will have a positive effect on the means.

2. (10 pts) Fit a straight line growth curve model through the same data also assuming equal spacing.

Table you results

<table>
<tr><td></td><td></td><td>BIC</td></tr>
<tr><td>random intercepts no grouping factor</td><td>
<table>
<tr><th colspan="5">Type 3 Tests of Fixed Effects</th></tr>
<tr><th>Effect</th><th>Num DF</th><th>Den DF</th><th>F Value</th><th>Pr > F</th></tr>
<tr><td>time0</td><td>1</td><td>329</td><td>0.88</td><td>0.3480</td></tr>
</table>
</td><td>2773.1</td></tr>
<tr><td>random intercepts and slopes no grouping factor</td><td>
<table>
<tr><th colspan="5">Type 3 Tests of Fixed Effects</th></tr>
<tr><th>Effect</th><th>Num DF</th><th>Den DF</th><th>F Value</th><th>Pr > F</th></tr>
<tr><td>time0</td><td>1</td><td>362</td><td>0.48</td><td>0.4885</td></tr>
</table>
</td><td>2819.6</td></tr>
<tr><td>random intercepts with grouping factor</td><td>
<table>
<tr><th colspan="5">Type 3 Tests of Fixed Effects</th></tr>
<tr><th>Effect</th><th>Num DF</th><th>Den DF</th><th>F Value</th><th>Pr > F</th></tr>
<tr><td>GRP</td><td>1</td><td>182</td><td>0.00</td><td>0.9943</td></tr>
<tr><td>time0</td><td>1</td><td>328</td><td>0.97</td><td>0.3257</td></tr>
<tr><td>time0*GRP</td><td>1</td><td>328</td><td>0.11</td><td>0.7360</td></tr>
</table>
</td><td>2771.0</td></tr>
<tr><td>random intercepts and slopes with grouping factor</td><td>
<table>
<tr><th colspan="5">Type 3 Tests of Fixed Effects</th></tr>
<tr><th>Effect</th><th>Num DF</th><th>Den DF</th><th>F Value</th><th>Pr > F</th></tr>
<tr><td>GRP</td><td>1</td><td>422</td><td>0.00</td><td>0.9921</td></tr>
<tr><td>time0</td><td>1</td><td>358</td><td>0.53</td><td>0.4688</td></tr>
<tr><td>time0*GRP</td><td>1</td><td>358</td><td>0.06</td><td>0.8038</td></tr>
</table>
</td><td>2817.6</td></tr>
</table>

Compare these results to the results for the linear trend with equal spacing above. What do you conclude? Do you two methods agree or differ?

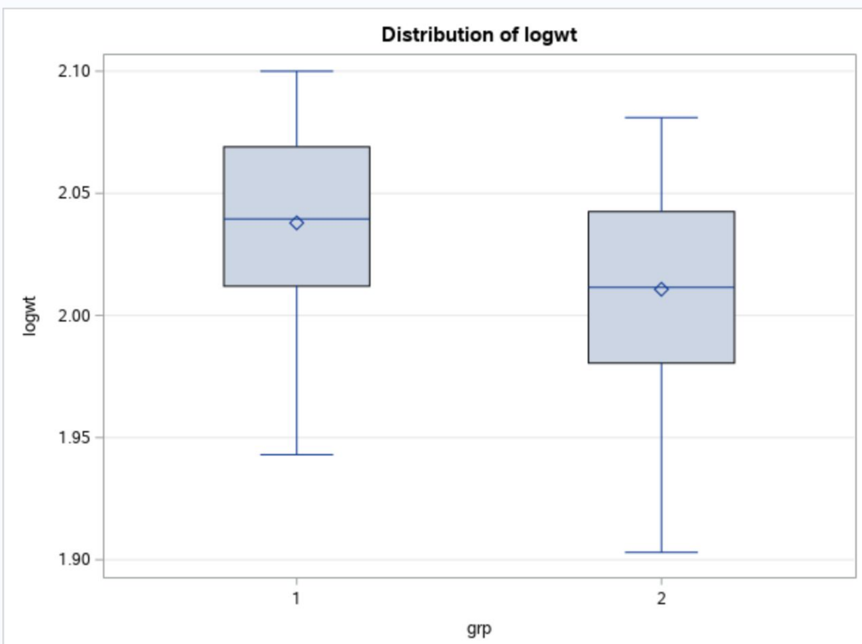
My results show that neither group effect, time effect or their interaction is significant in this problem.

My two methods differ.

3. (10 pts.) I've included 16 cases of cow growth data (5 occasions of weight gain) along with a grouping variable that indicates whether or not the cow is ill. The program to read these data (along with the data) is located in the file, cow.sas. You also have the data with a header, cowdata.forR.dat that can be used in R. Remember that the dependent variable which is measured on five equally spaced occasions is the scaled log of the cow's weight. The log of the true cow weight over this period follows a curve. We've looked at growth curves and repeated measures ANOVA in class. I would like you to use repeated measures ANOVA to model these data. Followup the omnibus test using the complete set of polynomial contrasts coefficients (linear, quadratic, cubic, and quartic) for 5 occasions of data (available in the file, Handouts first 3 weeks.pdf) to identify how the means are different. **Compare the results** obtained through the contrasts to what you would have learned if you had only looked at the ANOVA omnibus tests. **Table the omnibus tests and the contrast results** (you can cut and paste to do this). **Table the means and plot the means for the two groups**.

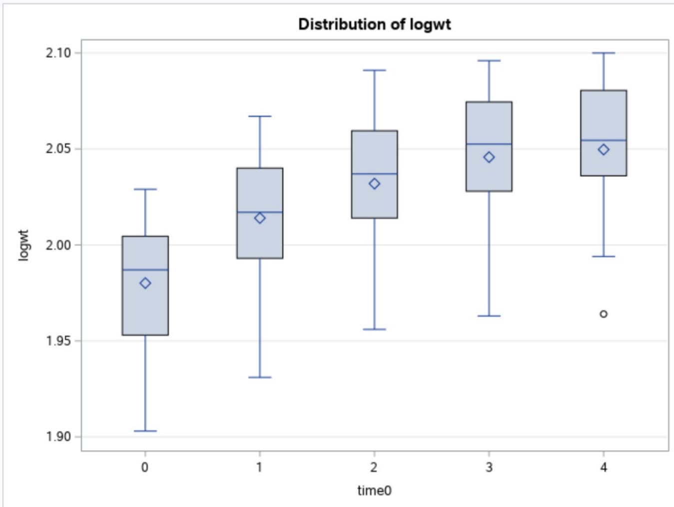
For the omnibus test you should be completing the following steps:

Group Effect:



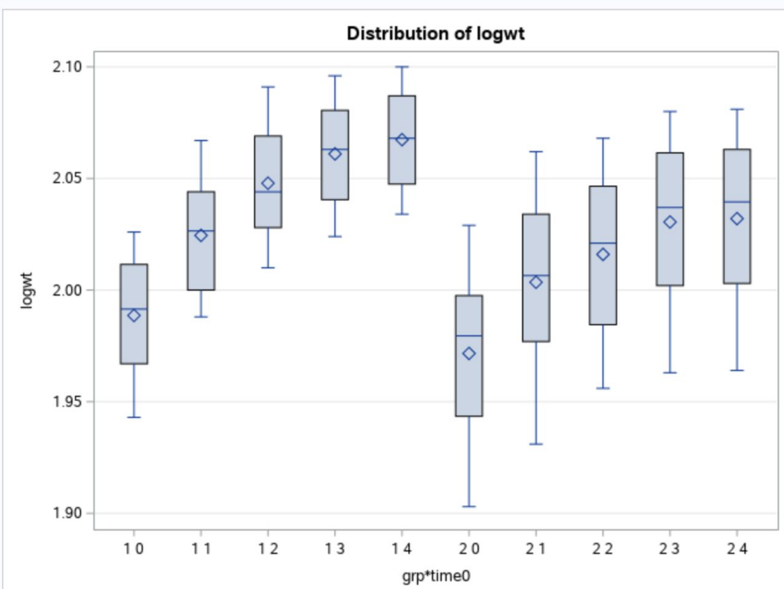
Level of grp	N	logwt Mean	logwt Std Dev
1	40	2.03787500	0.03842087
2	40	2.01072500	0.04386634

Time Effect:



Level of time0	N	logwt Mean	Std Dev
0	16	1.98012500	0.03480397
1	16	2.01400000	0.03554153
2	16	2.03193750	0.03616899
3	16	2.04575000	0.03561928
4	16	2.04968750	0.03656906

Interaction of Group and Time



Level of grp	Level of time0	N	logwt Mean	Std Dev
1	0	8	1.98862500	0.02866026
1	1	8	2.02450000	0.02707133
1	2	8	2.04787500	0.02743531
1	3	8	2.06100000	0.02521338
1	4	8	2.06737500	0.02418936
2	0	8	1.97162500	0.04011390
2	1	8	2.00350000	0.04149699
2	2	8	2.01600000	0.03834058
2	3	8	2.03050000	0.03938818
2	4	8	2.03200000	0.03956550

(1) **Table** the means

Least Squares Means							
Effect	grp	time0	Estimate	Standard Error	DF	t Value	Pr > |t|
grp	1		2.0379	0.01184	14	172.13	<.0001
grp	2		2.0107	0.01184	14	169.84	<.0001
time0		0	1.9801	0.008461	56	234.03	<.0001
time0		1	2.0140	0.008461	56	238.04	<.0001
time0		2	2.0319	0.008461	56	240.16	<.0001
time0		3	2.0458	0.008461	56	241.79	<.0001
time0		4	2.0497	0.008461	56	242.26	<.0001
grp*time0	1	0	1.9886	0.01197	56	166.20	<.0001
grp*time0	1	1	2.0245	0.01197	56	169.20	<.0001
grp*time0	1	2	2.0479	0.01197	56	171.15	<.0001
grp*time0	1	3	2.0610	0.01197	56	172.25	<.0001
grp*time0	1	4	2.0674	0.01197	56	172.78	<.0001
grp*time0	2	0	1.9716	0.01197	56	164.78	<.0001
grp*time0	2	1	2.0035	0.01197	56	167.44	<.0001
grp*time0	2	2	2.0160	0.01197	56	168.48	<.0001
grp*time0	2	3	2.0305	0.01197	56	169.70	<.0001
grp*time0	2	4	2.0320	0.01197	56	169.82	<.0001

(2) **Select the error structure** (describe briefly how you made this selection)

	AIC	BIC
Compound Symmetry	-449.1	-447.6
Autoregressive	-454.2	-452.7
Toeplitz	-452.2	-448.4
Unstructured	-443.7	-432.1
Heterogeneous Compound Symmetry	-443.9	-439.3
Heterogeneous Autoregressive	-447.9	-443.3

We select the model with error structure of autogressive because it has the least AIC and BIC

(3) Run the analysis with the best error structure and **table the results** including the covariance

matrix of the residuals and the Type III F-tests for each of the effects.

Covariance Parameter Estimates		
Cov Parm	**Subject**	**Estimate**
AR(1)	cowid	0.9867
Residual		0.001145

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
grp	1	14	2.63	0.1272
time0	4	56	223.29	<.0001
grp*time0	4	56	5.30	0.0011

Both time effect and the interaction effect are significant

For the contrasts use the best error structure from above. Run the contrasts making sure that you select the correct degrees of freedom for each contrast. You need the omnibus test results to get these. Remember what the default df will be. For some of the contrasts you may have to change from the default. What do the ANOVA contrasts tell you about how the cows are changing?

Estimates					
Label	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**
Linear (time)	0.1709	0.006962	56	24.54	<.0001
Quadratic (time)	-0.06400	0.004373	56	-14.64	<.0001
Cubic (time)	0.006062	0.002766	56	2.19	0.0326
Quartic (time)	-0.01756	0.006185	56	-2.84	0.0063
Linear (grp*time)	0.04625	0.01392	56	3.32	0.0016
Quadratic (grp*time)	-0.01050	0.008746	56	-1.20	0.2350
Cubic (grp*time)	-0.00062	0.005532	56	-0.11	0.9104
Quartic (grp*time)	0.03763	0.01237	56	3.04	0.0036

The contrast tells us the time effect could conduct either linear, quadratic, or quartic relationship to the cows' health. The interaction effect between group and time conduct either linear or quartic relationship to the cows' health.

4. (10 pts) Use a different set of contrasts to determine at what point sick cows diverge from healthy cows in terms of their weight gain. Use the following contrasts:

1) Is the difference between occasions 1 and 2 for healthy cows different than the different for the same two occasions for sick cows.
2) Repeat the test for occasions 1 and 3
3) Repeat the test for occasions 1 and 4
4) Repeat the test for occasions 1 and 5

Table your results.

Estimates					
Label	Estimate	Standard Error	DF	t Value	Pr > |t|
interaction followup 1: Occation 1, 2	0.004000	0.002757	56	1.45	0.1524
interaction followup 2: Occation 1, 3	0.01487	0.003886	56	3.83	0.0003
interaction followup 3: Occation 1, 4	0.01350	0.004743	56	2.85	0.0062
interaction followup 4: Occation 1, 5	0.01837	0.005459	56	3.37	0.0014

What do you conclude?

Followup 1 are insignificant, while followup 2, 3, 4 are significant. Which means the difference between occasions 1, 3, the difference between occasions 1, 4, and the difference between occasions 1, 5 for healthy cows significantly different than difference for the same two occasions for sick cows.

5. (10 pts) For the cow data, fit a quadratic growth curve model. That means that your model should include:

grp time grp*time time^2 grp*time^2

Select among the following error structures:

Intercept only
Intercept time
Intercept time time^2
Intercept time^2

Plot the curve for each group.

Table your results.

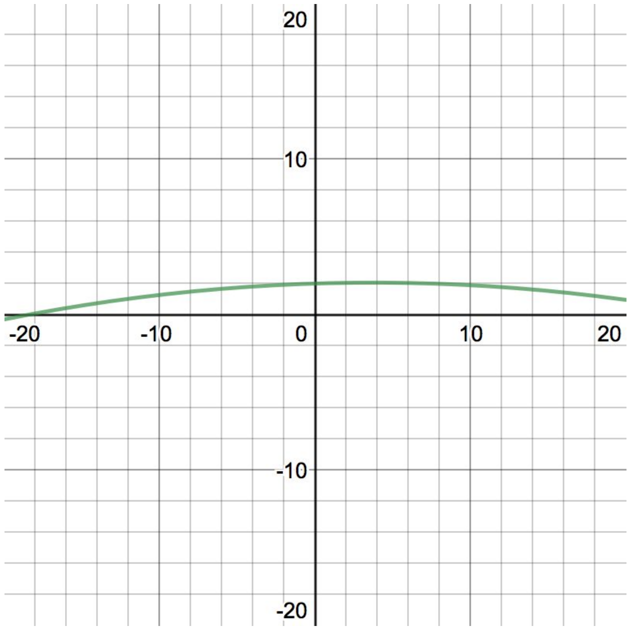
	AIC	BIC
Intercept only	-470.6	-469.1
Intercept time	-439.7	-426.5
Intercept time time^2	-472.0	-467.4
Intercept time^2	-475.6	-472.6

Intercept time^2 has the smallest AIC and BIC. Hence, I would choose that kind of error structure.

Solution for Fixed Effects						
Effect	grp	Estimate	Standard Error	DF	t Value	Pr > |t|
Intercept		1.9728	0.01227	14.2	160.76	<.0001
grp	1	0.01640	0.01735	14.2	0.94	0.3605
grp	2	0	.	.	.	.
time0		0.03156	0.001593	46	19.81	<.0001
time0*grp	1	0.007625	0.002253	46	3.38	0.0015
time0*grp	2	0	.	.	.	.
time0sq		-0.00420	0.000413	59.8	-10.17	<.0001
time0sq*grp	1	-0.00075	0.000583	59.8	-1.29	0.2036
time0sq*grp	2	0	.	.	.	.

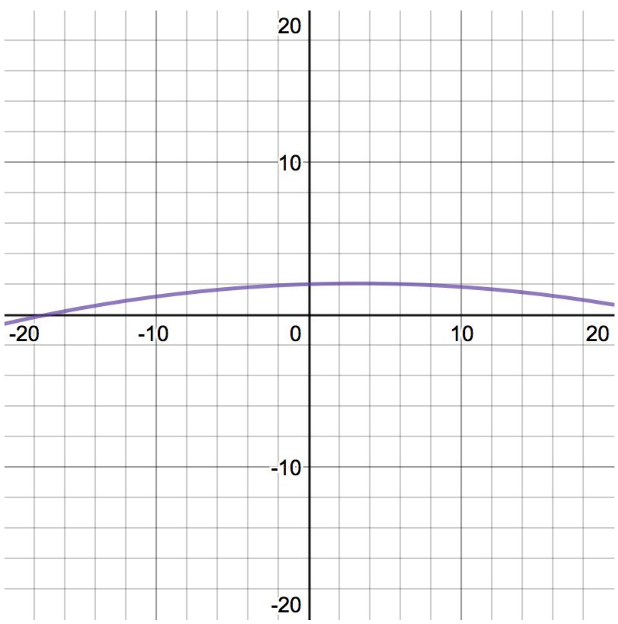
$y = 1.9728 + 0.0164\ \text{group} + 0.03156\ \text{time} + 0.007625\ \text{time*group} - 0.0042\ \text{time}^2 - 0.00075\ \text{grp*time}^2$

Group 1 (healthy): $y = 1.9728 + 0.03156\ \text{time} - 0.0042\ \text{time}^2$



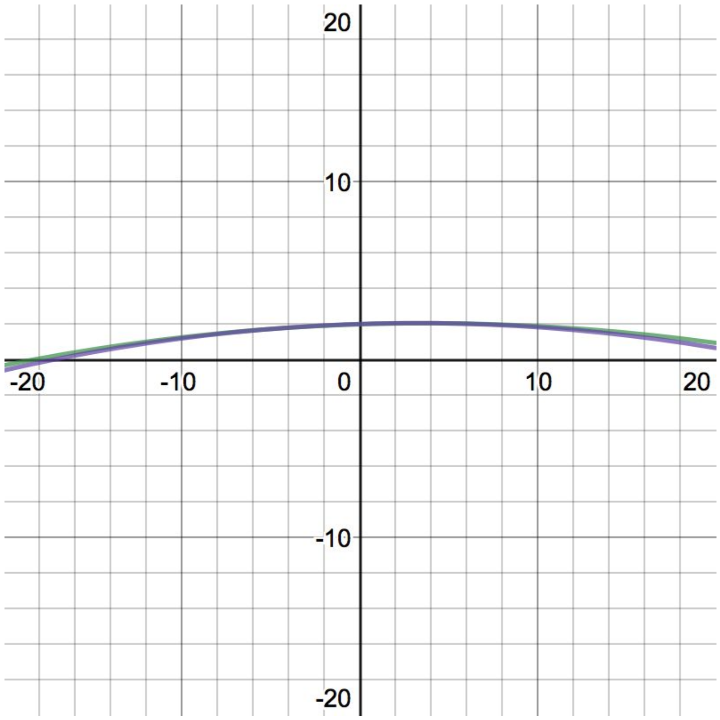
Plot of the Group 1

Group 2 (ill): $y = 1.9892+0.03156\ \text{time}-0.00495\ \text{time}^2$



Plot of the Group 2

What do you conclude?



By combining the two plots above, we see that they are almost the same. That indicates they have the same pattern, which means for either the healthy group or the ill group, the time factor conduct almost the same effect on the expectation of the weights of the cows.

Appendix:

SAS Code:

```
 :
OPTIONS LINESIZE=72 NODATE;
DATA FINALDAT;
INFILE '/folders/myfolders/sasuser.v94/famdata1.nomiss.dat';
INPUT ID 1-4 GRP 6 HJOBS1 11-15 HJOBS2 16-20 HJOBS3 21-25 HJOBS4 26-30
                HHAP1 31-35 HHAP2 36-40 HHAP3 41-45 HHAP4 46-50
#2               WMADJ1 11-15 WMADJ2 16-20 WMADJ3 21-25 WMADJ4 26-30
               HMADJ1 31-35 HMADJ2 36-40 HMADJ3 41-45 HMADJ4 46-50;


 HMADJ=HMADJ1; time0=0; output;
 HMADJ=HMADJ2; time0=1; output;
```

```
 HMADJ=HMADJ3; time0=2; output;
 HMADJ=HMADJ4; time0=3; output;
run;



proc glm;
  class ID GRP time0;
  model HMADJ = GRP ID(GRP) time0 GRP*time0;
  means GRP time0 GRP*time0;
  test h=GRP
       e=ID(GRP);
  random ID(GRP)/test;
run;

 proc mixed;
 class ID GRP time0;
 model HMADJ=GRP time0 GRP*time0 / s ;
 repeated time0 / type=cs sub=ID r rcorr;
 lsmeans GRP time0 GRP*time0;
 *lsmeans grp time0 grp*time0/ diff;
 run;

 proc mixed;
 class ID GRP time0;
 model HMADJ=GRP time0 time0*GRP / s ;
 repeated time0 / type=ar(1) sub=ID r rcorr;
 lsmeans GRP time0 GRP*time0;
 *lsmeans grp time0 grp*time0/ diff;
 run;

 proc mixed;
 class ID GRP time0;
 model HMADJ=GRP time0 time0*GRP / s ;
 repeated time0 / type=toep sub=ID r rcorr;
 lsmeans GRP time0 GRP*time0;
 *lsmeans grp time0 grp*time0/ diff;
 run;

 proc mixed;
 class ID GRP time0;
 model HMADJ=GRP time0 time0*GRP / s ;
 repeated time0 / type=un sub=ID r rcorr;
 lsmeans GRP time0 GRP*time0;
 *lsmeans grp time0 grp*time0/ diff;
```

```
 run;

 proc mixed;
 class ID GRP time0;
 model HMADJ=GRP time0 time0*grp / s ;
 repeated time0 / type=csh sub=id r rcorr;
 lsmeans grp time0 grp*time0;
 *lsmeans grp time0 grp*time0/ diff;
 run;

 proc mixed;
 class ID GRP time0;
 model HMADJ=GRP time0 time0*GRP / s ;
 repeated time0 / type=arh(1) sub=ID r rcorr;
 lsmeans GRP time0 GRP*time0;
 *lsmeans grp time0 grp*time0/ diff;
 run;

 proc mixed;
 class ID GRP time0;
 model HMADJ=GRP time0 time0*GRP / s ;
 repeated time0 / type=toeph sub=ID r rcorr;

 proc mixed covtest;
 class ID GRP time0;
 model HMADJ= GRP time0 time0*GRP / s ;
 repeated time0 / type=ar(1) sub=ID r rcorr;
 lsmeans time0;
 * followup contrasts;
 contrast 'linear'     time0 -3 -1 1 3/ e;
 contrast 'quadratic'  time0 1 -1 -1 1/ e;
 contrast 'cubic'      time0 -1 3 -3 1/ e;

 run;


* random intercepts no grouping factor;
proc mixed covtest;
 class ID;
 model HMADJ=time0 / ddfm=kenwardroger s;
 random intercept / type=ar(1) subject=ID g gcorr s;
run;

* random intercepts and slopes no grouping factor;
proc mixed covtest;
```

```
 class ID;
 model HMADJ=time0 / ddfm=kenwardroger s;
 random intercept time0/ type=ar(1) subject=ID g gcorr s;
run;


* random intercepts with grouping factor;
proc mixed covtest;
 class ID GRP;
 model HMADJ=GRP time0 GRP*time0/ ddfm=kenwardroger s;
 random intercept / type=ar(1) subject=ID g gcorr s;
 lsmeans GRP;
run;

* random intercepts and slopes with grouping factor;
proc mixed covtest;
 class ID GRP;
 model HMADJ=GRP time0 GRP*time0/ ddfm=kenwardroger s;
 random intercept time0/ type=ar(1) subject=ID g gcorr s;
 lsmeans GRP;
run;
```

Q3:

```
options linesize=72;
data cows;
infile cards;
input cowid grp logwt1 logwt2 logwt3
    logwt4 logwt5;
   logwt=logwt1; time0=0; output;
   logwt=logwt2; time0=1; output;
   logwt=logwt3; time0=2; output;
   logwt=logwt4; time0=3; output;
   logwt=logwt5; time0=4; output;
 * group 1 = well   2 = ill;
cards;
  1 1  1.957   1.998   2.019   2.032   2.034
  2 1  2.026   2.067   2.091   2.096   2.100
  3 1  2.014   2.043   2.068   2.079   2.080
  4 1  2.009   2.045   2.070   2.082   2.085
  5 1  1.986   2.024   2.037   2.056   2.056
  6 1  1.943   1.988   2.010   2.024   2.042
  7 1  1.977   2.002   2.037   2.049   2.053
  8 1  1.997   2.029   2.051   2.070   2.089
  9 2  2.029   2.062   2.068   2.080   2.081
 10 2  1.903   1.931   1.956   1.963   1.964
```

```
 11 2  1.938   1.972   1.979   1.993   1.994
 12 2  2.000   2.037   2.049   2.067   2.068
 13 2  1.949   1.982   1.990   2.011   2.012
 14 2  1.995   2.031   2.044   2.056   2.058
 15 2  1.988   2.010   2.024   2.037   2.038
 16 2  1.971   2.003   2.018   2.037   2.041
;
run;
proc glm;
  class cowid grp time0;
  model logwt = grp cowid(grp) time0 grp*time0;
  means grp time0 grp*time0;
  test h=grp
       e=cowid(grp);
  random cowid(grp)/test;
run;

 proc mixed;
 class cowid grp time0;
 model logwt=grp time0 grp*time0 / s ;
 repeated time0 / type=cs sub=cowid r rcorr;
 lsmeans grp time0 grp*time0;
 *lsmeans grp time0 grp*time0/ diff;
 run;

 proc mixed;
 class cowid grp time0;
 model logwt=grp time0 time0*grp / s ;
 repeated time0 / type=ar(1) sub=cowid r rcorr;
 lsmeans grp time0 grp*time0;
 *lsmeans grp time0 grp*time0/ diff;
 run;

 proc mixed;
 class cowid grp time0;
 model logwt=grp time0 time0*grp / s ;
 repeated time0 / type=toep sub=cowid r rcorr;
 lsmeans grp time0 grp*time0;
 *lsmeans grp time0 grp*time0/ diff;
 run;

 proc mixed;
 class cowid grp time0;
 model logwt=grp time0 time0*grp / s ;
 repeated time0 / type=un sub=cowid r rcorr;
```

```
lsmeans grp time0 grp*time0;
*lsmeans grp time0 grp*time0/ diff;
run;

proc mixed;
class cowid grp time0;
model logwt=grp time0 time0*grp / s ;
repeated time0 / type=csh sub=cowid r rcorr;
lsmeans grp time0 grp*time0;
*lsmeans grp time0 grp*time0/ diff;
run;

proc mixed;
class cowid grp time0;
model logwt=grp time0 time0*grp / s ;
repeated time0 / type=arh(1) sub=cowid r rcorr;
lsmeans grp time0 grp*time0;
*lsmeans grp time0 grp*time0/ diff;
run;

proc mixed;
class cowid grp time0;
model logwt=grp time0 time0*grp / s ;
repeated time0 / type=toeph sub=cowid r rcorr;
run;

proc mixed covtest;
class cowid grp time0;
model logwt=grp time0 time0*grp / s ;
repeated time0 / type=ar(1) sub=cowid r rcorr;
lsmeans grp time0 grp*time0;
* followup contrasts;
estimate 'Linear'     time0 -2 -1  0  1  2/ e;
estimate 'Quadratic'  time0 2 -1 -2 -1  2/ e;
estimate 'Cubic'      time0 -1 2 0 -2 1/ e;
estimate 'Quartic'    time0 1 -4 6 -4 1/e;
estimate 'Linear'     grp*time0 -2 -1 0 1 2 2 1 0 -1 -2/ e;
estimate 'Quadratic'  grp*time0 2 -1 -2 -1 2 -2 1 2 1 -2/ e;
estimate 'Cubic'      grp*time0 -1 2 0 -2 1 1 -2 0 2 -1/ e;
estimate 'Quartic'    grp*time0 1 -4 6 -4 1 -1 4 -6 4 -1/e;
run;
```

Q5:

```
options linesize=72;
data cows;
infile cards;
input cowid grp logwt1 logwt2 logwt3
    logwt4 logwt5;
   logwt=logwt1; time0=0; output;
   logwt=logwt2; time0=1; output;
   logwt=logwt3; time0=2; output;
   logwt=logwt4; time0=3; output;
   logwt=logwt5; time0=4; output;
 * group 1 = well   2 = ill;
cards;
  1 1  1.957   1.998   2.019   2.032   2.034
  2 1  2.026   2.067   2.091   2.096   2.100
  3 1  2.014   2.043   2.068   2.079   2.080
  4 1  2.009   2.045   2.070   2.082   2.085
  5 1  1.986   2.024   2.037   2.056   2.056
  6 1  1.943   1.988   2.010   2.024   2.042
  7 1  1.977   2.002   2.037   2.049   2.053
  8 1  1.997   2.029   2.051   2.070   2.089
  9 2  2.029   2.062   2.068   2.080   2.081
 10 2  1.903   1.931   1.956   1.963   1.964
 11 2  1.938   1.972   1.979   1.993   1.994
 12 2  2.000   2.037   2.049   2.067   2.068
 13 2  1.949   1.982   1.990   2.011   2.012
 14 2  1.995   2.031   2.044   2.056   2.058
 15 2  1.988   2.010   2.024   2.037   2.038
 16 2  1.971   2.003   2.018   2.037   2.041
;
run;
proc glm;
  class cowid grp time0;
  model logwt = grp cowid(grp) time0 grp*time0;
  means grp time0 grp*time0;
  test h=grp
       e=cowid(grp);
  random cowid(grp)/test;
run;

 proc mixed;
 class cowid grp time0;
 model logwt=grp time0 grp*time0 / s ;
 repeated time0 / type=cs sub=cowid r rcorr;
 lsmeans grp time0 grp*time0;
 *lsmeans grp time0 grp*time0/ diff;
```

```
run;

proc mixed;
class cowid grp time0;
model logwt=grp time0 time0*grp / s ;
repeated time0 / type=ar(1) sub=cowid r rcorr;
lsmeans grp time0 grp*time0;
*lsmeans grp time0 grp*time0/ diff;
run;

proc mixed;
class cowid grp time0;
model logwt=grp time0 time0*grp / s ;
repeated time0 / type=toep sub=cowid r rcorr;
lsmeans grp time0 grp*time0;
*lsmeans grp time0 grp*time0/ diff;
run;

proc mixed;
class cowid grp time0;
model logwt=grp time0 time0*grp / s ;
repeated time0 / type=un sub=cowid r rcorr;
lsmeans grp time0 grp*time0;
*lsmeans grp time0 grp*time0/ diff;
run;

proc mixed;
class cowid grp time0;
model logwt=grp time0 time0*grp / s ;
repeated time0 / type=csh sub=cowid r rcorr;
lsmeans grp time0 grp*time0;
*lsmeans grp time0 grp*time0/ diff;
run;

proc mixed;
class cowid grp time0;
model logwt=grp time0 time0*grp / s ;
repeated time0 / type=arh(1) sub=cowid r rcorr;
lsmeans grp time0 grp*time0;
*lsmeans grp time0 grp*time0/ diff;
run;

proc mixed;
class cowid grp time0;
model logwt=grp time0 time0*grp / s ;
```

```
 repeated time0 / type=toeph sub=cowid r rcorr;
 run;

 proc mixed covtest;
 class cowid grp time0;
 model logwt=grp time0 time0*grp / s ;
 repeated time0 / type=ar(1) sub=cowid r rcorr;
 lsmeans grp time0 grp*time0;
 * followup contrasts;
 estimate 'Linear'     time0 -2 -1  0  1  2/ e;
 estimate 'Quadratic'  time0 2 -1 -2 -1  2/ e;
 estimate 'Cubic'      time0 -1 2 0 -2 1/ e;
 estimate 'Quartic'    time0 1 -4 6 -4 1/e;
 estimate 'Linear'     grp*time0 -2 -1 0 1 2 2 1 0 -1 -2/ e;
 estimate 'Quadratic'  grp*time0 2 -1 -2 -1 2 -2 1 2 1 -2/ e;
 estimate 'Cubic'      grp*time0 -1 2 0 -2 1 1 -2 0 2 -1/ e;
 estimate 'Quartic'    grp*time0 1 -4 6 -4 1 -1 4 -6 4 -1/e;
 run;
```

Q4:

```
 proc mixed;
 class cowid grp time0;
 model logwt=grp time0 time0*grp /s;
 repeated time0 / type=ar(1) sub=cowid r rcorr;
 lsmeans grp time0 grp*time0
 contrast 'group 1 vs group 2'grp 1 -1 / df=14 e;
 estimate 'interaction followup1: Occation 1,2' grp*time0 -1 1 0 0 0 / e;
 estimate 'interaction followup2: Occation 1,3' grp*time0 -1 0 1 0 0 / e;
 estimate 'interaction followup3: Occation 1,4' grp*time0 -1 0 0 1 0 / e;
 estimate 'interaction followup4: Occation 1,5' grp*time0 -1 0 0 0 1 / e;
 run;
```

Q5:

```
options linesize=72 nodate;
data;
infile cards;
input id grp dep1 dep2 dep3 dep4 dep5;
time0=0; time0sq=0; dep=dep1; output;
time0=1; time0sq=1; dep=dep2; output;
time0=2; time0sq=4; dep=dep3; output;
time0=3; time0sq=9; dep=dep4; output;
time0=4; time0sq=16;dep=dep5; output;
* grp is gender with 1 = female 2 = male;
cards;
```

```
 1 1  1.957   1.998   2.019   2.032   2.034
 2 1  2.026   2.067   2.091   2.096   2.100
 3 1  2.014   2.043   2.068   2.079   2.080
 4 1  2.009   2.045   2.070   2.082   2.085
 5 1  1.986   2.024   2.037   2.056   2.056
 6 1  1.943   1.988   2.010   2.024   2.042
 7 1  1.977   2.002   2.037   2.049   2.053
 8 1  1.997   2.029   2.051   2.070   2.089
 9 2  2.029   2.062   2.068   2.080   2.081
10 2  1.903   1.931   1.956   1.963   1.964
11 2  1.938   1.972   1.979   1.993   1.994
12 2  2.000   2.037   2.049   2.067   2.068
13 2  1.949   1.982   1.990   2.011   2.012
14 2  1.995   2.031   2.044   2.056   2.058
15 2  1.988   2.010   2.024   2.037   2.038
16 2  1.971   2.003   2.018   2.037   2.041
;
run;


proc mixed covtest;
 class id grp;
 model dep=grp time0 grp*time0 time0sq grp*time0sq/ ddfm=kenwardroger s;
 random intercept / type=un subject=id g gcorr s;
run;

proc mixed covtest;
 class id grp time0;
 model dep=grp time0 grp*time0 time0sq grp*time0sq/ ddfm=kenwardroger s;
 random intercept time0 / type=un subject=id g gcorr s;
run;

proc mixed covtest;
 class id grp;
 model dep=grp time0 grp*time0 time0sq grp*time0sq/ ddfm=kenwardroger s;
 random intercept time0 time0sq/ type=un subject=id g gcorr s;
run;


proc mixed covtest;
 class id grp;
 model dep=grp time0 grp*time0 time0sq grp*time0sq/ ddfm=kenwardroger s;
 random intercept time0sq/ type=un subject=id g gcorr s;
run;
```