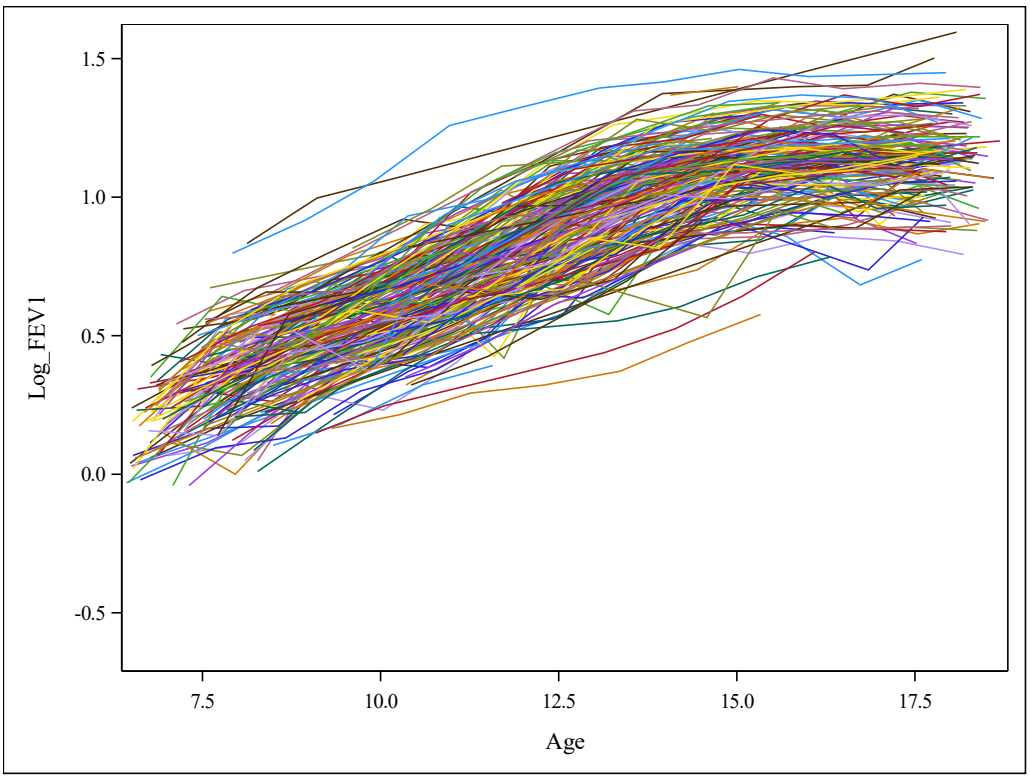
```
*The Six Cities Study of Air Pollution;

Here we are going to try to use splines to what we fit
previously.


data air_pol;
input  ID Height Age INI_Height  INI_Age  Log_FEV1;
L_INI_Height = log(INI_Height);
L_Age = log(Age);
L_INI_Age = log(INI_Age);
Age_fl = floor(Age);
Height_C = Height - 1.5;
datalines;
     1     1.20      9.3415      1.20     9.3415     0.21511
     1     1.28     10.3929      1.20     9.3415     0.37156
…..
   300     1.62     15.9398      1.44     11.9617    1.08181
   300     1.62     17.0075      1.44     11.9617    1.12817
   300     1.63     17.8645      1.44     11.9617    1.16938
;
   run;

Proc SGplot data = air_pol;
series x=Age y=Log_FEV1 / group =ID LineAttrs= (pattern=1 );
run;
```



```
proc mixed data = air_pol method=ML;
class ID Age_fl;
model Log_FEV1 =  Height Age_fl/ solution;
random intercept Height/type=UN subject=ID g gcorr v vcorr;
run;
```

| Fit Statistics | |
|---|---|
| **-2 Log Likelihood** | -4801.9 |
| **AIC (Smaller is Better)** | -4765.9 |
| **AICC (Smaller is Better)** | -4765.5 |
| **BIC (Smaller is Better)** | -4699.2 |

```
proc glimmix data = air_pol method=mmpl;
class ID;
effect spl = spline(Age/knotmethod=percentiles(4));
model Log_FEV1 =  Height spl/ solution;
random intercept Height/type=UN subject=ID g gcorr v vcorr;
run;
```

| Fit Statistics | |
|---|---|
| **-2 Log Likelihood** | -4826.51 |
| **AIC (smaller is better)** | -4800.51 |
| **AICC (smaller is better)** | -4800.32 |
| **BIC (smaller is better)** | -4752.40 |

```
proc glimmix data = air_pol outdesign=Splines;
class ID;
effect spl = spline(Age/knotmethod=percentiles(4));
model Log_FEV1 =  Height spl/ solution;
random intercept Height/type=UN subject=ID g gcorr v vcorr;
output out=air_pol_age_pred pred=pred pred(ilink
noblup)=pred_fixed;
ods output ParameterEstimates = PE;
run;
```

**The GLIMMIX Procedure**

| Model Information | |
|---|---|
| Data Set | WORK.AIR_POL |
| Response Variable | Log_FEV1 |
| Response Distribution | Gaussian |
| Link Function | Identity |
| Variance Function | Default |
| Variance Matrix Blocked By | ID |
| Estimation Technique | Restricted Maximum Likelihood |
| Degrees of Freedom Method | Kenward-Roger |
| Fixed Effects SE Adjustment | Kenward-Roger |

**Class Level Information**

| Class | Levels | Values |
|---|---|---|
| ID | 299 | 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 158 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 192 193 194 195 196 198 199 200 201 202 203 204 205 206 207 208 209 210 211 212 213 214 215 216 217 218 219 220 221 222 223 224 225 226 227 228 229 230 231 232 233 234 235 236 237 238 239 240 241 242 243 244 245 246 247 248 249 250 251 252 253 254 255 256 257 258 259 260 261 262 263 264 265 266 267 268 269 270 271 272 273 274 275 276 277 278 279 280 |

| Class Level Information | | |
|---|---|---|
| **Class** | **Levels** | **Values** |
| | | 281 282 283 284 285 286 287 288 289 290 291 292 293 294 295 296 297 298 299 300 |

| | |
|---|---|
| **Number of Observations Read** | 1993 |
| **Number of Observations Used** | 1993 |

| Dimensions | |
|---|---|
| **G-side Cov. Parameters** | 3 |
| **R-side Cov. Parameters** | 1 |
| **Columns in X** | 10 |
| **Columns in Z per Subject** | 2 |
| **Subjects (Blocks in V)** | 299 |
| **Max Obs per Subject** | 12 |

| Optimization Information | |
|---|---|
| **Optimization Technique** | Dual Quasi-Newton |
| **Parameters in Optimization** | 3 |
| **Lower Boundaries** | 2 |
| **Upper Boundaries** | 0 |
| **Fixed Effects** | Profiled |
| **Residual Variance** | Profiled |
| **Starting From** | Data |

| Iteration History | | | | | |
|---|---|---|---|---|---|
| Iteration | Restarts | Evaluations | Objective Function | Change | Max Gradient |
| 0 | 0 | 4 | -4759.992955 | . | 32.64273 |
| 1 | 0 | 3 | -4761.134901 | 1.14194630 | 18.34915 |
| 2 | 0 | 2 | -4762.677863 | 1.54296190 | 3.983505 |
| 3 | 0 | 2 | -4762.77554 | 0.09767701 | 1.281671 |
| 4 | 0 | 4 | -4762.846949 | 0.07140906 | 3.888124 |
| 5 | 0 | 4 | -4763.322691 | 0.47574180 | 2.562102 |
| 6 | 0 | 3 | -4763.536862 | 0.21417166 | 0.518294 |
| 7 | 0 | 3 | -4763.537892 | 0.00102917 | 0.033912 |
| 8 | 0 | 3 | -4763.537902 | 0.00001073 | 0.00025 |

Convergence criterion (GCONV=1E-8) satisfied.

| Fit Statistics | |
|---|---|
| -2 Res Log Likelihood | -4763.54 |
| AIC (smaller is better) | -4755.54 |
| AICC (smaller is better) | -4755.52 |
| BIC (smaller is better) | -4740.74 |
| CAIC (smaller is better) | -4736.74 |
| HQIC (smaller is better) | -4749.61 |
| Generalized Chi-Square | 6.12 |
| Gener. Chi-Square / DF | 0.00 |

**Estimated G Matrix**

| Effect | Row | Col1 | Col2 |
|---|---|---|---|
| Intercept | 1 | 0.07741 | -0.05208 |
| Height | 2 | -0.05208 | 0.03920 |

**Estimated G Correlation Matrix**

| Effect | Row | Col1 | Col2 |
|---|---|---|---|
| Intercept | 1 | 1.0000 | -0.9455 |
| Height | 2 | -0.9455 | 1.0000 |

**Estimated V Matrix for ID 1**

| Row | Col1 | Col2 | Col3 | Col4 | Col5 | Col6 | Col7 |
|---|---|---|---|---|---|---|---|
| 1 | 0.01195 | 0.008457 | 0.008205 | 0.007752 | 0.007449 | 0.007348 | 0.007248 |
| 2 | 0.008457 | 0.01139 | 0.008210 | 0.008038 | 0.007924 | 0.007886 | 0.007848 |
| 3 | 0.008205 | 0.008210 | 0.01130 | 0.008218 | 0.008221 | 0.008222 | 0.008223 |
| 4 | 0.007752 | 0.008038 | 0.008218 | 0.01163 | 0.008755 | 0.008827 | 0.008899 |
| 5 | 0.007449 | 0.007924 | 0.008221 | 0.008755 | 0.01220 | 0.009230 | 0.009349 |
| 6 | 0.007348 | 0.007886 | 0.008222 | 0.008827 | 0.009230 | 0.01245 | 0.009499 |
| 7 | 0.007248 | 0.007848 | 0.008223 | 0.008899 | 0.009349 | 0.009499 | 0.01274 |

**Estimated V Correlation Matrix for ID 1**

| Row | Col1 | Col2 | Col3 | Col4 | Col5 | Col6 | Col7 |
|---|---|---|---|---|---|---|---|
| 1 | 1.0000 | 0.7250 | 0.7063 | 0.6577 | 0.6171 | 0.6025 | 0.5876 |
| 2 | 0.7250 | 1.0000 | 0.7237 | 0.6985 | 0.6723 | 0.6622 | 0.6516 |
| 3 | 0.7063 | 0.7237 | 1.0000 | 0.7170 | 0.7003 | 0.6932 | 0.6855 |

| Estimated V Correlation Matrix for ID 1 | | | | | | | |
|---|---|---|---|---|---|---|---|
| Row | Col1 | Col2 | Col3 | Col4 | Col5 | Col6 | Col7 |
| 4 | 0.6577 | 0.6985 | 0.7170 | 1.0000 | 0.7352 | 0.7337 | 0.7313 |
| 5 | 0.6171 | 0.6723 | 0.7003 | 0.7352 | 1.0000 | 0.7490 | 0.7501 |
| 6 | 0.6025 | 0.6622 | 0.6932 | 0.7337 | 0.7490 | 1.0000 | 0.7544 |
| 7 | 0.5876 | 0.6516 | 0.6855 | 0.7313 | 0.7501 | 0.7544 | 1.0000 |

| Covariance Parameter Estimates | | | |
|---|---|---|---|
| Cov Parm | Subject | Estimate | Standard Error |
| UN(1,1) | ID | 0.07741 | 0.01324 |
| UN(2,1) | ID | -0.05208 | 0.009135 |
| UN(2,2) | ID | 0.03920 | 0.006490 |
| Residual | | 0.003086 | 0.000115 |

| Solutions for Fixed Effects | | | | | | |
|---|---|---|---|---|---|---|
| Effect | spl | Estimate | Standard Error | DF | t Value | Pr > \|t\| |
| Intercept | | -1.5841 | 0.09482 | 1465 | -16.71 | <.0001 |
| Height | | 1.6587 | 0.05774 | 1405 | 28.73 | <.0001 |
| spl | 1 | -0.2433 | 0.03247 | 1931 | -7.49 | <.0001 |
| spl | 2 | -0.1628 | 0.02842 | 1898 | -5.73 | <.0001 |
| spl | 3 | -0.1244 | 0.02505 | 1955 | -4.96 | <.0001 |
| spl | 4 | -0.1387 | 0.01703 | 1796 | -8.15 | <.0001 |
| spl | 5 | -0.07001 | 0.01703 | 1512 | -4.11 | <.0001 |
| spl | 6 | 0.03440 | 0.01296 | 1501 | 2.65 | 0.0081 |

**Solutions for Fixed Effects**

| Effect | spl | Estimate | Standard Error | DF | t Value | Pr > \|t\| |
|---|---|---|---|---|---|---|
| spl | 7 | -0.01584 | 0.02291 | 1489 | -0.69 | 0.4894 |
| spl | 8 | 0 | . | . | . | . |

**Type III Tests of Fixed Effects**

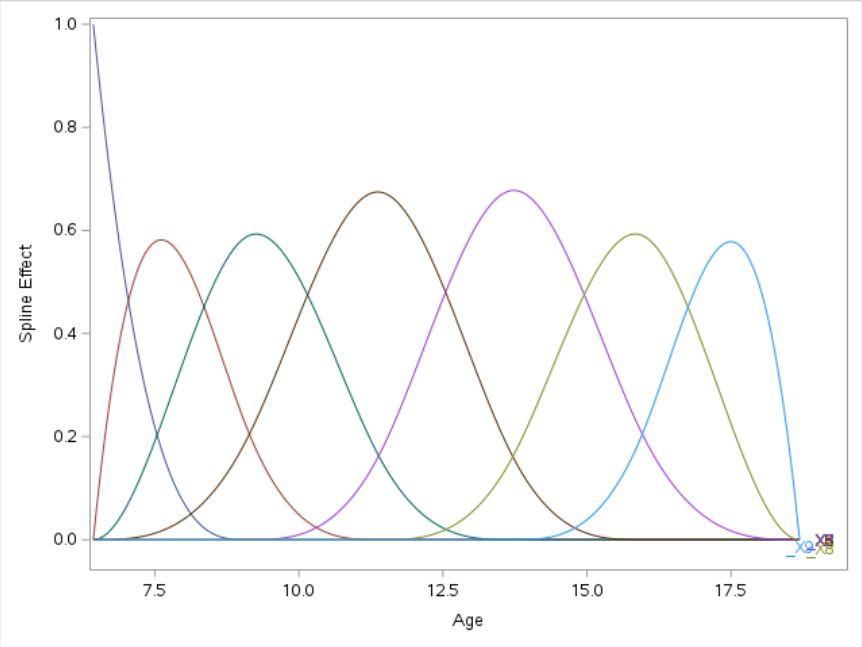
| Effect | Num DF | Den DF | F Value | Pr > F |
|---|---|---|---|---|
| Height | 1 | 1405 | 825.29 | <.0001 |
| spl | 7 | 1723 | 56.56 | <.0001 |

**Solution for Random Effects**

| Effect | Subject | Estimate | Std Err Pred | DF | t Value | Pr > \|t\| |
|---|---|---|---|---|---|---|
| Intercept | ID 1 | -0.09935 | 0.1911 | 313.4 | -0.52 | 0.6034 |
| Height | ID 1 | 0.06597 | 0.1368 | 315.7 | 0.48 | 0.6299 |
| Intercept | ID 2 | 0.4574 | 0.1478 | 761.9 | 3.09 | 0.0020 |
| Height | ID 2 | -0.2696 | 0.1015 | 774.8 | -2.66 | 0.0081 |
| Intercept | ID 3 | 0.5782 | 0.1454 | 795.7 | 3.98 | <.0001 |
| Height | ID 3 | -0.3285 | 0.1010 | 805.1 | -3.25 | 0.0012 |
| Intercept | ID 300 | -0.04221 | 0.2427 | 125.1 | -0.17 | 0.8622 |
| Height | ID 300 | 0.02605 | 0.1553 | 127.8 | 0.17 | 0.8671 |

```
proc sgplot data=Splines;
   series x=Age y=_X3 / curvelabel;
   series x=Age y=_X4 / curvelabel;
   series x=Age y=_X5 / curvelabel;
   series x=Age y=_X6 / curvelabel;
   series x=Age y=_X7 / curvelabel;
```

```
   series x=Age y=_X8 / curvelabel;
   series x=Age y=_X9 / curvelabel;
   yaxis label="Spline Effect";
run;
```




```
proc print data=PE;
run;
```

| Obs | Effect | spl | Estimate | StdErr | DF | tValue | Probt |
|---|---|---|---|---|---|---|---|
| 1 | Intercept | | -1.5841 | 0.09482 | 1465 | -16.71 | <.0001 |
| 2 | Height | | 1.6587 | 0.05774 | 1405 | 28.73 | <.0001 |
| 3 | spl | 1 | -0.2433 | 0.03247 | 1931 | -7.49 | <.0001 |
| 4 | spl | 2 | -0.1628 | 0.02842 | 1898 | -5.73 | <.0001 |
| 5 | spl | 3 | -0.1244 | 0.02505 | 1955 | -4.96 | <.0001 |
| 6 | spl | 4 | -0.1387 | 0.01703 | 1796 | -8.15 | <.0001 |
| 7 | spl | 5 | -0.07001 | 0.01703 | 1512 | -4.11 | <.0001 |
| 8 | spl | 6 | 0.03440 | 0.01296 | 1501 | 2.65 | 0.0081 |

| Obs | Effect | spl | Estimate | StdErr | DF | tValue | Probt |
|---|---|---|---|---|---|---|---|
| 9 | spl | 7 | -0.01584 | 0.02291 | 1489 | -0.69 | 0.4894 |
| 10 | spl | 8 | 0 | . | . | . | . |

```
data PE2;
set PE;
if effect = "spl";
run;

proc iml;
use PE2; read all var "Estimate" into b; close;
use Splines; read all var {"_X3" "_X4" "_X5" "_X6" "_X7" "_X8"
"_X9" "_X10"} into X; close;
Pred = X*b;
create SplineFit var "Pred"; append; close;
quit;

data All;
merge Splines SplineFit;
run;

proc sgplot data=All;
   series x=Age y=Pred / curvelabel;
   yaxis label="Spline Coefficient";
run;
```