BMI Health Study

Naive Regression

```
/********************* bmi1.sas *************************/
options linesize=79 noovp formdlim=' ';
title 'BMI and Health: Read data and analyze ignoring measurement error';

data health;
     infile 'bmihealth2.data';
     input age1 bmi1 fat1 cholest1 diastol1
           age2 bmi2 fat2 cholest2 diastol2;
           /* fat1 and fat2 are percent body fat */
     age = (age1+age2)/2; bmi = (bmi1+bmi2)/2; fat = (fat1+fat2)/2;
     cholest = (cholest1+cholest2)/2 ; diastol = (diastol1+diastol2)/2;

proc means;
     var age1 -- diastol;

proc reg;
     title2 'Regression on average measurements';
     model cholest diastol = age bmi fat;
     BMI: mtest bmi=0; /* Multivariate test */
```

```
       BMI and Health: Read data and analyze ignoring measurement error       1

                              The MEANS Procedure
```

Variable	N	Mean	Std Dev	Minimum	Maximum
age1	500	44.1300000	12.9561114	3.0000000	80.0000000
bmi1	500	25.4786000	4.6790543	12.8000000	39.4000000
fat1	500	19.4780000	7.7567319	0	44.6000000
cholest1	500	263.8172000	55.7074960	113.4000000	440.3000000
diastol1	500	88.5940000	18.0461767	16.0000000	146.0000000
age2	500	45.5820000	12.4130352	6.0000000	78.0000000
bmi2	500	25.6574000	3.7869522	14.3000000	37.1000000
fat2	500	19.4778000	7.4274451	0	45.8000000
cholest2	500	265.3700000	56.7716240	106.0000000	445.6000000
diastol2	500	89.3420000	13.2834459	52.0000000	131.0000000
age	500	44.8560000	12.4336824	4.5000000	79.0000000
bmi	500	25.5680000	3.9567218	13.9000000	37.2000000
fat	500	19.4779000	7.1693749	0	44.8500000
cholest	500	264.5936000	55.0124311	118.6500000	442.9500000
diastol	500	88.9680000	13.7890628	39.5000000	132.5000000

Regression on average measurements

The REG Procedure
Model: MODEL1
Dependent Variable: cholest

Number of Observations Read	500
Number of Observations Used	500

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	146506	48835	17.76	<.0001
Error	496	1363651	2749.29688		
Corrected Total	499	1510157			

Root MSE	52.43374	R-Square	0.0970
Dependent Mean	264.59360	Adj R-Sq	0.0916
Coeff Var	19.81671		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	1	220.06103	21.01086	10.47	<.0001
age	1	-0.27139	0.20017	-1.36	0.1758
bmi	1	0.51641	1.01541	0.51	0.6113
fat	1	2.23342	0.57920	3.86	0.0001

Regression on average measurements

The REG Procedure
Model: MODEL1
Dependent Variable: diastol

Number of Observations Read	500
Number of Observations Used	500

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	31627	10542	82.67	<.0001
Error	496	63252	127.52449		
Corrected Total	499	94879			

Root MSE	11.29267	R-Square	0.3333
Dependent Mean	88.96800	Adj R-Sq	0.3293
Coeff Var	12.69296		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	1	49.69194	4.52512	10.98	<.0001
age	1	0.12648	0.04311	2.93	0.0035
bmi	1	0.82627	0.21869	3.78	0.0002
fat	1	0.64056	0.12474	5.14	<.0001

Regression on average measurements

The REG Procedure
Model: MODEL1
Multivariate Test: BMI

Multivariate Statistics and Exact F Statistics

S=1 M=0 N=246.5

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.97130971	7.31	2	495	0.0007
Pillai's Trace	0.02869029	7.31	2	495	0.0007
Hotelling-Lawley Trace	0.02953773	7.31	2	495	0.0007
Roy's Greatest Root	0.02953773	7.31	2	495	0.0007

Measurement Error Regression

```
/******************** bmi2.sas ************************/
options linesize=79 pagesize = 500 noovp formdlim='_';
title 'BMI and Health: Use the Double Measurement Design';

data health;
     infile 'bmihealth2.data'; /* bmihealth2.data is a big improvement */
     input age1 bmi1 fat1 cholest1 diastol1
           age2 bmi2 fat2 cholest2 diastol2;
           /* fat1 and fat2 are percent body fat */
     age = (age1+age2)/2; bmi = (bmi1+bmi2)/2; fat = (fat1+fat2)/2;
     cholest = (cholest1+cholest2)/2 ; diastol = (diastol1+diastol2)/2;

proc calis cov;     /* Analyze covariance matrix - default is corr */
     title2 'Full Model';
     var age1 -- diastol2; /* Name the observed variables */
     /* Now give simultaneous equations, separated by commas. Latent
        variables begin with F for factor. Error terms begin with
        E for error or D for disturbance. SAS is not case sensitive.
        You must name all the parameters. Optional starting values in
        parentheses may be given after the parameters. */
     lineqs
          Fcholest = beta11 Fage + beta12 Fbmi + beta13 Ffat + epsilon1,
          Fdiastol = beta21 Fage + beta22 Fbmi + beta23 Ffat + epsilon2,
          age1     = Fage + e11,
          bmi1     = Fbmi + e12,
          fat1     = Ffat + e13,
          cholest1 = Fcholest + e14,
          diastol1 = Fdiastol + e15,
          age2     = Fage + e21,
          bmi2     = Fbmi + e22,
          fat2     = Ffat + e23,
          cholest2 = Fcholest + e24,
          diastol2 = Fdiastol + e25;
     std                  /* Variances (not standard deviations) */
          Fage = phi11, Fbmi = phi22, Ffat = phi33,
          epsilon1 = psi11, epsilon2 = psi22,
          e11 = omega111, e12 = omega122, e13 = omega133,
          e14 = omega144, e15 = omega155,
          e21 = omega211, e22 = omega222, e23 = omega233,
          e24 = omega244, e25 = omega255;
     cov                  /* Covariances */
          Fage Fbmi = phi12, Fage Ffat = phi13, Fbmi Ffat = phi23,
          epsilon1 epsilon2 = psi12,
          e11 e12 = omega112, e11 e13 = omega113, e11 e14 = omega114,
          e11 e15 = omega115,
          e12 e13 = omega123, e12 e14 = omega124, e12 e15 = omega125,
          e13 e14 = omega134,  e13 e15 = omega135,
          e14 e15 = omega145,
          e21 e22 = omega212, e21 e23 = omega213, e21 e24 = omega214,
          e21 e25 = omega215,
          e22 e23 = omega223, e22 e24 = omega224, e22 e25 = omega225,
          e23 e24 = omega234,  e23 e25 = omega235,
          e24 e25 = omega245;
     bounds               /* Variances are positive */
          0.0 < phi11 phi22 phi33 psi11 psi22
                omega111 omega122 omega133 omega144 omega155
                omega211 omega222 omega233 omega244 omega255;
```

```
/*  Now fit a reduced model to test H0: beta12 = beta22 = 0,
    meaning BMI is unrelated to either cholesterol or blood pressure
    if we allow for age and percent body fat.  Copy the code; only
    the last line is different.  */

proc calis cov maxiter=300;  /* Default number of iterations is 200. Got
                                an error message with that. */
     title2 'Reduced Model with beta12=beta22=0';
     var age1 -- diastol2; /* Name the observed variables */
     /* Now give simultaneous equations, separated by commas. Latent
        variables begin with F for factor. Error terms begin with
        E for error or D for disturbance. SAS is not case sensitive.
        You must name all the parameters. Optional starting values in
        parentheses may be given after the parameters. */
     lineqs
          Fcholest = beta11 Fage + beta12 Fbmi + beta13 Ffat + epsilon1,
          Fdiastol = beta21 Fage + beta22 Fbmi + beta23 Ffat + epsilon2,
          age1     = Fage + e11,
          bmi1     = Fbmi + e12,
          fat1     = Ffat + e13,
          cholest1 = Fcholest + e14,
          diastol1 = Fdiastol + e15,
          age2     = Fage + e21,
          bmi2     = Fbmi + e22,
          fat2     = Ffat + e23,
          cholest2 = Fcholest + e24,
          diastol2 = Fdiastol + e25;
     std                   /* Variances (not standard deviations) */
          Fage = phi11, Fbmi = phi22, Ffat = phi33,
          epsilon1 = psi11, epsilon2 = psi22,
          e11 = omega111, e12 = omega122, e13 = omega133,
          e14 = omega144, e15 = omega155,
          e21 = omega211, e22 = omega222, e23 = omega233,
          e24 = omega244, e25 = omega255;
     cov                   /* Covariances */
          Fage Fbmi = phi12, Fage Ffat = phi13, Fbmi Ffat = phi23,
          epsilon1 epsilon2 = psi12,
          e11 e12 = omega112, e11 e13 = omega113, e11 e14 = omega114,
          e11 e15 = omega115,
          e12 e13 = omega123, e12 e14 = omega124, e12 e15 = omega125,
          e13 e14 = omega134,  e13 e15 = omega135,
          e14 e15 = omega145,
          e21 e22 = omega212, e21 e23 = omega213, e21 e24 = omega214,
          e21 e25 = omega215,
          e22 e23 = omega223, e22 e24 = omega224, e22 e25 = omega225,
          e23 e24 = omega234,  e23 e25 = omega235,
          e24 e25 = omega245;
     bounds                /* Variances are positive */
          0.0 < phi11 phi22 phi33 psi11 psi22
                omega111 omega122 omega133 omega144 omega155
                omega211 omega222 omega233 omega244 omega255;
     lincon beta11=0, beta22=0;

proc iml;
     title2 'Calculate Likelihood ratio test of H0: beta12=beta22=0';
     G = 500 * (0.0162319938 - 0.0093716565);
     /* Difference between final objective function values */
     pval = 1 - probchi(G,2);
     print G,pval;
```

The CALIS Procedure
Covariance Structure Analysis: Pattern and Initial Values

LINEQS Model Statement

		Matrix	Rows	Columns	------Matrix Type-------	
Term 1	1	_SEL_	10	27	SELECTION	
	2	_BETA_	27	27	EQSBETA	IMINUSINV
	3	_GAMMA_	27	15	EQSGAMMA	
	4	_PHI_	15	15	SYMMETRIC	

The 12 Endogenous Variables

Manifest	age1	bmi1	fat1	cholest1	diastol1	age2
	bmi2	fat2	cholest2	diastol2		
Latent	Fcholest	Fdiastol				

The 15 Exogenous Variables

Manifest						
Latent	Fage	Fbmi	Ffat			
Error	epsilon1	epsilon2	e11	e12	e13	e14
	e15	e21	e22	e23	e24	e25

The CALIS Procedure
Covariance Structure Analysis: Pattern and Initial Values

Manifest Variable Equations with Initial Estimates

```
age1     =   1.0000 Fage     +  1.0000 e11
bmi1     =   1.0000 Fbmi     +  1.0000 e12
fat1     =   1.0000 Ffat     +  1.0000 e13
cholest1 =   1.0000 Fcholest +  1.0000 e14
diastol1 =   1.0000 Fdiastol +  1.0000 e15
age2     =   1.0000 Fage     +  1.0000 e21
bmi2     =   1.0000 Fbmi     +  1.0000 e22
fat2     =   1.0000 Ffat     +  1.0000 e23
cholest2 =   1.0000 Fcholest +  1.0000 e24
diastol2 =   1.0000 Fdiastol +  1.0000 e25
```

The CALIS Procedure
Covariance Structure Analysis: Pattern and Initial Values

Latent Variable Equations with Initial Estimates

```
Fcholest =        .*Fage     +       .*Fbmi     +       .*Ffat
                   beta11             beta12             beta13

                        +  1.0000 epsilon1


Fdiastol =        .*Fage     +       .*Fbmi     +       .*Ffat
                   beta21             beta22             beta23

                        +  1.0000 epsilon2
```

Variances of Exogenous Variables

Variable	Parameter	Estimate
Fage	phi11	.
Fbmi	phi22	.
Ffat	phi33	.
epsilon1	psi11	.
epsilon2	psi22	.
e11	omega111	.
e12	omega122	.
e13	omega133	.
e14	omega144	.
e15	omega155	.
e21	omega211	.
e22	omega222	.
e23	omega233	.
e24	omega244	.
e25	omega255	.

Covariances Among Exogenous Variables

Var1	Var2	Parameter	Estimate
Fage	Fbmi	phi12	.
Fage	Ffat	phi13	.
Fbmi	Ffat	phi23	.
epsilon1	epsilon2	psi12	.
e11	e12	omega112	.
e11	e13	omega113	.
e12	e13	omega123	.
e11	e14	omega114	.
e12	e14	omega124	.
e13	e14	omega134	.
e11	e15	omega115	.
e12	e15	omega125	.
e13	e15	omega135	.
e14	e15	omega145	.
e21	e22	omega212	.
e21	e23	omega213	.

```
e22      e23      omega223              .
e21      e24      omega214              .
e22      e24      omega224              .
e23      e24      omega234              .
e21      e25      omega215              .
e22      e25      omega225              .
e23      e25      omega235              .
e24      e25      omega245              .
```

The CALIS Procedure
Covariance Structure Analysis: Maximum Likelihood Estimation

Observations	500	Model Terms	1
Variables	10	Model Matrices	4
Informations	55	Parameters	45

Variable	Mean	Std Dev
age1	44.13000	12.95611
bmi1	25.47860	4.67905
fat1	19.47800	7.75673
cholest1	263.81720	55.70750
diastol1	88.59400	18.04618
age2	45.58200	12.41304
bmi2	25.65740	3.78695
fat2	19.47780	7.42745
cholest2	265.37000	56.77162
diastol2	89.34200	13.28345

NOTE: Some initial estimates computed by two-stage LS method.

The CALIS Procedure
Covariance Structure Analysis: Maximum Likelihood Estimation

Vector of Initial Estimates

	Parameter	Estimate	Type
1	beta11	-0.58777	Matrix Entry: _GAMMA_[11:1]
2	beta12	-4.21299	Matrix Entry: _GAMMA_[11:2]
3	beta13	5.10065	Matrix Entry: _GAMMA_[11:3]
4	beta21	0.11397	Matrix Entry: _GAMMA_[12:1]
5	beta22	0.77885	Matrix Entry: _GAMMA_[12:2]
6	beta23	0.76017	Matrix Entry: _GAMMA_[12:3]
7	phi11	148.22078	Matrix Entry: _PHI_[1:1]
8	phi12	5.17639	Matrix Entry: _PHI_[2:1]
9	phi22	13.19402	Matrix Entry: _PHI_[2:2]
10	phi13	24.28980	Matrix Entry: _PHI_[3:1]
11	phi23	22.77768	Matrix Entry: _PHI_[3:2]
12	phi33	45.13296	Matrix Entry: _PHI_[3:3]
13	psi11	2529	Matrix Entry: _PHI_[4:4]
14	psi12	-27.60219	Matrix Entry: _PHI_[5:4]
15	psi22	61.11121	Matrix Entry: _PHI_[5:5]

16	omega111	19.64004	Matrix Entry: _PHI_[6:6]
17	omega112	3.76307	Matrix Entry: _PHI_[7:6]
18	omega122	8.69953	Matrix Entry: _PHI_[7:7]
19	omega113	1.76457	Matrix Entry: _PHI_[8:6]
20	omega123	6.99456	Matrix Entry: _PHI_[8:7]
21	omega133	15.03393	Matrix Entry: _PHI_[8:8]
22	omega114	4.11877	Matrix Entry: _PHI_[9:6]
23	omega124	-0.83674	Matrix Entry: _PHI_[9:7]
24	omega134	4.52217	Matrix Entry: _PHI_[9:8]
25	omega144	213.76117	Matrix Entry: _PHI_[9:9]
26	omega115	8.92824	Matrix Entry: _PHI_[10:6]
27	omega125	7.47654	Matrix Entry: _PHI_[10:7]
28	omega135	-0.41936	Matrix Entry: _PHI_[10:8]
29	omega145	13.85209	Matrix Entry: _PHI_[10:9]
30	omega155	196.44520	Matrix Entry: _PHI_[10:10]
31	omega211	5.86266	Matrix Entry: _PHI_[11:11]
32	omega212	-2.06758	Matrix Entry: _PHI_[12:11]
33	omega222	1.14699	Matrix Entry: _PHI_[12:12]
34	omega213	-2.02535	Matrix Entry: _PHI_[13:11]
35	omega223	-3.47470	Matrix Entry: _PHI_[13:12]
36	omega233	10.03398	Matrix Entry: _PHI_[13:13]
37	omega214	-3.35828	Matrix Entry: _PHI_[14:11]
38	omega224	-0.52526	Matrix Entry: _PHI_[14:12]
39	omega234	-5.78938	Matrix Entry: _PHI_[14:13]
40	omega244	333.45335	Matrix Entry: _PHI_[14:14]
41	omega215	-2.45635	Matrix Entry: _PHI_[15:11]
42	omega225	-1.08673	Matrix Entry: _PHI_[15:12]
43	omega235	-3.13527	Matrix Entry: _PHI_[15:13]
44	omega245	-19.05685	Matrix Entry: _PHI_[15:14]
45	omega255	47.23065	Matrix Entry: _PHI_[15:15]

The CALIS Procedure
Covariance Structure Analysis: Maximum Likelihood Estimation

Dual Quasi-Newton Optimization

Dual Broyden - Fletcher - Goldfarb - Shanno Update (DBFGS)

Parameter Estimates	45
Functions (Observations)	55
Lower Bounds	15
Upper Bounds	0

Optimization Start

Active Constraints 0 Objective Function 0.2768223813
Max Abs Gradient Element 0.1013655982

Iter	Restarts	Func Calls	Act Con	Objective Function	Obj Fun Change	Max Abs Gradient Element	Step Size	Slope Search Direc
1	0	2	0	0.20762	0.0692	0.1252	0.100	-1.364
2	0	4	0	0.20021	0.00741	0.1004	0.100	-0.171
3	0	6	0	0.13874	0.0615	0.2003	2.027	-0.0646
4	0	8	0	0.11183	0.0269	0.1015	0.176	-0.240
5	0	9	0	0.09759	0.0142	0.0241	1.000	-0.0271
6	0	10	0	0.08714	0.0104	0.0716	3.196	-0.0111
7	0	11	0	0.07694	0.0102	0.0113	1.404	-0.0186

```
   8       0      12         0       0.07425  0.00269   0.0365   5.422  -0.0047
   9       0      14         0       0.06329   0.0110   0.0180   1.101  -0.0192
```

Skipping ...

```
 138       0     242         0       0.00938 1.787E-7 0.000030  45.366  -61E-10
 139       0     243         0       0.00938 1.609E-7 0.000027   2.161  -207E-9
 140       0     244         0       0.00938 2.418E-7 0.000022   3.373  -119E-9
 141       0     246         0       0.00938 2.247E-6 0.000084  11.465  -392E-9
 142       0     247         0       0.00937 2.813E-6 0.000015   2.348  -239E-8
 143       0     249         0       0.00937 7.609E-8 0.000015   1.218  -125E-9
 144       0     252         0       0.00937  1.49E-6 0.000358   708.9  -42E-10
 145       0     254         0       0.00937 4.393E-7 6.152E-6   1.007  -871E-9

                          Optimization Results

Iterations                           145  Function Calls                     255
Gradient Calls                       202  Active Constraints                   0
Objective Function          0.0093716565  Max Abs Gradient Element  6.1521254E-6
Slope of Search Direction -8.707051E-7

ABSGCONV convergence criterion satisfied.
```

```
                             The CALIS Procedure
         Covariance Structure Analysis: Maximum Likelihood Estimation

         Fit Function                                             0.0094
         Goodness of Fit Index (GFI)                              0.9981
         GFI Adjusted for Degrees of Freedom (AGFI)               0.9898
         Root Mean Square Residual (RMR)                          4.4533
         Standardized Root Mean Square Residual (SRMR)            0.0114
         Parsimonious GFI (Mulaik, 1989)                          0.2218
         Chi-Square                                               4.6765
         Chi-Square DF                                                10
         Pr > Chi-Square                                          0.9117
         Independence Model Chi-Square                            4055.5
         Independence Model Chi-Square DF                             45
         RMSEA Estimate                                           0.0000
         RMSEA 90% Lower Confidence Limit                              .
         RMSEA 90% Upper Confidence Limit                         0.0188
         ECVI Estimate                                            0.1938
         ECVI 90% Lower Confidence Limit                               .
         ECVI 90% Upper Confidence Limit                          0.2081
         Probability of Close Fit                                 0.9987
         Bentler's Comparative Fit Index                          1.0000
         Normal Theory Reweighted LS Chi-Square                   4.6516
         Akaike's Information Criterion                         -15.3235
         Bozdogan's (1987) CAIC                                 -67.4696
         Schwarz's Bayesian Criterion                           -57.4696
         McDonald's (1989) Centrality                             1.0053
         Bentler & Bonett's (1980) Non-normed Index               1.0060
         Bentler & Bonett's (1980) NFI                            0.9988
         James, Mulaik, & Brett (1982) Parsimonious NFI           0.2220
         Z-Test of Wilson & Hilferty (1931)                      -1.3522
         Bollen (1986) Normed Index Rho1                          0.9948
         Bollen (1988) Non-normed Index Delta2                    1.0013
         Hoelter's (1983) Critical N                                1955
```

The CALIS Procedure
Covariance Structure Analysis: Maximum Likelihood Estimation

Manifest Variable Equations with Estimates

```
age1     =   1.0000 Fage     +  1.0000 e11
bmi1     =   1.0000 Fbmi     +  1.0000 e12
fat1     =   1.0000 Ffat     +  1.0000 e13
cholest1 =   1.0000 Fcholest +  1.0000 e14
diastol1 =   1.0000 Fdiastol +  1.0000 e15
age2     =   1.0000 Fage     +  1.0000 e21
bmi2     =   1.0000 Fbmi     +  1.0000 e22
fat2     =   1.0000 Ffat     +  1.0000 e23
cholest2 =   1.0000 Fcholest +  1.0000 e24
diastol2 =   1.0000 Fdiastol +  1.0000 e25
```


The CALIS Procedure
Covariance Structure Analysis: Maximum Likelihood Estimation

Latent Variable Equations with Estimates

```
Fcholest =  -0.3217*Fage     +  0.3797*Fbmi     +  2.7856*Ffat
Std Err      0.2276 beta11      1.7069 beta12      0.9796 beta13
t Value     -1.4134             0.2224             2.8436

                        +  1.0000 epsilon1


Fdiastol =   0.0203*Fage     + -0.4807*Fbmi     +  1.4811*Ffat
Std Err      0.0501 beta21      0.4194 beta22      0.2349 beta23
t Value      0.4049            -1.1462             6.3057

                        +  1.0000 epsilon2
```

Variances of Exogenous Variables

Variable	Parameter	Estimate	Standard Error	t Value
Fage	phi11	147.74323	9.73561	15.18
Fbmi	phi22	13.37232	0.98951	13.51
Ffat	phi33	44.58932	3.11144	14.33
epsilon1	psi11	2529	171.13826	14.78
epsilon2	psi22	56.23345	9.25109	6.08
e11	omega111	18.62676	2.92365	6.37
e12	omega122	8.68693	0.71020	12.23
e13	omega133	16.17909	1.66488	9.72
e14	omega144	209.88001	57.62772	3.64
e15	omega155	195.54840	14.37263	13.61

e21	omega211	6.86996	2.71016	2.53
e22	omega222	1.08795	0.49228	2.21
e23	omega233	9.33584	1.54339	6.05
e24	omega244	335.24205	60.16281	5.57
e25	omega255	48.47136	8.27364	5.86

Covariances Among Exogenous Variables

Var1	Var2	Parameter	Estimate	Standard Error	t Value
Fage	Fbmi	phi12	4.17268	2.14808	1.94
Fage	Ffat	phi13	23.38544	3.99961	5.85
Fbmi	Ffat	phi23	21.02692	1.58923	13.23
epsilon1	epsilon2	psi12	-46.44684	25.02196	-1.86
e11	e12	omega112	4.00945	0.94794	4.23
e11	e13	omega113	2.40079	1.51037	1.59
e12	e13	omega123	8.99604	0.95907	9.38
e11	e14	omega114	2.80748	9.12757	0.31
e12	e14	omega124	-0.73764	4.19785	-0.18
e13	e14	omega134	8.23408	6.77082	1.22
e11	e15	omega115	10.59611	3.83639	2.76
e12	e15	omega125	10.09720	2.28163	4.43
e13	e15	omega135	-2.91518	3.42064	-0.85
e14	e15	omega145	0.23474	16.98119	0.01
e21	e22	omega212	-0.66460	0.73726	-0.90
e21	e23	omega213	-2.71502	1.37351	-1.98
e22	e23	omega223	-1.86062	0.70705	-2.63
e21	e24	omega214	-2.04657	8.97177	-0.23
e22	e24	omega224	-2.80291	3.48347	-0.80
e23	e24	omega234	-11.65691	6.55528	-1.78
e21	e25	omega215	2.27546	2.71856	0.84
e22	e25	omega225	2.64850	1.49147	1.78
e23	e25	omega235	-4.87289	2.54460	-1.91
e24	e25	omega245	-9.20550	12.62968	-0.73

BMI and Health: Use the Double Measurement Design 10
Full Model

The CALIS Procedure
Covariance Structure Analysis: Maximum Likelihood Estimation

Manifest Variable Equations with Standardized Estimates

Skipping this part ...

Skip a lot of this.

Optimization Start

Active Constraints	2	Objective Function	0.3661236564
Max Abs Gradient Element	0.3783819304		

Iter	Restarts	Func Calls	Act Con	Objective Function	Obj Fun Change	Max Abs Gradient Element	Step Size	Slope Search Direc
1	0	2	2	0.29275	0.0734	0.4584	0.100	-2.297
2	0	3	2	0.26136	0.0314	0.2680	1.000	-0.140
3	0	4	2	0.23231	0.0290	0.0434	1.000	-0.0456
4	0	6	2	0.20735	0.0250	0.1816	2.812	-0.0176
5	0	8	2	0.15112	0.0562	0.0438	4.451	-0.0239
6	0	11	2	0.13909	0.0120	0.0355	2.800	-0.0125
7	0	12	2	0.13054	0.00855	0.0263	2.642	-0.0114

Skipping ...

261	1	485	2	0.01624	2.747E-6	0.000069	56.369	-97E-9
262	1	487	2	0.01624	1.842E-7	0.000147	3.141	-117E-9
263	1	489	2	0.01623	2.579E-6	0.000030	19.382	-238E-9
264	1	490	2	0.01623	1.685E-6	0.000112	10.000	-379E-9
265	1	492	2	0.01623	1.602E-7	6.822E-6	1.088	-295E-9

Optimization Results

Iterations	265	Function Calls	493
Gradient Calls	388	Active Constraints	2
Objective Function	0.0162319938	Max Abs Gradient Element	6.8217673E-6
Slope of Search Direction	-2.94649E-7		

ABSGCONV convergence criterion satisfied.

WARNING: There are 2 active constraints at the solution. The standard errors and Chi-Square test statistic assume the solution is located in the interior of the parameter space and hence do not apply if it is likely that some different set of inequality constraints could be active.

NOTE: The degrees of freedom are increased by the number of active constraints (see Dijkstra, 1992). The number of parameters in calculating fit indices is decreased by the number of active constraints. To turn off the adjustment, use the NOADJDF option.

```
            BMI and Health: Use the Double Measurement Design             19
                   Reduced Model with beta12=beta22=0

                          The CALIS Procedure
     Covariance Structure Analysis: Maximum Likelihood Estimation

     Fit Function                                              0.0162
     Goodness of Fit Index (GFI)                               0.9968
     GFI Adjusted for Degrees of Freedom (AGFI)                0.9853
     Root Mean Square Residual (RMR)                          11.9600
     Standardized Root Mean Square Residual (SRMR)             0.0190
     Parsimonious GFI (Mulaik, 1989)                           0.2658
     Chi-Square                                                8.0998
     Chi-Square DF                                                 12
     Pr > Chi-Square                                           0.7773
```

Skipping ....

```
            BMI and Health: Use the Double Measurement Design             20
                   Reduced Model with beta12=beta22=0

                          The CALIS Procedure
     Covariance Structure Analysis: Maximum Likelihood Estimation

              Manifest Variable Equations with Estimates


            age1     =   1.0000 Fage     +  1.0000 e11
            bmi1     =   1.0000 Fbmi     +  1.0000 e12
            fat1     =   1.0000 Ffat     +  1.0000 e13
            cholest1 =   1.0000 Fcholest +  1.0000 e14
            diastol1 =   1.0000 Fdiastol +  1.0000 e15
            age2     =   1.0000 Fage     +  1.0000 e21
            bmi2     =   1.0000 Fbmi     +  1.0000 e22
            fat2     =   1.0000 Ffat     +  1.0000 e23
            cholest2 =   1.0000 Fcholest +  1.0000 e24
            diastol2 =   1.0000 Fdiastol +  1.0000 e25
```

```
            BMI and Health: Use the Double Measurement Design             21
                   Reduced Model with beta12=beta22=0

                          The CALIS Procedure
     Covariance Structure Analysis: Maximum Likelihood Estimation

               Latent Variable Equations with Estimates


  Fcholest =        0*Fage     +  1.3559*Fbmi     +  2.1122*Ffat
  Std Err           0 beta11      1.4802 beta12      0.8097 beta13
  t Value           .             0.9160             2.6086

                         +  1.0000 epsilon1


  Fdiastol =   0.0465*Fage     +       0*Fbmi     +  1.2336*Ffat
  Std Err      0.0419 beta21           0 beta22      0.0822 beta23
  t Value      1.1087                  .            14.9988

                         +  1.0000 epsilon2
```

Variances of Exogenous Variables

Variable	Parameter	Estimate	Standard Error	t Value
Fage	phi11	147.56282	9.72371	15.18
Fbmi	phi22	13.37885	0.98904	13.53
Ffat	phi33	44.62980	3.10829	14.36
epsilon1	psi11	2537	170.95483	14.84
epsilon2	psi22	60.47272	8.37726	7.22
e11	omega111	18.68610	2.92220	6.39
e12	omega122	8.65224	0.70834	12.21
e13	omega133	15.86717	1.65508	9.59
e14	omega144	198.65851	57.37704	3.46
e15	omega155	195.89782	14.39318	13.61
e21	omega211	6.75861	2.70530	2.50
e22	omega222	1.09150	0.49091	2.22
e23	omega233	9.47819	1.55131	6.11
e24	omega244	347.73689	60.36335	5.76
e25	omega255	45.40396	7.77887	5.84

Covariances Among Exogenous Variables

Var1	Var2	Parameter	Estimate	Standard Error	t Value
Fage	Fbmi	phi12	4.14055	2.14649	1.93
Fage	Ffat	phi13	23.14662	3.99363	5.80
Fbmi	Ffat	phi23	20.88056	1.58392	13.18
epsilon1	epsilon2	psi12	-40.93758	24.34795	-1.68
e11	e12	omega112	3.96709	0.94608	4.19
e11	e13	omega113	2.40280	1.50524	1.60
e12	e13	omega123	9.02054	0.95513	9.44
e11	e14	omega114	2.87348	9.10842	0.32
e12	e14	omega124	-0.88162	4.18202	-0.21
e13	e14	omega134	8.67287	6.71633	1.29
e11	e15	omega115	10.77598	3.84830	2.80
e12	e15	omega125	10.18861	2.29085	4.45
e13	e15	omega135	-2.16005	3.36573	-0.64
e14	e15	omega145	0.12083	17.00848	0.01
e21	e22	omega212	-0.65780	0.73442	-0.90
e21	e23	omega213	-2.57992	1.37286	-1.88
e22	e23	omega223	-1.78824	0.70627	-2.53
e21	e24	omega214	-2.53016	8.96890	-0.28
e22	e24	omega224	-2.77805	3.48097	-0.80
e23	e24	omega234	-12.06924	6.56696	-1.84
e21	e25	omega215	1.68214	2.66026	0.63
e22	e25	omega225	2.05697	1.39227	1.48
e23	e25	omega235	-4.79373	2.53685	-1.89
e24	e25	omega245	-9.12906	12.58363	-0.73

```
                BMI and Health: Use the Double Measurement Design              22
                       Reduced Model with beta12=beta22=0

                             The CALIS Procedure
         Covariance Structure Analysis: Maximum Likelihood Estimation

            Manifest Variable Equations with Standardized Estimates
```

Always ignore this part of the output.

```
                BMI and Health: Use the Double Measurement Design              24
             Calculate Likelihood ratio test of H0: beta12=beta22=0

                                       G

                                   3.4301687
                                      pval

                                   0.1799485
```

```
/********************* bmi3.sas ************************/
options linesize=79 pagesize = 500 noovp formdlim='_' nodate;
title 'BMI and Health: Like bmi2.sas, but try to make it shorter';

data health;
     infile 'bmihealth2.data';
     input age1 bmi1 fat1 cholest1 diastol1
           age2 bmi2 fat2 cholest2 diastol2;
           /* fat1 and fat2 are percent body fat */
     age = (age1+age2)/2; bmi = (bmi1+bmi2)/2; fat = (fat1+fat2)/2;
     cholest = (cholest1+cholest2)/2 ; diastol = (diastol1+diastol2)/2;

proc calis cov;     /* Analyze covariance matrix - default is corr */
     title2 'Full Model';
     var age1 -- diastol2; /* Name the observed variables */
     /* Now give simultaneous equations, separated by commas. Latent
        variables begin with F for factor. Error terms begin with
        E for error or D for disturbance. SAS is not case sensitive.
        You must name all the parameters. Optional starting values in
        parentheses may be given after the parameters. */
     lineqs
          Fcholest = beta11 Fage + beta12 Fbmi + beta13 Ffat + epsilon1,
          Fdiastol = beta21 Fage + beta22 Fbmi + beta23 Ffat + epsilon2,
          age1     = Fage + e11,
          bmi1     = Fbmi + e12,
          fat1     = Ffat + e13,
          cholest1 = Fcholest + e14,
          diastol1 = Fdiastol + e15,
          age2     = Fage + e21,
          bmi2     = Fbmi + e22,
          fat2     = Ffat + e23,
          cholest2 = Fcholest + e24,
          diastol2 = Fdiastol + e25;
     std   /* Variances (not standard deviations) will be
              called V-something. Colon means fill in the numbers. */
          Fage Fbmi Ffat epsilon1 epsilon2 e11-e15 e21-e25 = 15 * v: ;
     cov   /* Covariances: If not mentioned, it's zero.  */
          Fage Ffat Fbmi = 3 * phi: , epsilon1 epsilon2 = psi12 ,
          e11-e15 = 10 * omega1_: , e21-e25 = 10 * omega2_: ;
     /* If you don't count the variances and covariances you get a warning.
        It's better to count them.  */
     bounds 0.0 < v1-v15;  /* Variances are positive */
```