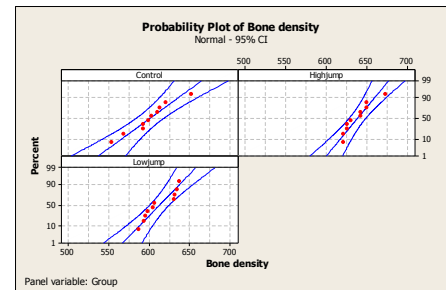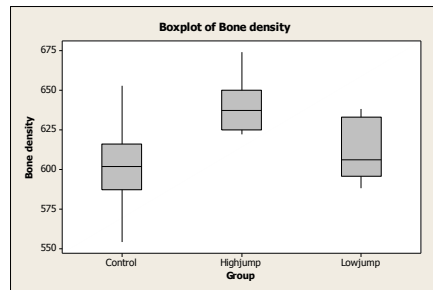# One-Way ANOVA Example: Exercise and Healthy Bones

Many studies have suggested that there is a link between exercise and healthy bones. Exercise stresses the bones and this causes them to get stronger. One study examined the effect of jumping on the bone density of growing rats (Collaborative Research Support Program in Food Intake and Human Function, *Management Entity Final Report*, University of California, Berkeley, 1988). There were 3 treatments (we'll assume they were assigned at random): a control with no jumping, a low-jump condition (the jump height was 30 cm), and a high-jump condition (60 cm). After 8 weeks of 10 jumps per day, 5 days per week, the bone density of the rats (in mg/cm^3) was measured. The data and summaries are shown below.

Group	Bone density
Control	611
Control	621
Control	614
Control	593
Control	593
Control	653
Control	600
Control	554
Control	603
Control	569
Lowjump	635
Lowjump	605
Lowjump	638
Lowjump	594
Lowjump	599
Lowjump	632
Lowjump	631
Lowjump	588
Lowjump	607
Lowjump	596
Highjump	650
Highjump	622
Highjump	626
Highjump	626
Highjump	631
Highjump	622
Highjump	643
Highjump	674
Highjump	643
Highjump	650

Bone Density Statistics	*Control*	*Lowjump*	*Highjump*
Mean	601.1	612.5	638.7
Standard Error	8.653130455	6.112373607	5.247327362
Median	601.5	606	637
Mode	593	#N/A	650
Standard Deviation	27.36360113	19.32902251	16.59350609
Sample Variance	748.7666667	373.6111111	275.3444444
Kurtosis	0.893255198	-1.947481544	0.834288722
Skewness	0.082533096	0.252716264	1.008124503
Range	99	50	52
Minimum	554	588	622
Maximum	653	638	674
Sum	6011	6125	6387
Count	10	10	10

Use these data to determine whether there are differences among the 3 treatments with respect to mean bone density. If you determine that there are differences, say where they are.

One-way ANOVA: Bone density versus Group

```
Source  DF     SS    MS     F      P
Group    2   7434  3717  7.98  0.002
Error   27  12580   466
Total   29  20013

S = 21.58   R-Sq = 37.14%   R-Sq(adj) = 32.49%


                                 Individual 95% CIs For Mean Based on
                                 Pooled StDev
Level       N    Mean  StDev  ------+---------+---------+---------+---
Control    10  601.10  27.36  (------*------)
Highjump   10  638.70  16.59                      (------*------)
Lowjump    10  612.50  19.33       (------*------)
                               ------+---------+---------+---------+---
                                   600       620       640       660


Pooled StDev = 21.58



Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of Group

Individual confidence level = 98.04%


Group = Control subtracted from:

Group      Lower  Center  Upper  -------+---------+---------+---------+--
Highjump   13.64   37.60  61.56                         (-------*-------)
Lowjump   -12.56   11.40  35.36                 (-------*-------)
                                 -------+---------+---------+---------+--
                                      -30         0        30        60


Group = Highjump subtracted from:

Group      Lower  Center  Upper  -------+---------+---------+---------+--
Lowjump   -50.16  -26.20  -2.24  (-------*-------)
                                 -------+---------+---------+---------+--
                                      -30         0        30        60
```