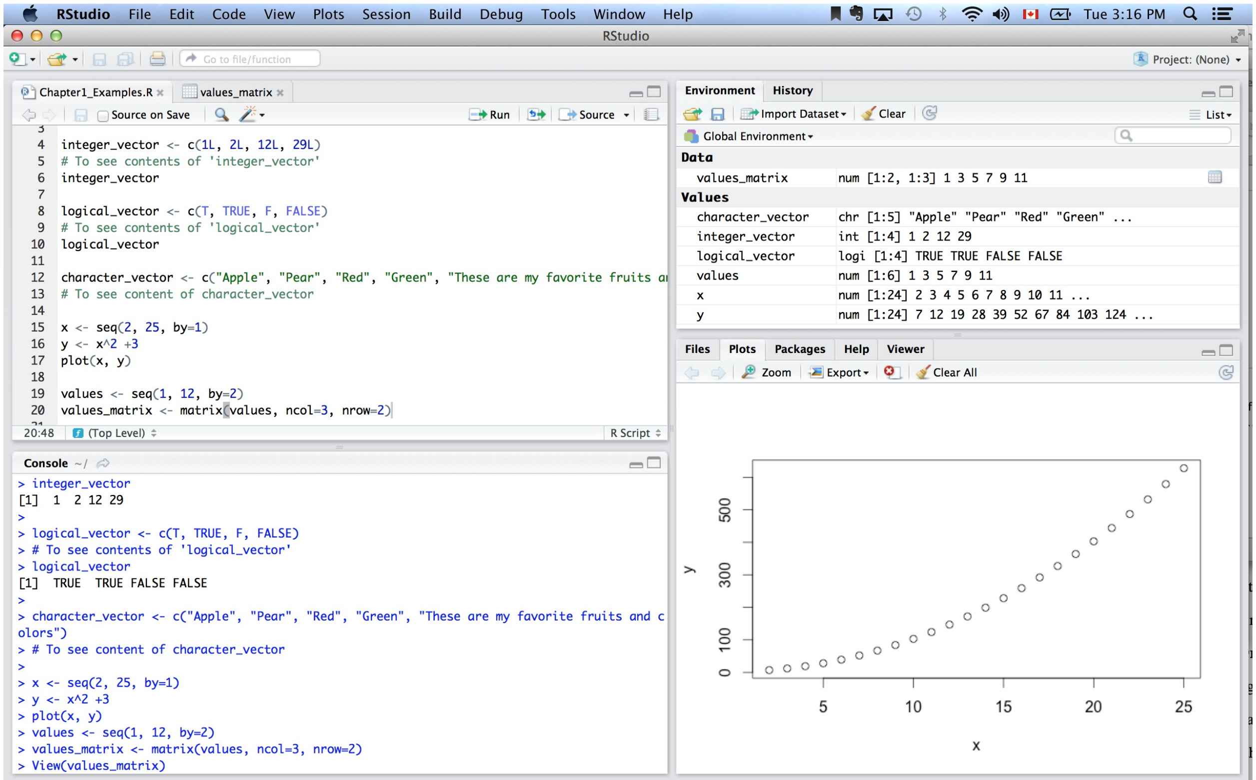
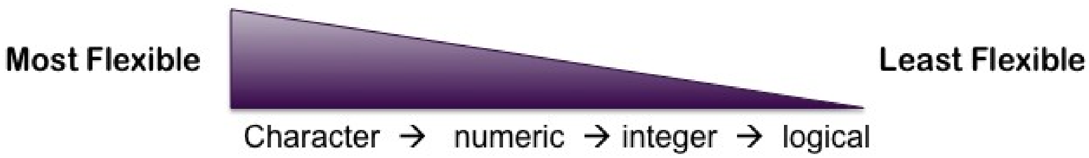
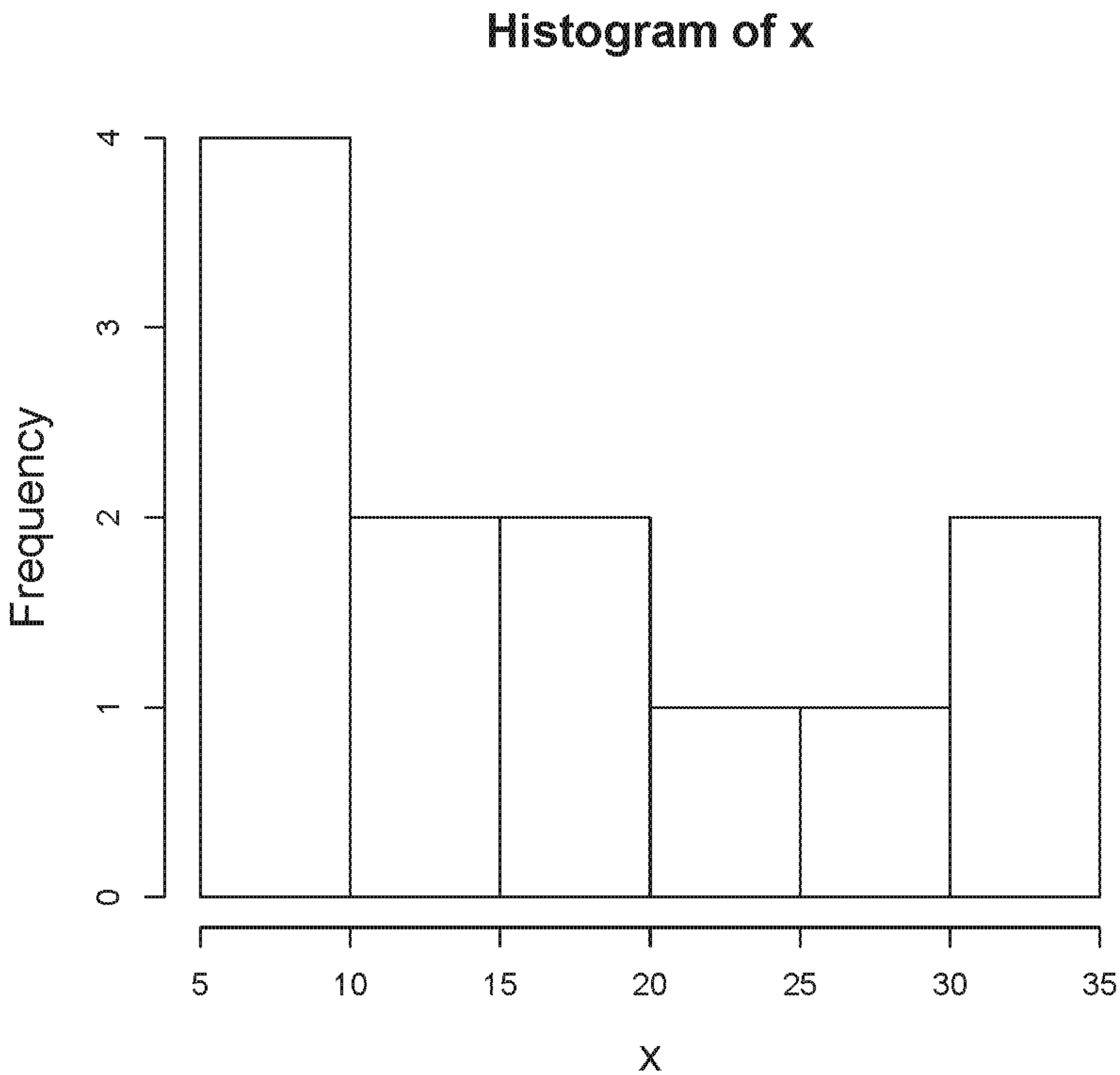
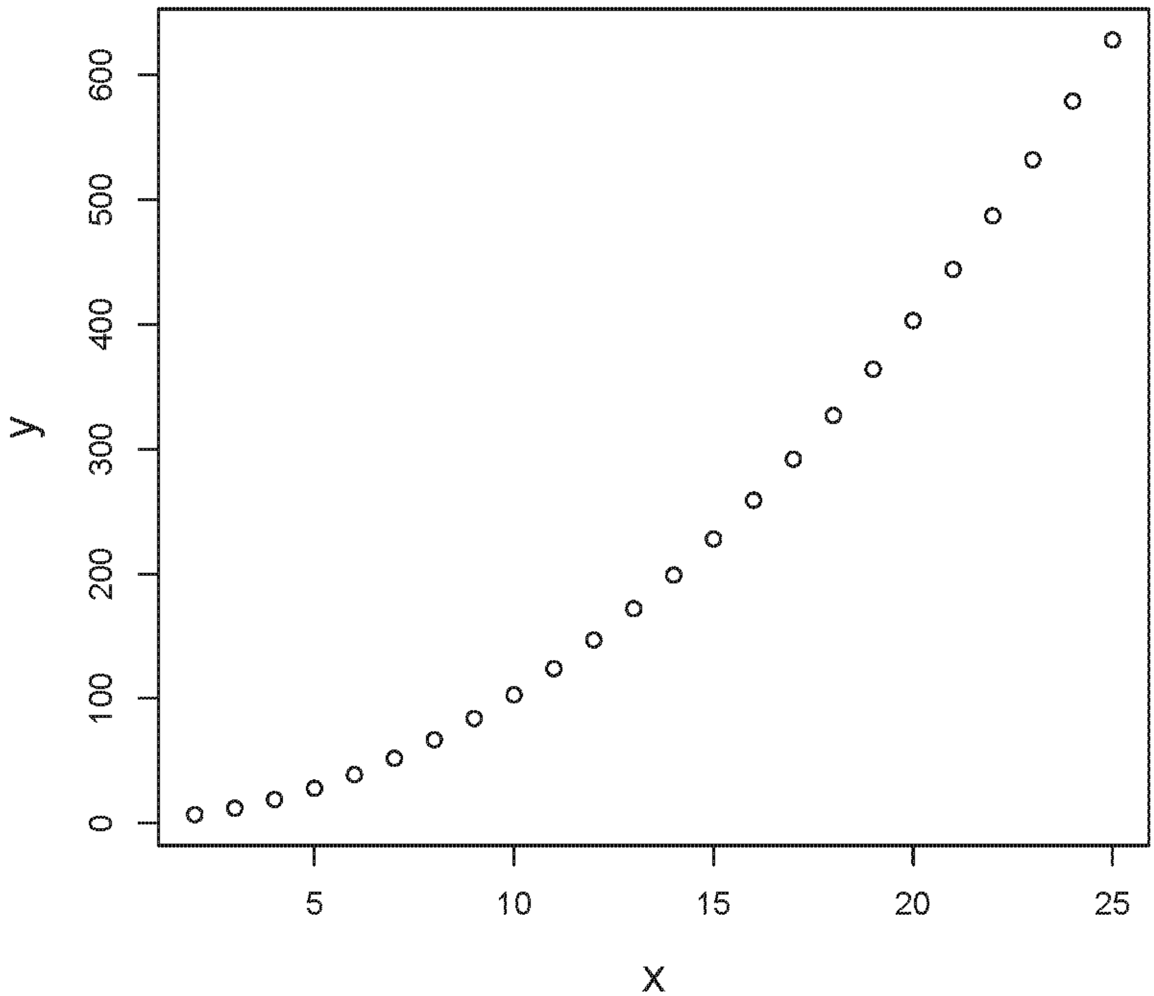
Chapter 1: Programming with R

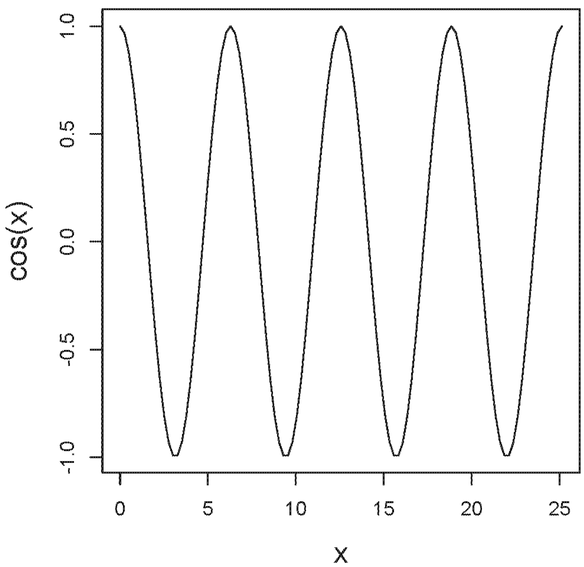
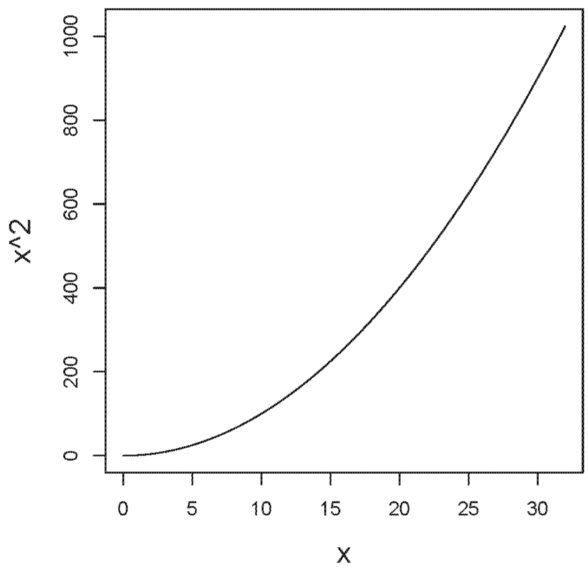


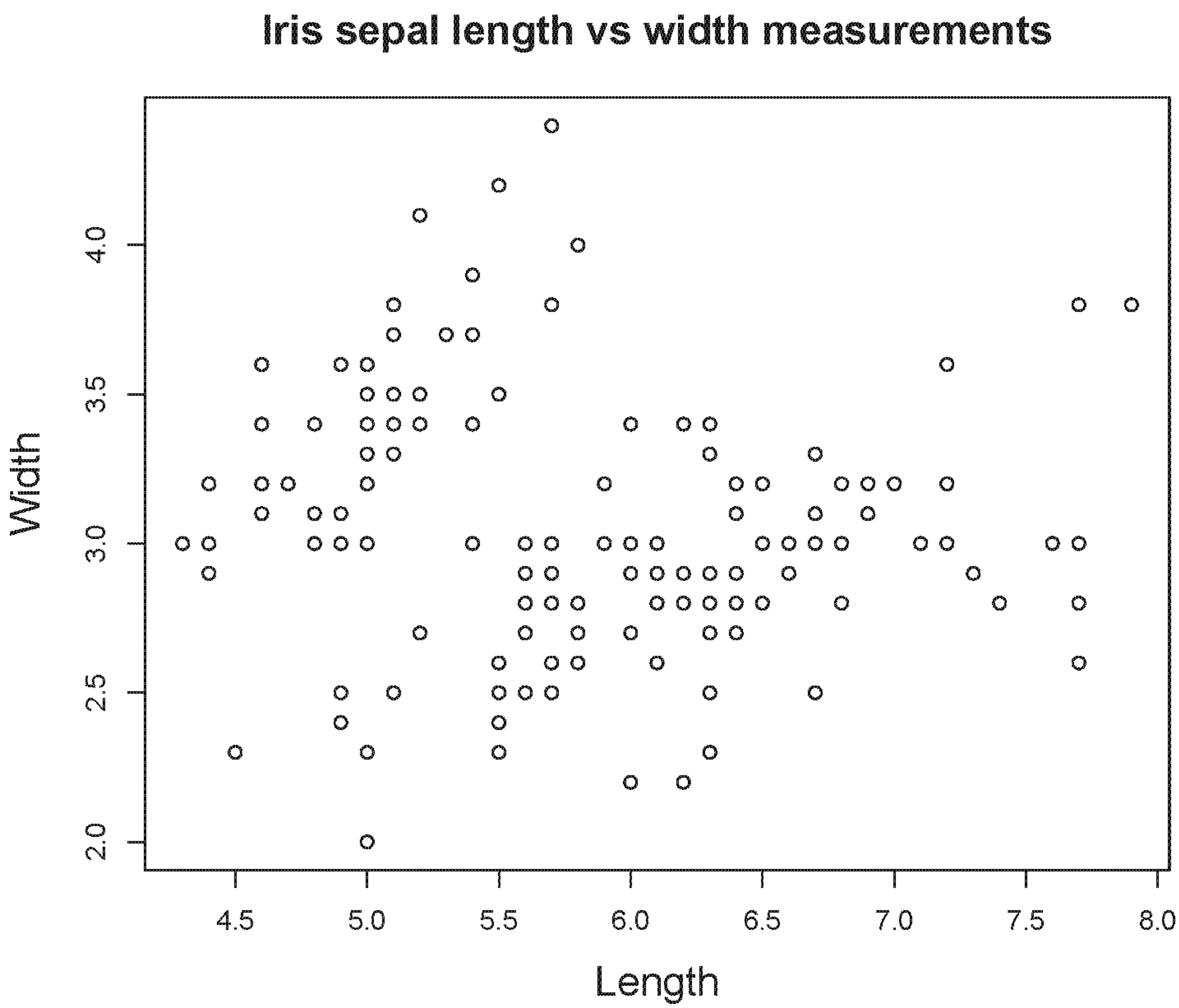

Most Flexible
Least Flexible
Character → numeric → integer → logical


Histogram of x
Frequency
0
1
2
3
4
5
10
15
20
25
30
35
x

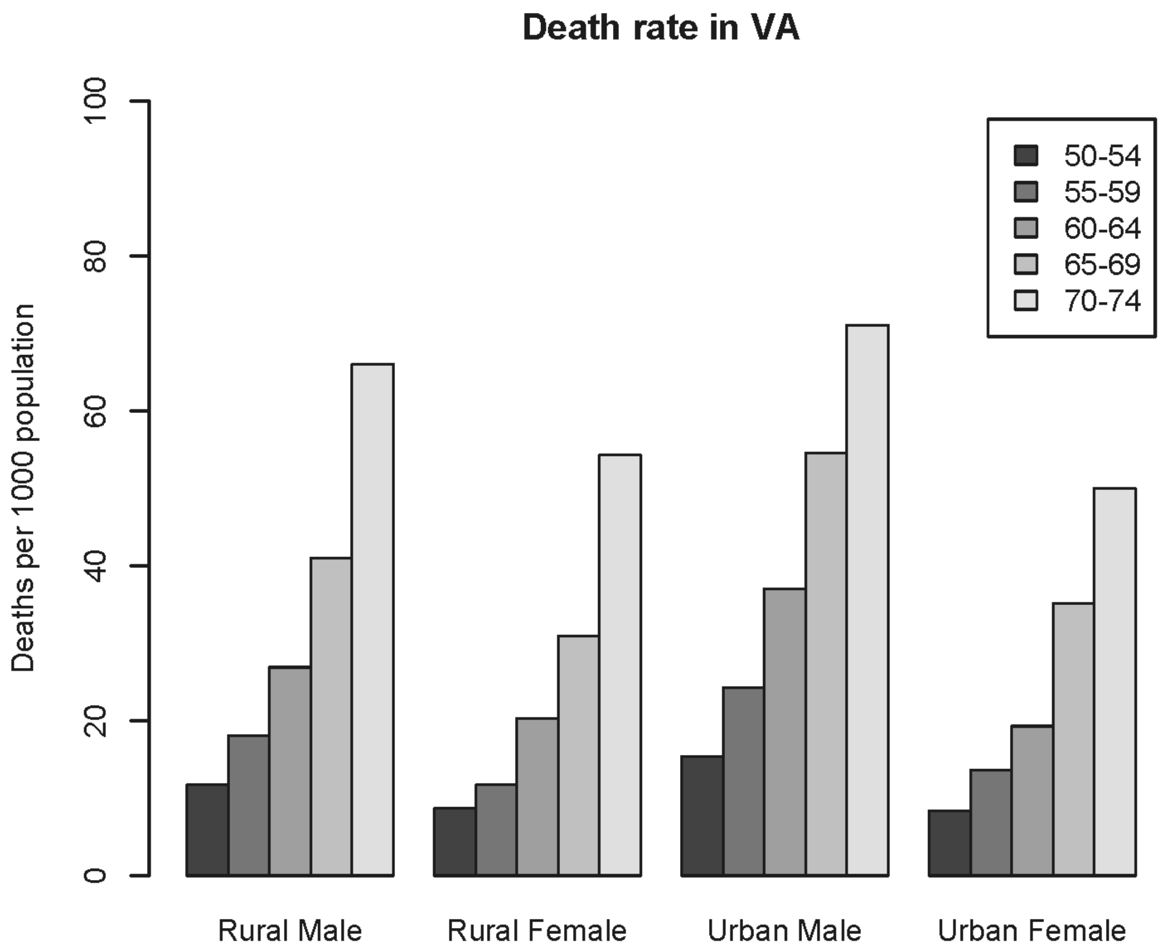


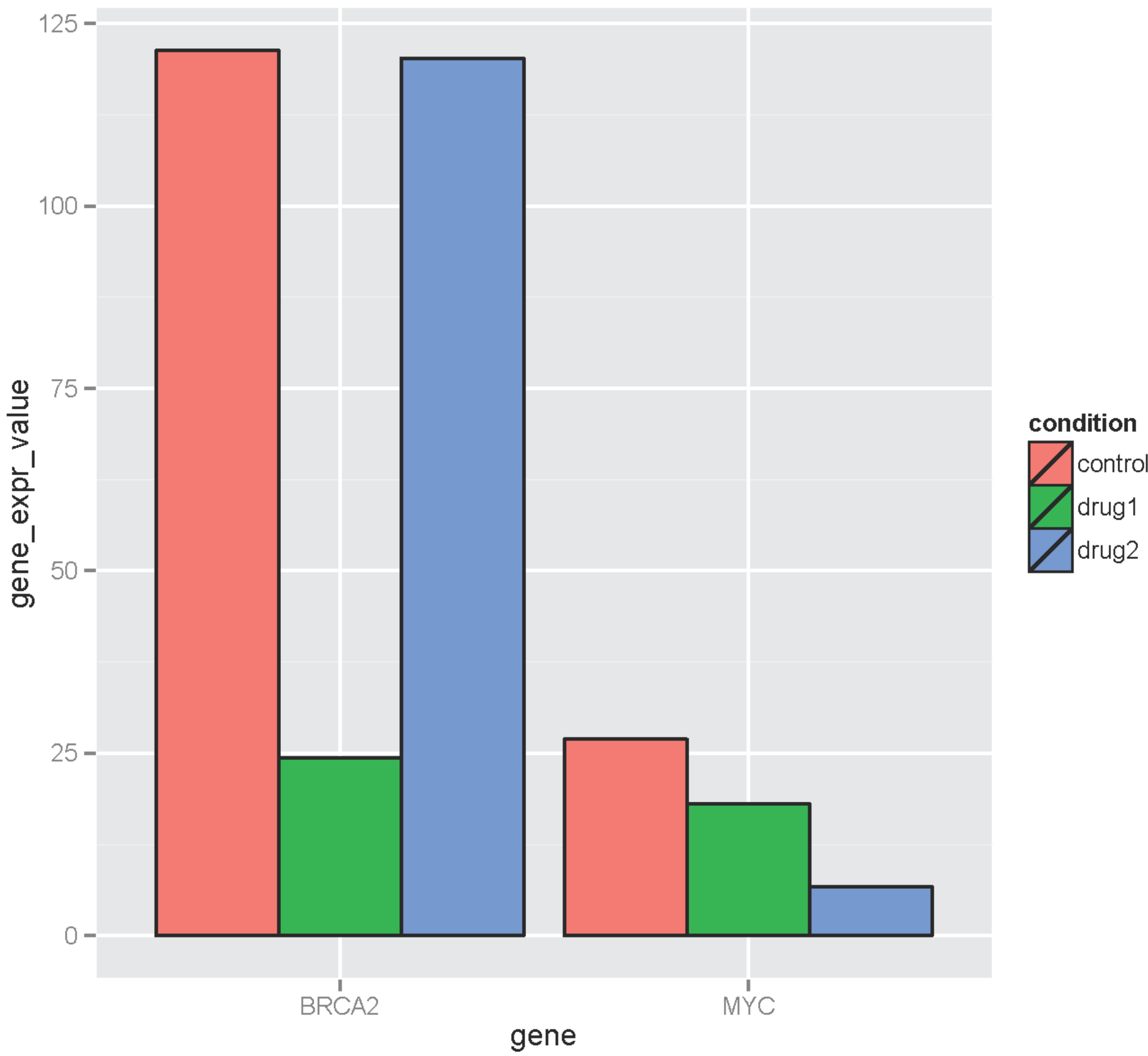
y
0
100
200
300
400
500
600
x
5
10
15
20
25


cos(x)
1.0
0.5
0.0
-0.5
-1.0
0
5
10
15
20
25
x

x^2
1000
800
600
400
200
0
0
5
10
15
20
25
30
x

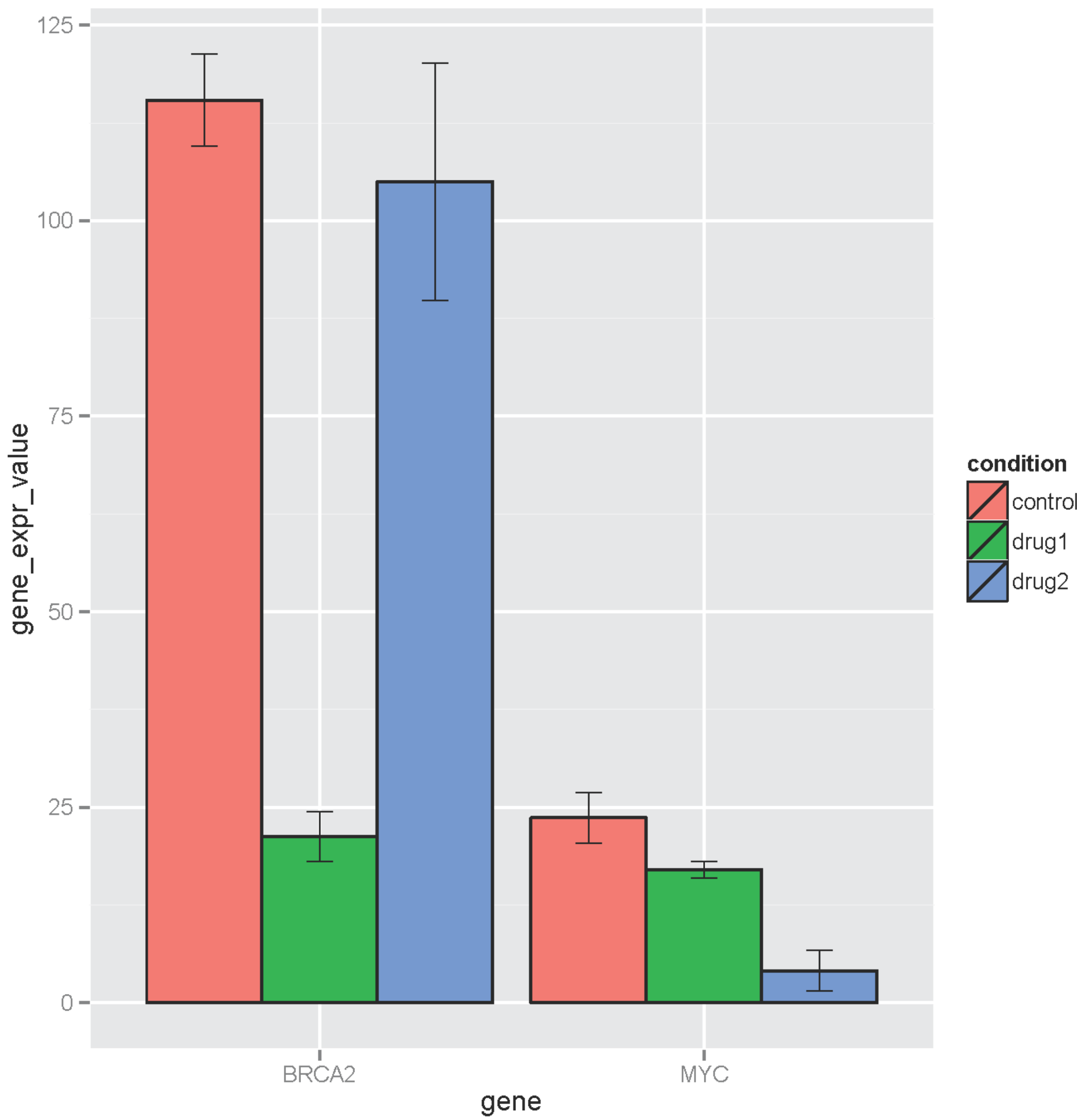


Iris sepal length vs width measurements
Width
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0
Length

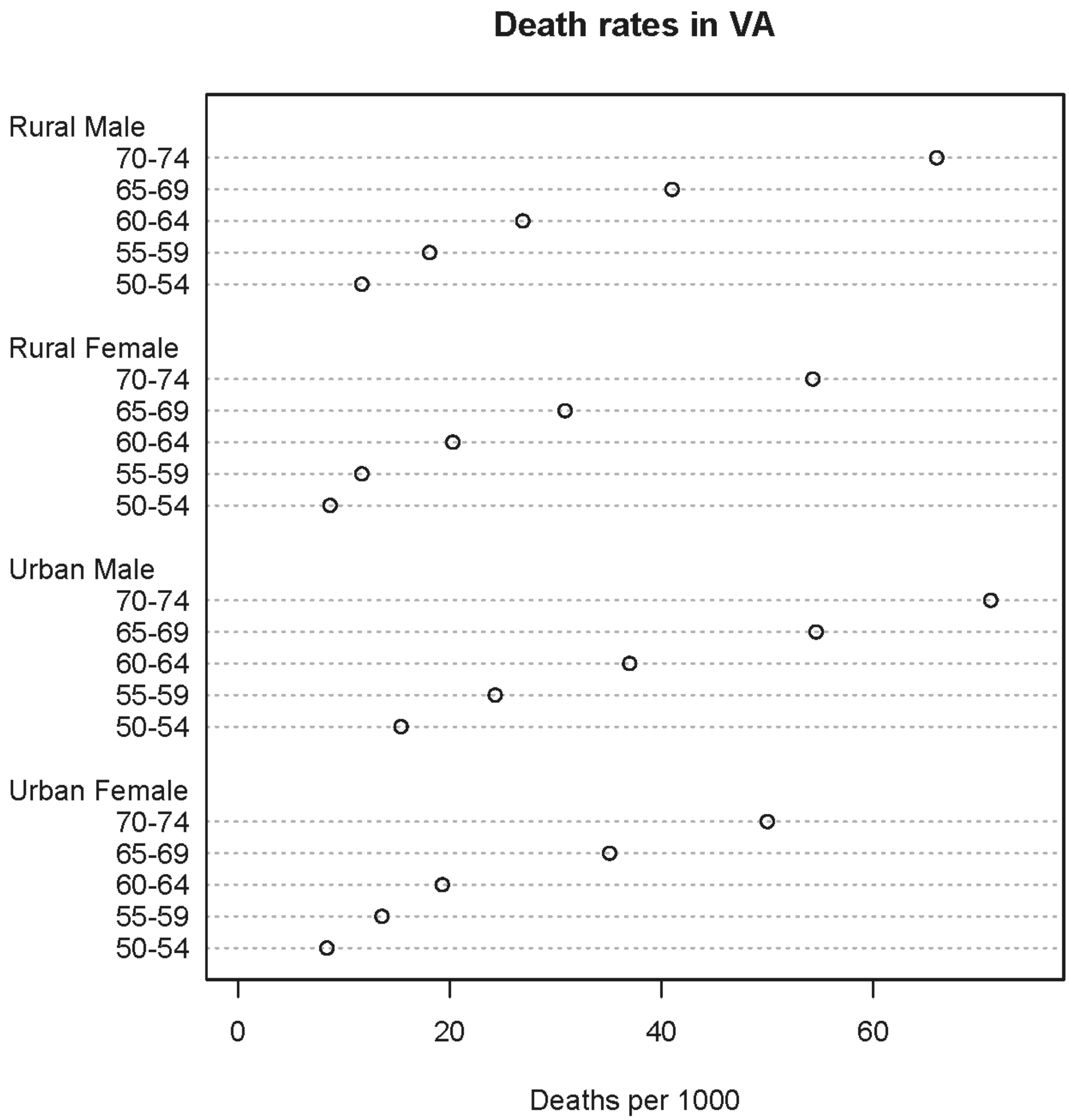

Death rate in VA
Deaths per 1000 population
0
20
40
60
80
100
50-54
55-59
60-64
65-69
70-74
Rural Male
Rural Female
Urban Male
Urban Female

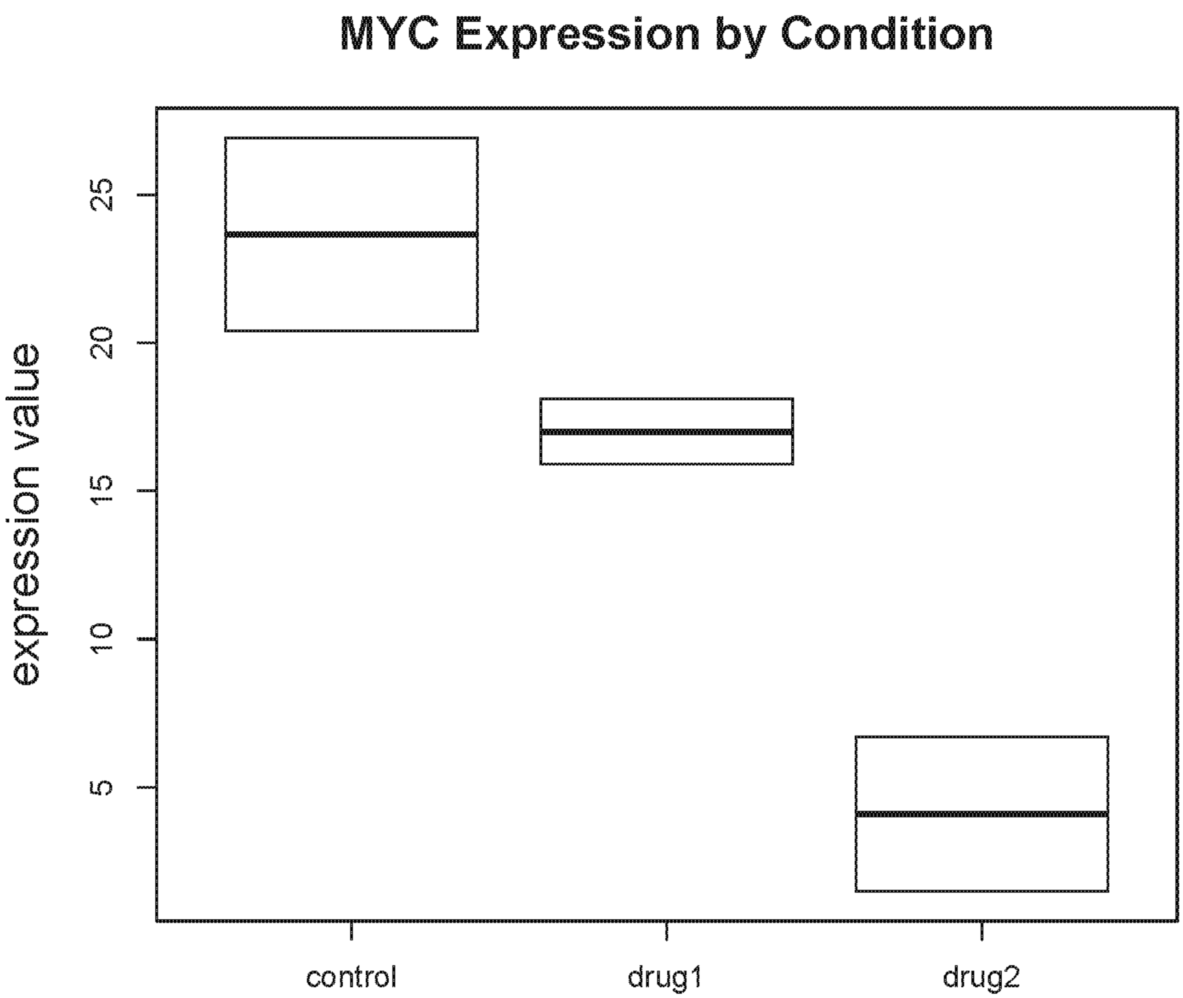


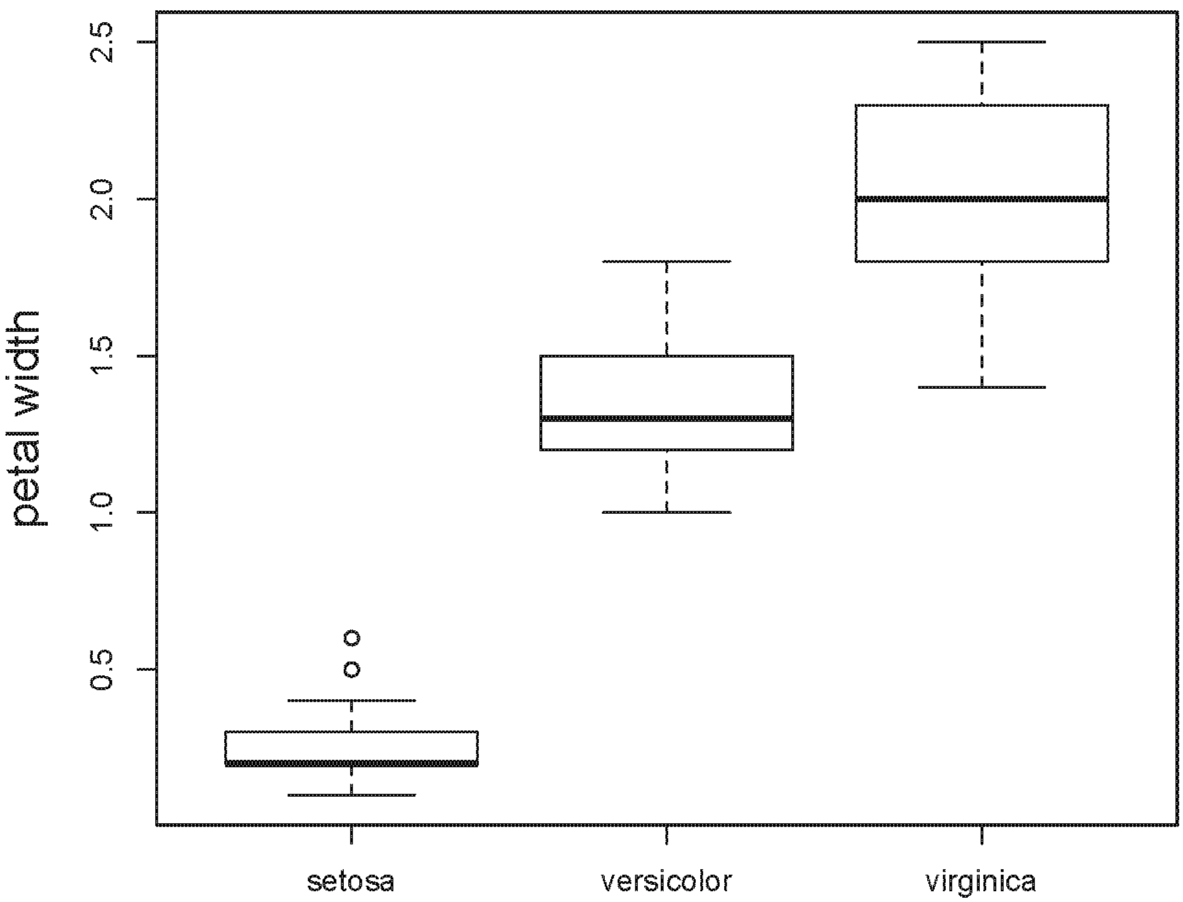
125
100
75
50
25
0
gene_expr_value
BRCA2
MYC
gene
condition
control
drug1
drug2



125
100
75
50
25
0
gene_expr_value
BRCA2
MYC
gene
condition
control
drug1
drug2


Death rates in VA
Rural Male
70-74
65-69
60-64
55-59
50-54
Rural Female
70-74
65-69
60-64
55-59
50-54
Urban Male
70-74
65-69
60-64
55-59
50-54
Urban Female
70-74
65-69
60-64
55-59
50-54
0
20
40
60
Deaths per 1000

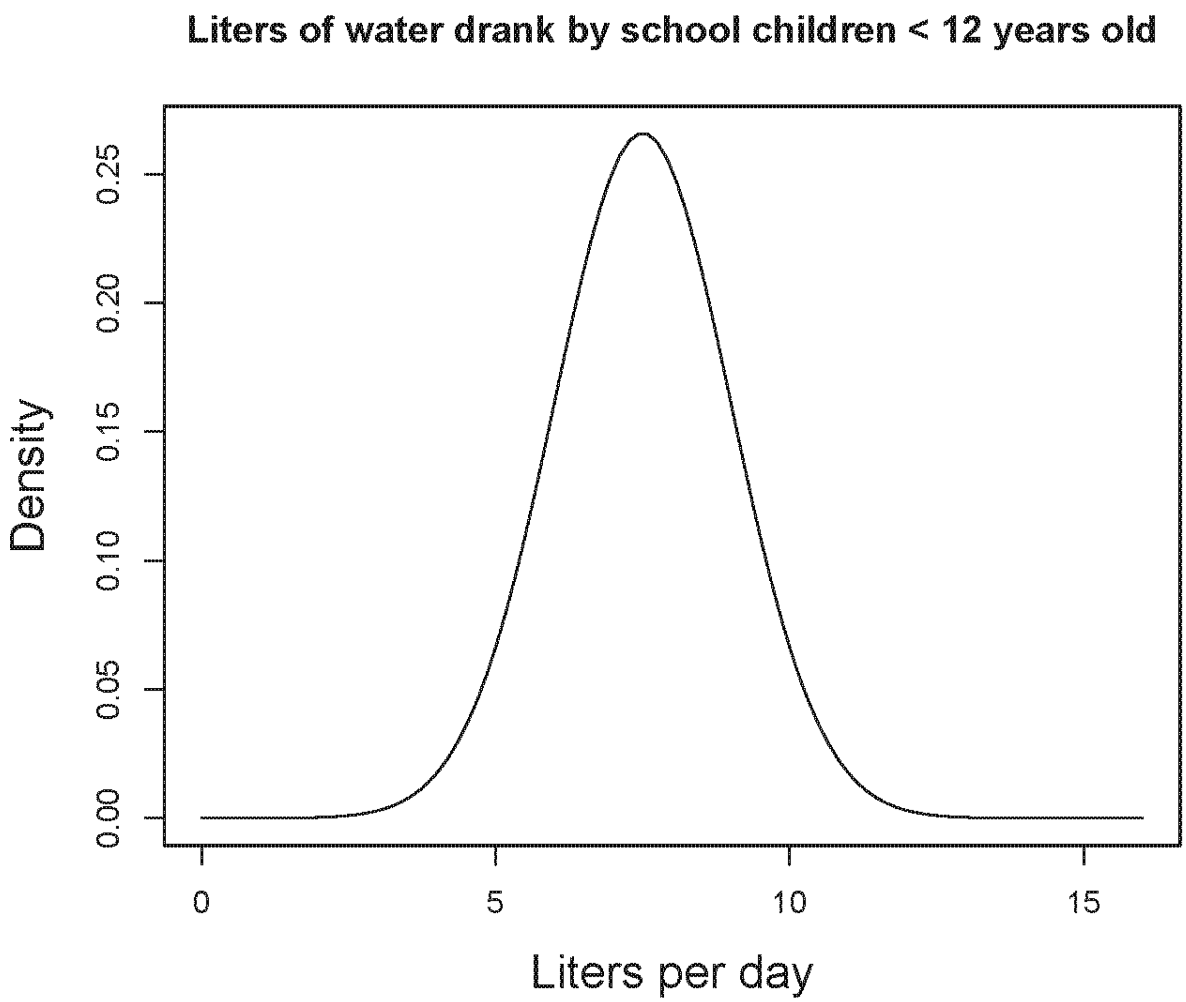

MYC Expression by Condition
expression value
5
10
15
20
25
control
drug1
drug2

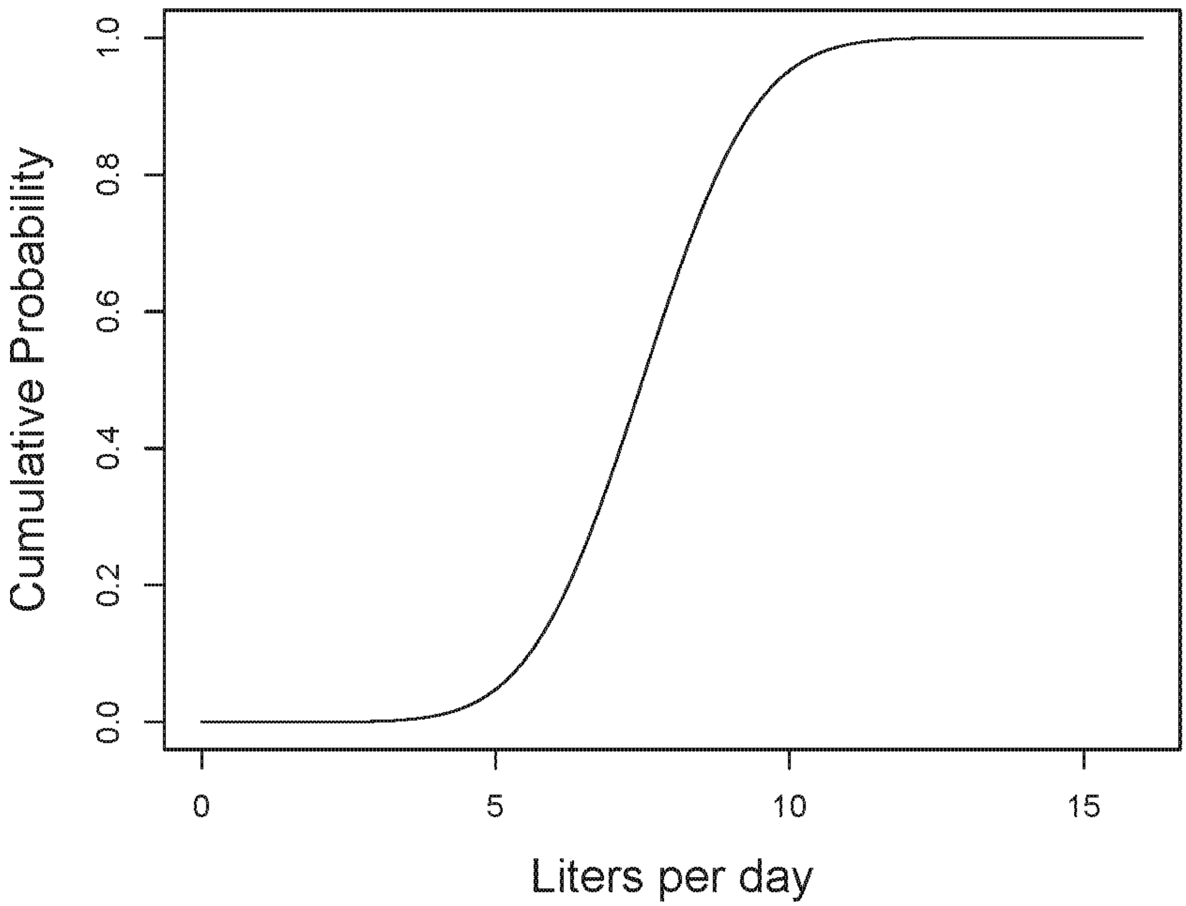

petal width
2.5
2.0
1.5
1.0
0.5
setosa
versicolor
virginica

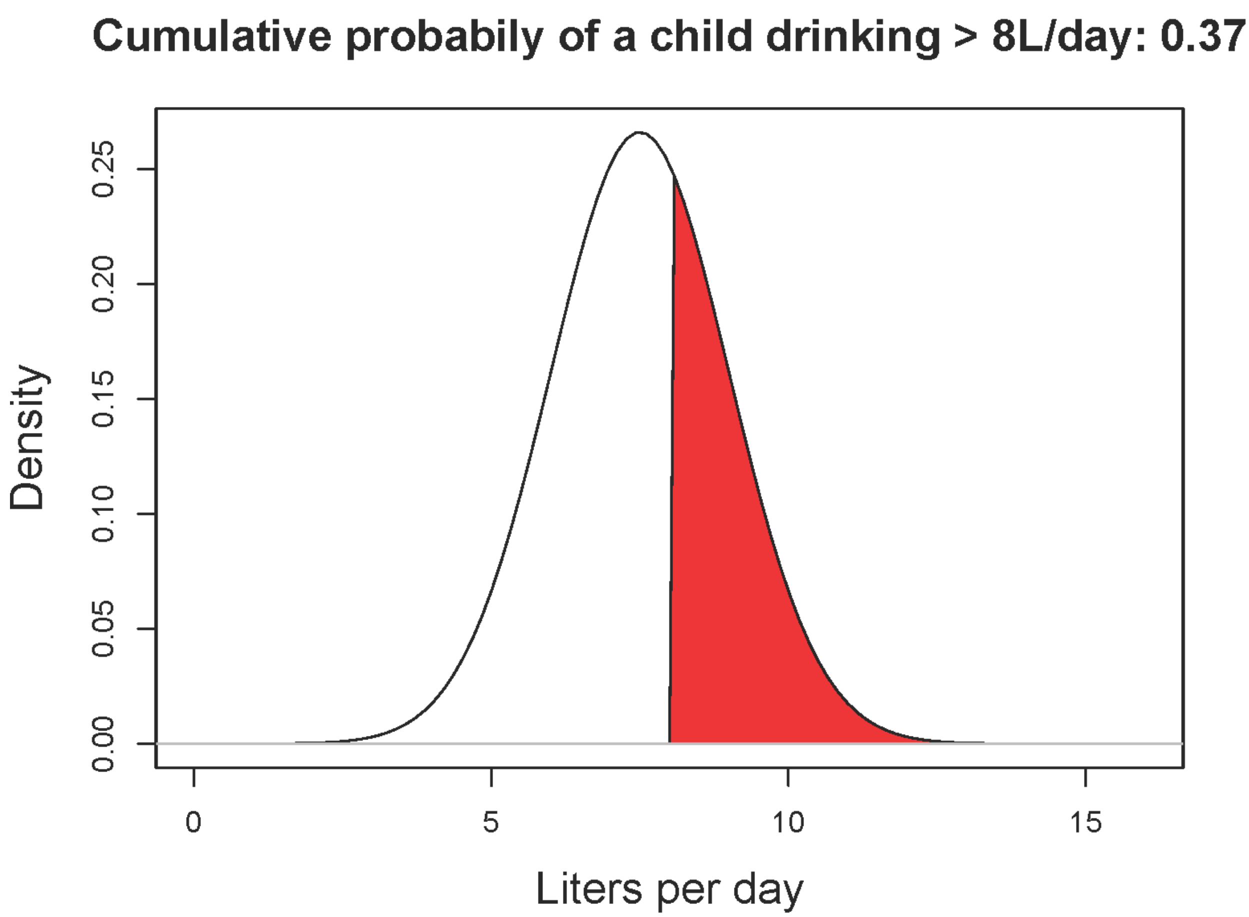
Help topics matching ‘mean’

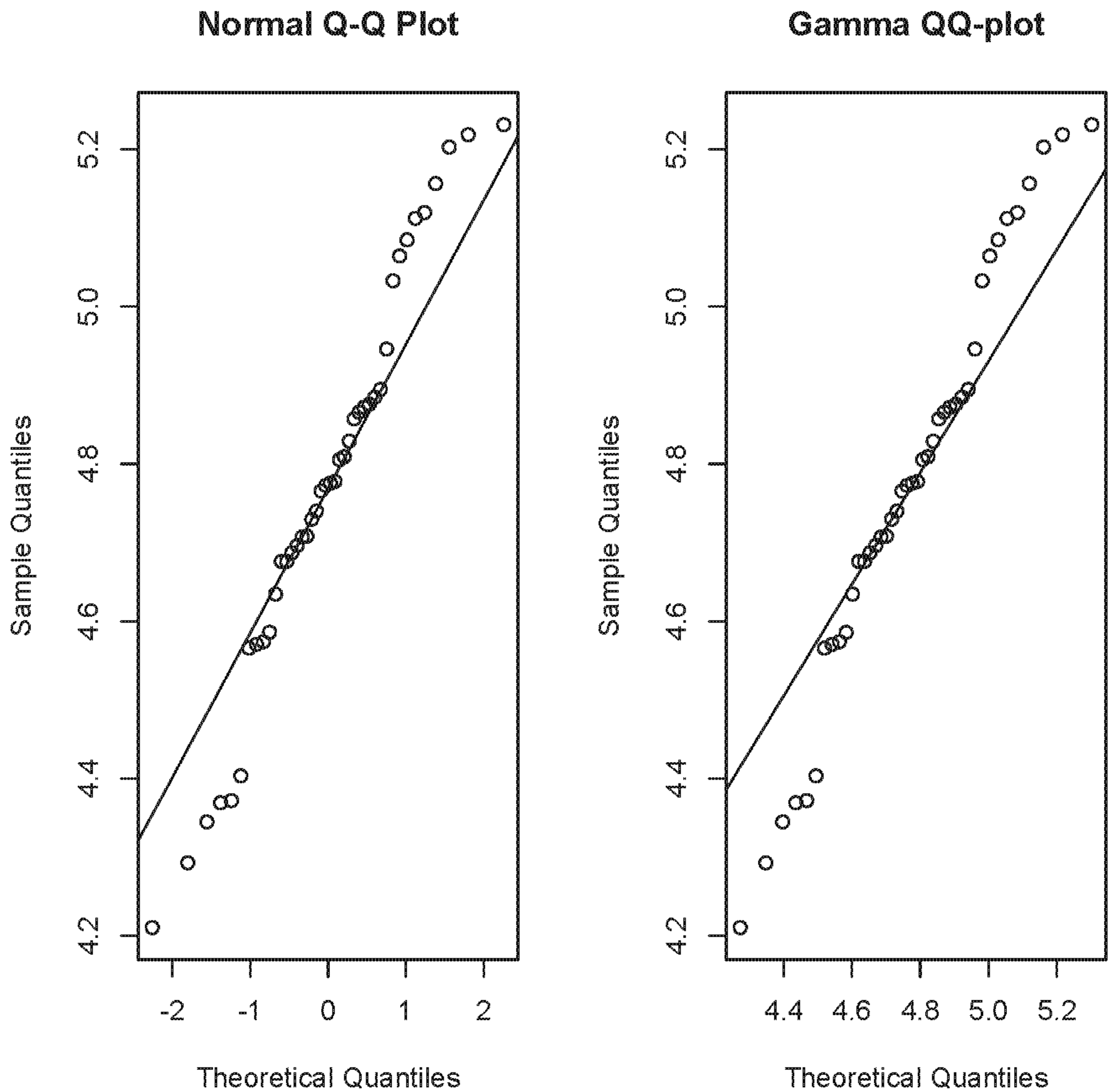
Topic	Package	Description
DateTimeClasses	base	Date-Time Classes
Date	base	Date Class
colSums	base	Form Row and Column Sums and Means
difftime	base	Time Intervals
mean	base	Arithmetic Mean
sunspot	boot	Annual Mean Sunspot Numbers
runmean	caTools	Mean of a Moving Window
dates	chron	Generate Dates and Times Components from Input
CKME	clue	Cassini Data Partitions Obtained by K-Means
meanabsdev	cluster	Internal cluster functions
effectiveSize	coda	Effective sample size for estimating the mean
dispersionPlot	cummeRbund	Mean count vs dispersion plot
IDate	data.table	Integer based date class
fitDispersionFunction	DEXSeq	Fit the mean-variance function.
dglmStdResid	edgeR	Visualize the mean-variance relationship in DGE data using standardized residuals
loessByCol	edgeR	Locally Weighted Mean By Column
binMeanVar	edgeR	Explore the mean-variance relationship for DGE data
ghMoments	fBasics	Generalized Hyperbolic Distribution Moments
ghtMoments	fBasics	Generalized Hyperbolic Student-t Moments
hypMoments	fBasics	Hyperbolic Distribution Moments
nigMoments	fBasics	Moments for the Normal Inverse Gaussian
%in%-methods	flowCore	Filter-specific membership methods
kmeansFilter	flowCore	Class "kmeansFilter"

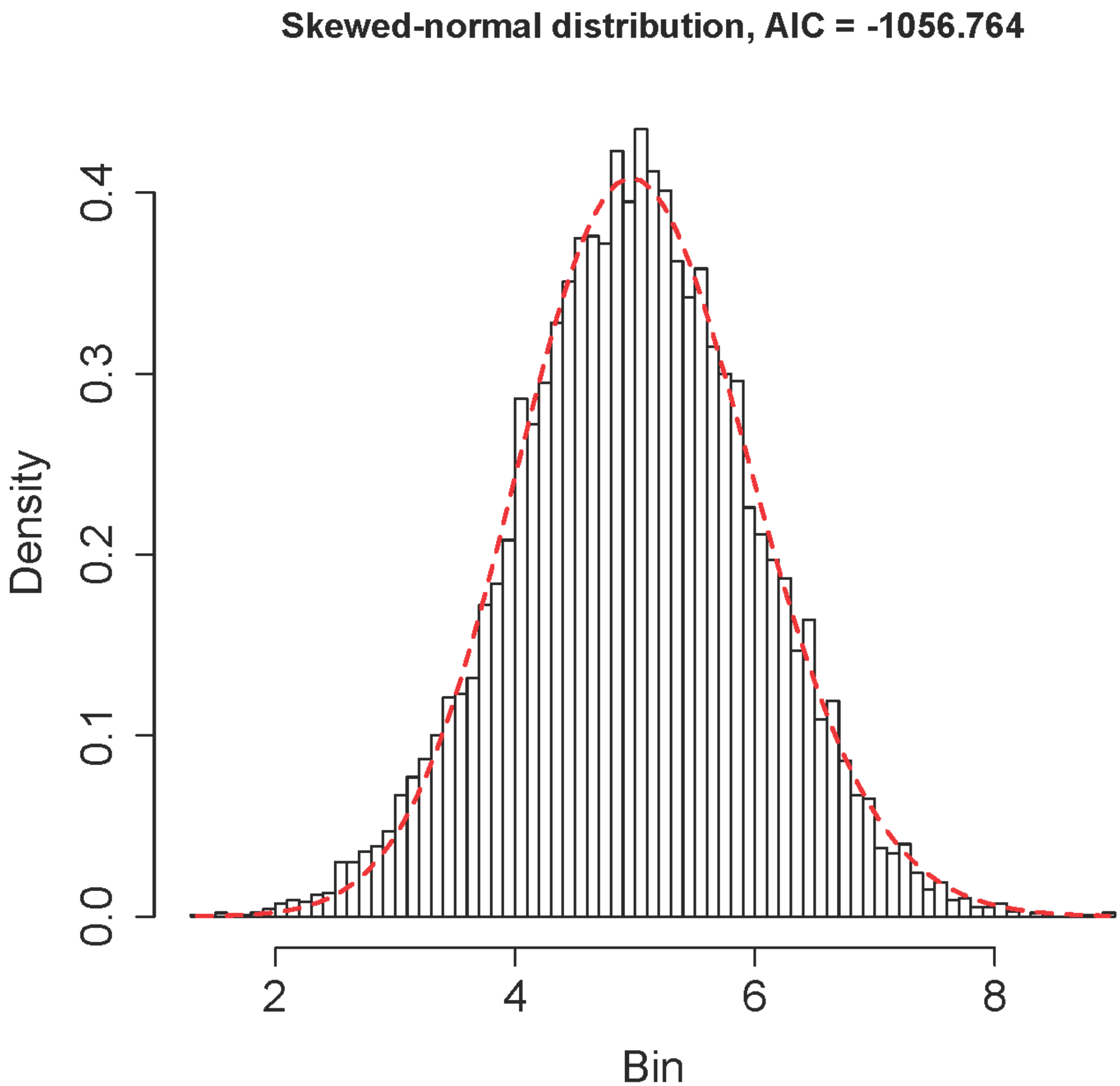
Chapter 2: Statistical Methods with R


Liters of water drank by school children < 12 years old
Density
0.00
0.05
0.10
0.15
0.20
0.25
0
5
10
15
Liters per day

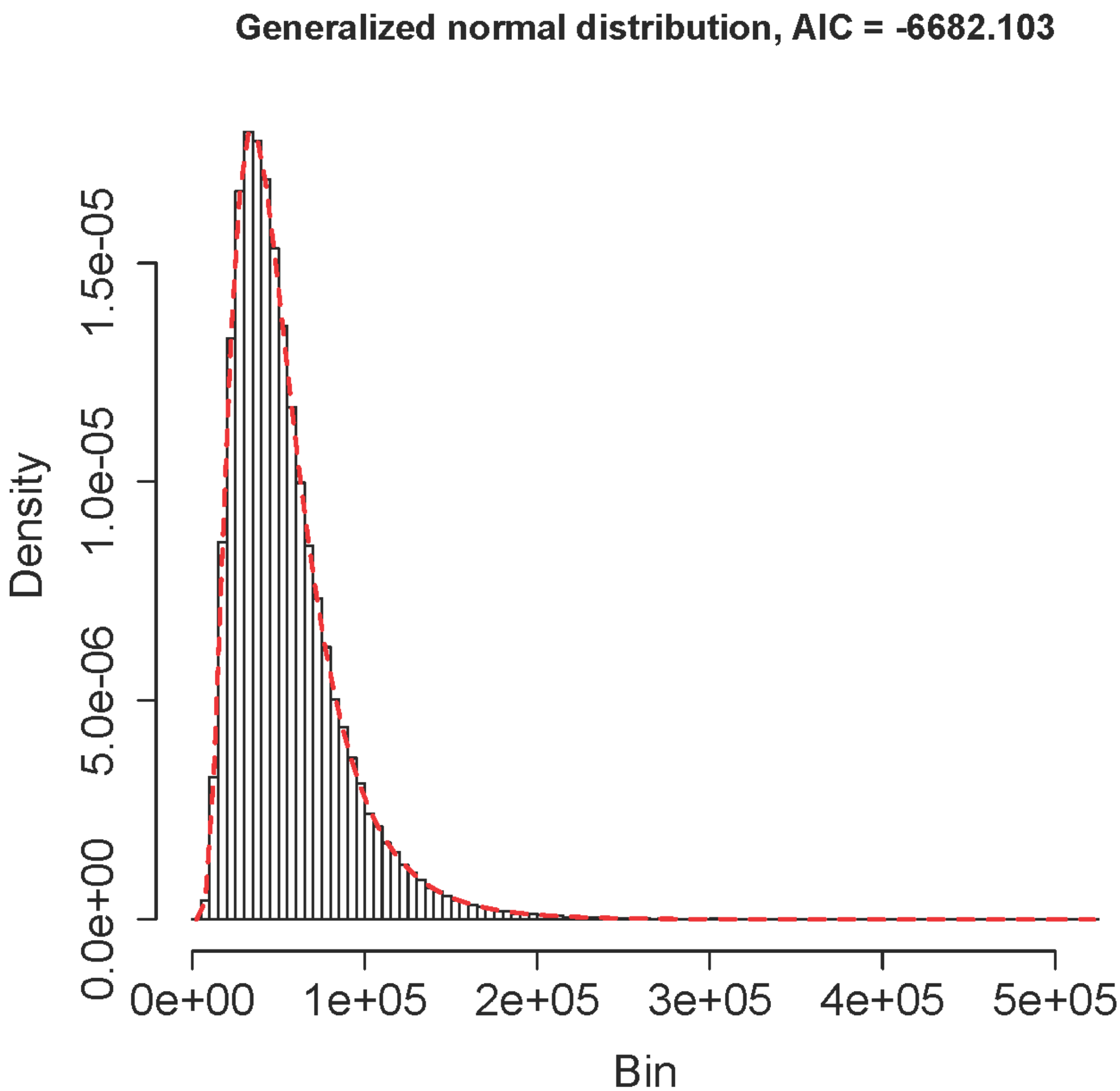

Cumulative Probability
0.0
0.2
0.4
0.6
0.8
1.0
0
5
10
15
Liters per day

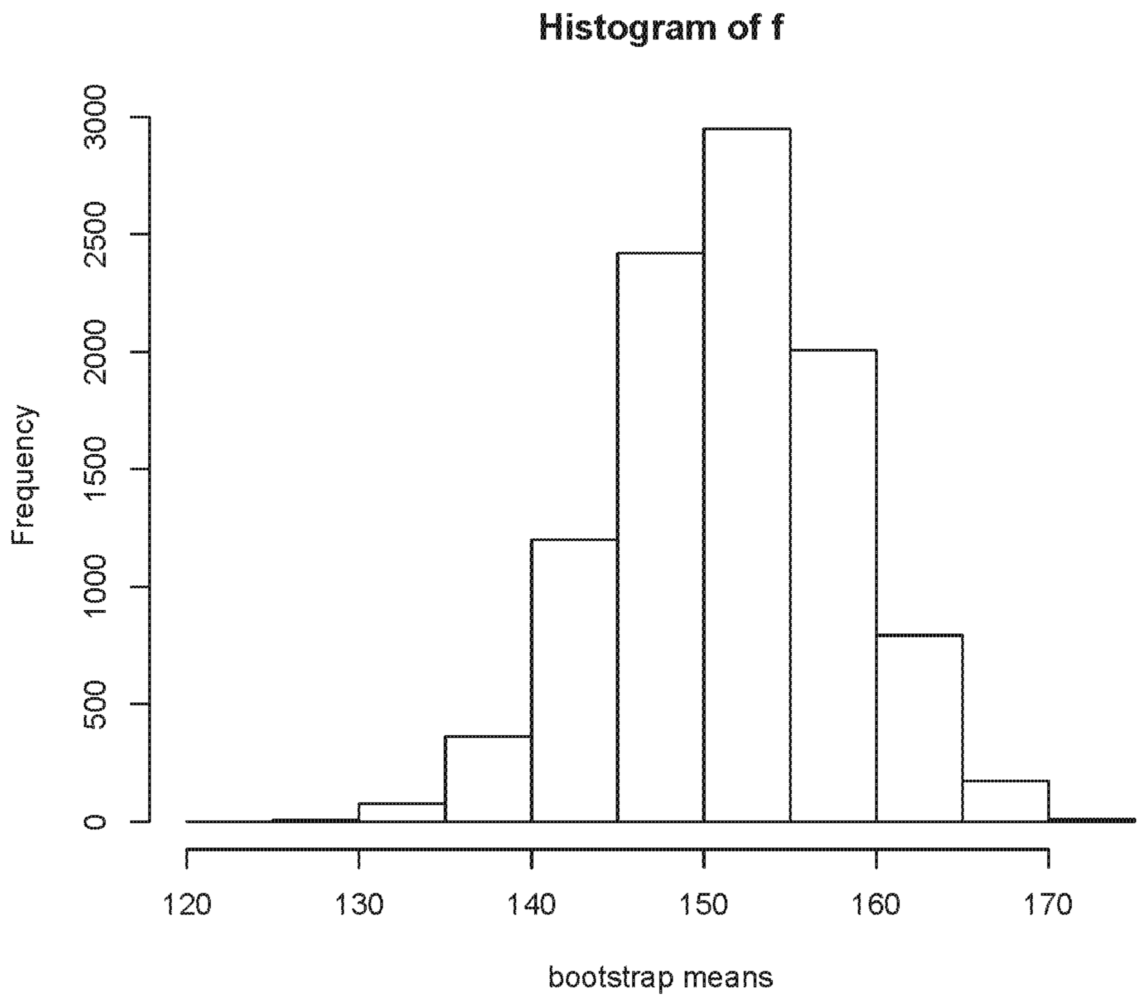

Cumulative probabily of a child drinking > 8L/day: 0.37
Density
0.00
0.05
0.10
0.15
0.20
0.25
0
5
10
15
Liters per day

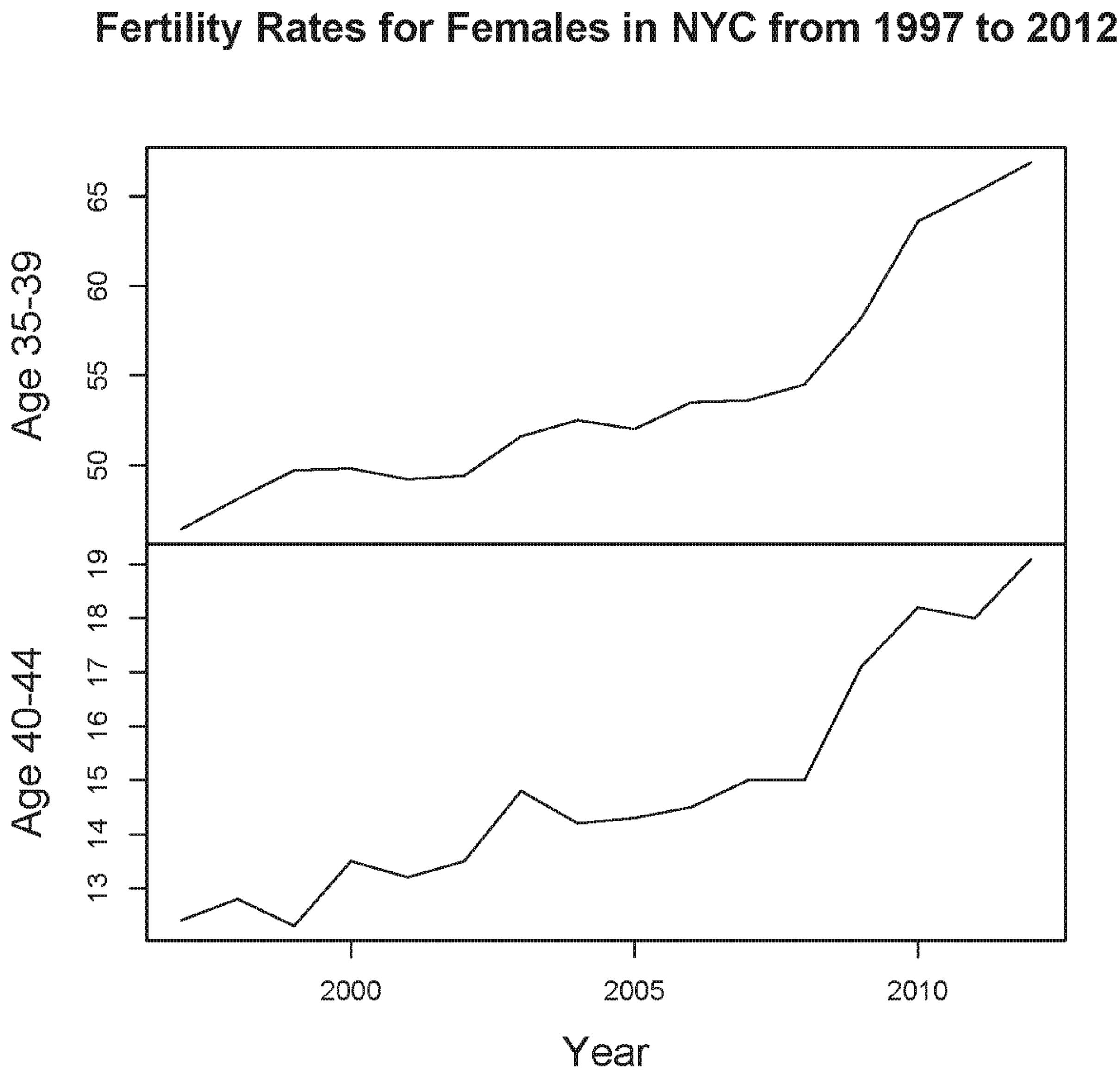

Normal Q-Q Plot
Sample Quantiles
Theoretical Quantiles
4.2
4.4
4.6
4.8
5.0
5.2
-2
-1
0
1
2
Gamma QQ-plot
Sample Quantiles
Theoretical Quantiles
4.2
4.4
4.6
4.8
5.0
5.2
4.4
4.6
4.8
5.0
5.2



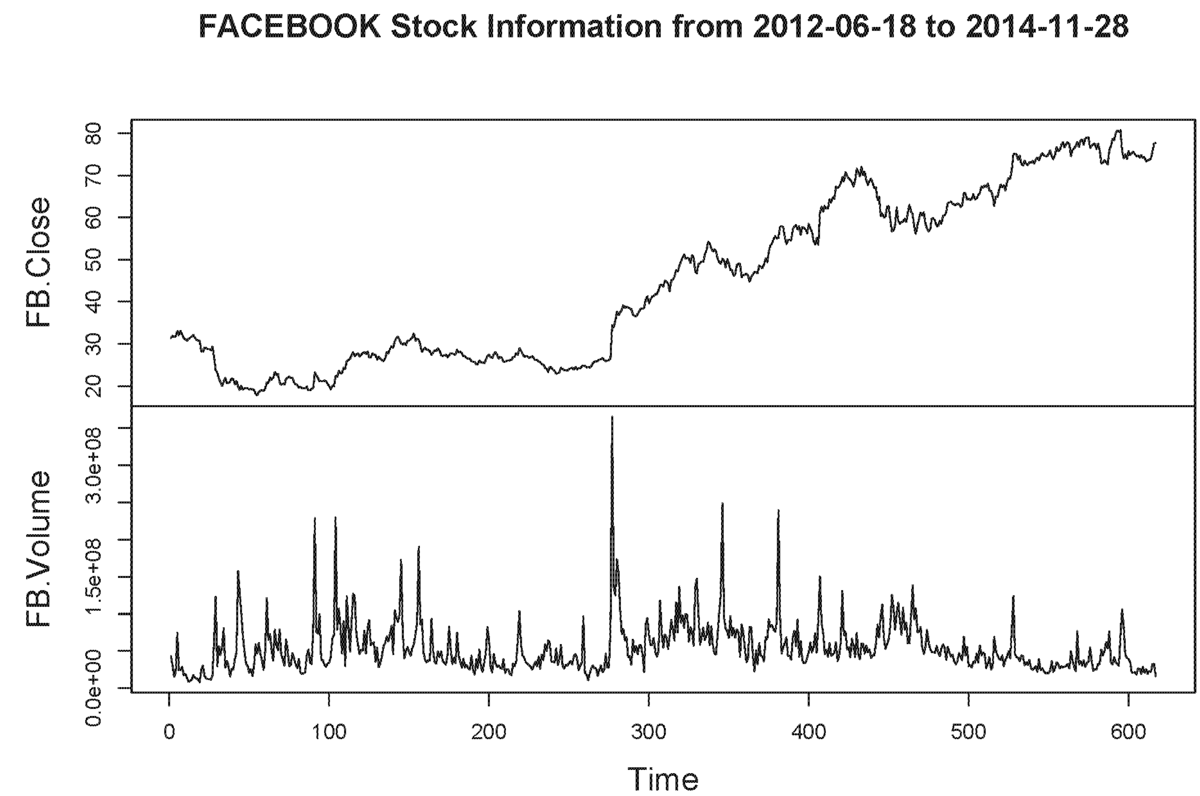
Skewed-normal distribution, AIC = -1056.764
Density
0.0
0.1
0.2
0.3
0.4
2
4
6
8
Bin


Generalized normal distribution, AIC = -6682.103
Density
0.0e+00
5.0e-06
1.0e-05
1.5e-05
0e+00
1e+05
2e+05
3e+05
4e+05
5e+05
Bin

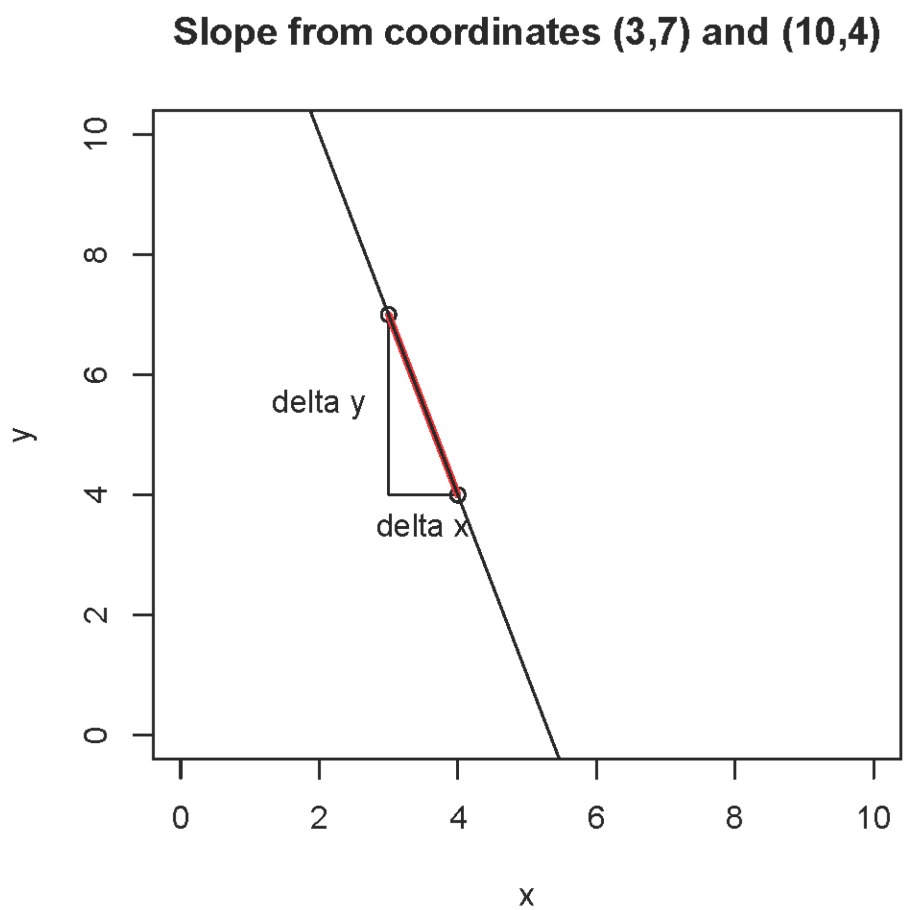

Histogram of f
Frequency
0
500
1000
1500
2000
2500
3000
120
130
140
150
160
170
bootstrap means

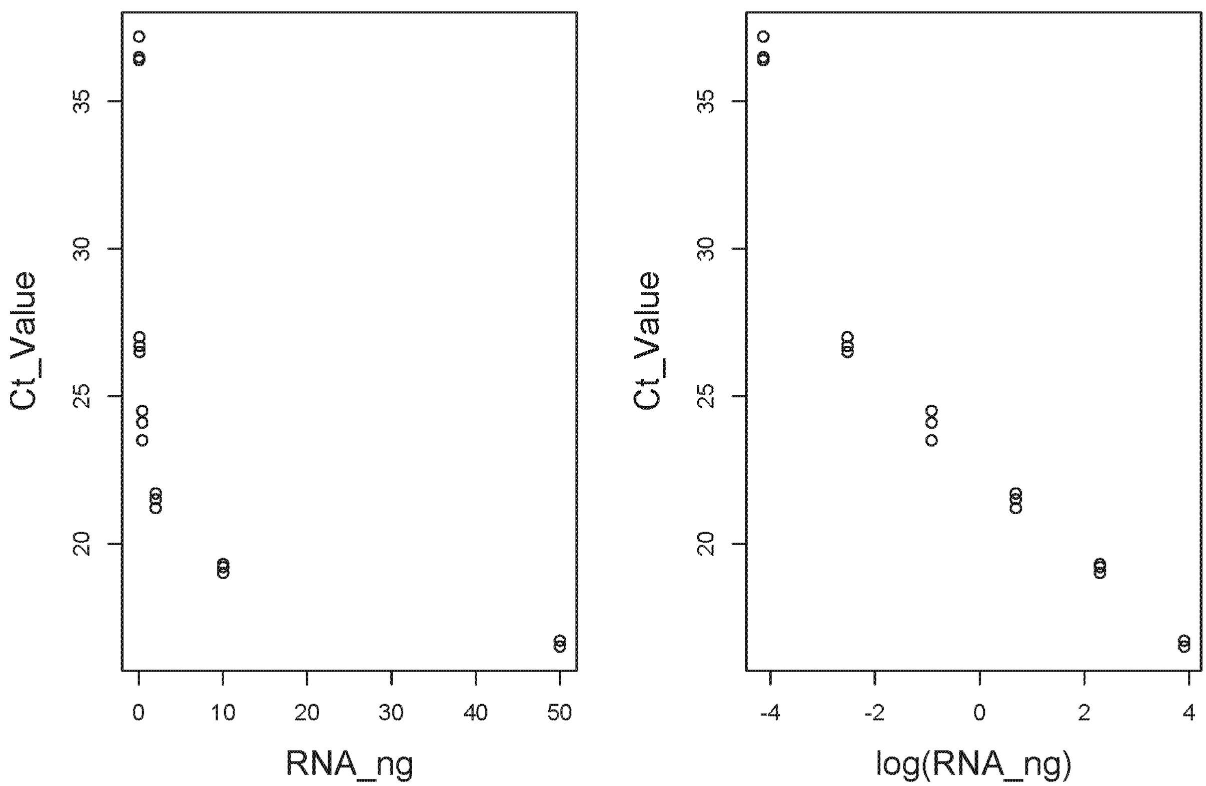

Fertility Rates for Females in NYC from 1997 to 2012
Age 35-39
65
60
55
50
Age 40-44
19
18
17
16
15
14
13
2000
2005
2010
Year

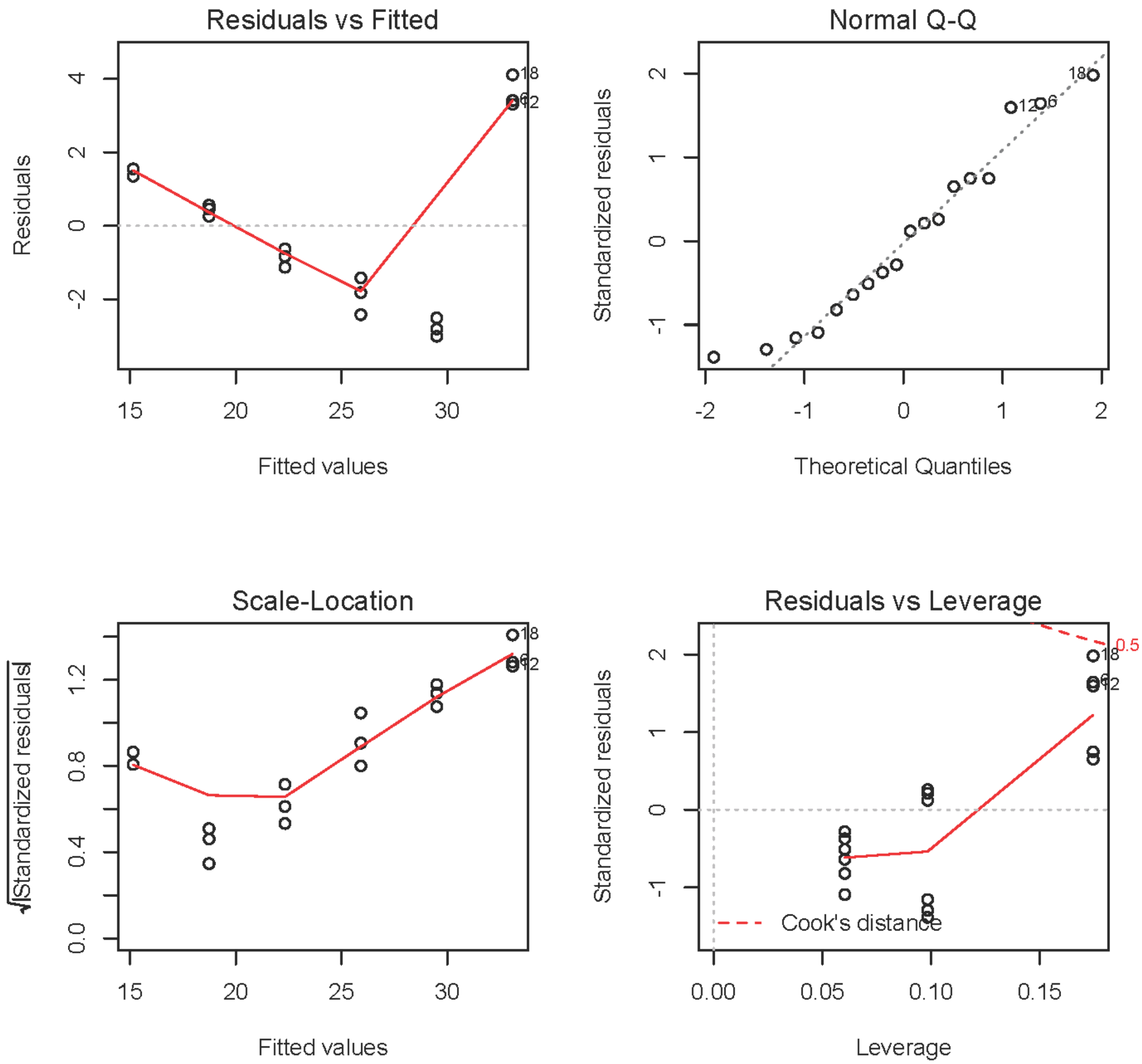

fbstock
[2012-06-18/2014-11-28]
4:5
Last 77.7
80
70
60
50
40
30
20
350
300
250
200
150
100
50
0
Volume (millions):
15,992,000
Jun 18 2012
Dec 03 2012
Jun 03 2013
Dec 02 2013
Jun 02 2014
Nov 28 2014

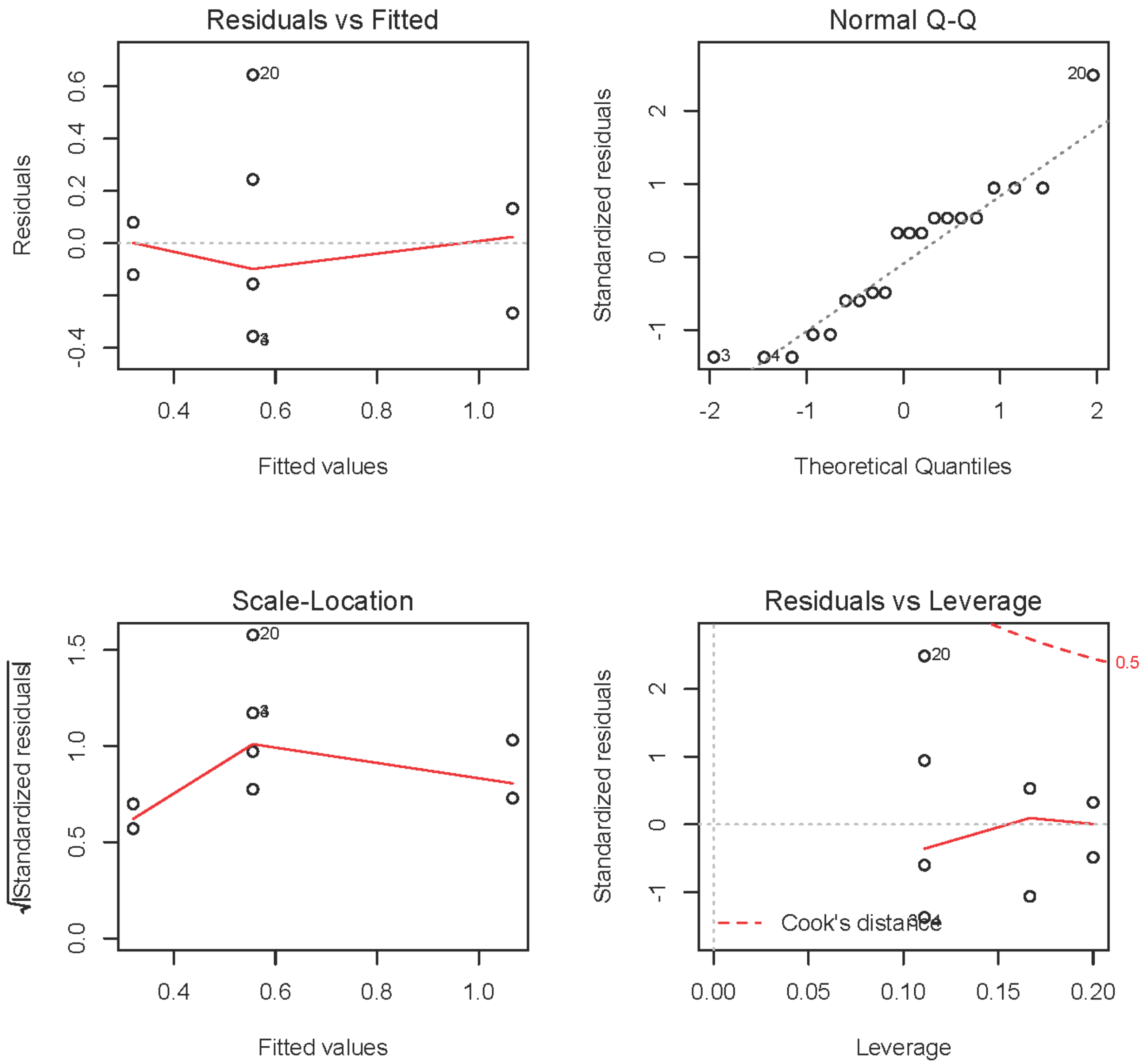


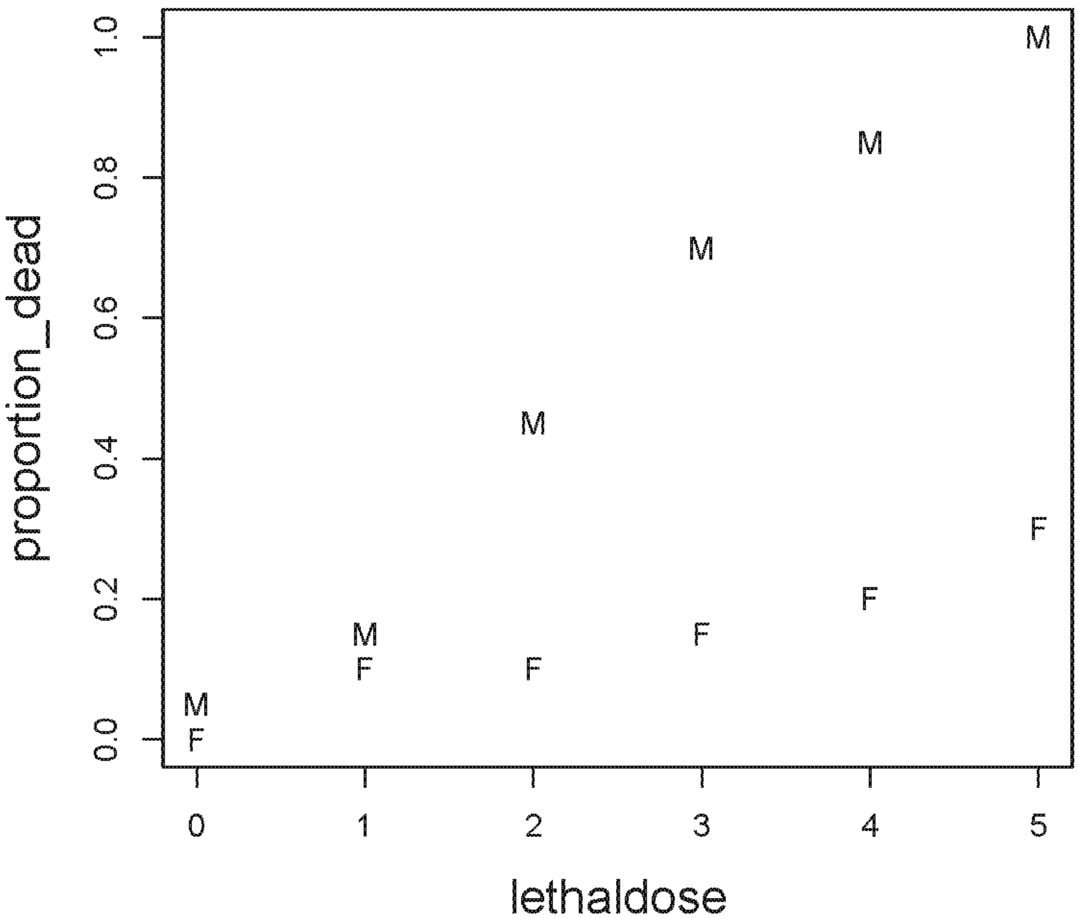
Chapter 3: Linear Models

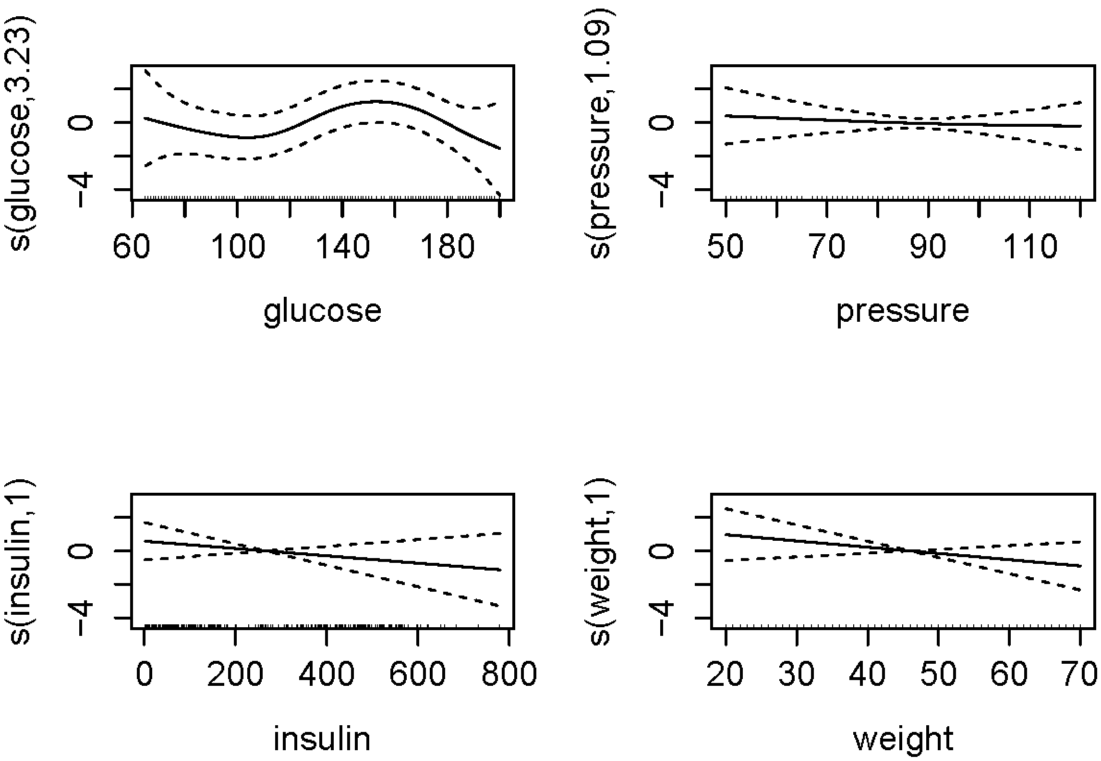

Slope from coordinates (3,7) and (10,4)
delta y
delta x
0
2
4
6
8
10
0
2
4
6
8
10
x
y

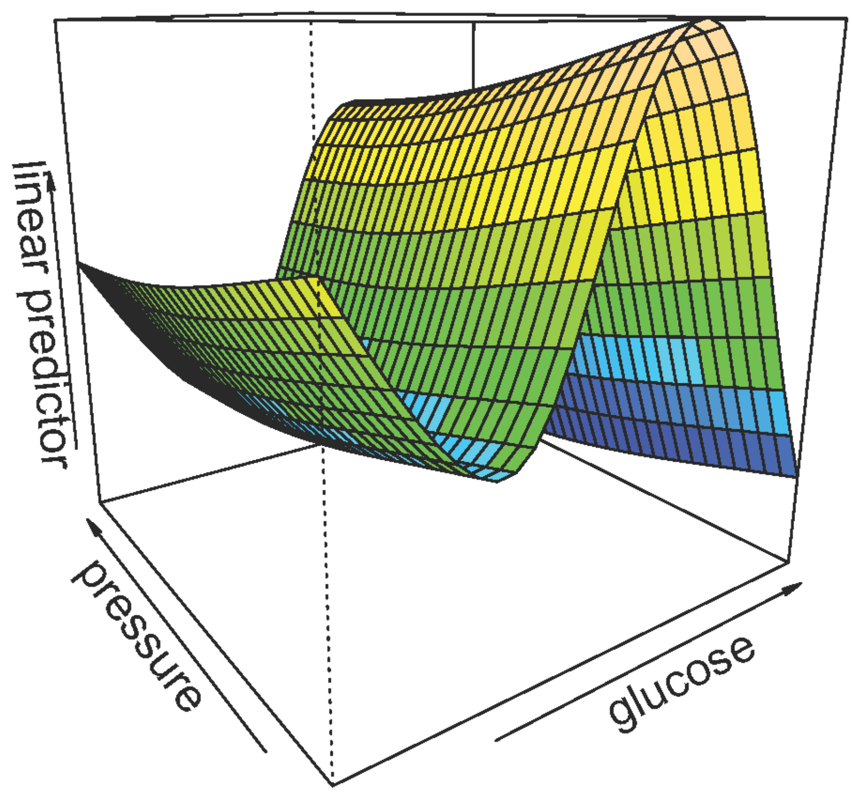

Ct_Value
35
30
25
20
0
10
20
30
40
50
RNA_ng
Ct_Value
35
30
25
20
-4
-2
0
2
4
log(RNA_ng)

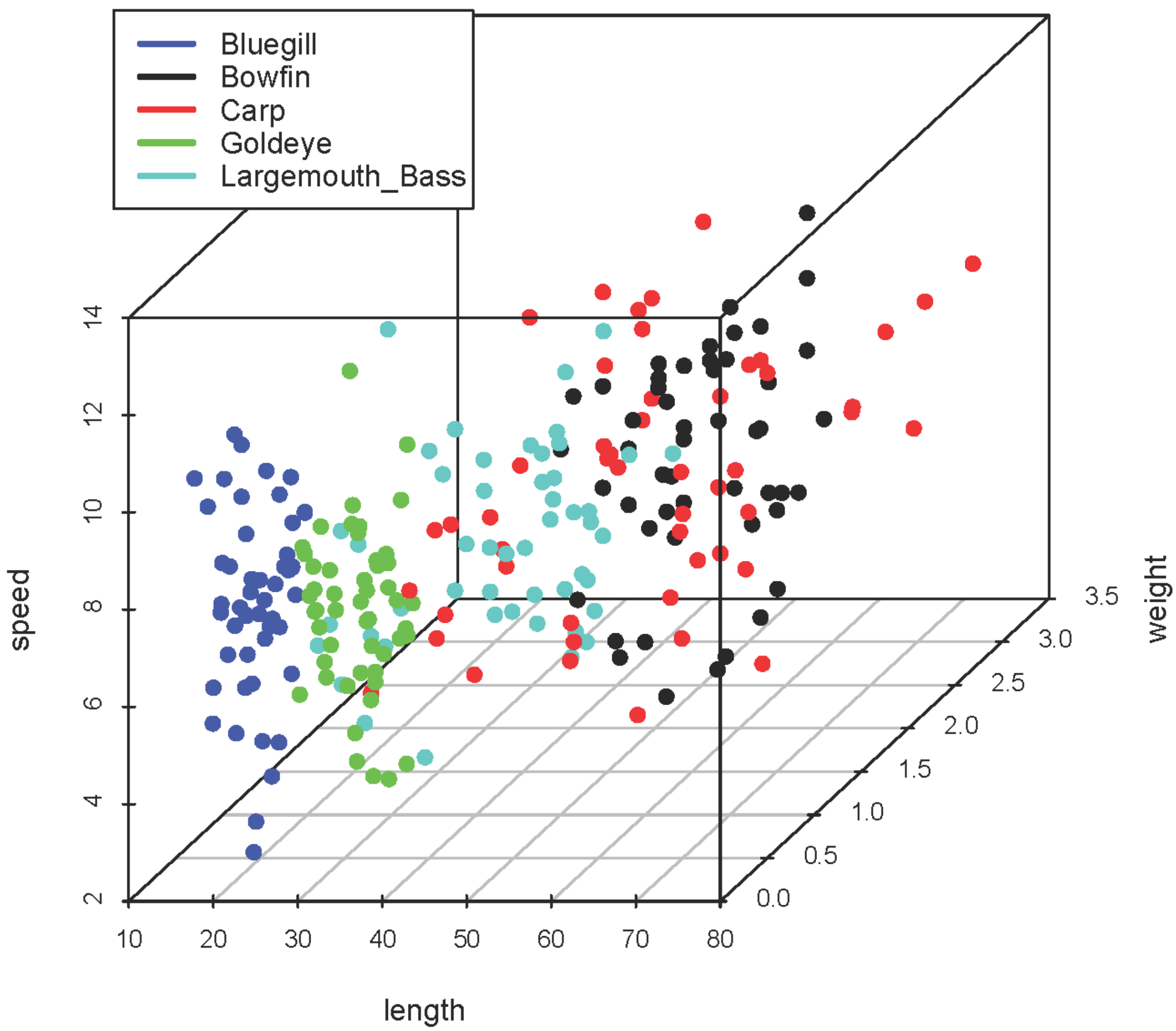

Residuals vs Fitted
Residuals
Fitted values
Normal Q-Q
Standardized residuals
Theoretical Quantiles
Scale-Location
√|Standardized residuals|
Fitted values
Residuals vs Leverage
Standardized residuals
Cook's distance
0.5
Leverage


Residuals vs Fitted
Residuals
Fitted values
Normal Q-Q
Standardized residuals
Theoretical Quantiles
Scale-Location
√|Standardized residuals|
Fitted values
Residuals vs Leverage
Standardized residuals
Cook's distance
0.5
Leverage

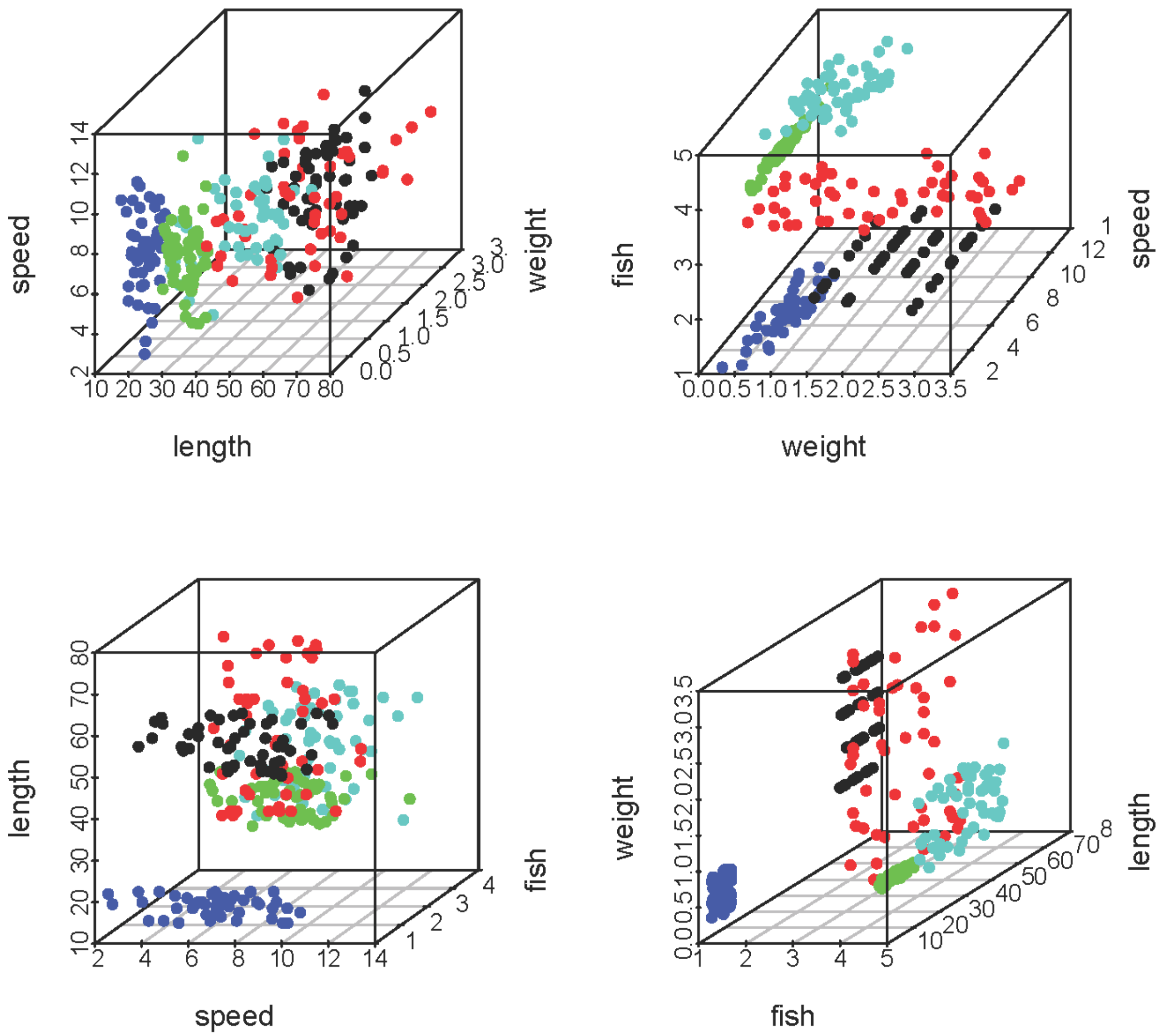

proportion_dead
1.0
0.8
0.6
0.4
0.2
0.0
0
1
2
3
4
5
lethaldose
M
F


s(glucose,3.23)
0
−4
60
100
140
180
glucose
s(pressure,1.09)
0
−4
50
70
90
110
pressure
s(insulin,1)
0
−4
0
200
400
600
800
insulin
s(weight,1)
0
−4
20
30
40
50
60
70
weight

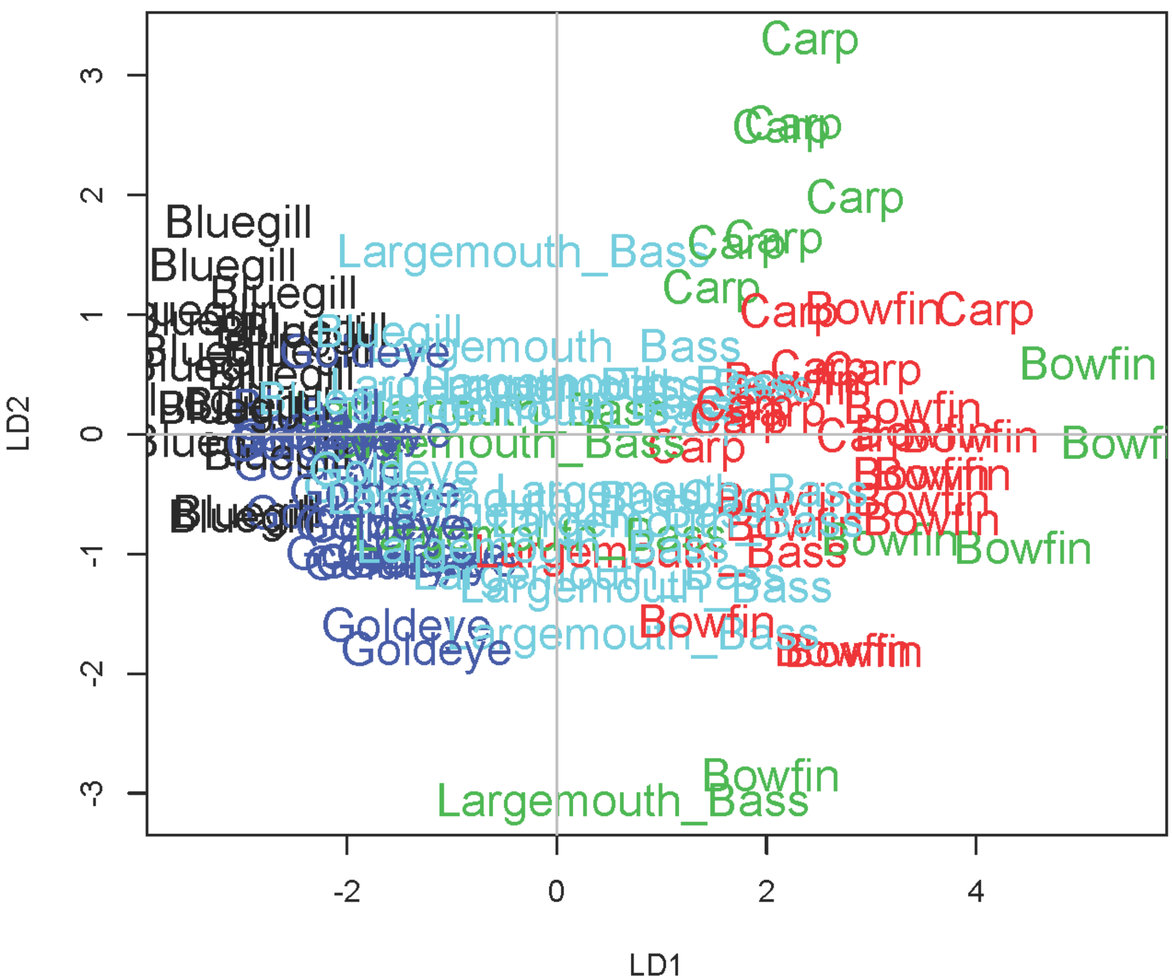

linear predictor
pressure
glucose

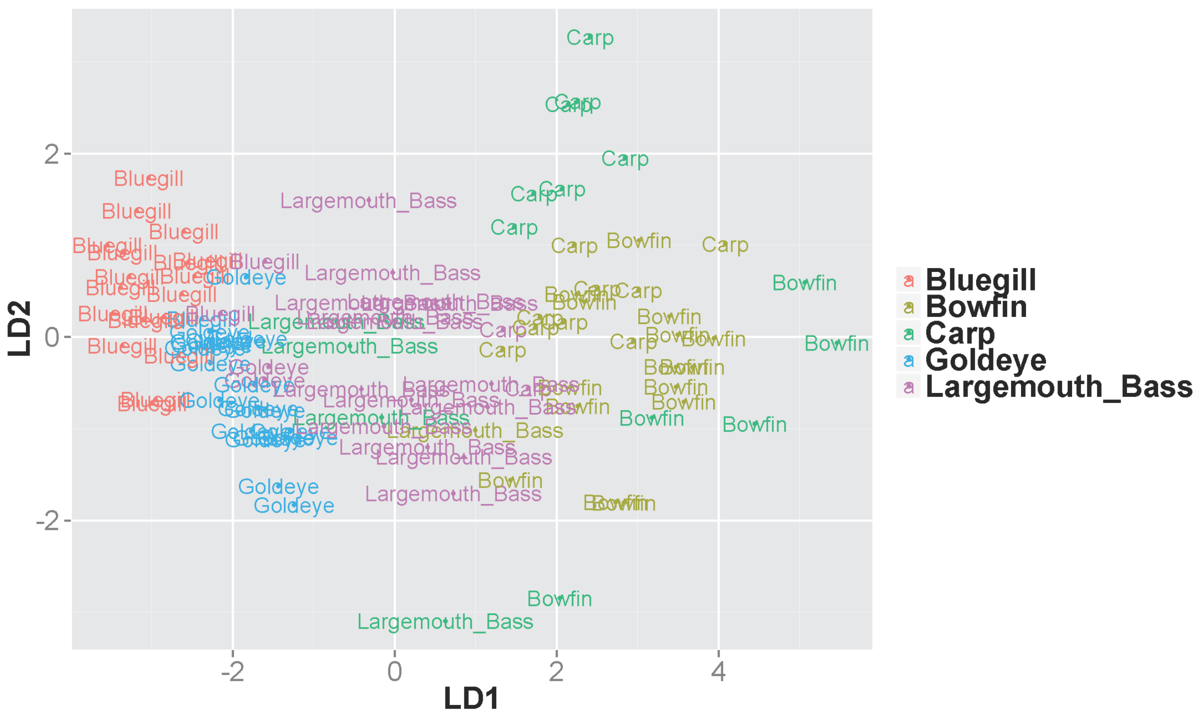


Bluegill
Bowfin
Carp
Goldeye
Largemouth_Bass
speed
2
4
6
8
10
12
14
10
20
30
40
50
60
70
80
length
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
weight

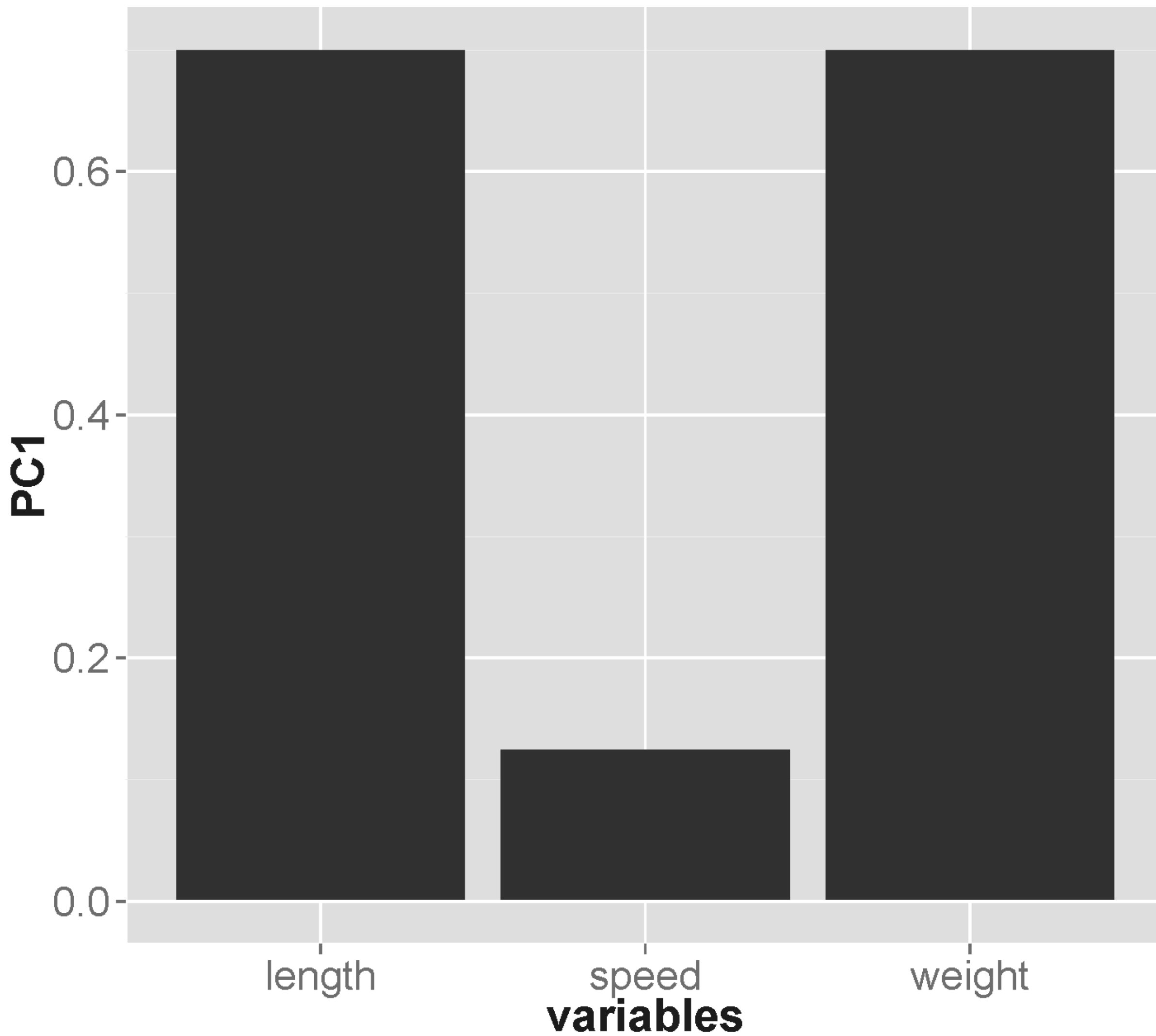

speed
2 4 6 8 10 12 14
10 20 30 40 50 60 70 80
length
0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.
weight
fish
1 2 3 4 5
0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5
weight
2 4 6 8 10 12 1
speed
length
10 20 30 40 50 60 70 80
2 4 6 8 10 12 14
speed
1 2 3 4
fish
weight
0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5
1 2 3 4 5
fish
10 20 30 40 50 60 70 8
length

TrainingSetLDA Results(n=50)

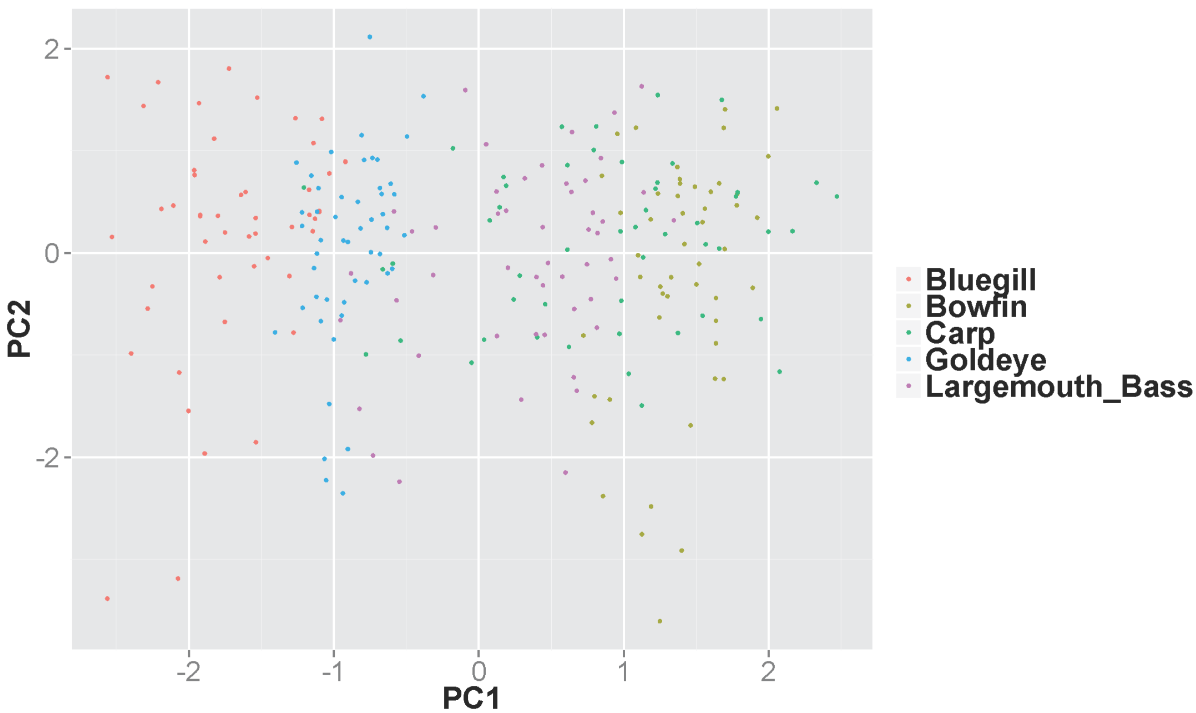




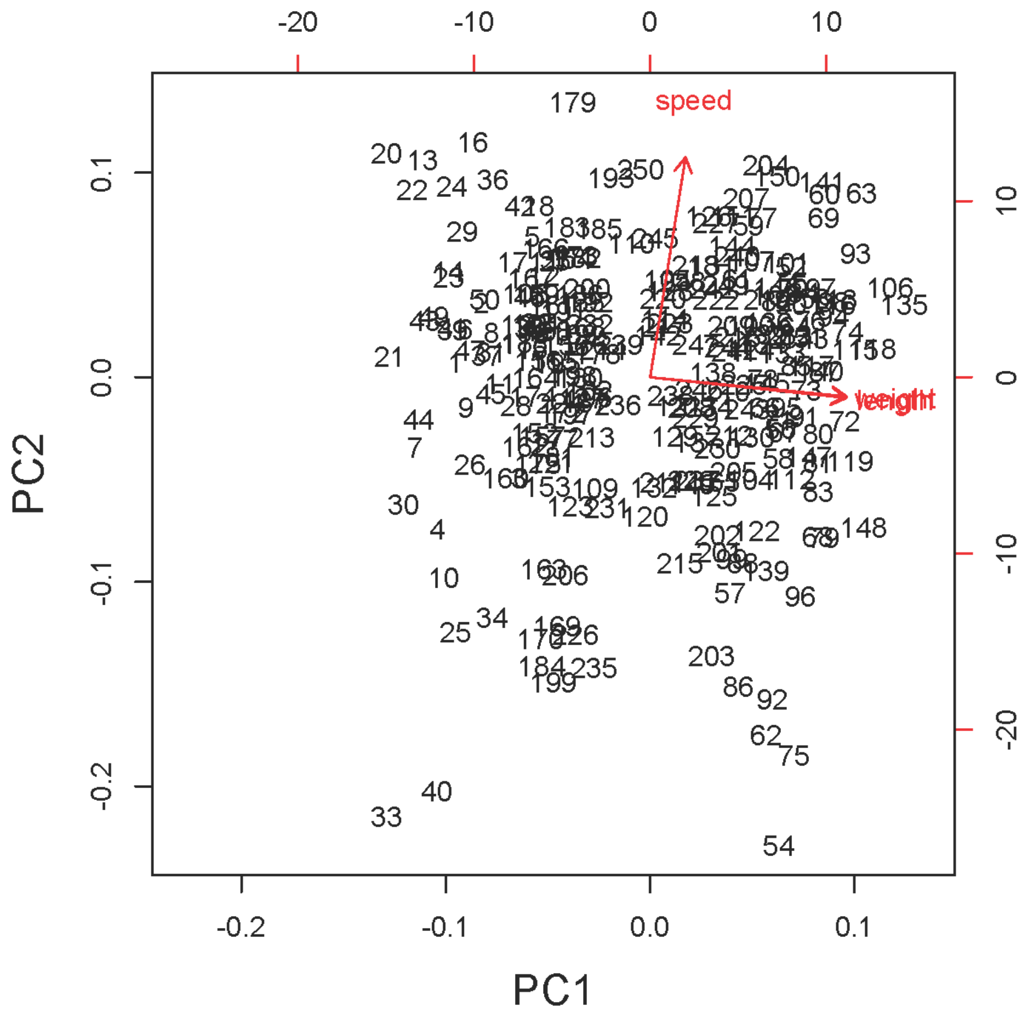
LD1
LD2
-2
0
2
4
Bluegill
Bowfin
Carp
Goldeye
Largemouth_Bass



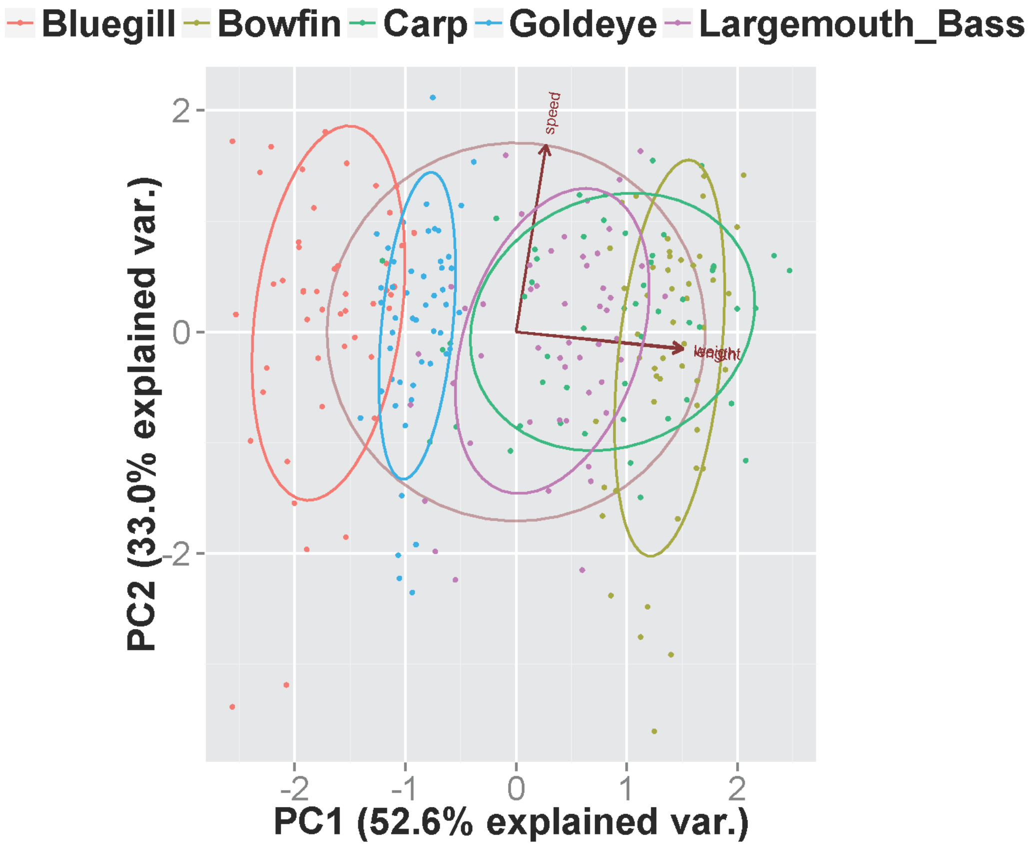
PC1
0.6
0.4
0.2
0.0
length
speed
weight
variables

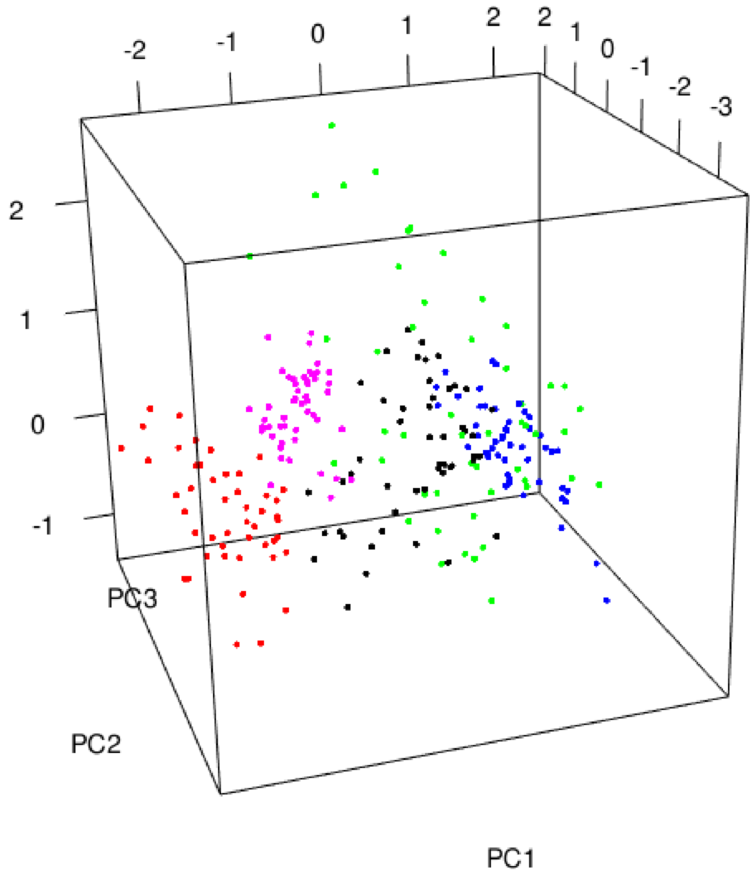


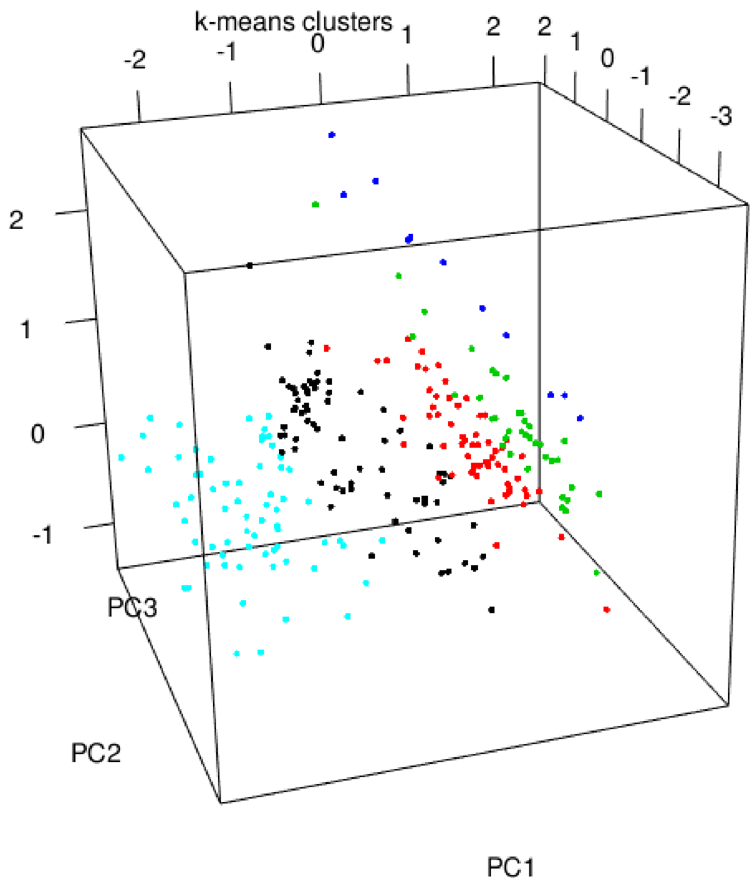
PC2
2
0
-2
-2
-1
0
1
2
PC1
Bluegill
Bowfin
Carp
Goldeye
Largemouth_Bass

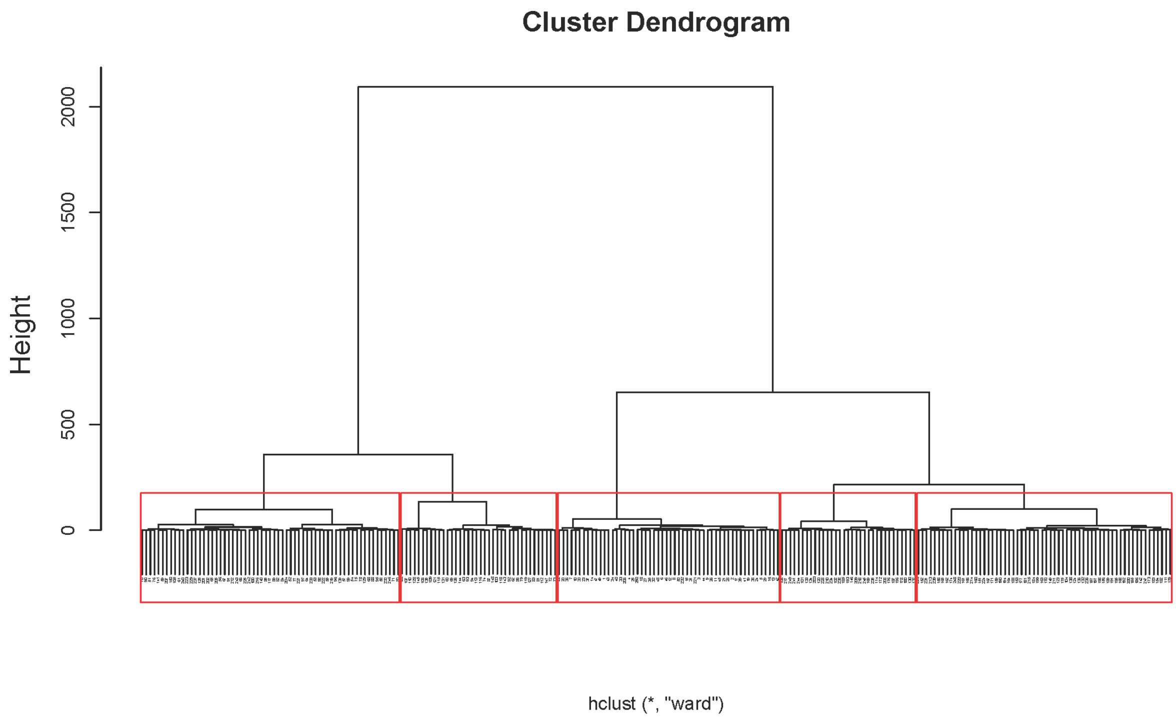


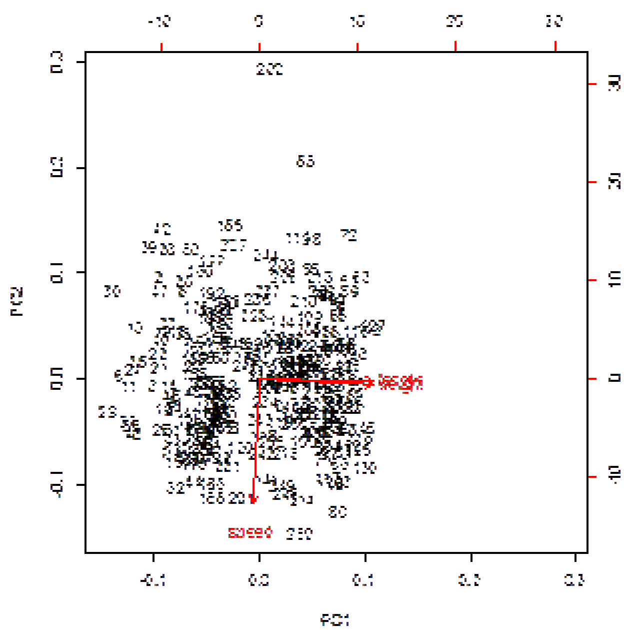
speed
weight
PC1
PC2
-0.2
-0.1
0.0
0.1
-20
-10
0
10


Bluegill
Bowfin
Carp
Goldeye
Largemouth_Bass
speed
length
PC2 (33.0% explained var.)
PC1 (52.6% explained var.)
2
0
-2
-2
-1
0
1
2

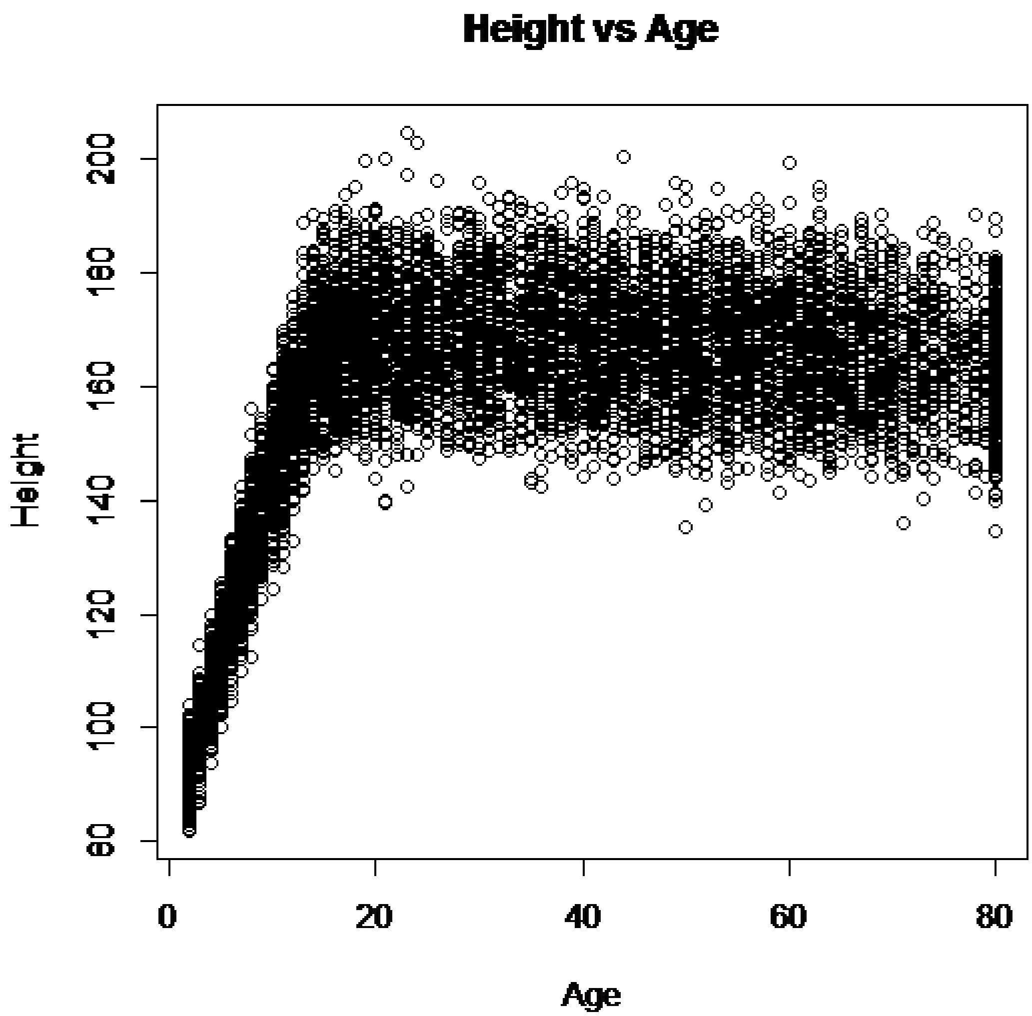

-2
-1
0
1
2
2
1
0
-1
-2
-3
2
1
0
-1
PC3
PC2
PC1

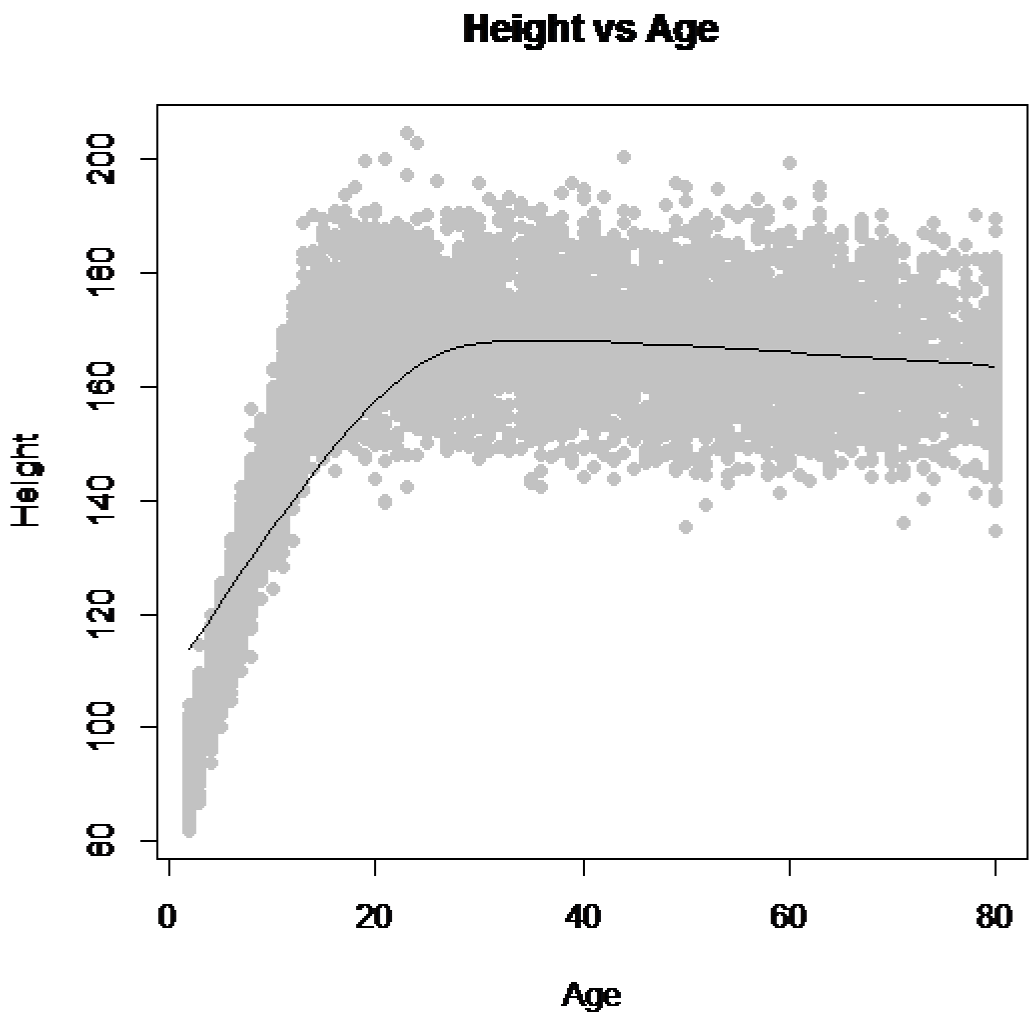

k-means clusters
-2
-1
0
1
2
2
1
0
-1
-2
-3
2
1
0
-1
PC3
PC2
PC1



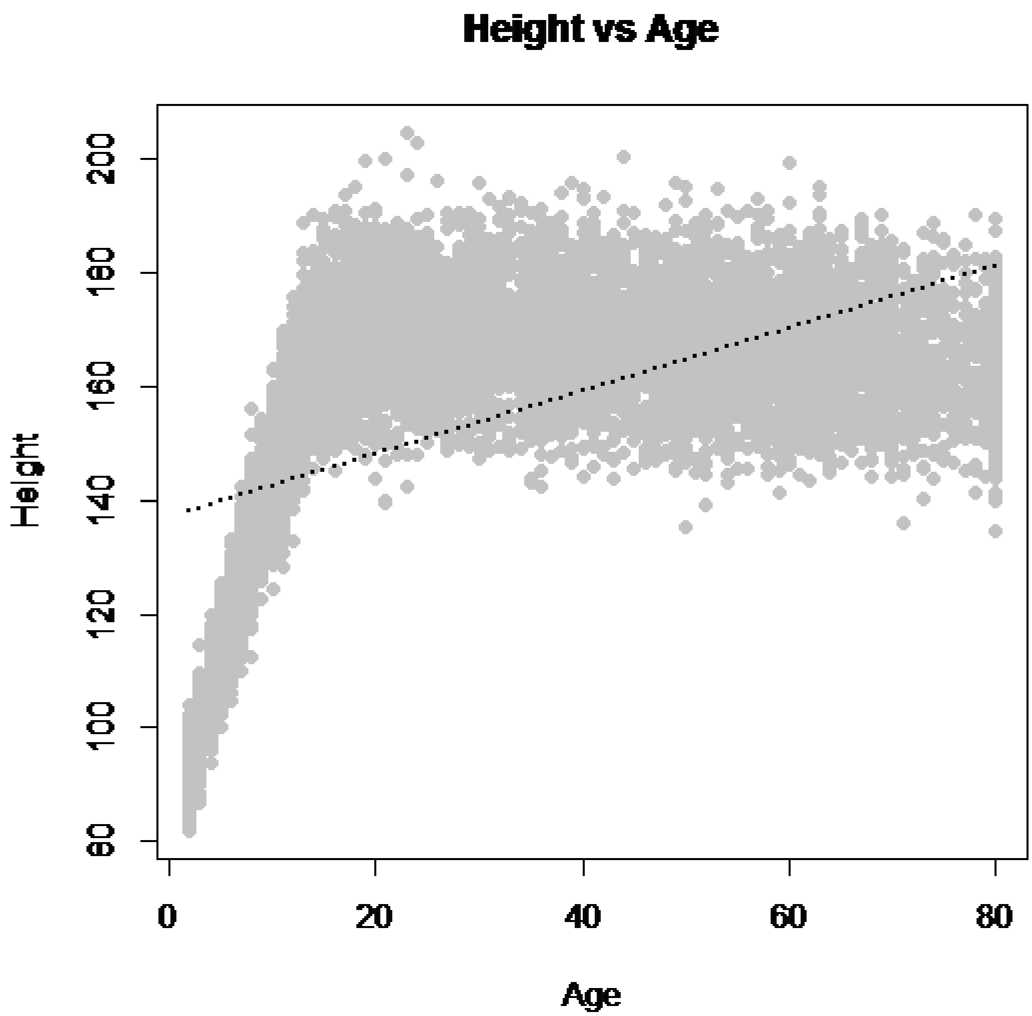


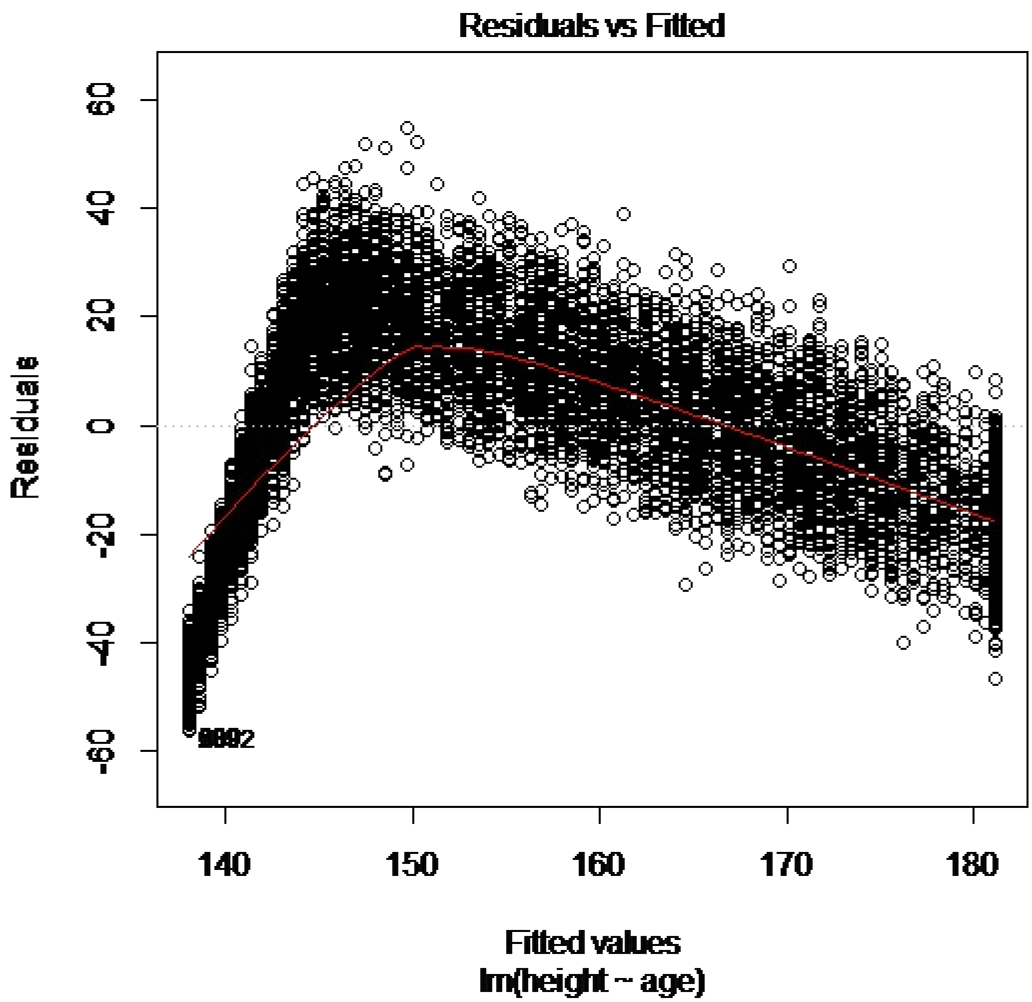
Chapter 4: Nonlinear Methods

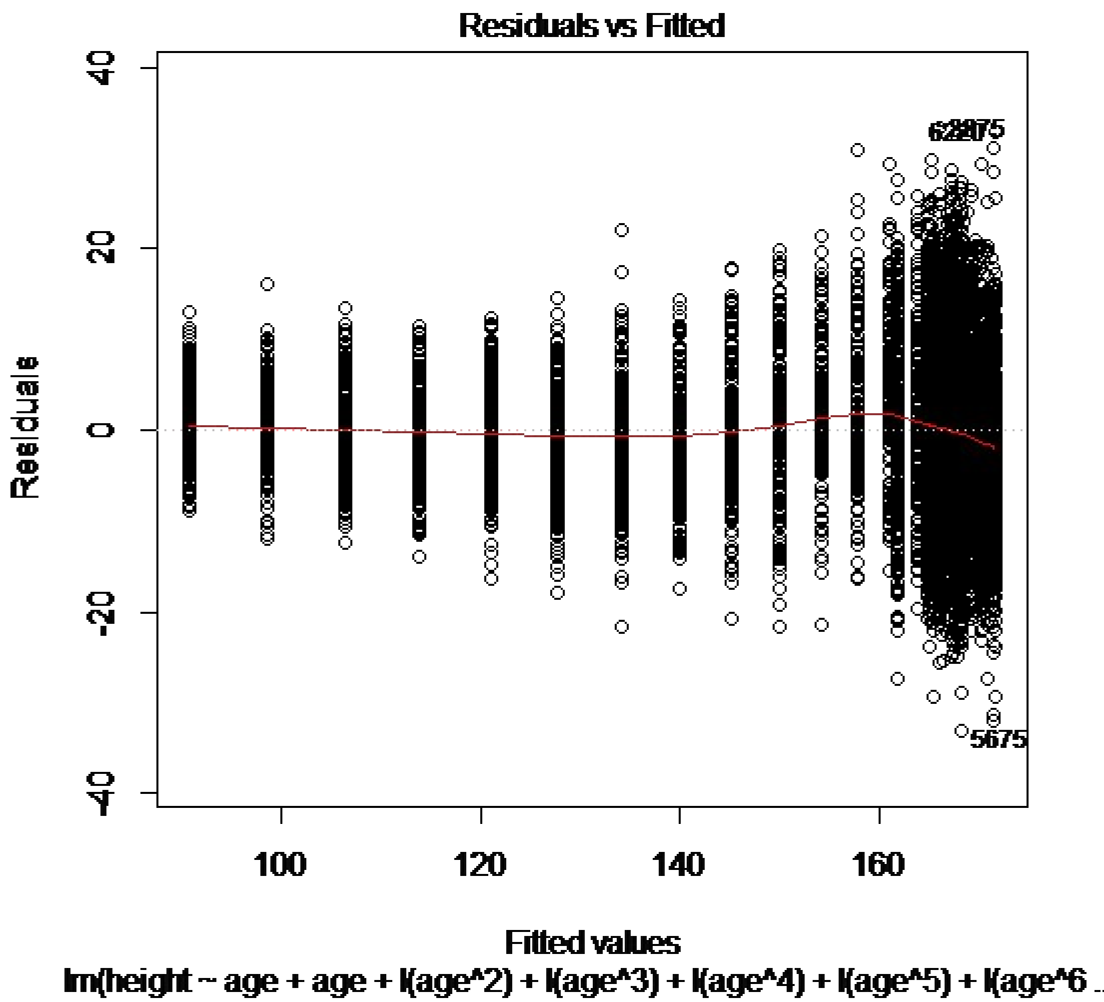

Height vs Age
Height
80
100
120
140
160
180
200
0
20
40
60
80
Age

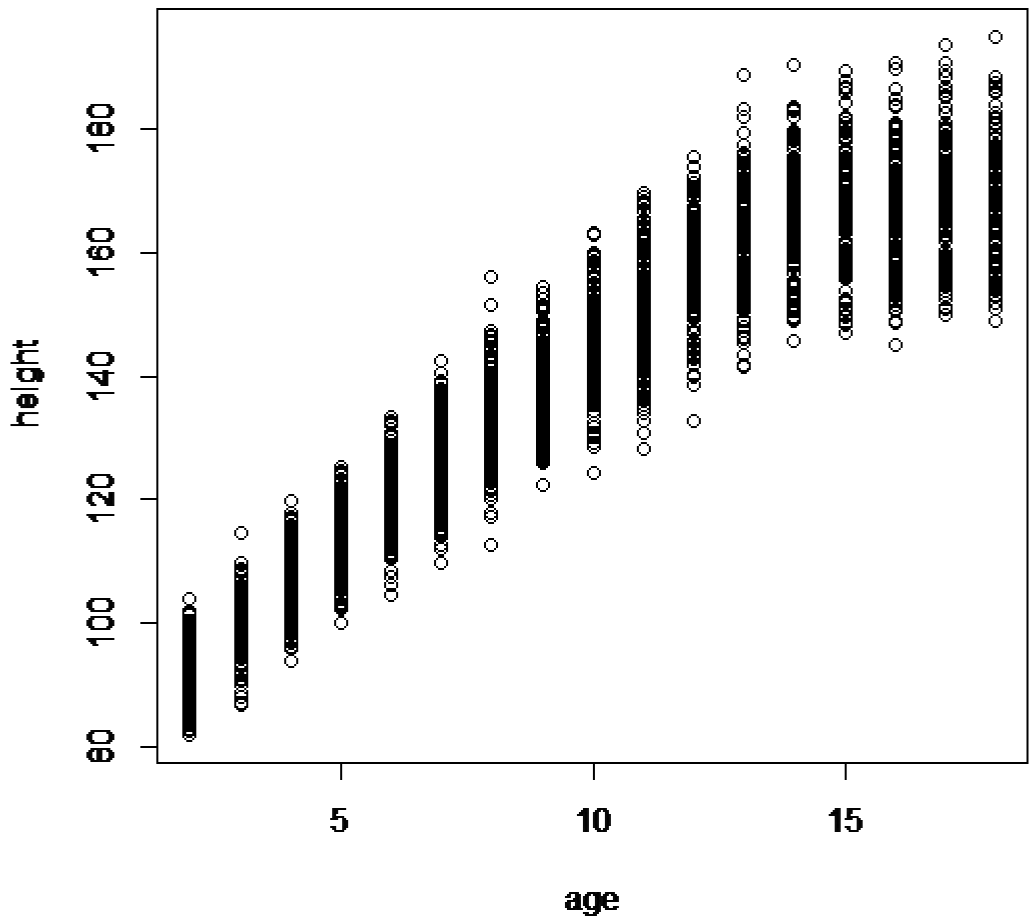


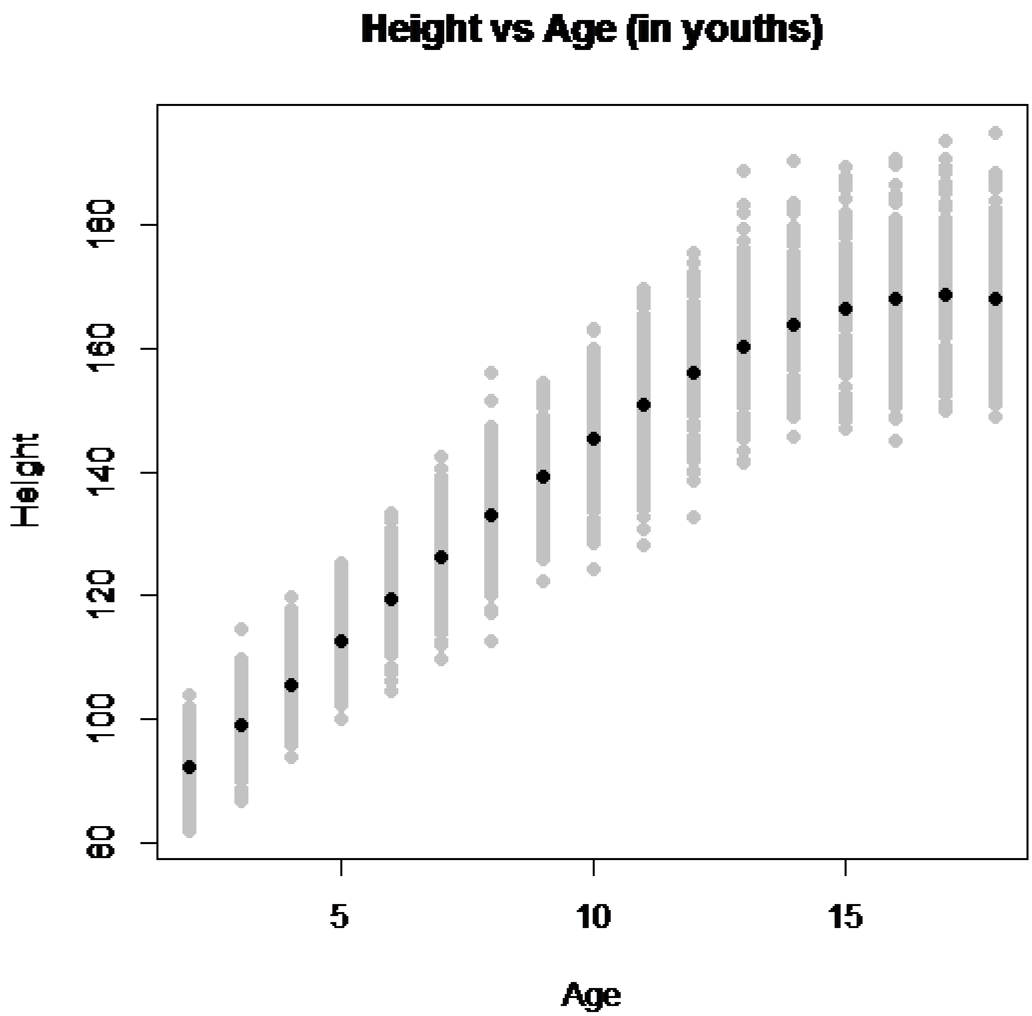
Height vs Age
Height
80
100
120
140
160
180
200
0
20
40
60
80
Age

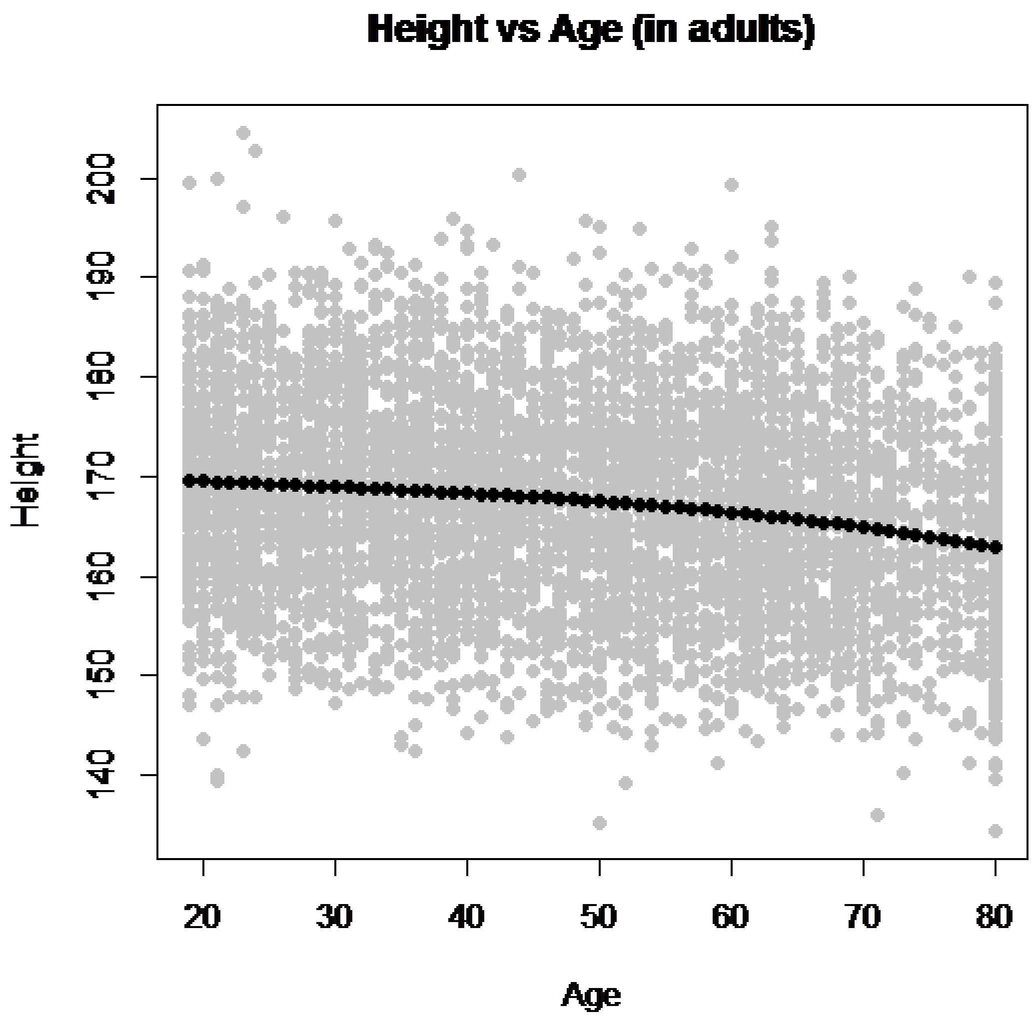

Height vs Age
Height
Age
0
20
40
60
80
80
100
120
140
160
180
200


Residuals vs Fitted
Residuals
Fitted values
lm(height ~ age)
60
40
20
0
-20
-40
-60
140
150
160
170
180
9892

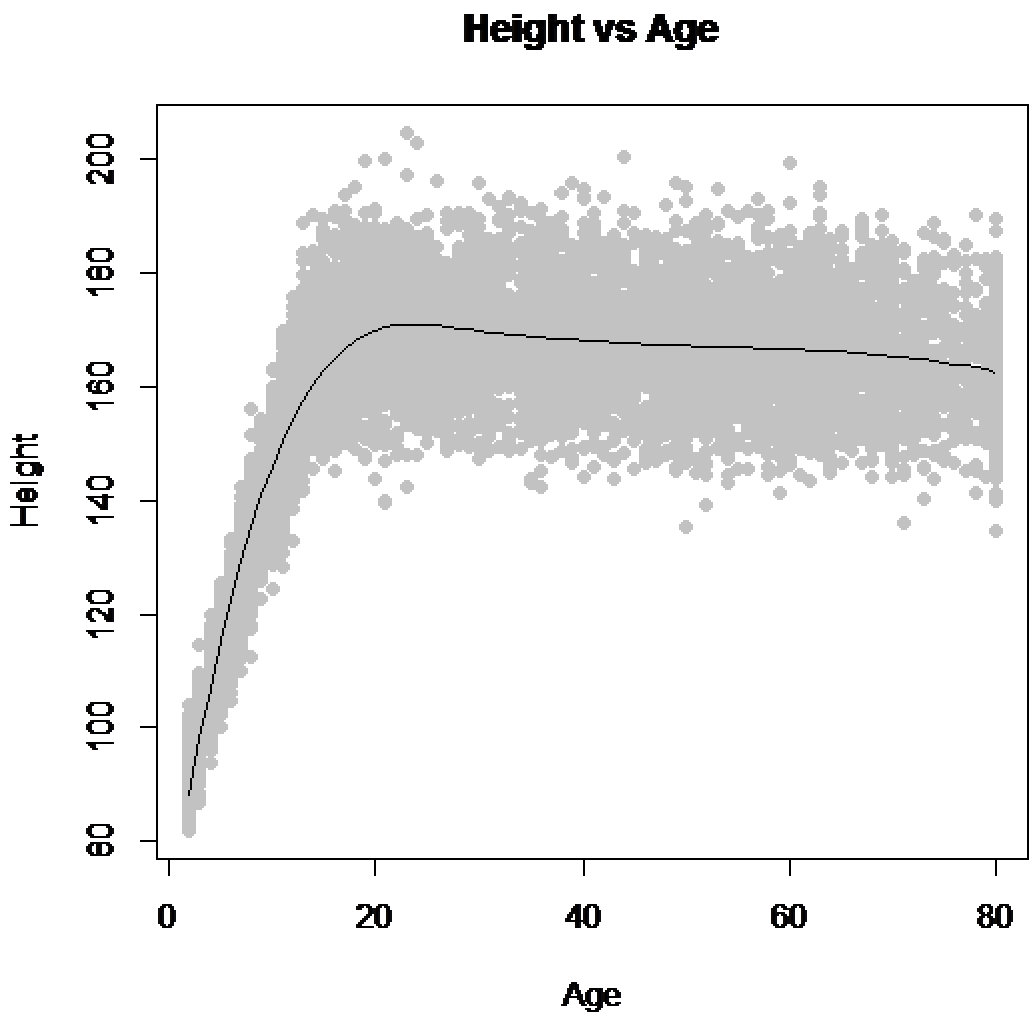

Residuals vs Fitted
Residuals
40
20
0
-20
-40
100
120
140
160
Fitted values
lm(height ~ age + age + I(age^2) + I(age^3) + I(age^4) + I(age^5) + I(age^6 ..
5675

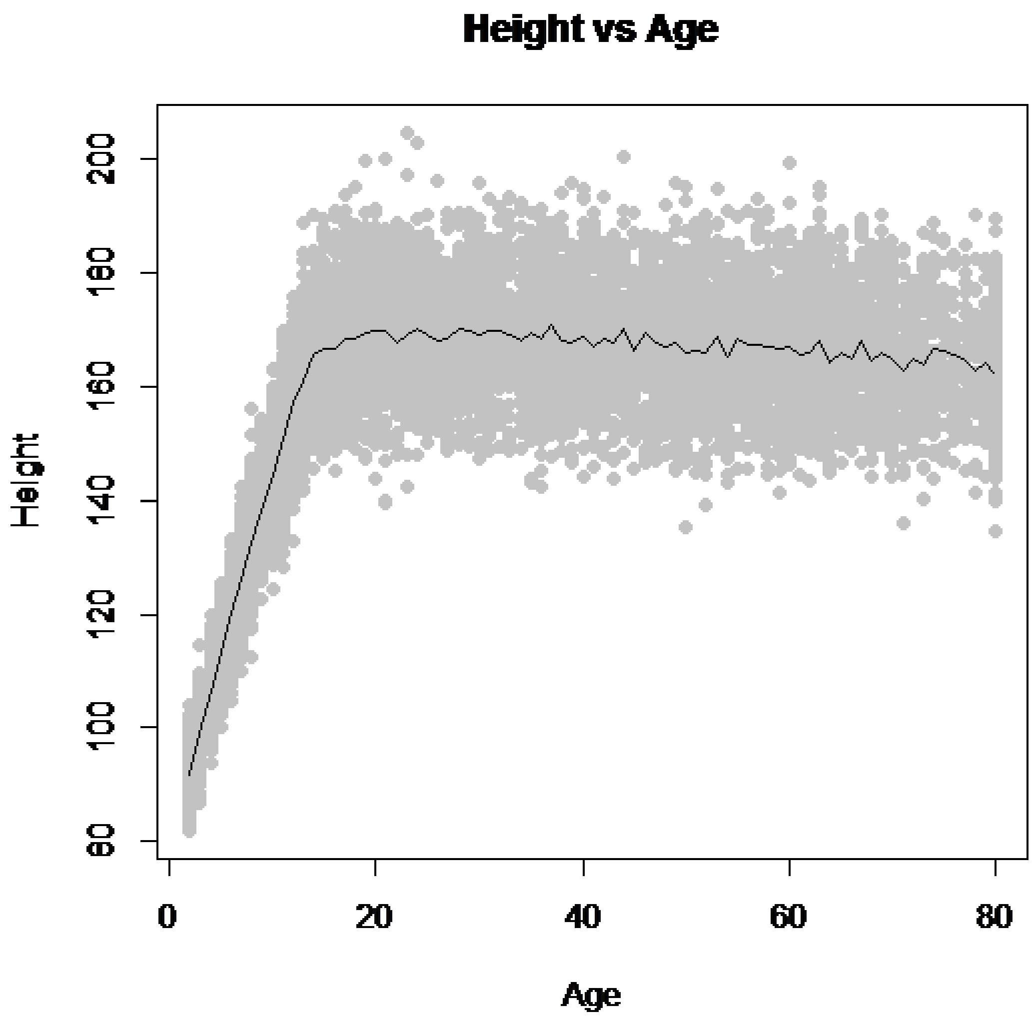

height
80
100
120
140
160
180
5
10
15
age


Height vs Age (in youths)
Height
80
100
120
140
160
180
5
10
15
Age



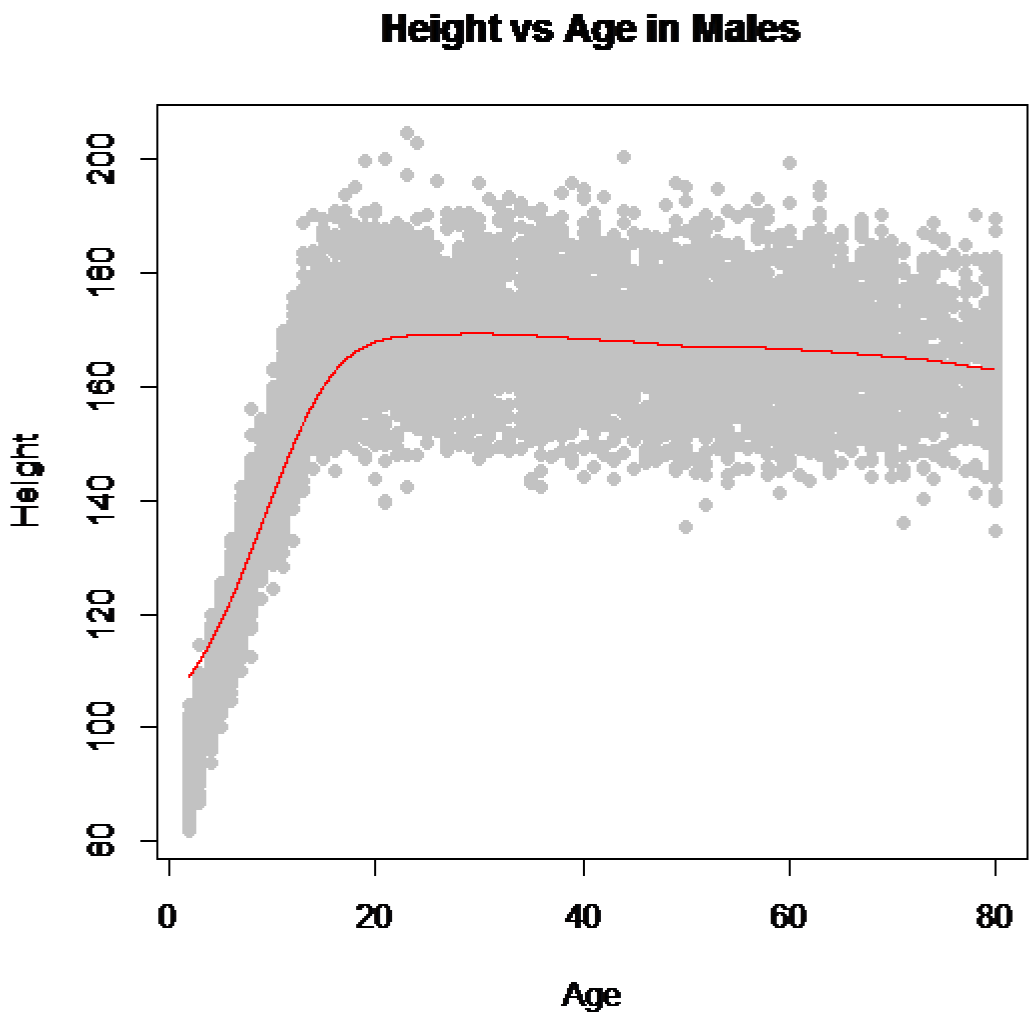
Height vs Age (in adults)
Height
140
150
160
170
180
190
200
20
30
40
50
60
70
80
Age


Height vs Age
Height
200
180
160
140
120
100
80
0
20
40
60
80
Age

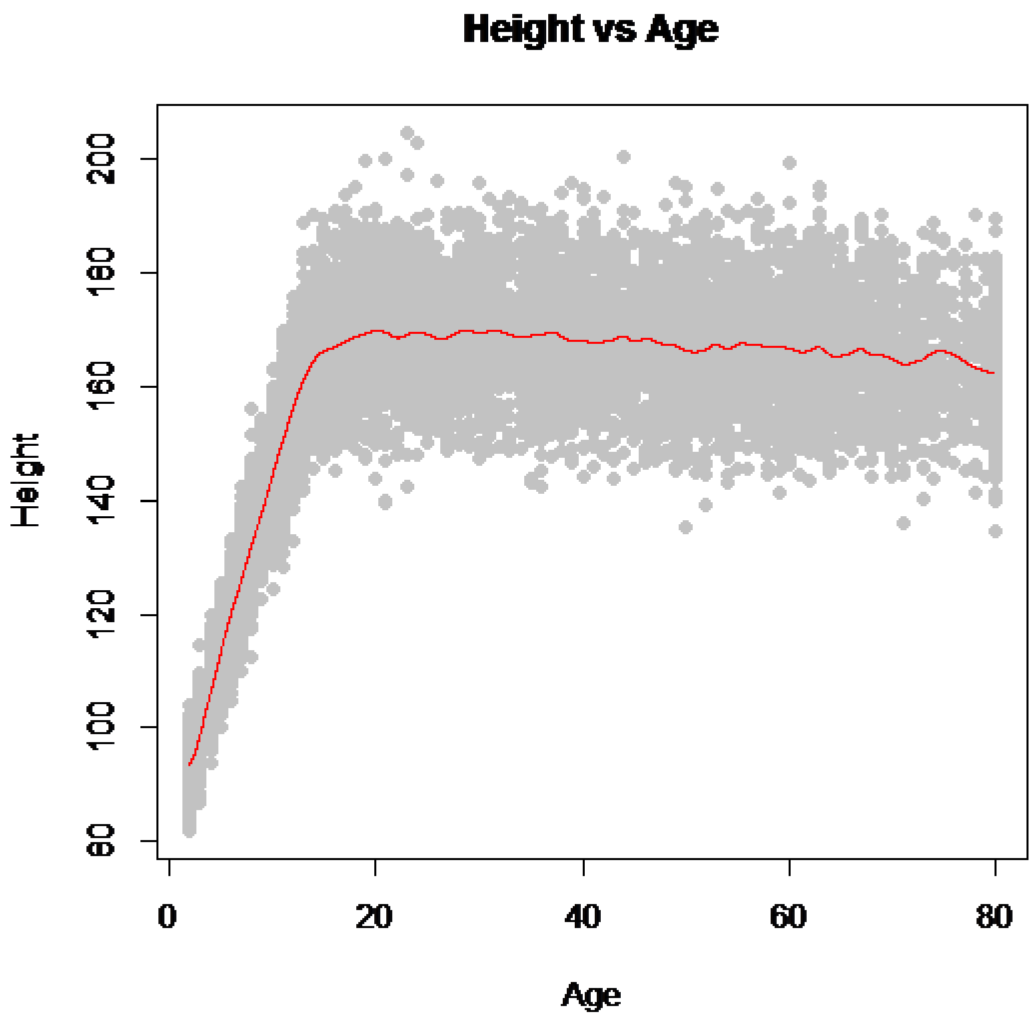


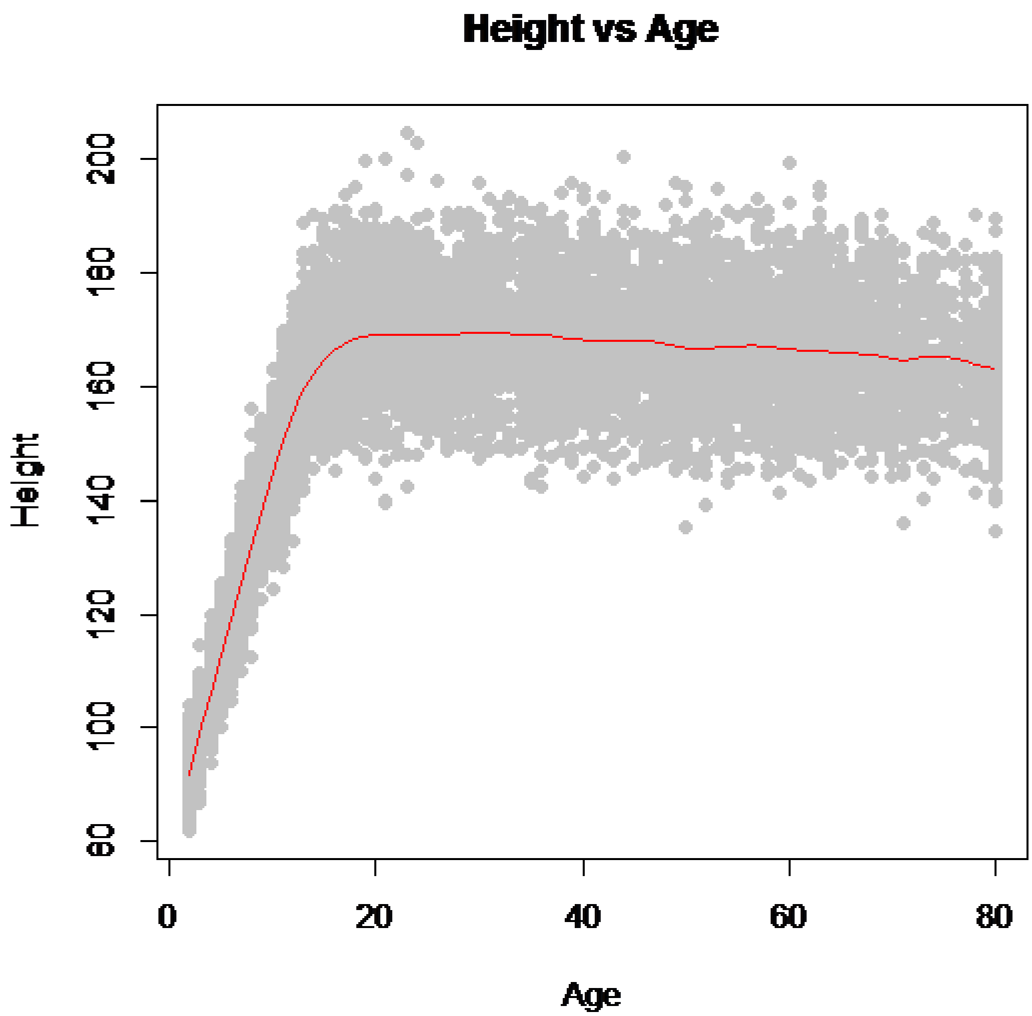
Height vs Age
200
180
160
140
120
100
80
Height
0
20
40
60
80
Age


Height vs Age
Height
80
100
120
140
160
180
200
2
7
13
20
27
34
41
48
55
62
69
76
Age

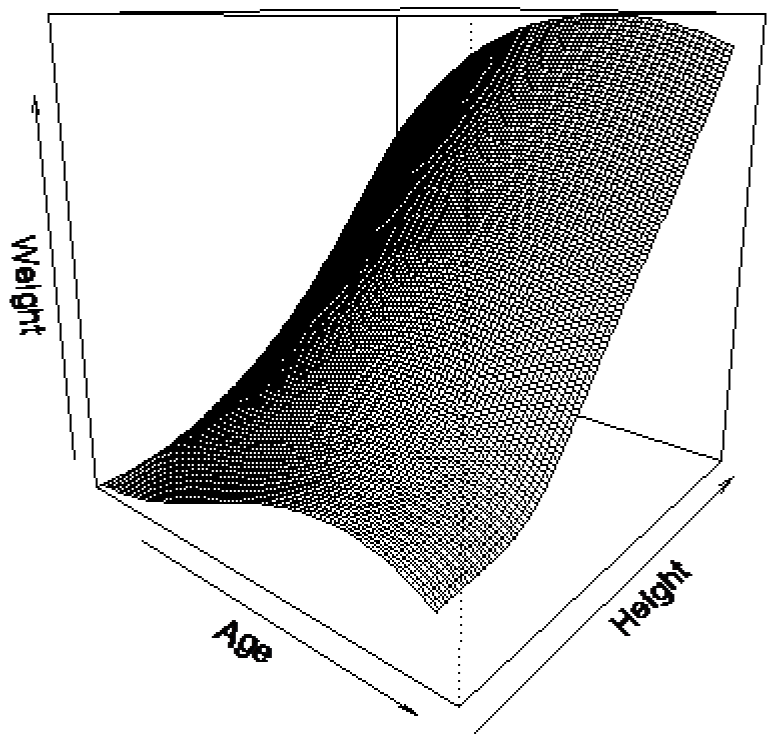


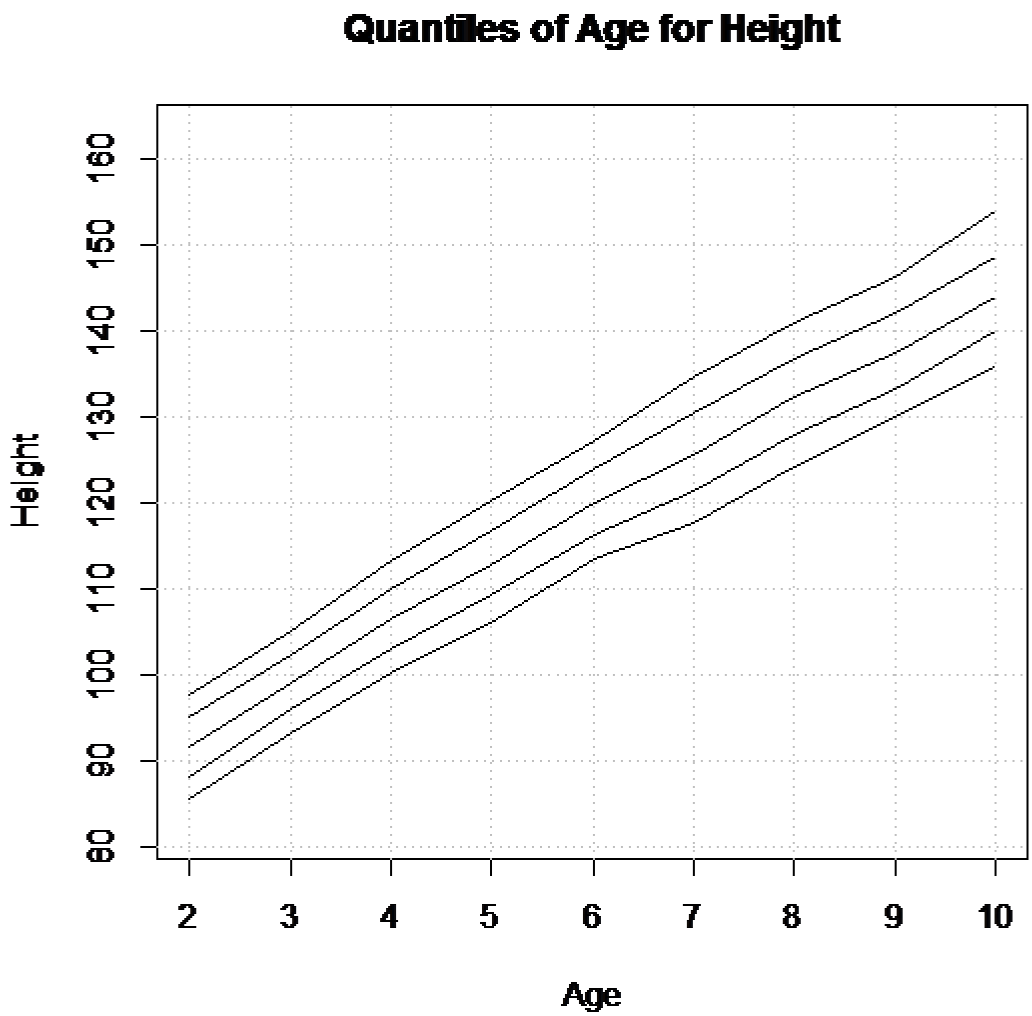
Height vs Age in Males
Height
Age
80
100
120
140
160
180
200
0
20
40
60
80

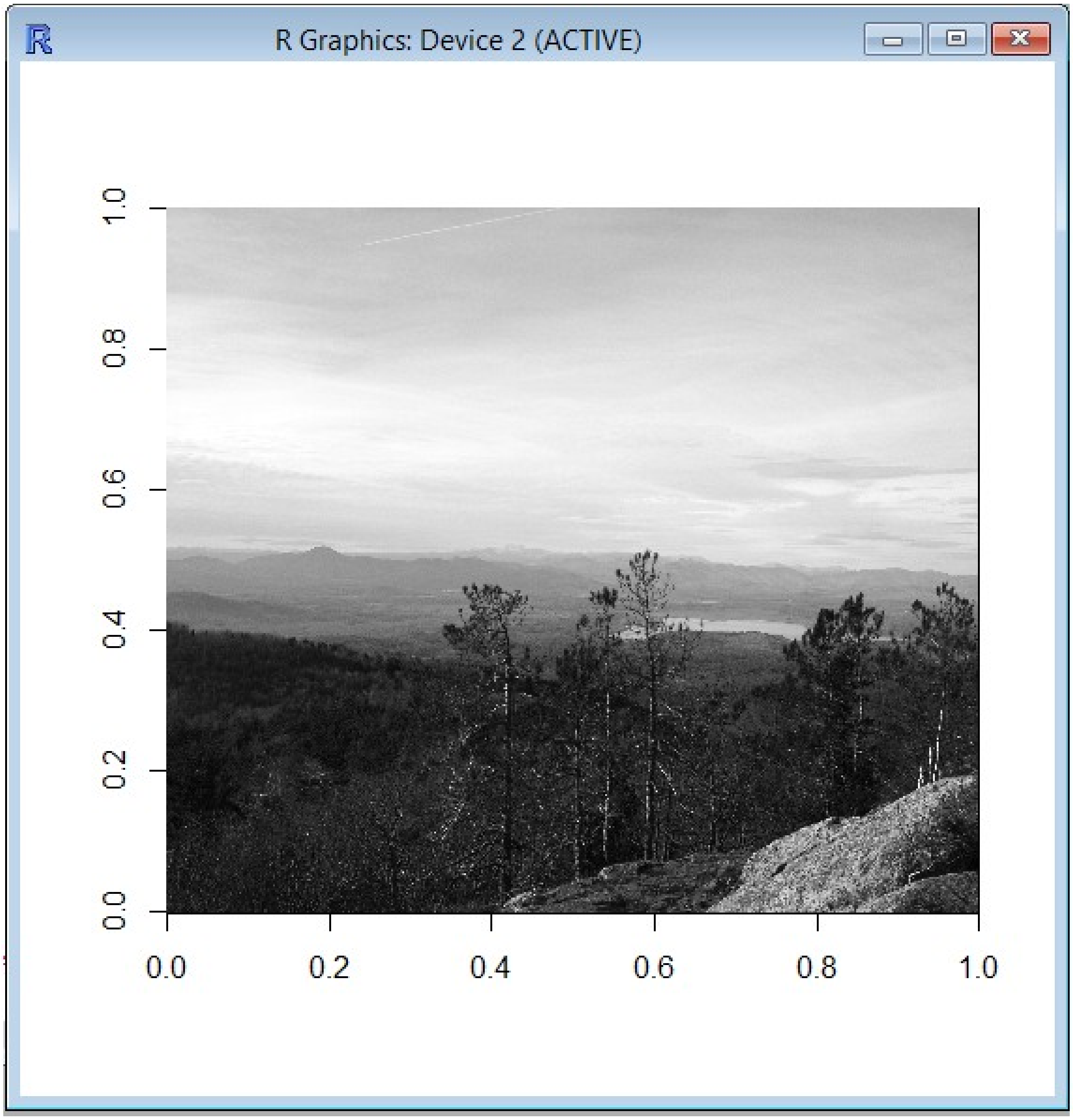

Height vs Age
Height
200
180
160
140
120
100
80
0
20
40
60
80
Age

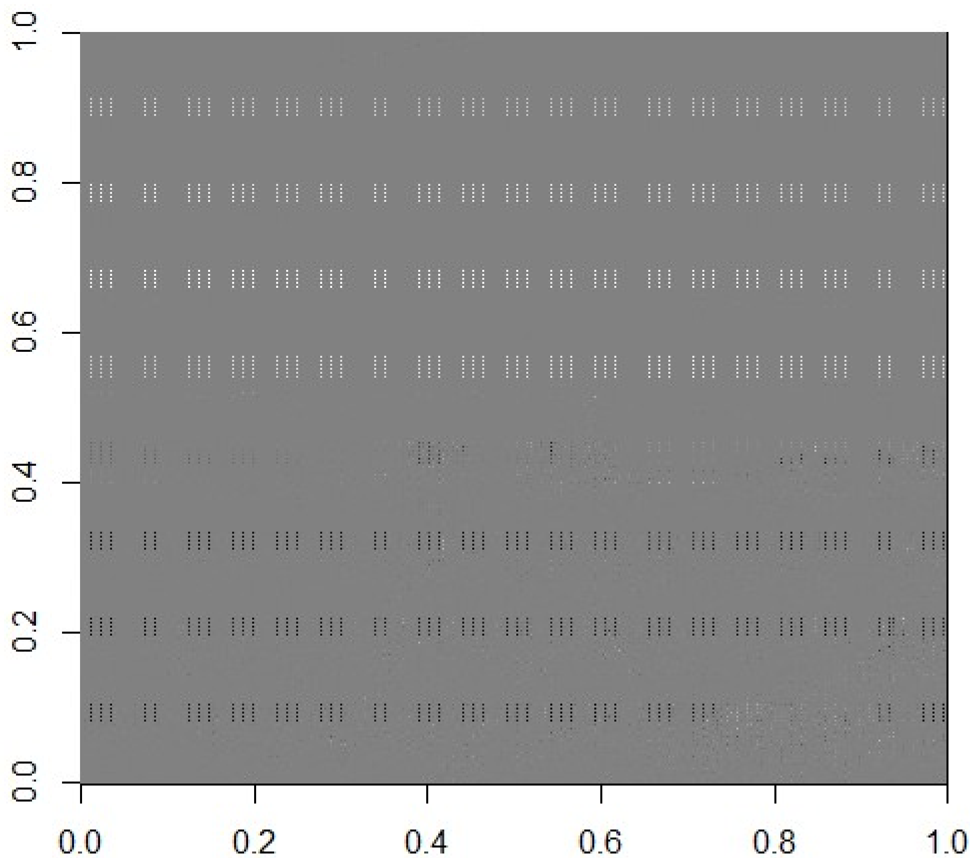


Height vs Age
Height
200
180
160
140
120
100
80
0
20
40
60
80
Age

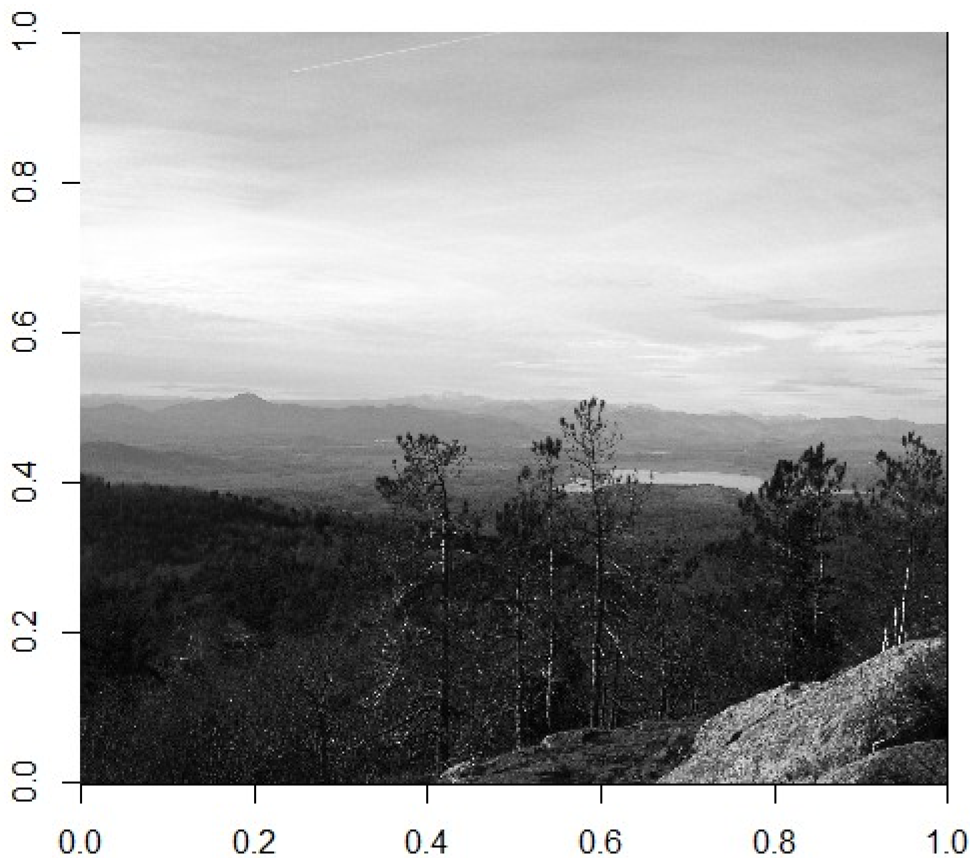

Weight
Age
Height


Quantiles of Age for Height
Height
80
90
100
110
120
130
140
150
160
2
3
4
5
6
7
8
9
10
Age

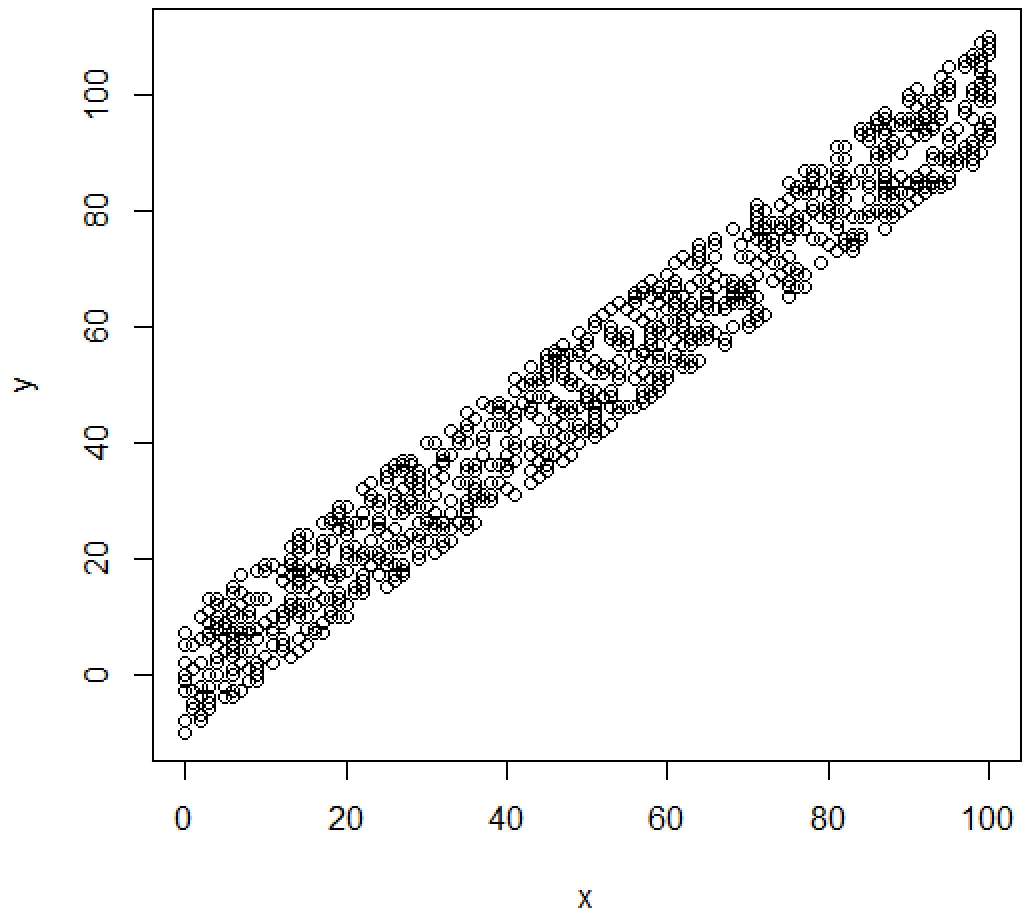

R Graphics: Device 2 (ACTIVE)
0.0
0.2
0.4
0.6
0.8
1.0
0.0
0.2
0.4
0.6
0.8
1.0

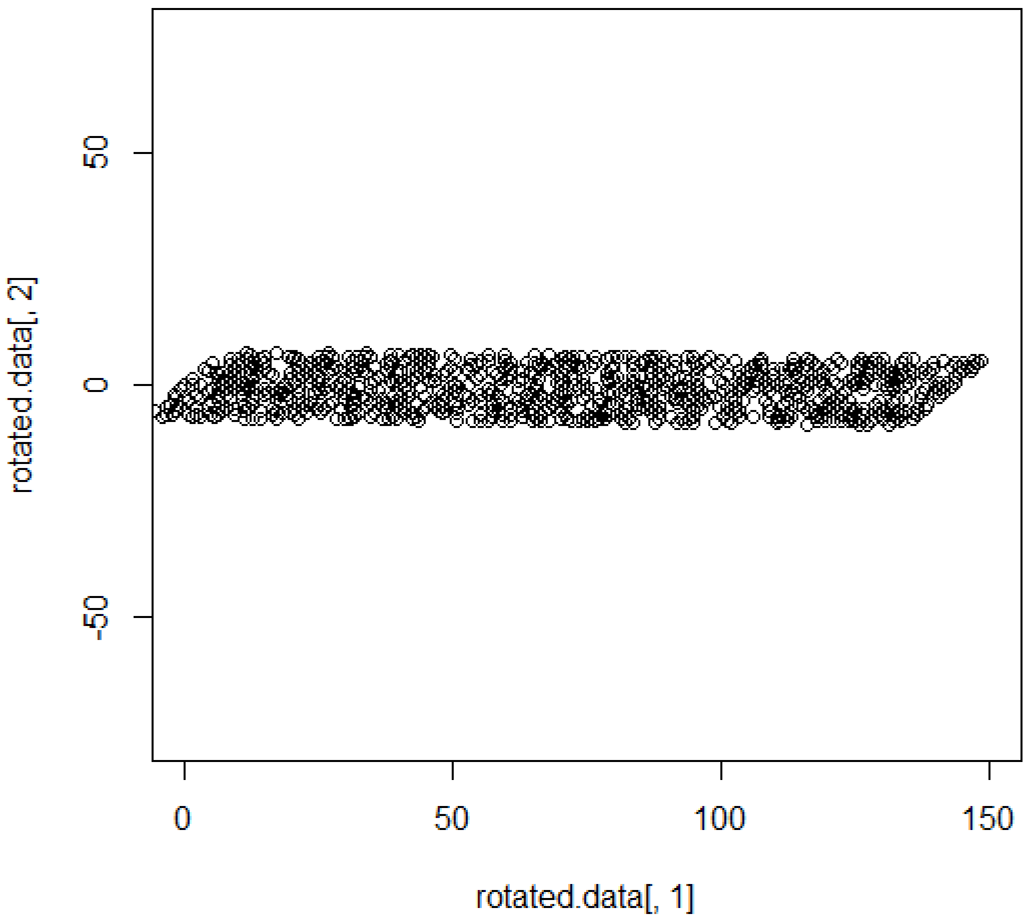


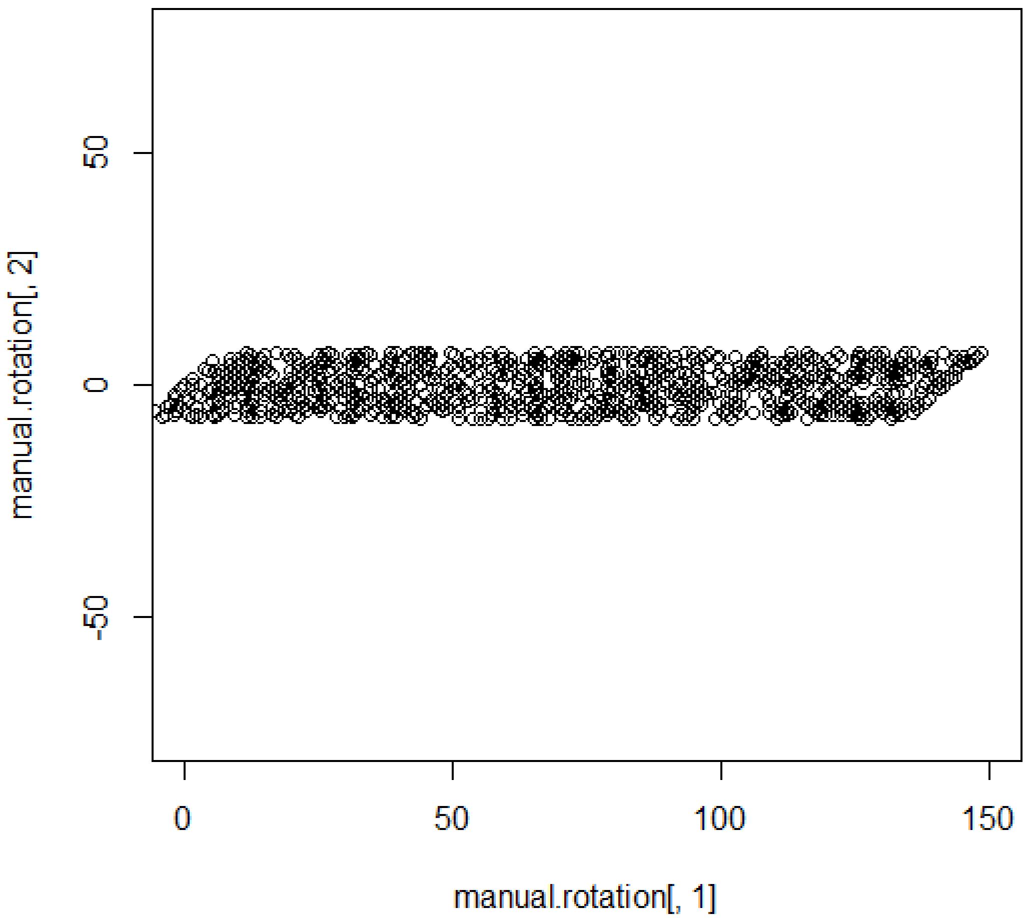
0.0
0.2
0.4
0.6
0.8
1.0
0.0
0.2
0.4
0.6
0.8
1.0



Chapter 6: Principal Component Analysis and the Common Factor Model


0
20
40
60
80
100
x
y

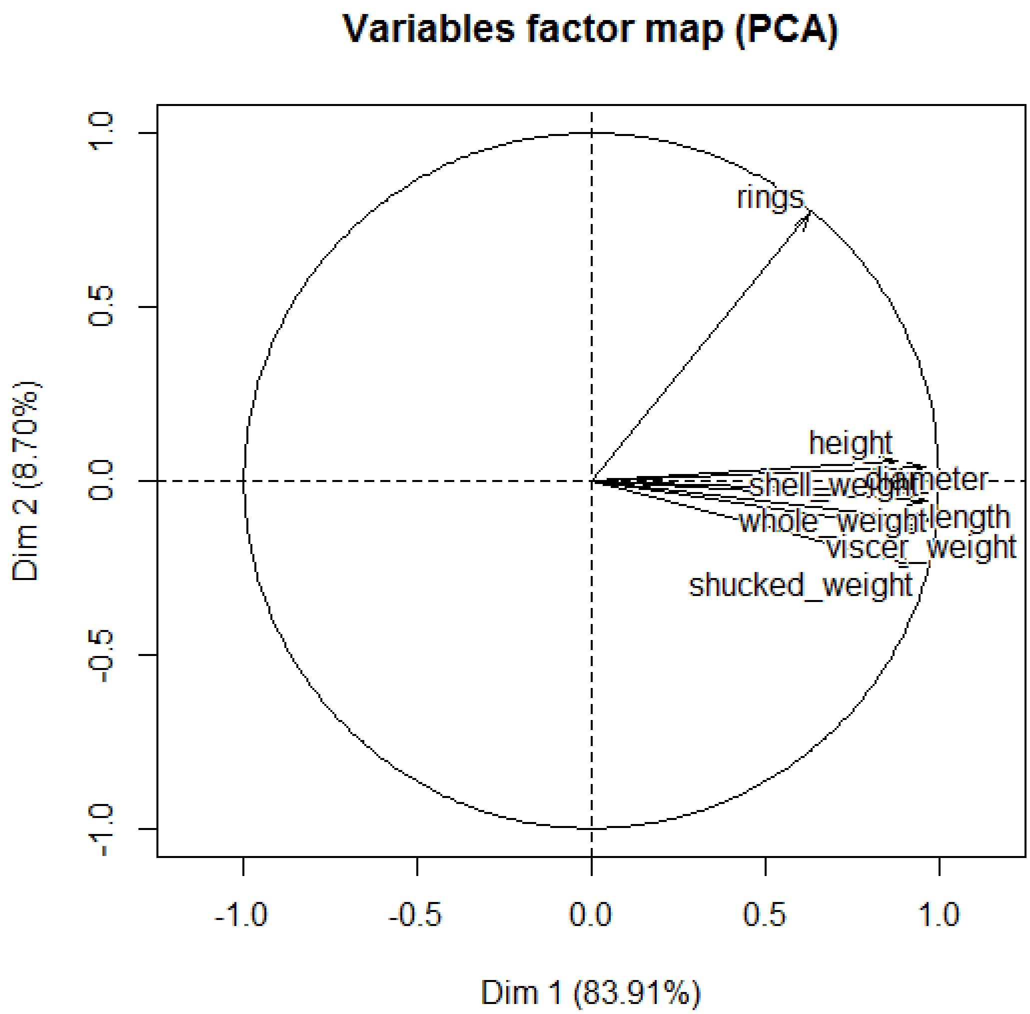

50
0
-50
rotated.data[, 2]
0
50
100
150
rotated.data[, 1]

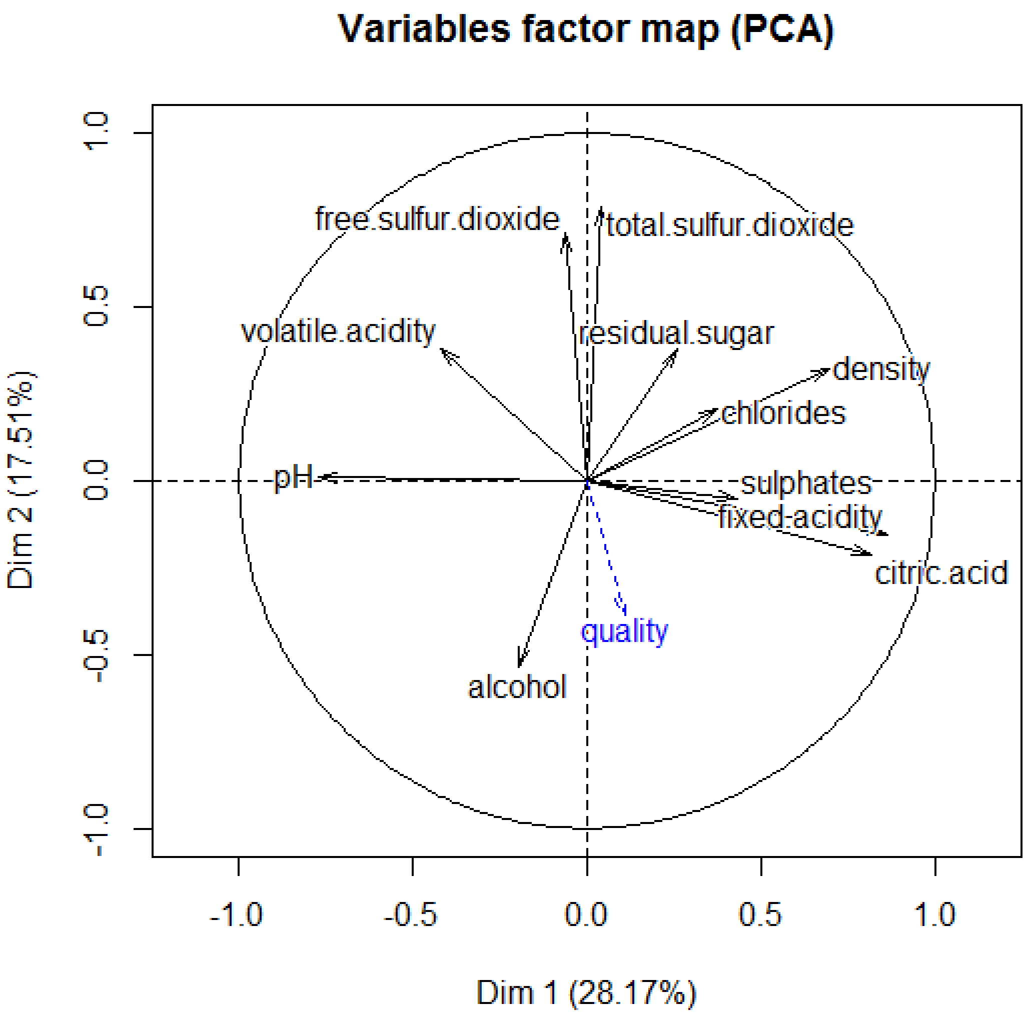


manual.rotation[, 2]
50
0
-50
0
50
100
150
manual.rotation[, 1]

R Console

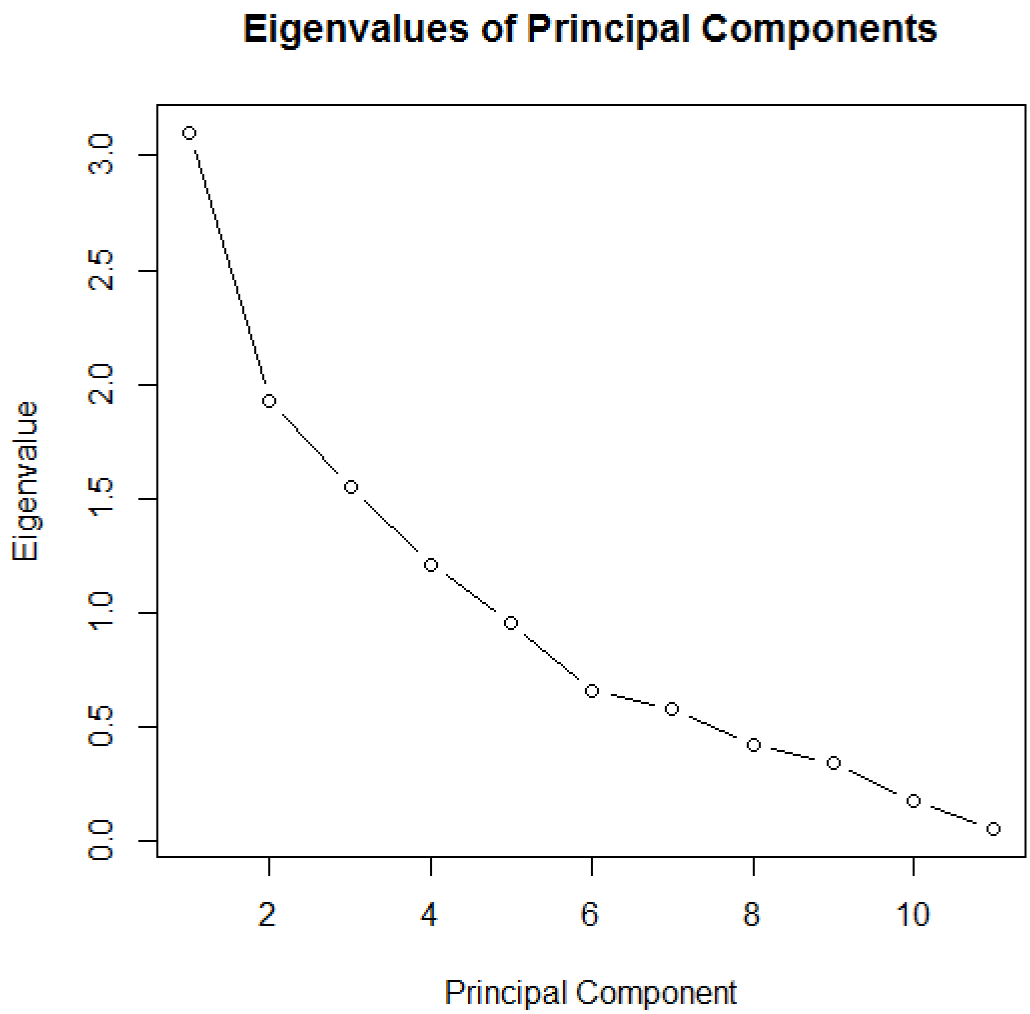
```
> summary(wine.prcomp)
Importance of components:
                           PC1     PC2     PC3     PC4     PC5
Standard deviation     33.6721 7.61153 1.76105 1.34886 1.02291
Proportion of Variance  0.9466 0.04837 0.00259 0.00152 0.00087
Cumulative Proportion   0.9466 0.99495 0.99753 0.99905 0.99993
                           PC6     PC7     PC8     PC9    PC10
Standard deviation     0.20346 0.15229 0.10652 0.10039 0.03814
Proportion of Variance 0.00003 0.00002 0.00001 0.00001 0.00000
Cumulative Proportion  0.99996 0.99998 0.99999 1.00000 1.00000
                            PC11
Standard deviation     0.0007493
Proportion of Variance 0.0000000
Cumulative Proportion  1.0000000
> summary(wine.prcomp.scaled)
Importance of components:
                          PC1    PC2    PC3    PC4     PC5     PC6
Standard deviation     1.7604 1.3878 1.2452 1.1015 0.97943 0.81216
Proportion of Variance 0.2817 0.1751 0.1410 0.1103 0.08721 0.05996
Cumulative Proportion  0.2817 0.4568 0.5978 0.7081 0.79528 0.85525
                           PC7     PC8     PC9    PC10    PC11
Standard deviation     0.76406 0.65035 0.58706 0.42583 0.24405
Proportion of Variance 0.05307 0.03845 0.03133 0.01648 0.00541
Cumulative Proportion  0.90832 0.94677 0.97810 0.99459 1.00000
>
>
```

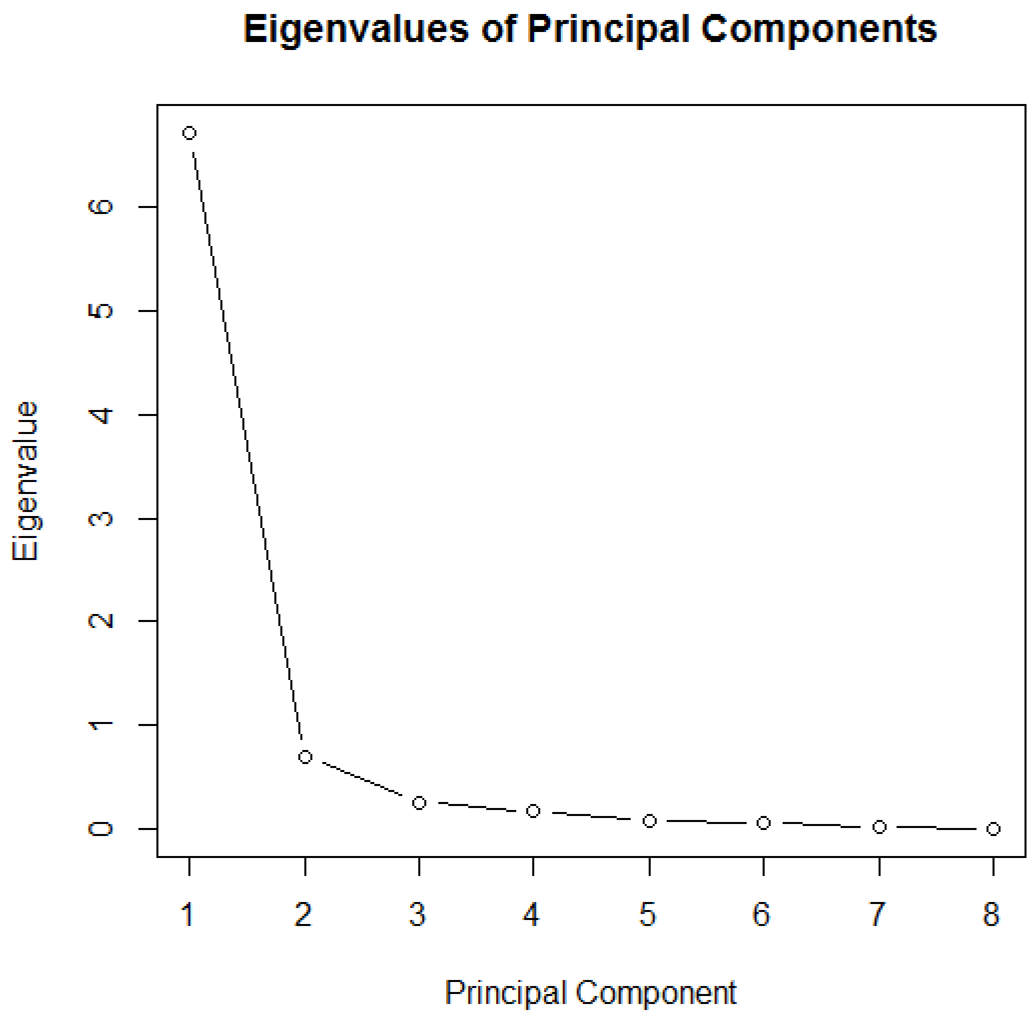

Variables factor map (PCA)
rings
height
shell_weight
diameter
length
whole_weight
viscer_weight
shucked_weight
Dim 1 (83.91%)
Dim 2 (8.70%)
-1.0
-0.5
0.0
0.5
1.0


Variables factor map (PCA)
free.sulfur.dioxide
total.sulfur.dioxide
volatile.acidity
residual.sugar
density
chlorides
pH
sulphates
fixed.acidity
citric.acid
quality
alcohol
Dim 1 (28.17%)
Dim 2 (17.51%)
-1.0
-0.5
0.0
0.5
1.0

R Console

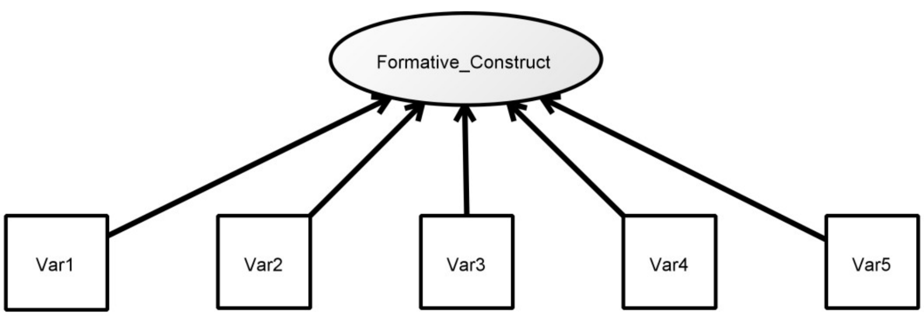
```
> summary(wine.pca)

Call:
PCA(red.wine, quanti.sup = 12)


Eigenvalues
                       Dim.1   Dim.2   Dim.3   Dim.4   Dim.5   Dim.6   Dim.7   Dim.8   Dim.9  Dim.10  Dim.11
Variance               3.099   1.926   1.551   1.213   0.959   0.660   0.584   0.423   0.345   0.181   0.060
% of var.             28.174  17.508  14.096  11.029   8.721   5.996   5.307   3.845   3.133   1.648   0.541
Cumulative % of var.  28.174  45.682  59.778  70.807  79.528  85.525  90.832  94.677  97.810  99.459 100.000

Individuals (the 10 first)
                        Dist    Dim.1    ctr   cos2    Dim.2    ctr   cos2    Dim.3    ctr   cos2
1                    |  2.645 | -1.620  0.053  0.375 |  0.451  0.007  0.029 | -1.774  0.127  0.450 |
2                    |  2.824 | -0.799  0.013  0.080 |  1.857  0.112  0.432 | -0.912  0.034  0.104 |
3                    |  1.936 | -0.748  0.011  0.149 |  0.882  0.025  0.208 | -1.171  0.055  0.366 |
4                    |  3.045 |  2.358  0.112  0.600 | -0.270  0.002  0.008 |  0.243  0.002  0.006 |
5                    |  2.645 | -1.620  0.053  0.375 |  0.451  0.007  0.029 | -1.774  0.127  0.450 |
6                    |  2.540 | -1.584  0.051  0.389 |  0.569  0.011  0.050 | -1.538  0.095  0.367 |
7                    |  2.115 | -1.101  0.024  0.271 |  0.608  0.012  0.083 | -1.076  0.047  0.259 |
8                    |  2.726 | -2.249  0.102  0.681 | -0.417  0.006  0.023 | -0.987  0.039  0.131 |
9                    |  2.093 | -1.087  0.024  0.270 | -0.309  0.003  0.022 | -1.518  0.093  0.526 |
10                   |  3.302 |  0.655  0.009  0.039 |  1.665  0.090  0.254 |  1.209  0.059  0.134 |

Variables (the 10 first)
                        Dim.1    ctr   cos2    Dim.2    ctr   cos2    Dim.3    ctr   cos2
fixed.acidity        |  0.861 23.943  0.742 | -0.153  1.221  0.024 | -0.154  1.520  0.024 |
volatile.acidity     | -0.420  5.692  0.176 |  0.382  7.559  0.146 | -0.560 20.247  0.314 |
citric.acid          |  0.816 21.495  0.666 | -0.211  2.304  0.044 |  0.297  5.676  0.088 |
residual.sugar       |  0.257  2.135  0.066 |  0.378  7.403  0.143 |  0.126  1.026  0.016 |
chlorides            |  0.374  4.505  0.140 |  0.205  2.192  0.042 | -0.115  0.858  0.013 |
free.sulfur.dioxide  | -0.064  0.131  0.004 |  0.713 26.375  0.508 |  0.534 18.386  0.285 |
total.sulfur.dioxide |  0.042  0.056  0.002 |  0.790 32.432  0.625 |  0.401 10.395  0.161 |
density              |  0.696 15.630  0.484 |  0.324  5.456  0.105 | -0.422 11.483  0.178 |
pH                   | -0.772 19.230  0.596 |  0.009  0.005  0.000 |  0.072  0.333  0.005 |
sulphates            |  0.428  5.901  0.183 | -0.052  0.141  0.003 |  0.348  7.828  0.121 |

Supplementary continuous variable
                        Dim.1   cos2    Dim.2   cos2    Dim.3   cos2
quality              |  0.110  0.012 | -0.387  0.150 |  0.399  0.159 |
>
```

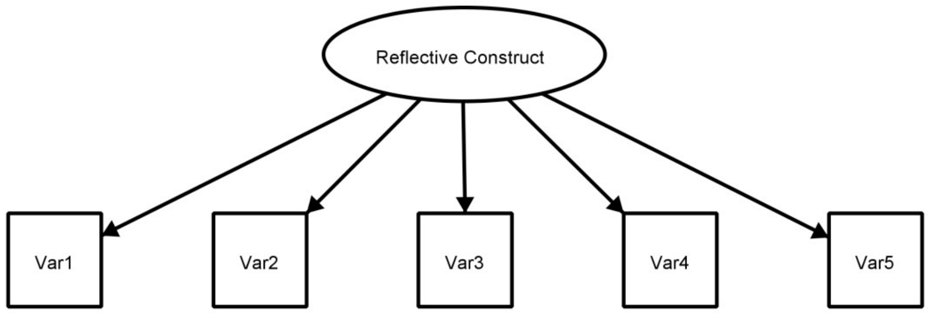

Eigenvalues of Principal Components
Eigenvalue
0.0
0.5
1.0
1.5
2.0
2.5
3.0
2
4
6
8
10
Principal Component

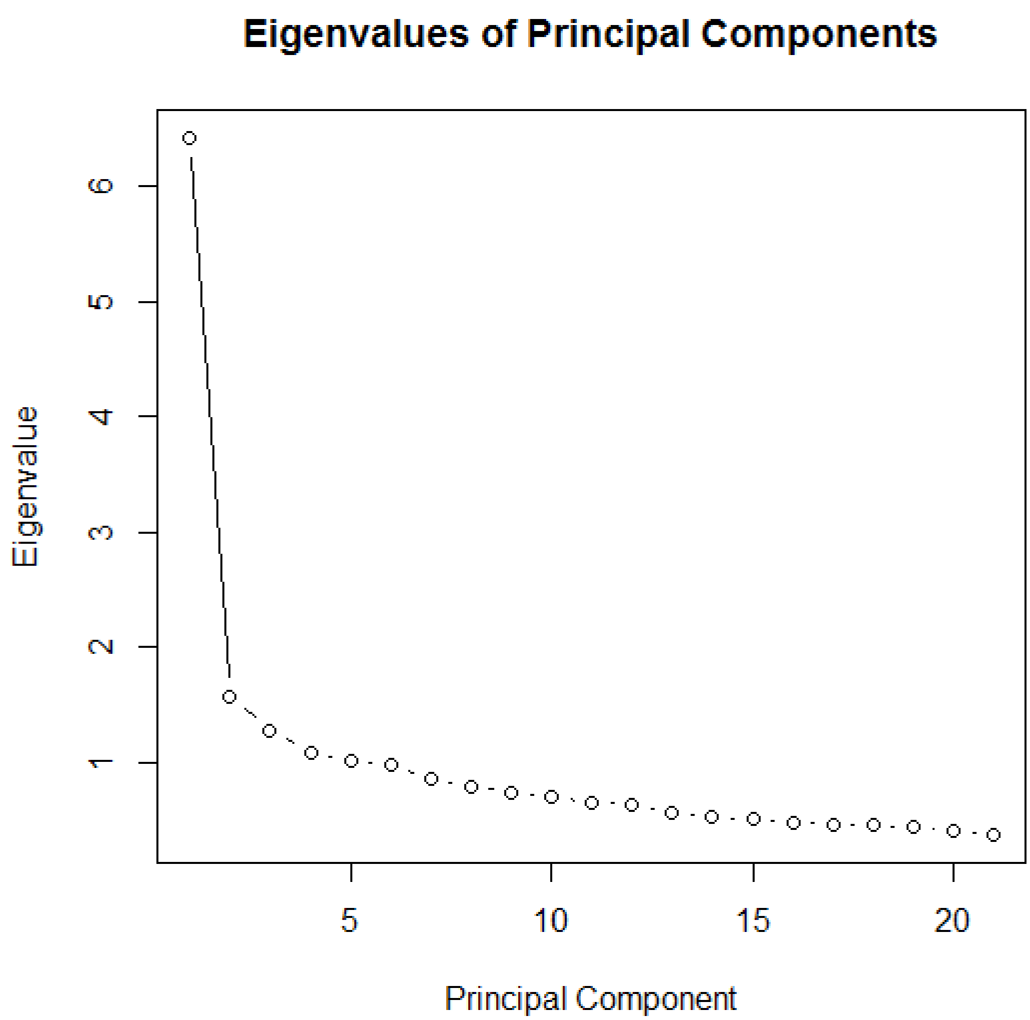

Eigenvalues of Principal Components
Eigenvalue
0
1
2
3
4
5
6
1
2
3
4
5
6
7
8
Principal Component

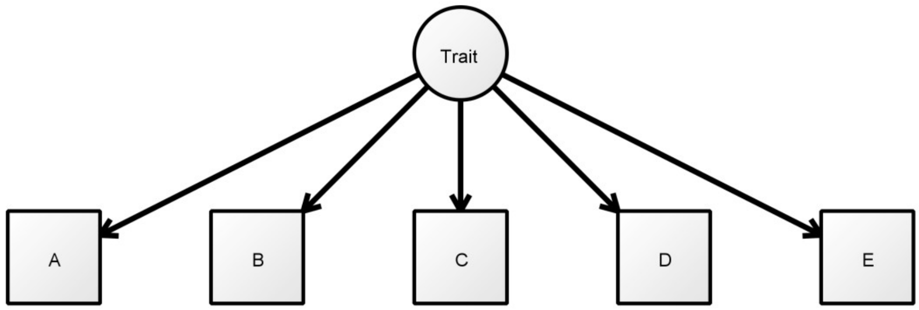
R Console

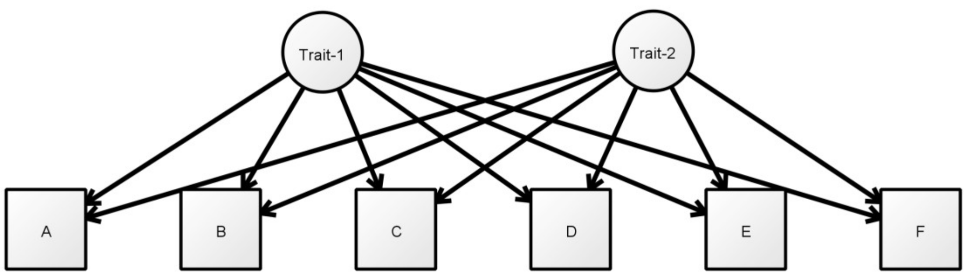
```
> summary(wine.pca, ncp = 4, )

Call:
PCA(red.wine, quanti.sup = 12)


Eigenvalues
                       Dim.1   Dim.2   Dim.3   Dim.4   Dim.5   Dim.6   Dim.7   Dim.8   Dim.9  Dim.10  Dim.11
Variance               3.099   1.926   1.551   1.213   0.959   0.660   0.584   0.423   0.345   0.181   0.060
% of var.             28.174  17.508  14.096  11.029   8.721   5.996   5.307   3.845   3.133   1.648   0.541
Cumulative % of var.  28.174  45.682  59.778  70.807  79.528  85.525  90.832  94.677  97.810  99.459 100.000

Individuals (the 10 first)
                        Dist    Dim.1    ctr   cos2    Dim.2    ctr   cos2    Dim.3    ctr   cos2    Dim.4    ctr   cos2  
1                    |  2.645 | -1.620  0.053  0.375 |  0.451  0.007  0.029 | -1.774  0.127  0.450 |  0.044  0.000  0.000 |
2                    |  2.824 | -0.799  0.013  0.080 |  1.857  0.112  0.432 | -0.912  0.034  0.104 |  0.548  0.015  0.038 |
3                    |  1.936 | -0.748  0.011  0.149 |  0.882  0.025  0.208 | -1.171  0.055  0.366 |  0.411  0.009  0.045 |
4                    |  3.045 |  2.358  0.112  0.600 | -0.270  0.002  0.008 |  0.243  0.002  0.006 | -0.928  0.044  0.093 |
5                    |  2.645 | -1.620  0.053  0.375 |  0.451  0.007  0.029 | -1.774  0.127  0.450 |  0.044  0.000  0.000 |
6                    |  2.540 | -1.584  0.051  0.389 |  0.569  0.011  0.050 | -1.538  0.095  0.367 |  0.024  0.000  0.000 |
7                    |  2.115 | -1.101  0.024  0.271 |  0.608  0.012  0.083 | -1.076  0.047  0.259 | -0.344  0.006  0.026 |
8                    |  2.726 | -2.249  0.102  0.681 | -0.417  0.006  0.023 | -0.987  0.039  0.131 | -0.001  0.000  0.000 |
9                    |  2.093 | -1.087  0.024  0.270 | -0.309  0.003  0.022 | -1.518  0.093  0.526 |  0.003  0.000  0.000 |
10                   |  3.302 |  0.655  0.009  0.039 |  1.665  0.090  0.254 |  1.209  0.059  0.134 | -0.825  0.035  0.062 |

Variables (the 10 first)
                       Dim.1    ctr   cos2    Dim.2    ctr   cos2    Dim.3    ctr   cos2    Dim.4    ctr   cos2  
fixed.acidity        |  0.861 23.943  0.742 | -0.153  1.221  0.024 | -0.154  1.520  0.024 | -0.253  5.272  0.064 |
volatile.acidity     | -0.420  5.692  0.176 |  0.382  7.559  0.146 | -0.560 20.247  0.314 |  0.087  0.623  0.008 |
citric.acid          |  0.816 21.495  0.666 | -0.211  2.304  0.044 |  0.297  5.676  0.088 | -0.087  0.631  0.008 |
residual.sugar       |  0.257  2.135  0.066 |  0.378  7.403  0.143 |  0.126  1.026  0.016 | -0.411 13.897  0.169 |
chlorides            |  0.374  4.505  0.140 |  0.205  2.192  0.042 | -0.115  0.858  0.013 |  0.734 44.382  0.538 |
free.sulfur.dioxide  | -0.064  0.131  0.004 |  0.713 26.375  0.508 |  0.534 18.386  0.285 | -0.048  0.190  0.002 |
total.sulfur.dioxide |  0.042  0.056  0.002 |  0.790 32.432  0.625 |  0.401 10.395  0.161 | -0.038  0.120  0.001 |
density              |  0.696 15.630  0.484 |  0.324  5.456  0.105 | -0.422 11.483  0.178 | -0.192  3.045  0.037 |
pH                   | -0.772 19.230  0.596 |  0.009  0.005  0.000 |  0.072  0.333  0.005 | -0.004  0.001  0.000 |
sulphates            |  0.428  5.901  0.183 | -0.052  0.141  0.003 |  0.348  7.828  0.121 |  0.607 30.346  0.368 |

Supplementary continuous variable
                       Dim.1   cos2    Dim.2   cos2    Dim.3   cos2    Dim.4   cos2  
quality              |  0.110  0.012 | -0.387  0.150 |  0.399  0.159 | -0.044  0.002 |
```



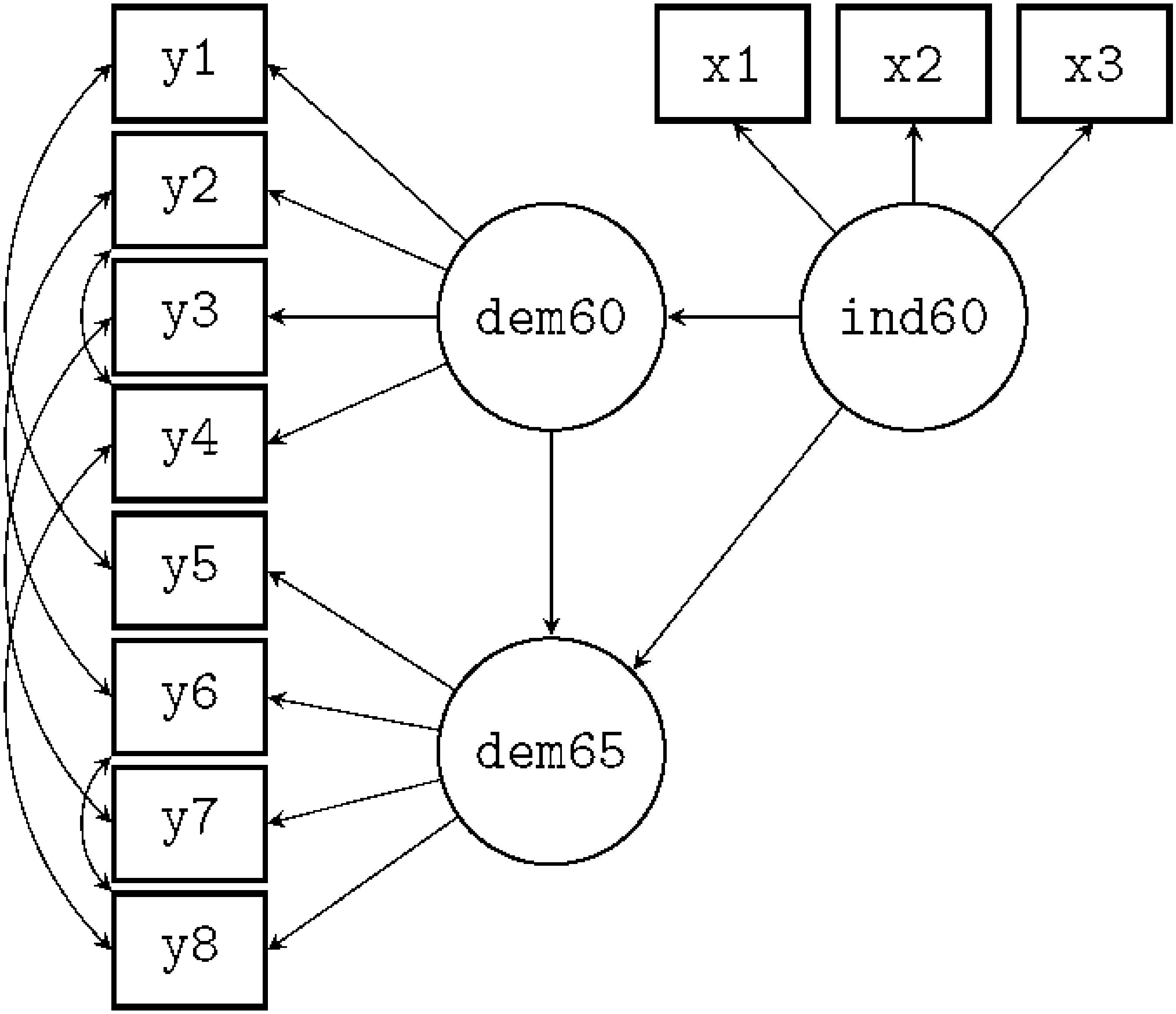

Reflective Construct
Var1
Var2
Var3
Var4
Var5

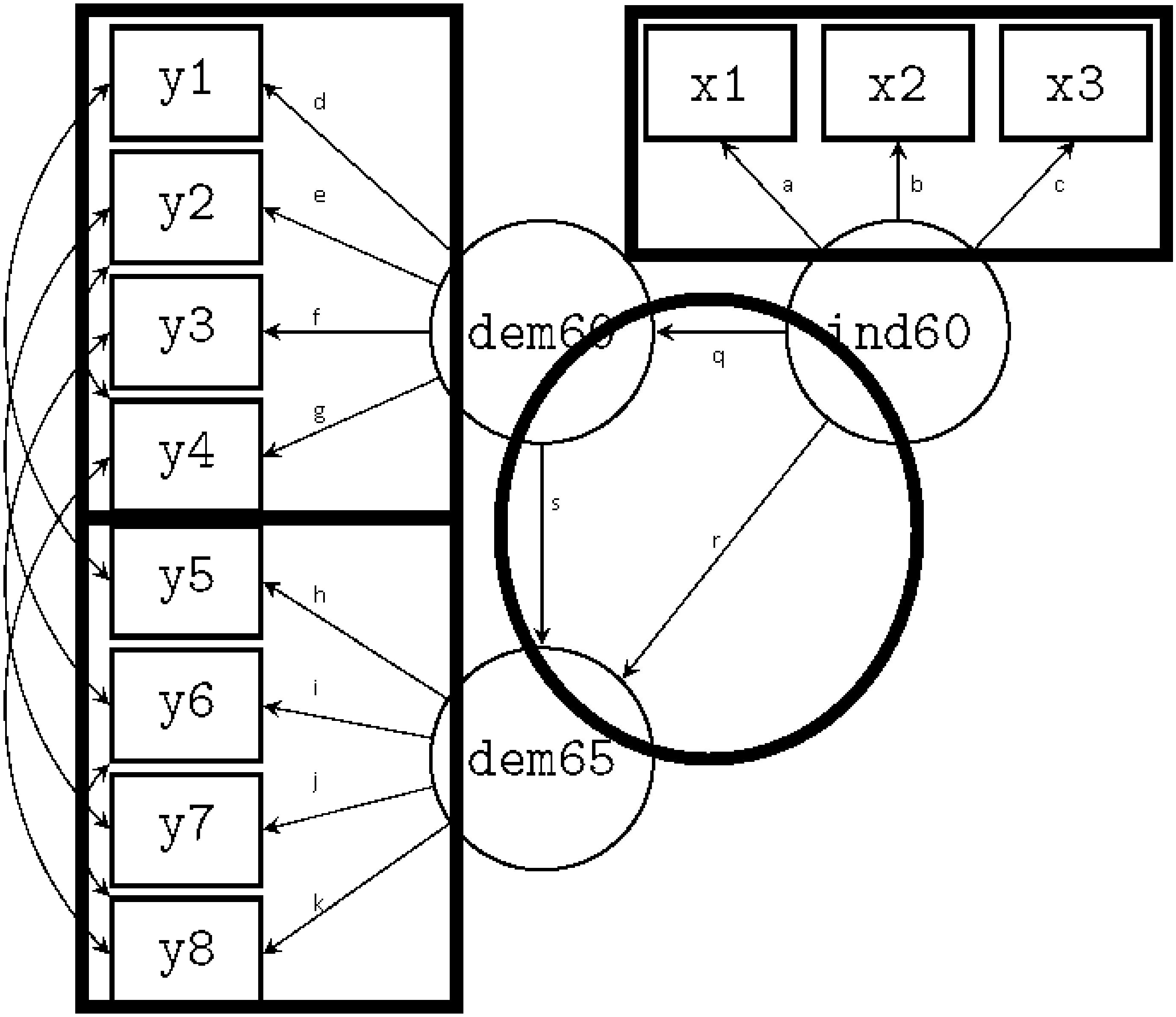

Eigenvalues of Principal Components
Eigenvalue
1
2
3
4
5
6
5
10
15
20
Principal Component





Chapter 7: Structural Equation Modeling and Confirmatory Factor Analysis


y1
y2
y3
y4
y5
y6
y7
y8
x1
x2
x3
dem60
ind60
dem65


y1
y2
y3
y4
y5
y6
y7
y8
x1
x2
x3
dem60
ind60
dem65
a
b
c
d
e
f
g
h
i
j
k
q
r
s

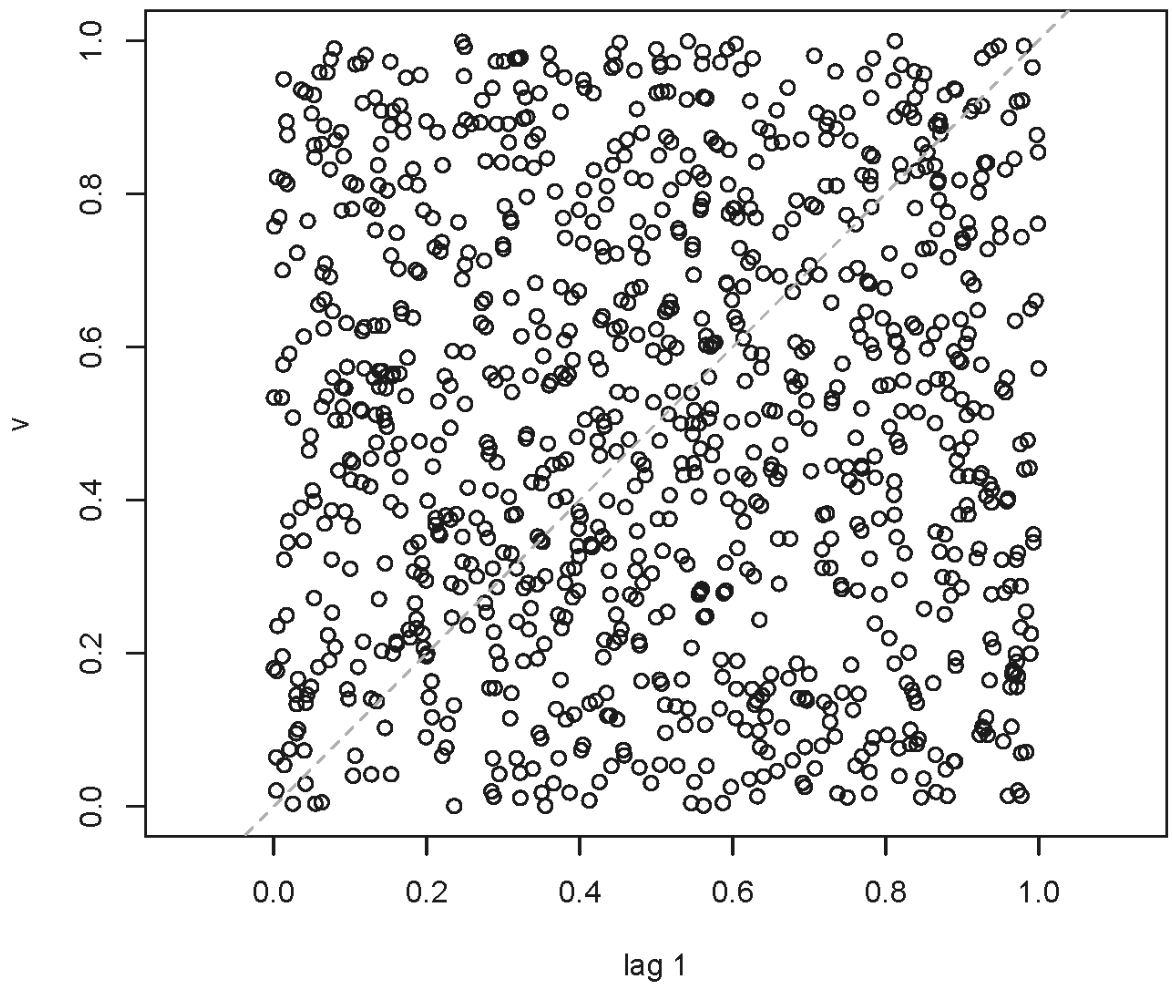
R Console

```
> summary(mxRun(factorModel.2))
Running Political Democracy Model
data:
$`Political Democracy Model.data`
$`Political Democracy Model.data`$cov
          y1         y2         y3        y4       y5         y6        y7$
y1 6.8785658  6.2513659  5.8388354  6.088643 5.063811  5.7458262  5.8119432$
y2 6.2513659 15.5798162  5.8386258  9.508553 5.603072  9.3862893  7.5354623$
y3 5.8388354  5.8386258 10.7642473  6.687937 4.939027  4.7273963  7.0064347$
y4 6.0886427  9.5085534  6.6879370 11.218932 5.702059  7.4421821  7.4879988$
y5 5.0638108  5.6030723  4.9390271  5.702059 6.825690  4.9768045  5.8213662$
y6 5.7458262  9.3862893  4.7273963  7.442182 4.976805 11.3753251  6.7481190$
y7 5.8119432  7.5354623  7.0064347  7.487999 5.821366  6.7481190 10.7993719$
y8 5.6710576  7.7582132  5.6391391  8.012646 5.339386  8.2468297  7.5924331$
x1 0.7343930  0.6194955  0.7868787  1.150461 1.081626  0.8527889  0.9368373$
x2 1.2733939  1.4912729  1.5519351  2.240957 2.063733  1.8054863  1.9955952$
x3 0.9114547  1.1698131  1.0390796  1.838023 1.583465  1.5720662  1.6259535$


The final iterate satisfies the optimality conditions to the accuracy reque$

free parameters:
                                 name matrix row col   Estimate  Std.Error $
1   Political Democracy Model.A[10,12]      A  10  12 2.18036325 0.13994831 $
2   Political Democracy Model.A[11,12]      A  11  12 1.81850749 0.15321581 $
3   Political Democracy Model.A[13,12]      A  13  12 1.48299937 0.40003769 $
4   Political Democracy Model.A[14,12]      A  14  12 0.57233772 0.23532664 $
5    Political Democracy Model.A[2,13]      A   2  13 1.25674159 0.18676663 $
6    Political Democracy Model.A[3,13]      A   3  13 1.05771456 0.14934347 $
7    Political Democracy Model.A[4,13]      A   4  13 1.26478130 0.15176605 $
8   Political Democracy Model.A[14,13]      A  14  13 0.83734401 0.09946018 $
9    Political Democracy Model.A[6,14]      A   6  14 1.18569339 0.17251176 $
10   Political Democracy Model.A[7,14]      A   7  14 1.27950966 0.16146294 $
```

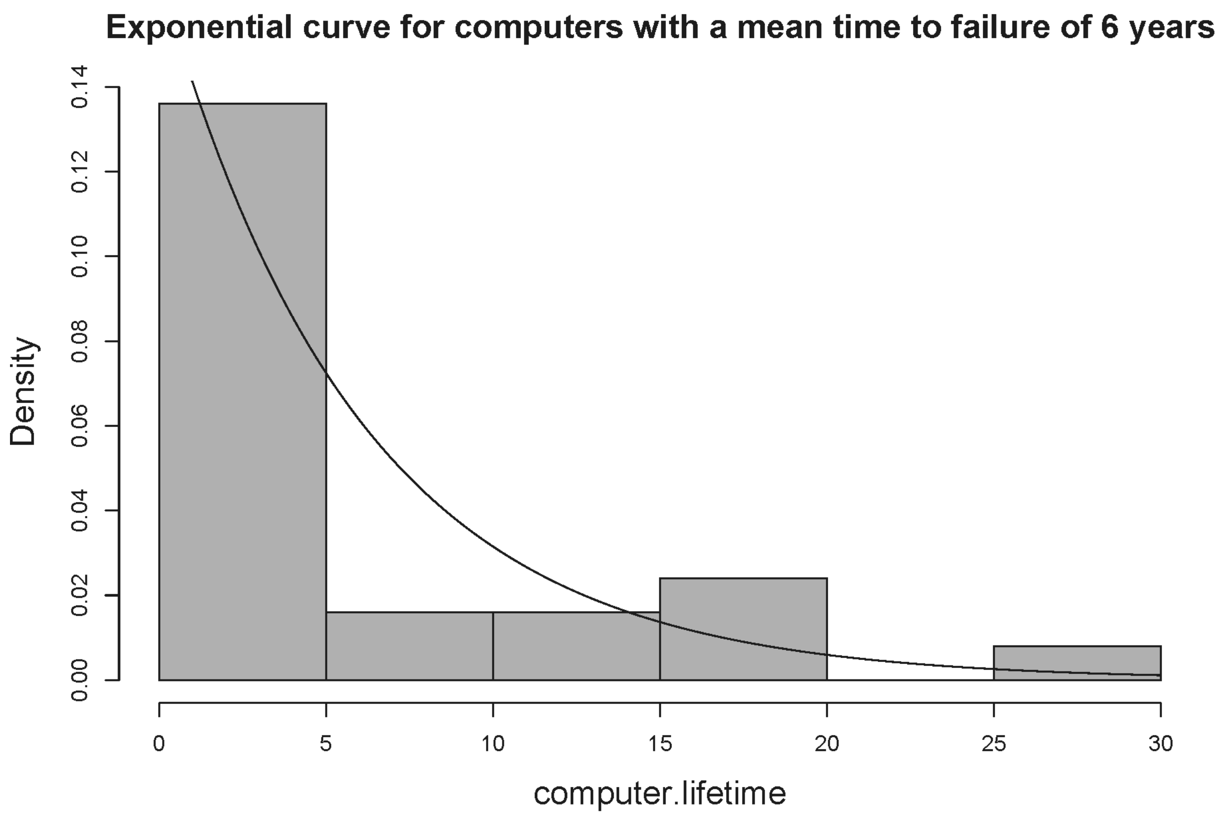
```
> summary(fit.hs.lavaan)
lavaan (0.5-15) converged normally after  22 iterations

  Number of observations                           301

  Estimator                                         ML
  Minimum Function Test Statistic               85.306
  Degrees of freedom                                24
  P-value (Chi-square)                           0.000

Parameter estimates:

  Information                                 Expected
  Standard Errors                             Standard

                   Estimate  Std.err  Z-value  P(>|z|)
Latent variables:
  visual =~
    x1                0.900    0.081   11.127    0.000
    x2                0.498    0.077    6.429    0.000
    x3                0.656    0.074    8.817    0.000
  textual =~
    x4                0.990    0.057   17.474    0.000
    x5                1.102    0.063   17.576    0.000
    x6                0.917    0.054   17.082    0.000
  speed =~
    x7                0.619    0.070    8.903    0.000
    x8                0.731    0.066   11.090    0.000
    x9                0.670    0.065   10.305    0.000

Covariances:
  visual ~~
    textual           0.459    0.064    7.189    0.000
```

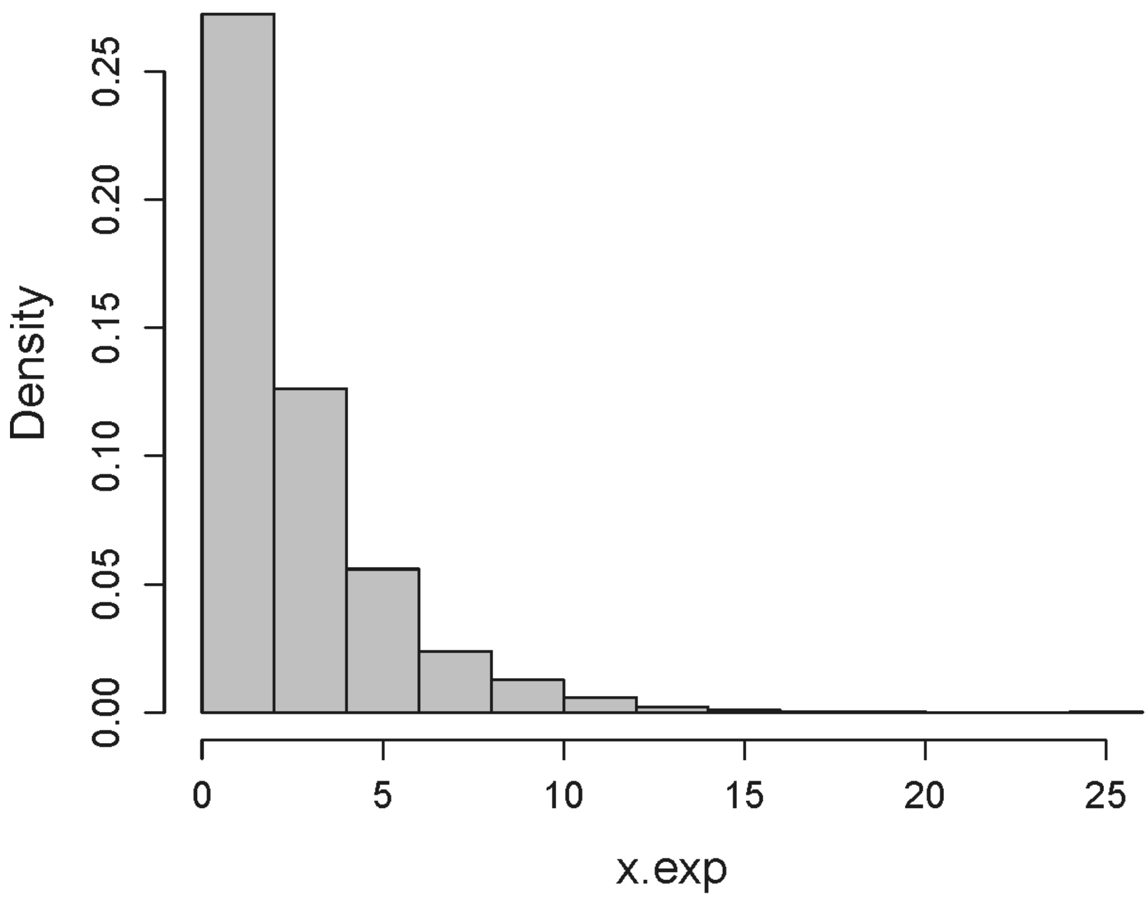
```
R Console

> summary(fit.hs.open.mx)
data:
$`Holzinger Swineford.data`
$`Holzinger Swineford.data`$cov
            x1          x2         x3        x4        x5        x6         $
x1 1.36289774  0.40872923 0.58183232 0.5065178 0.4420843 0.4563242  0.085047$
x2 0.40872923  1.38638981 0.45256748 0.2096198 0.2117947 0.2483697 -0.097073$
x3 0.58183232  0.45256748 1.27911441 0.2088635 0.1126706 0.2449227  0.088636$
x4 0.50651778  0.20961978 0.20886351 1.3551667 1.1014120 0.8985008  0.220475$
x5 0.44208426  0.21179471 0.11267061 1.1014120 1.6653184 1.0179058  0.143476$
x6 0.45632416  0.24836972 0.24492268 0.8985008 1.0179058 1.2003462  0.144558$
x7 0.08504799 -0.09707352 0.08863631 0.2204751 0.1434762 0.1445587  1.187083$
x8 0.26471714  0.11002492 0.21303038 0.1260120 0.1812072 0.1659824  0.537029$
x9 0.45986634  0.24482282 0.37509875 0.2441739 0.2962255 0.2367836  0.374541$


free parameters:
                           name matrix     row     col  Estimate  Std.Error $
1   Holzinger Swineford.A[1,10]      A      x1  visual 0.9011177 0.08351138 $
2   Holzinger Swineford.A[2,10]      A      x2  visual 0.4987688 0.08105689 $
3   Holzinger Swineford.A[3,10]      A      x3  visual 0.6572487 0.07783756 $
4   Holzinger Swineford.A[4,11]      A      x4 textual 0.9913408 0.05687873 $
5   Holzinger Swineford.A[5,11]      A      x5 textual 1.1034381 0.06279691 $
6   Holzinger Swineford.A[6,11]      A      x6 textual 0.9181265 0.05393494 $
7   Holzinger Swineford.A[7,12]      A      x7   speed 0.6205055 0.07455608 $
8   Holzinger Swineford.A[8,12]      A      x8   speed 0.7321655 0.07574673 $
9   Holzinger Swineford.A[9,12]      A      x9   speed 0.6710954 0.07778219 $
10   Holzinger Swineford.S[1,1]      S      x1      x1 0.5508846 0.11964676 $
11   Holzinger Swineford.S[2,2]      S      x2      x2 1.1376195 0.10478550 $
12   Holzinger Swineford.S[3,3]      S      x3      x3 0.8471385 0.09555064 $
13   Holzinger Swineford.S[4,4]      S      x4      x4 0.3724102 0.04820283 $
14   Holzinger Swineford.S[5,5]      S      x5      x5 0.4477426 0.05822352 $
15   Holzinger Swineford.S[6,6]      S      x6      x6 0.3573899 0.04365787 $
```

Chapter 8: Simulations

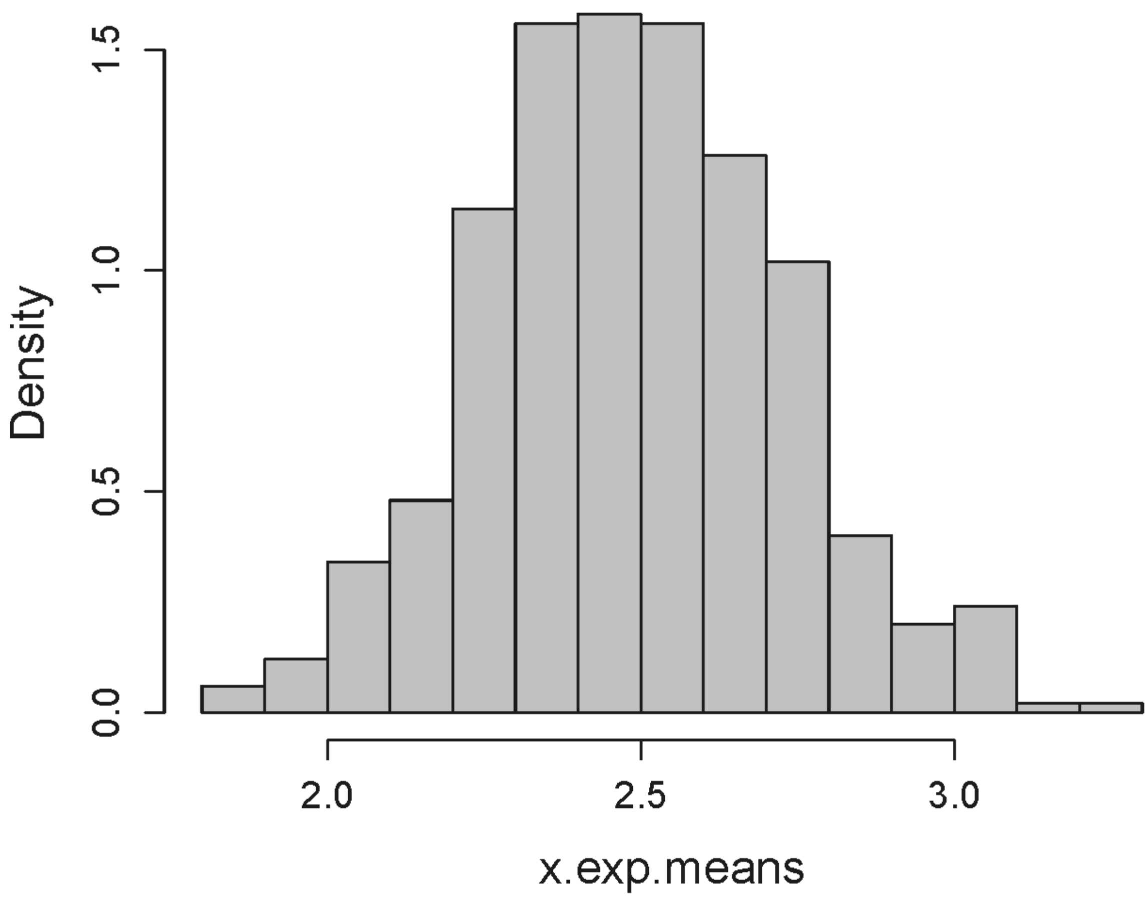


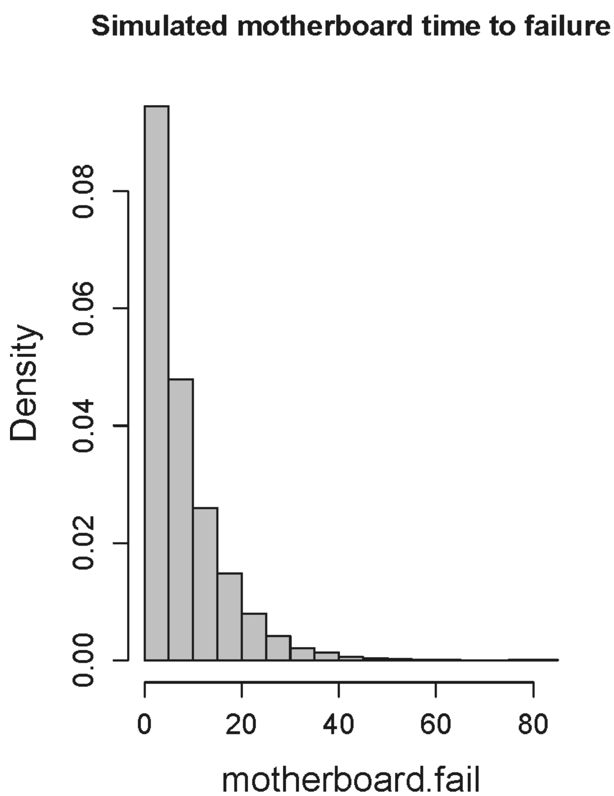
v
lag 1
0.0
0.2
0.4
0.6
0.8
1.0

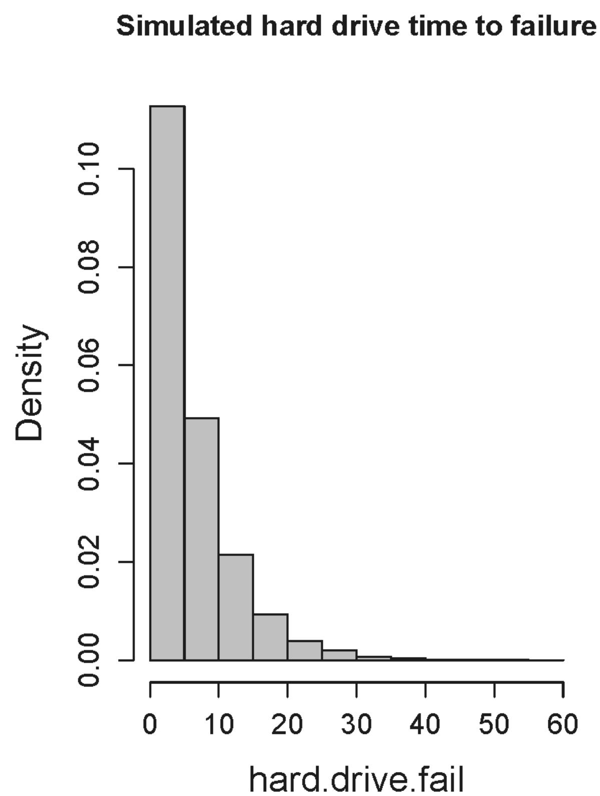

Exponential curve for computers with a mean time to failure of 6 years
Density
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0
5
10
15
20
25
30
computer.lifetime

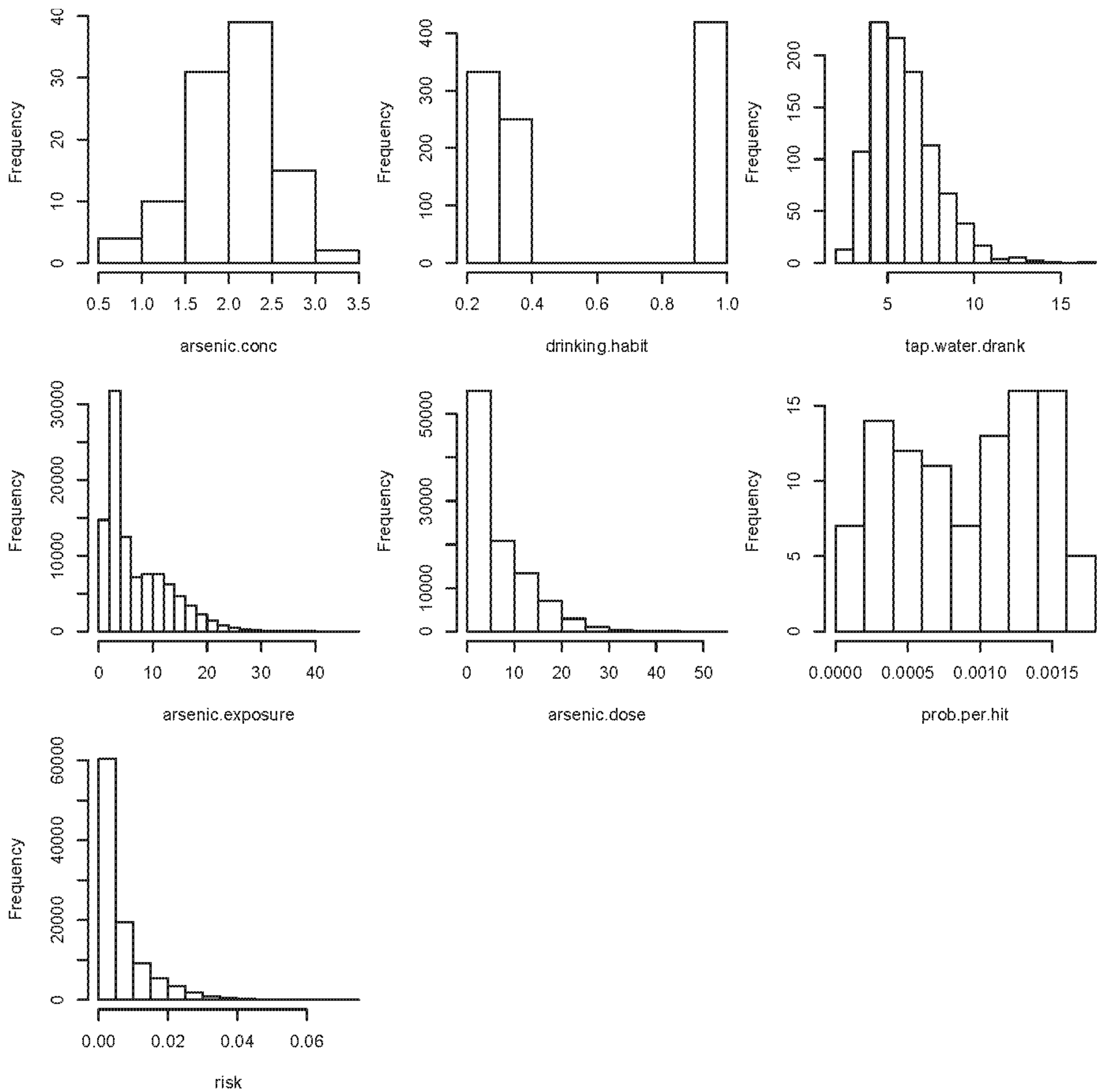


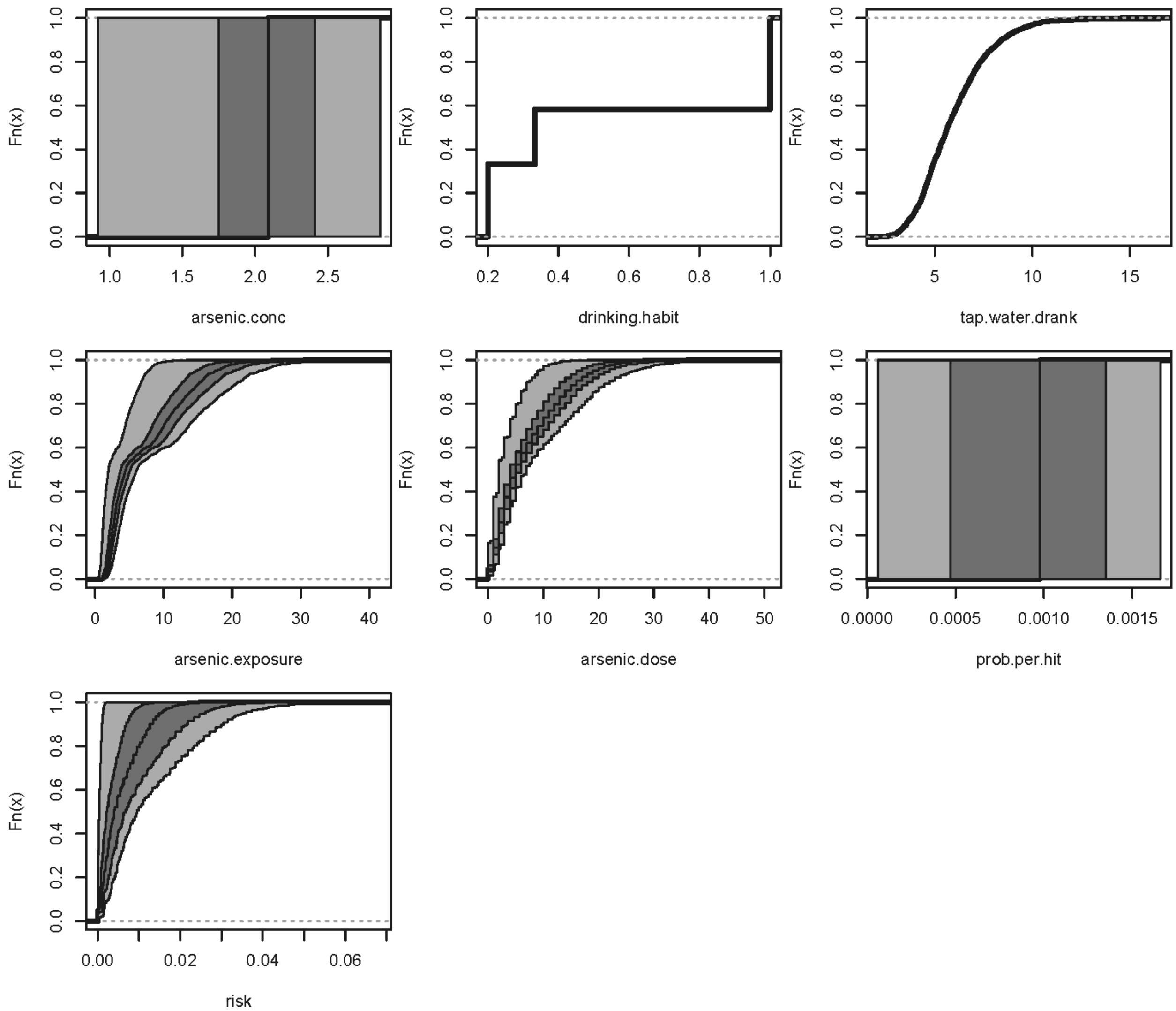
Density
0.00
0.05
0.10
0.15
0.20
0.25
0
5
10
15
20
25
x.exp

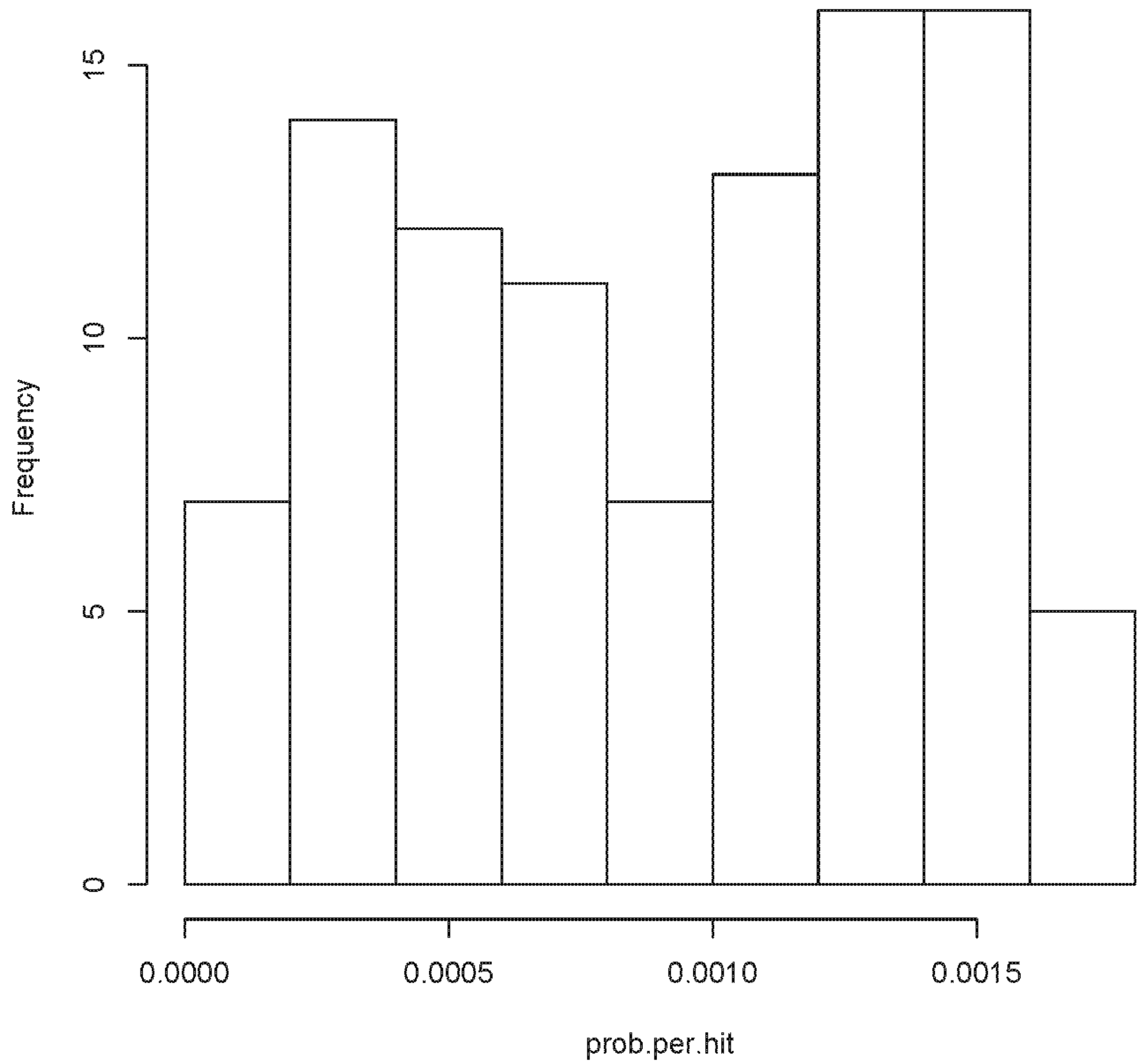

Density
0.0
0.5
1.0
1.5
2.0
2.5
3.0
x.exp.means

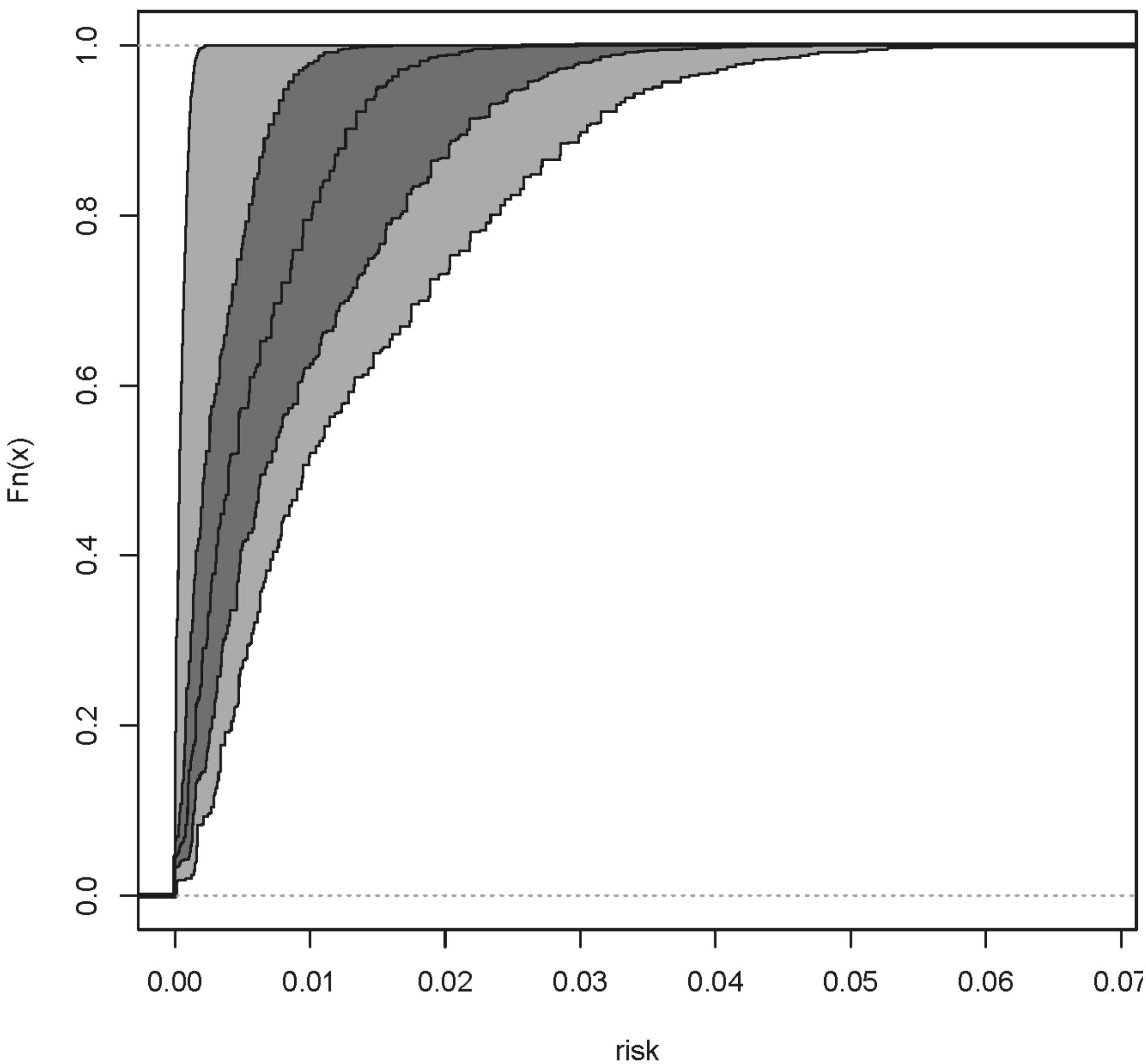

Simulated motherboard time to failure
Density
0.00
0.02
0.04
0.06
0.08
0
20
40
60
80
motherboard.fail

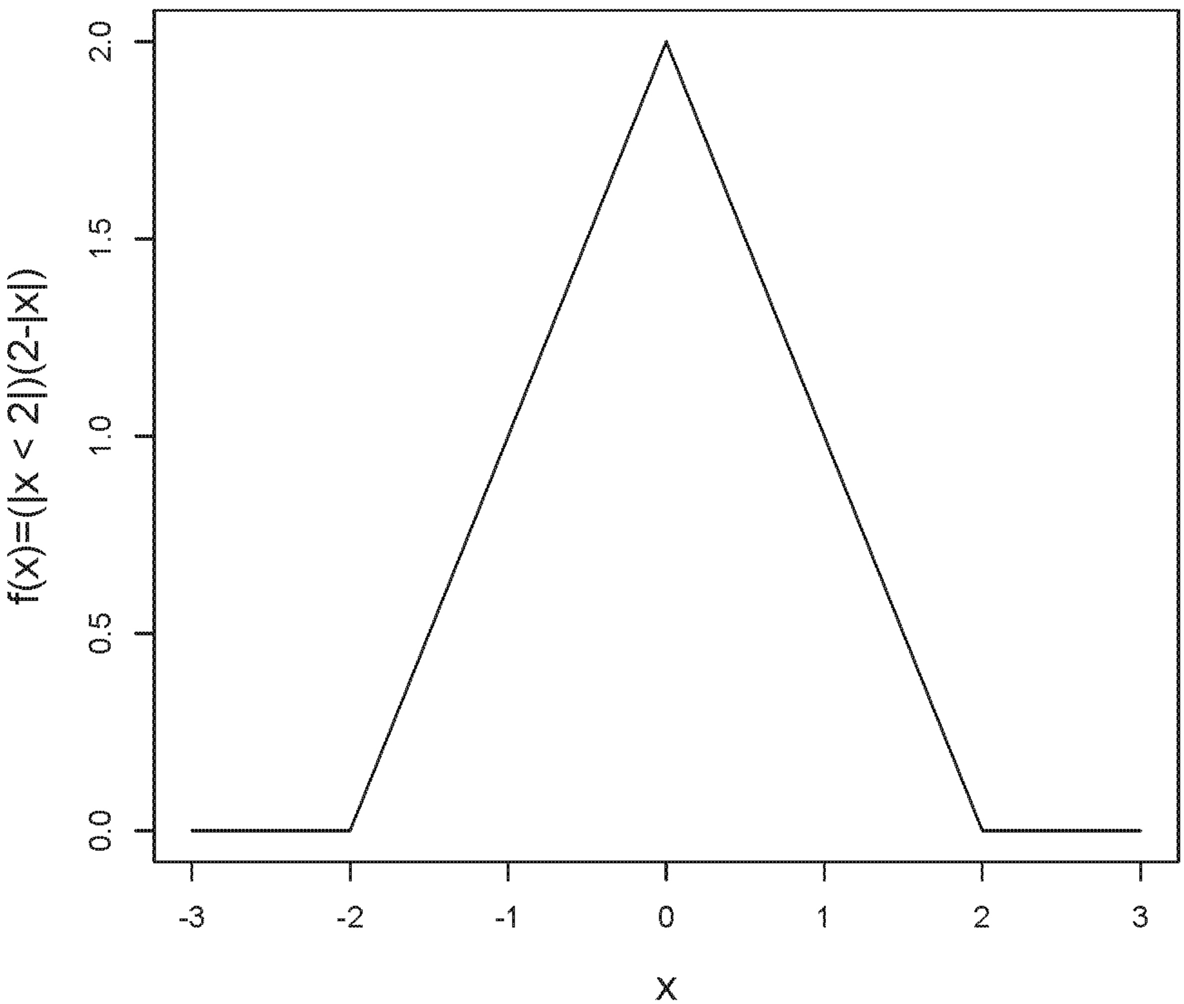

Simulated hard drive time to failure
Density
0.00
0.02
0.04
0.06
0.08
0.10
0
10
20
30
40
50
60
hard.drive.fail

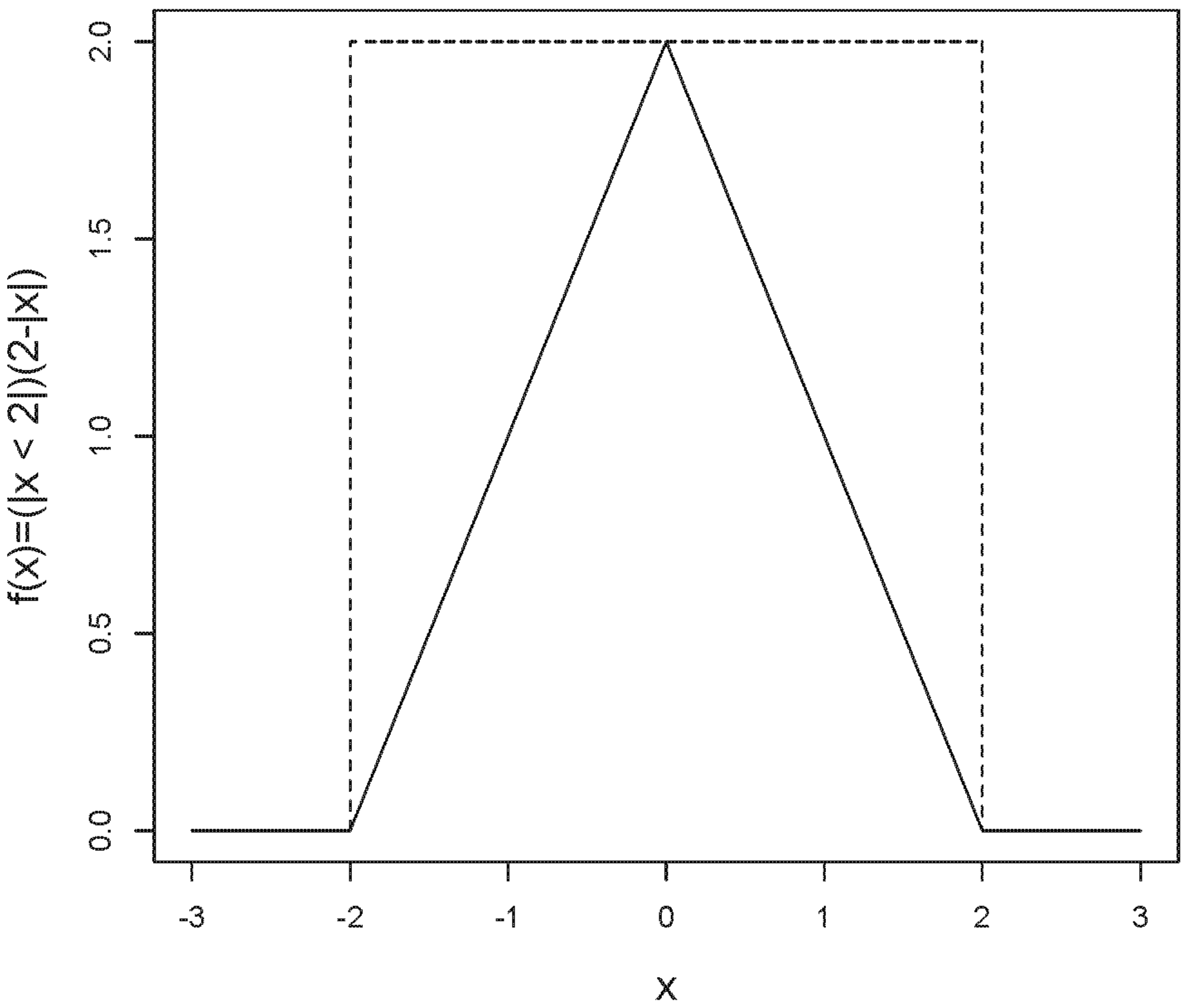

Frequency
arsenic.conc
drinking.habit
tap.water.drank
arsenic.exposure
arsenic.dose
prob.per.hit
risk


Fn(x)
arsenic.conc
drinking.habit
tap.water.drank
arsenic.exposure
arsenic.dose
prob.per.hit
risk

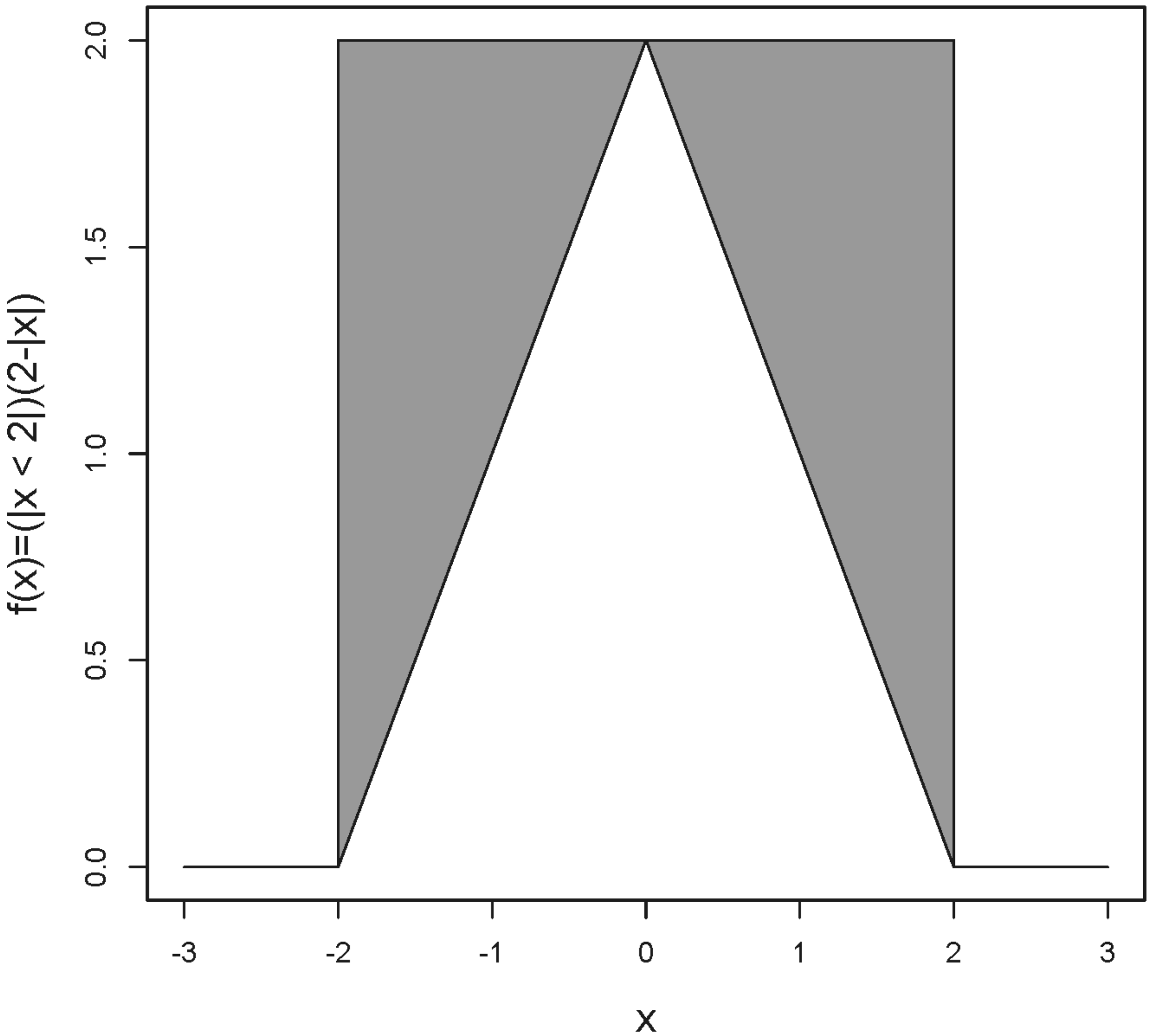

Frequency
0
5
10
15
0.0000
0.0005
0.0010
0.0015
prob.per.hit


1.0
0.8
0.6
0.4
0.2
0.0
Fn(x)
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
risk

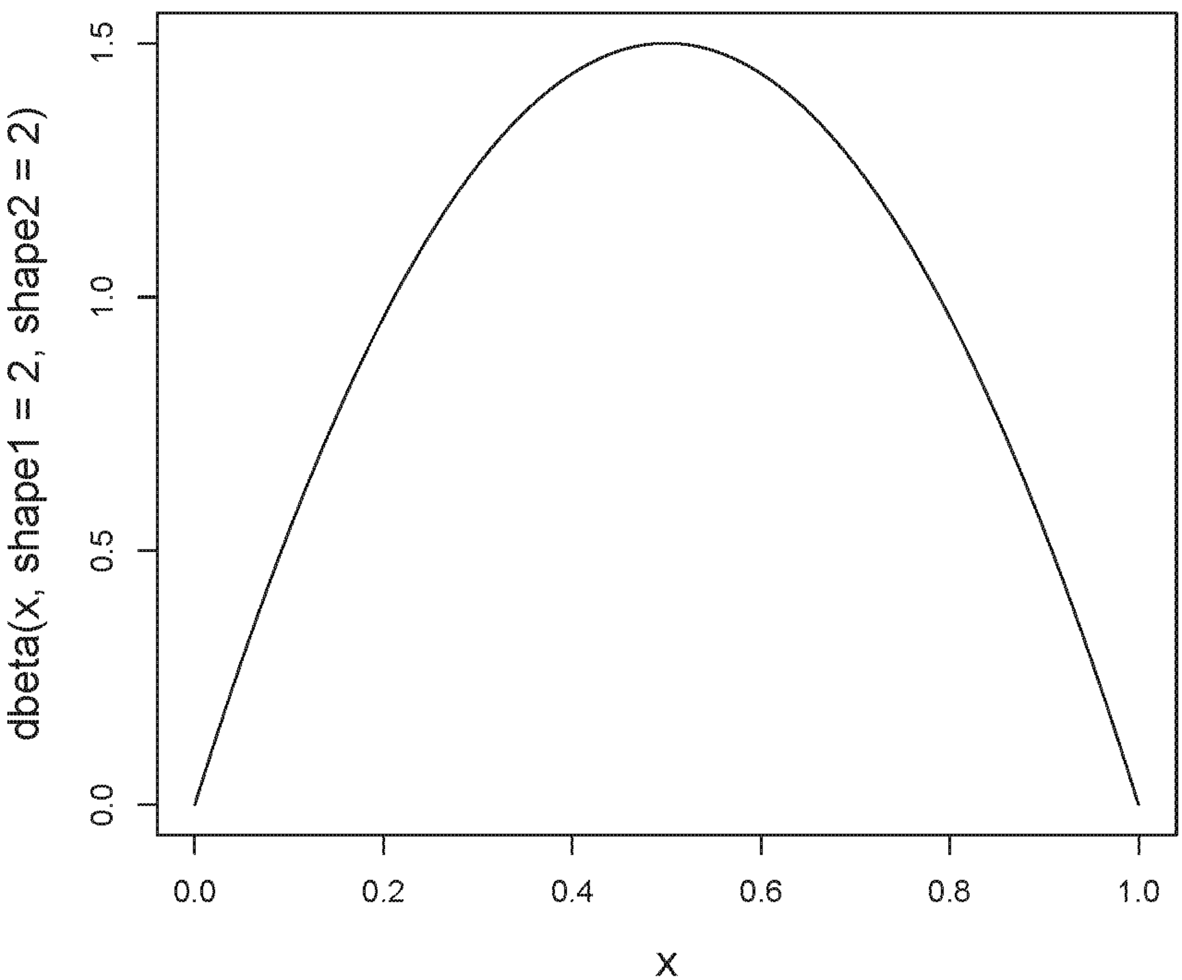

f(x)=(|x < 2|)(2-|x|)
2.0
1.5
1.0
0.5
0.0
-3
-2
-1
0
1
2
3
x



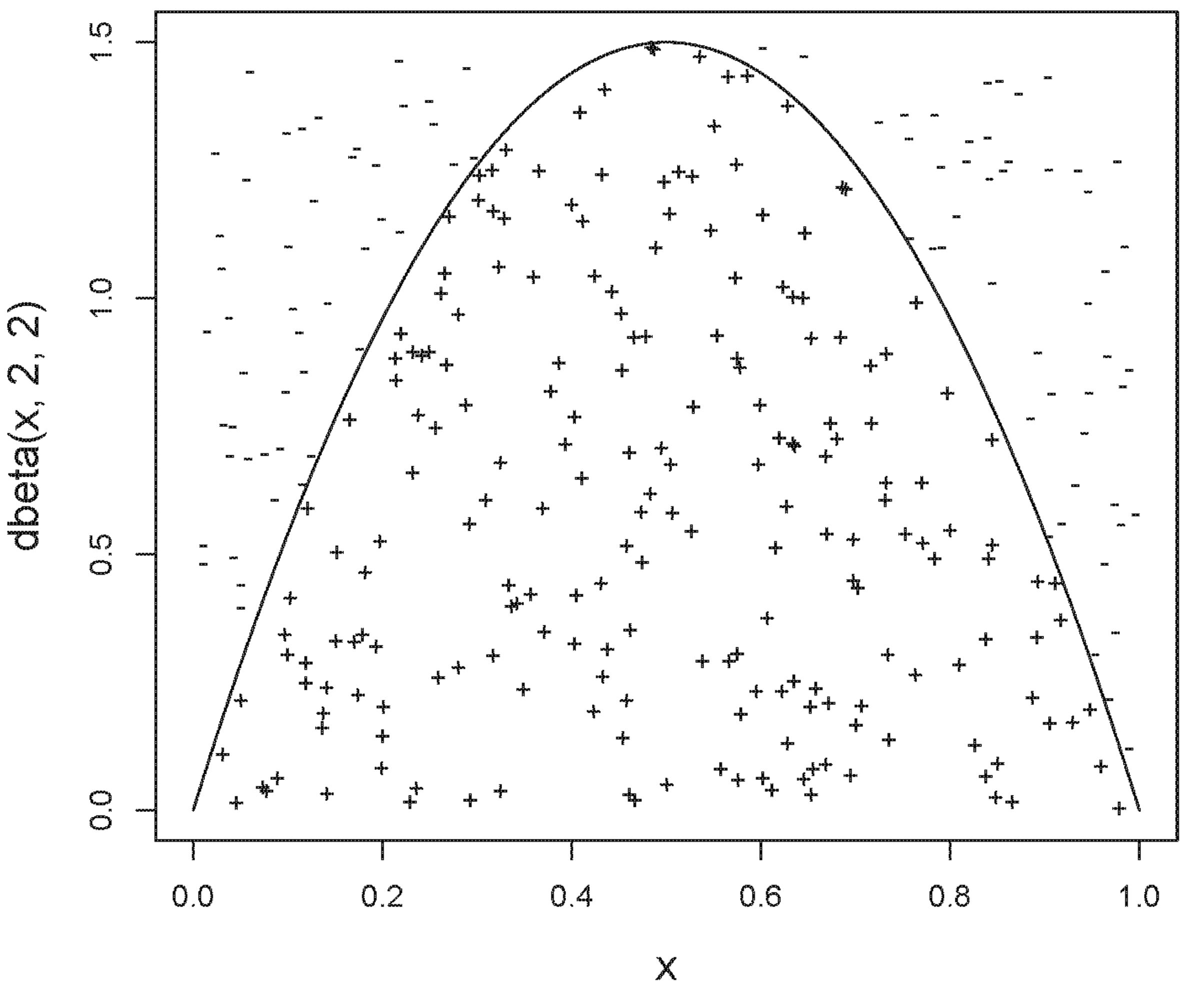
f(x)=(|x < 2|)(2-|x|)
0.0
0.5
1.0
1.5
2.0
-3
-2
-1
0
1
2
3
x

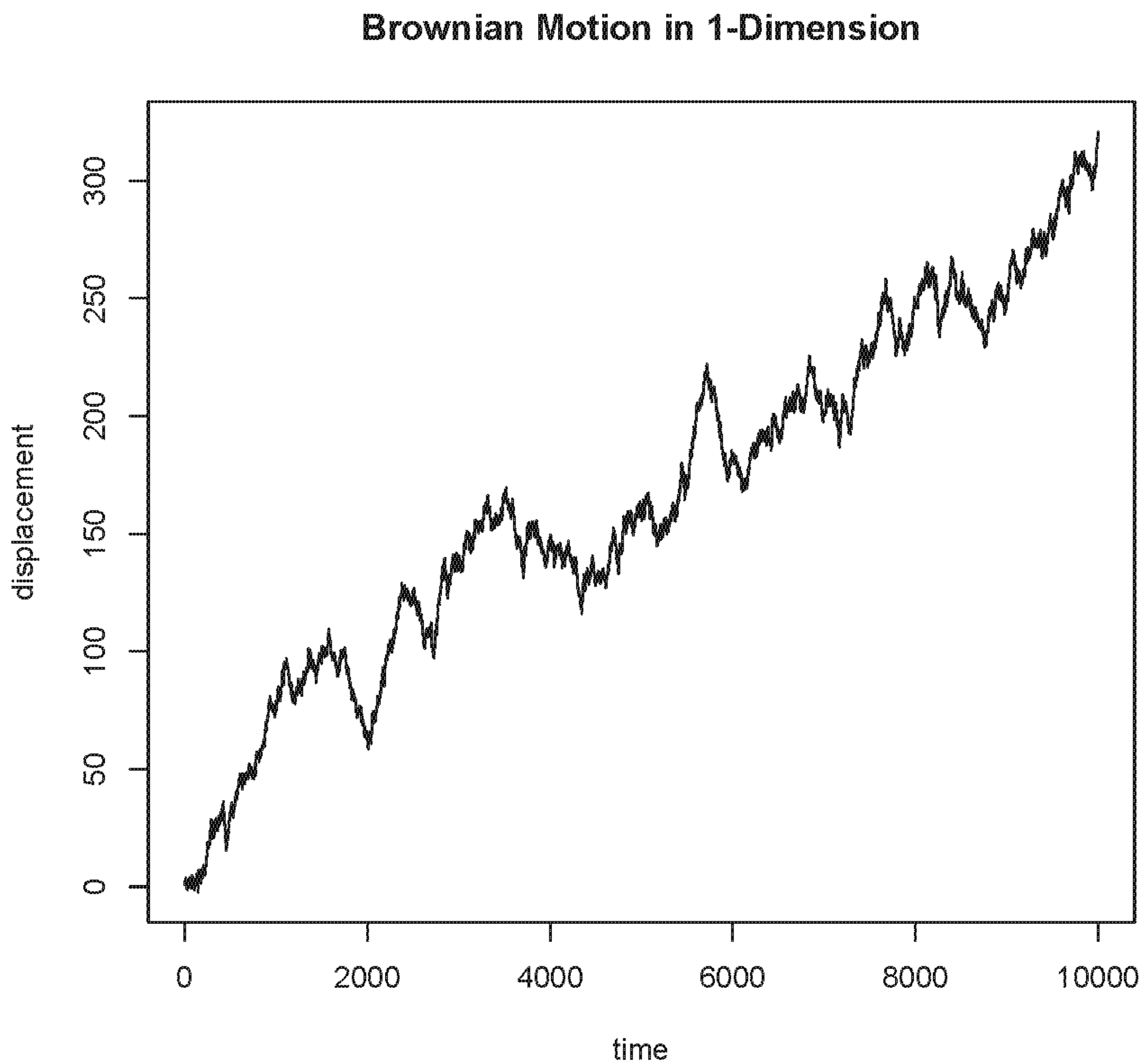


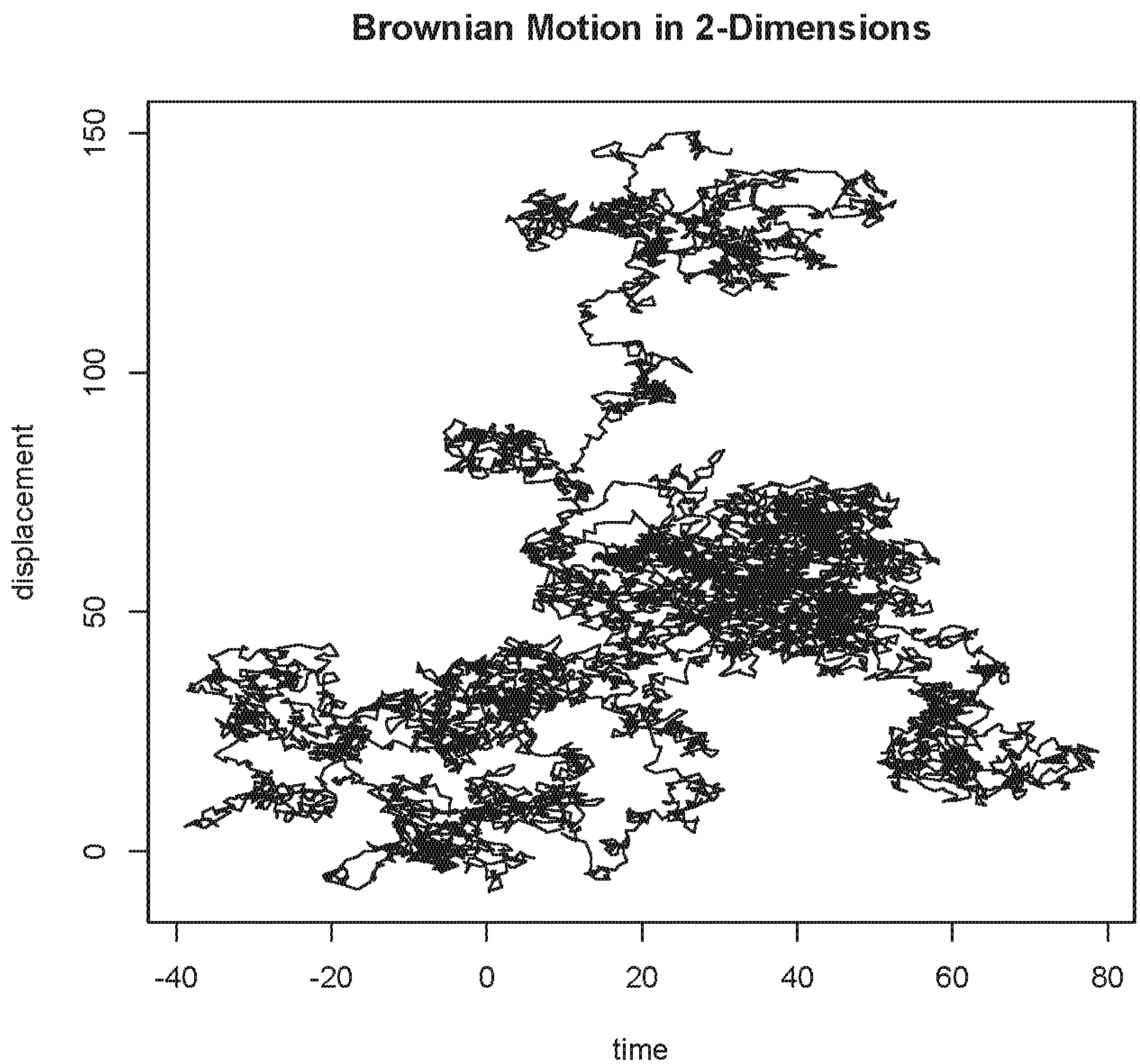
2.0
1.5
1.0
0.5
0.0
f(x)=(|x < 2|)(2-|x|)
-3
-2
-1
0
1
2
3
x



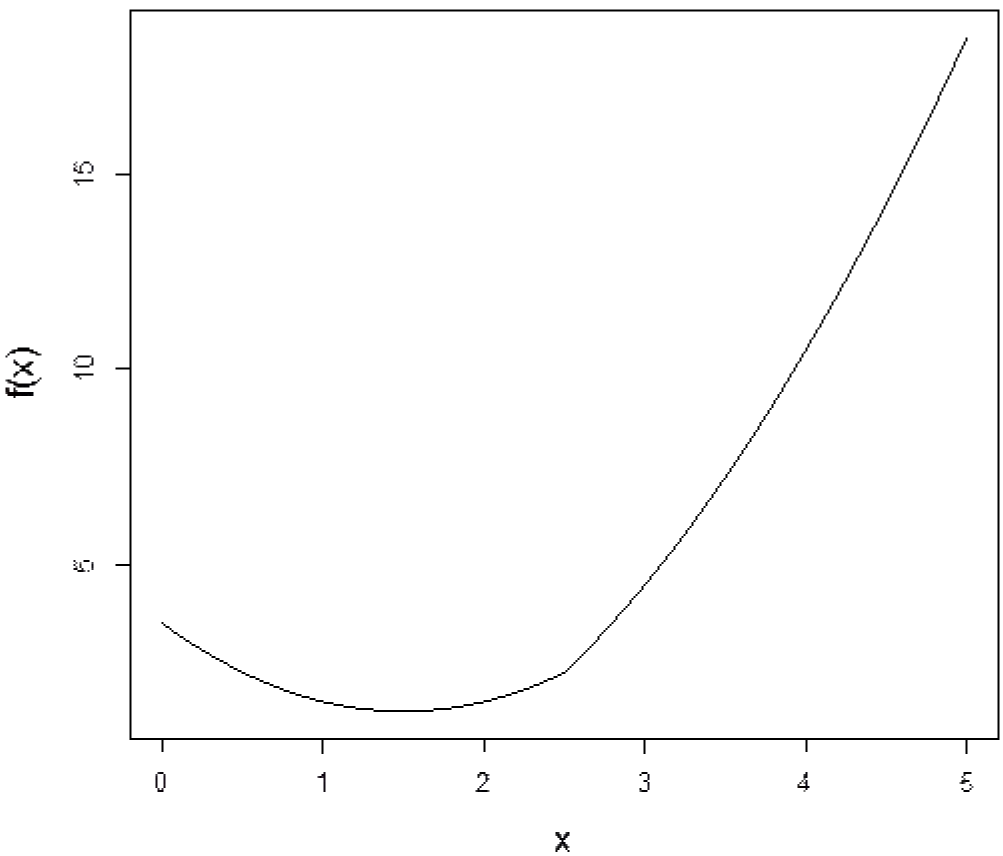
dbeta(x, shape1 = 2, shape2 = 2)
0.0
0.5
1.0
1.5
0.0
0.2
0.4
0.6
0.8
1.0
x

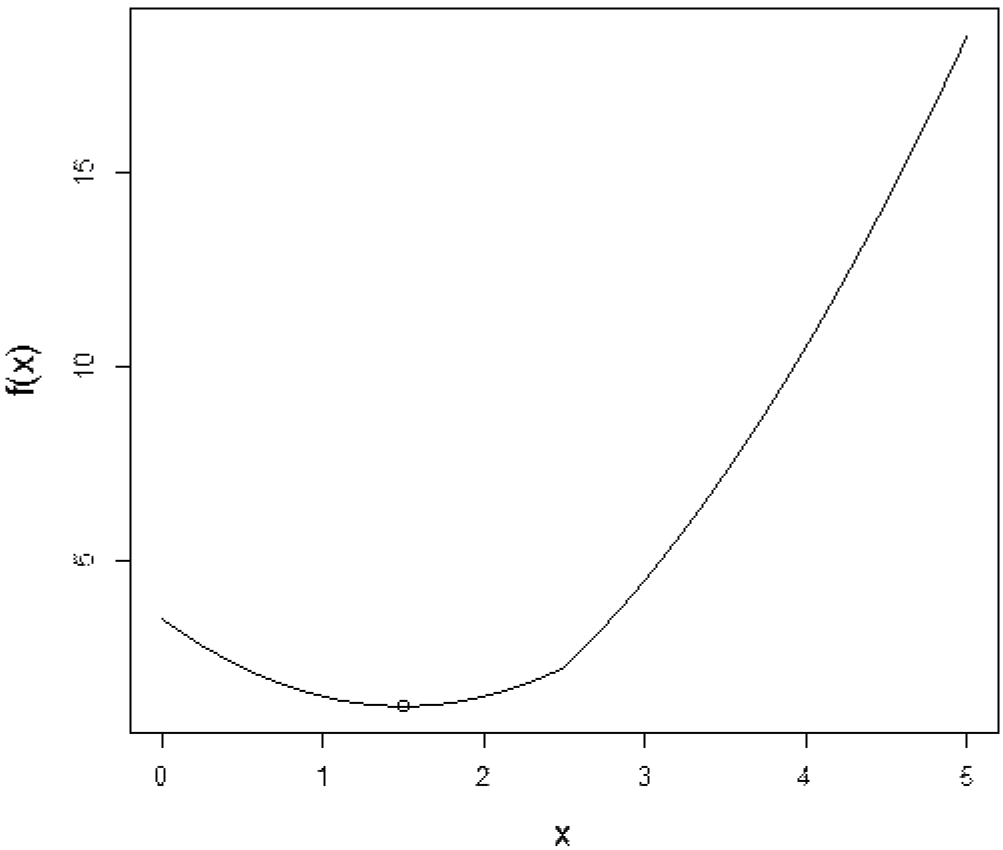

dbeta(x, 2, 2)
0.0
0.5
1.0
1.5
0.0
0.2
0.4
0.6
0.8
1.0
x


Brownian Motion in 1-Dimension
displacement
time
0
50
100
150
200
250
300
0
2000
4000
6000
8000
10000

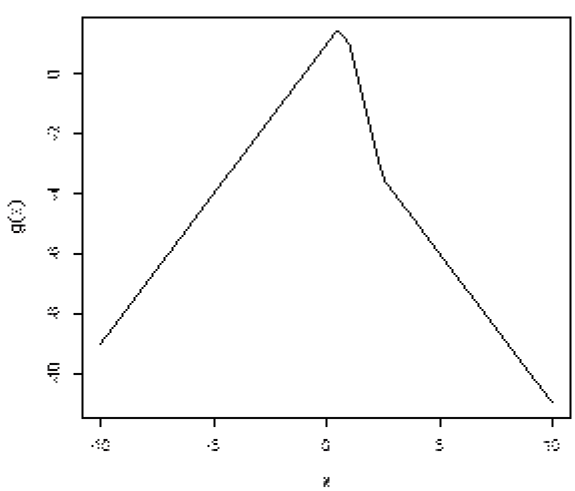


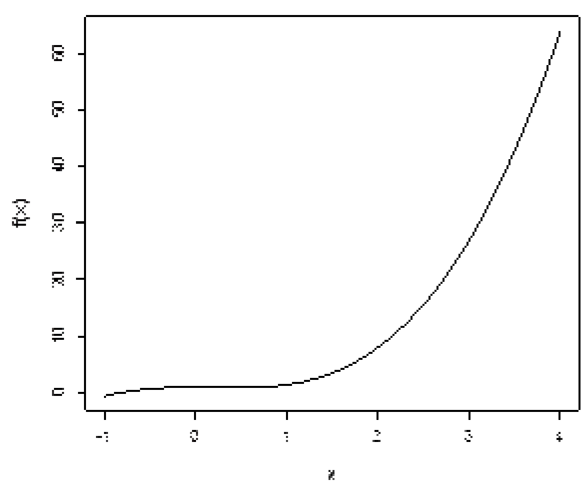
Chapter 9: Optimization

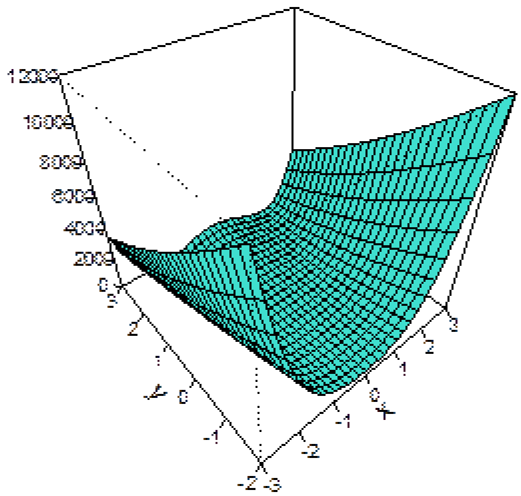

f(x)
15
10
5
0
1
2
3
4
5
x

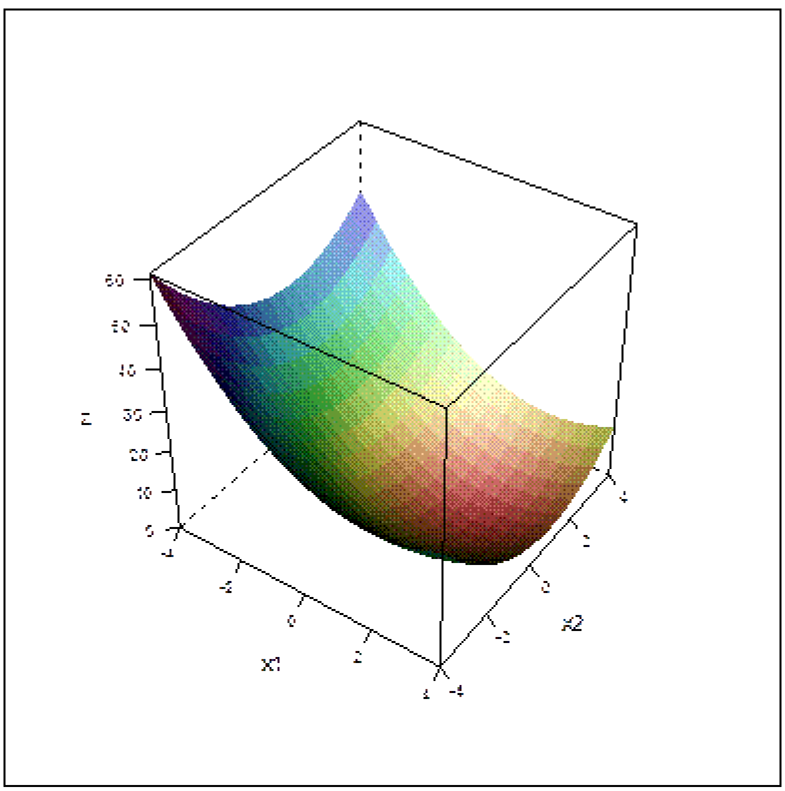


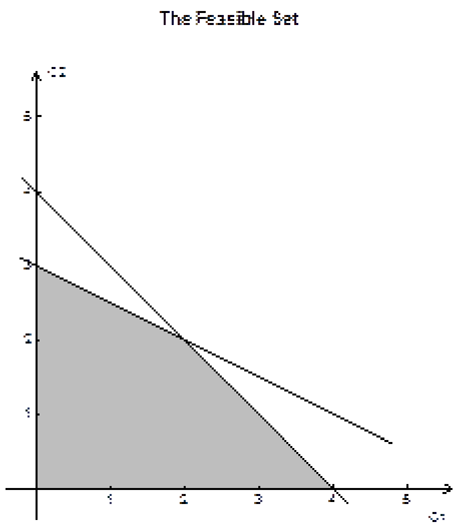
f(x)
x
0
1
2
3
4
5
5
10
15



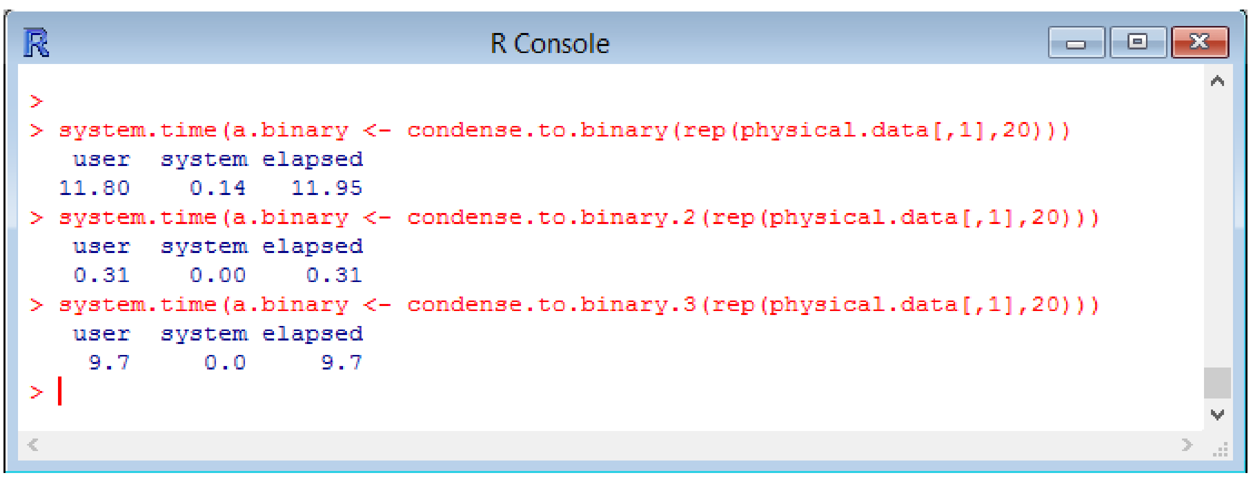


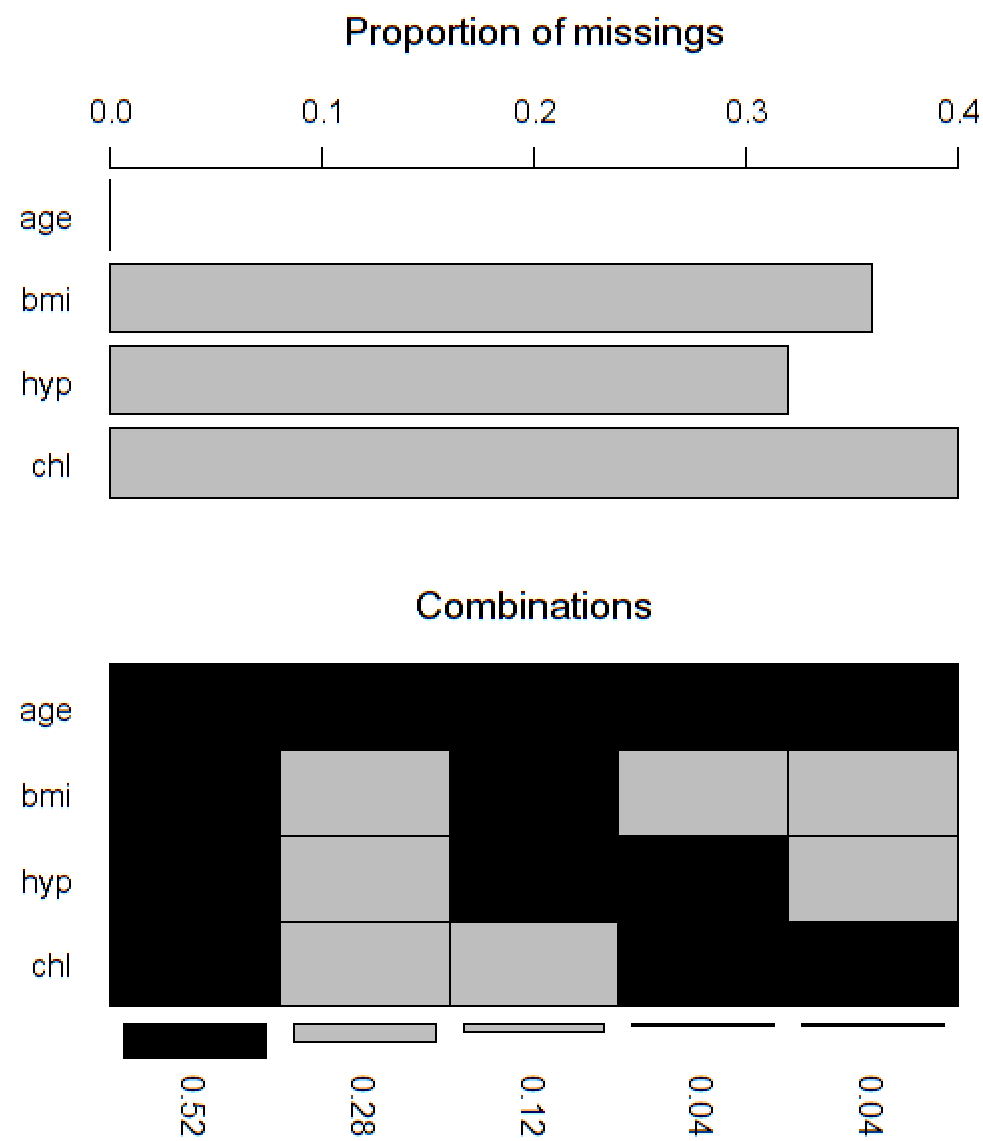

12000
10000
8000
6000
4000
2000
0
y
x

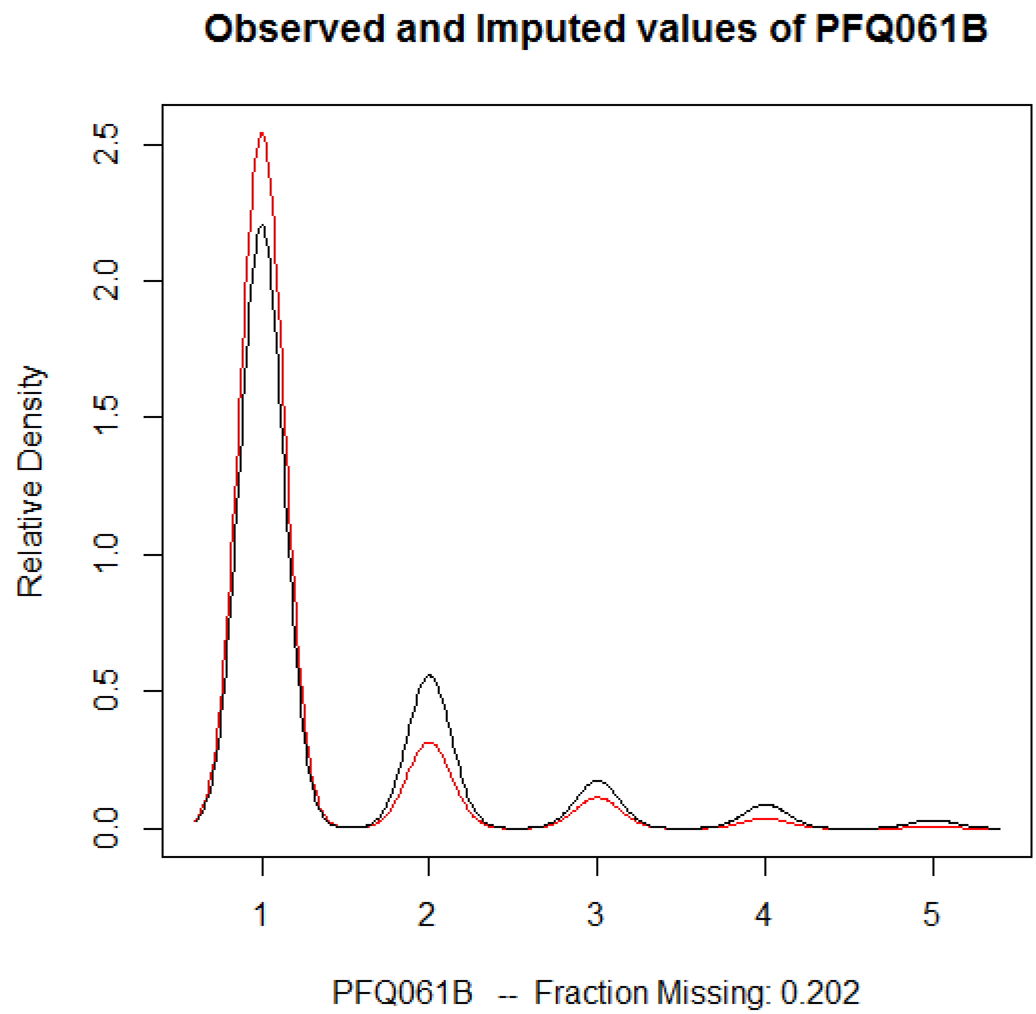

z
x1
x2



Chapter 10: Advanced Data Management

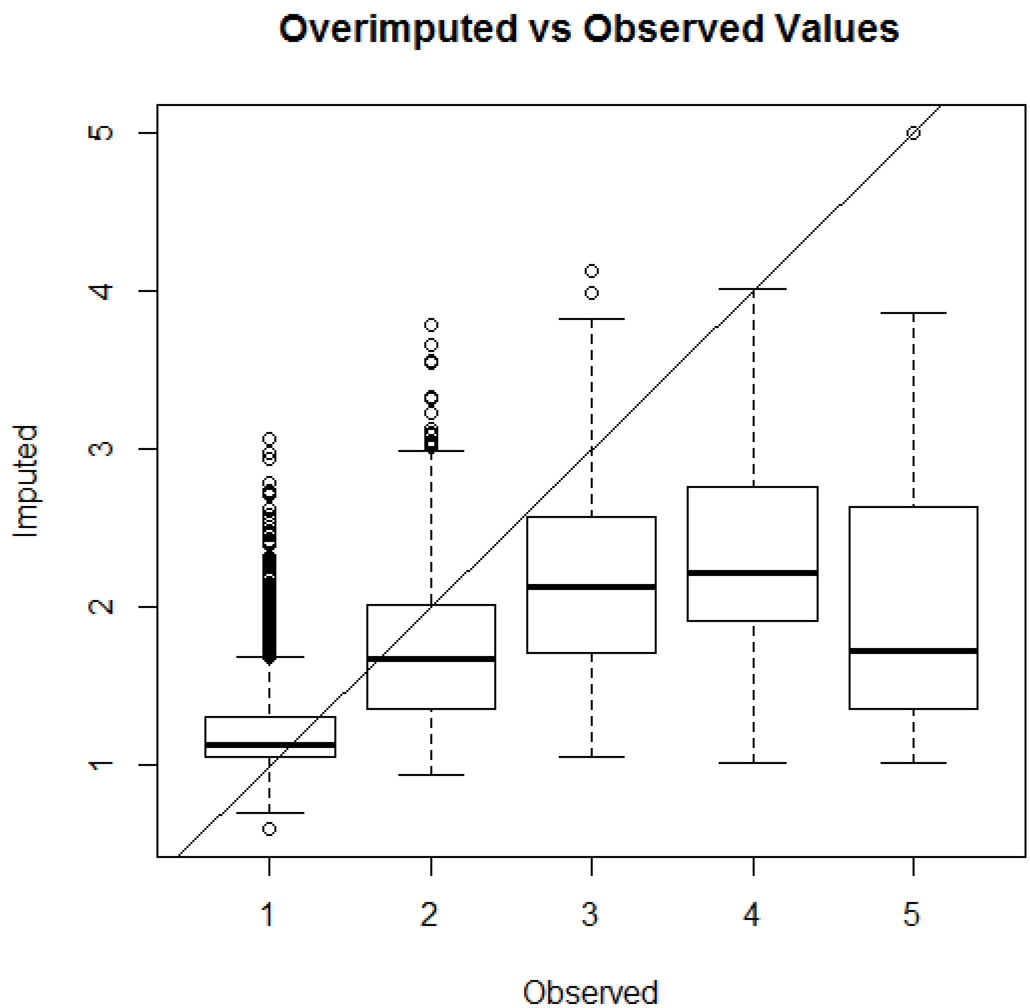



Proportion of missings
0.0
0.1
0.2
0.3
0.4
age
bmi
hyp
chl
Combinations
age
bmi
hyp
chl
0.52
0.28
0.12
0.04
0.04


Observed and Imputed values of PFQ061B
Relative Density
0.0
0.5
1.0
1.5
2.0
2.5
1
2
3
4
5
PFQ061B -- Fraction Missing: 0.202

R Console

```
> B.ov.imp <- overimpute(phys.imp, var = 'PFQ061B')
> summary(B.ov.imp)
      row             orig        mean.overimputed
 Min.   :   1   Min.   :1.000   Min.   :0.5973
 1st Qu.:1134   1st Qu.:1.000   1st Qu.:1.0737
 Median :2260   Median :1.000   Median :1.2195
 Mean   :2267   Mean   :1.422   Mean   :1.4204
 3rd Qu.:3399   3rd Qu.:2.000   3rd Qu.:1.6093
 Max.   :4528   Max.   :5.000   Max.   :4.8089
 lower.overimputed  upper.overimputed   prcntmiss
 Min.   :-0.69836   Min.   :1.615     Min.   :0.05
 1st Qu.: 0.01989   1st Qu.:2.063     1st Qu.:0.20
 Median : 0.18296   Median :2.248     Median :0.25
 Mean   : 0.35850   Mean   :2.419     Mean   :0.24
 3rd Qu.: 0.55965   3rd Qu.:2.624     3rd Qu.:0.30
 Max.   : 3.26388   Max.   :6.004     Max.   :0.60
> 
```


Overimputed vs Observed Values
Imputed
Observed
1
2
3
4
5
1
2
3
4
5

R Console

```
> imputation.means <- sapply(phys.imp$imputations, colMeans)
> imputation.means
            imp1     imp2     imp3     imp4     imp5
PFQ061A 1.314267 1.309629 1.316917 1.312721 1.318463
PFQ061B 1.456714 1.448322 1.441034 1.445230 1.440150
PFQ061C 1.272747 1.282906 1.277164 1.275398 1.275177
PFQ061D 1.612191 1.616829 1.606228 1.610424 1.614620
PFQ061E 1.399956 1.396422 1.389355 1.383834 1.386263
PFQ061F 1.378534 1.385601 1.374337 1.382730 1.384055
PFQ061G 1.292624 1.299691 1.290194 1.289532 1.289532
PFQ061H 1.045936 1.040415 1.045716 1.041961 1.043507
PFQ061I 1.199205 1.212898 1.204726 1.207597 1.199647
PFQ061J 1.170936 1.169390 1.169832 1.171820 1.170053
PFQ061K 1.060733 1.059408 1.065592 1.062058 1.061617
PFQ061L 1.119258 1.130521 1.127208 1.127208 1.126767
PFQ061M 1.667182 1.668507 1.677120 1.675574 1.681316
PFQ061N 1.321334 1.312500 1.309629 1.317800 1.317800
PFQ061O 1.231670 1.234320 1.227473 1.230124 1.224602
PFQ061P 1.187058 1.177783 1.191254 1.184408 1.184850
PFQ061Q 1.302562 1.313383 1.310512 1.306095 1.303224
PFQ061R 1.319788 1.322659 1.323542 1.319125 1.310733
PFQ061S 1.088339 1.084806 1.080389 1.086572 1.084143
PFQ061T 1.636042 1.626325 1.624337 1.619920 1.633834
> rowMeans(imputation.means)
 PFQ061A  PFQ061B  PFQ061C  PFQ061D  PFQ061E  PFQ061F  PFQ061G  PFQ061H
1.314399 1.446290 1.276678 1.612058 1.391166 1.381051 1.292314 1.043507
 PFQ061I  PFQ061J  PFQ061K  PFQ061L  PFQ061M  PFQ061N  PFQ061O  PFQ061P
1.204814 1.170406 1.061882 1.126193 1.673940 1.315813 1.229638 1.185071
 PFQ061Q  PFQ061R  PFQ061S  PFQ061T
1.307155 1.319170 1.084850 1.628092
> 
```

R Console

```
>
> legs.v.arms.models <- with(imputed.phys.func, lm( I(B+C+D+H+I+J+M+N) ~ I(E+F+G$
> leg.v.arm.pool <- pool(legs.v.arms.models)
> summary(leg.v.arm.pool)
                                    est         se        t        df
(Intercept)                   4.5689783 0.14504376 31.50069 145.12519
I(E + F + G + K + L + O + P + T) 0.5965278 0.01409243 42.32966  83.49253
                              Pr(>|t|)     lo 95     hi 95 nmis       fmi
(Intercept)                          0 4.2823073 4.8556494   NA 0.1741114
I(E + F + G + K + L + O + P + T)        0 0.5685009 0.6245546   NA 0.2344096
                                 lambda
(Intercept)                   0.1628075
I(E + F + G + K + L + O + P + T) 0.2162875
> 
```