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LIMITS OF AGREEMENT METHOD FOR COMPARING PAVEMENT FRICTION MEASUREMENTS

Presented by

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Conclusions

Objectives

- Pavement friction equipment comparisons: which is the equivalent value (Harmonization)
- LOA method – Bland & Altman 1986
  - Define “a priori” boundaries (limits)
  - These limits are defined by the use of the measurements
  - Should it replace the use of correlations?

Objectives

- Illustrate the use of LOA to compare two pavement friction devices based on agreement
- Good agreement allows interchangeability
- Is good agreement always possible?
- 3 Examples

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Methods: LOA

- Assuming Normal Distribution, for 95% confidence, $z = 1.96$ (≈2)
- Repeatability

$$r_i = 1.96\sqrt{2}s_i = 2.77\sqrt{s_i^2}$$

  - r_1 and r_2, for each device, respectively
- Limits of Agreement (LOA) between the two devices

$$LOA = 1.96\sqrt{s_c}$$

- Can it replace reproducibility (R)?

Methods: LOA

- **Limits of Agreement (Bland & Altman)**
- **Three components: combines variability of each device (2) and third one capturing their interaction**
- **Variances:**

s_1^2 var device1, s_2^2 var device2, and s_D^2 var interaction

- **Combined effects:**

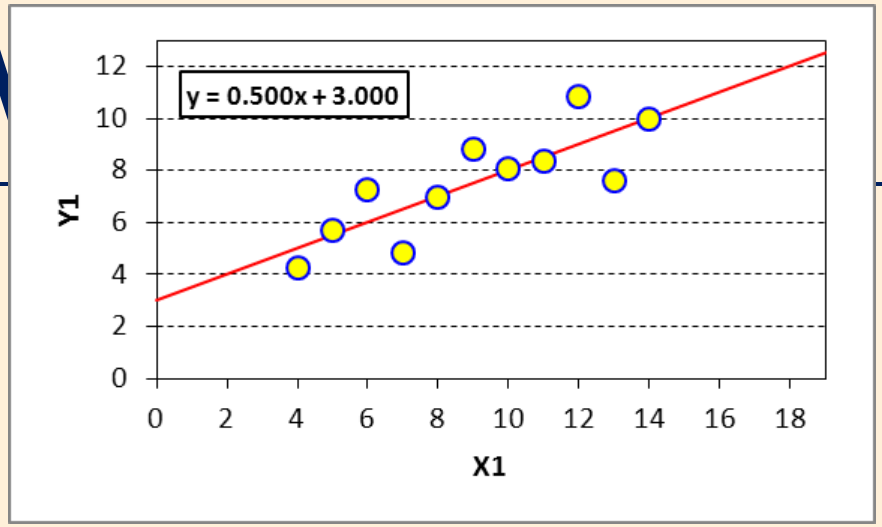
$$s_c = \sqrt{s_D^2 + \left(f_1\right) s_1^2 + \left(f_2\right) s_2^2}$$

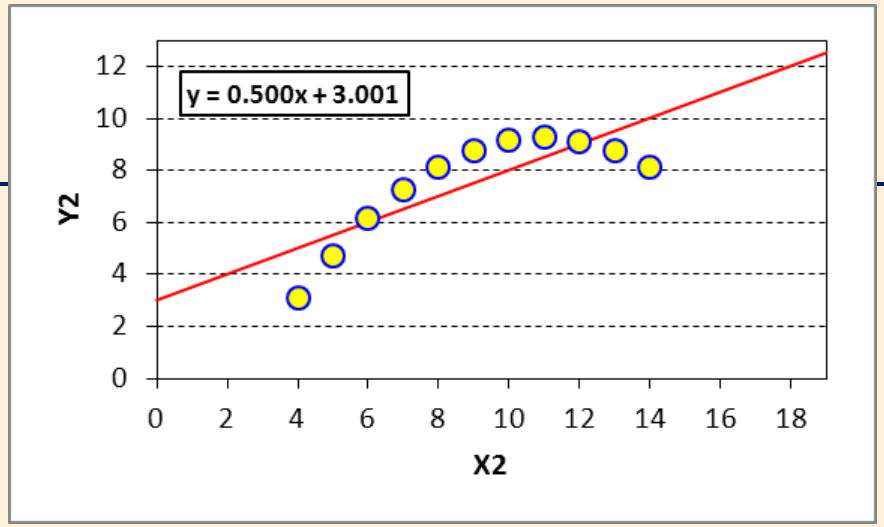
$$f_1 = \left(1 - \frac{1}{m_1}\right) \qquad f_2 = \left(1 - \frac{1}{m_2}\right) \qquad f = \left(1 - \frac{1}{n}\sum \frac{1}{m_i}\right)$$

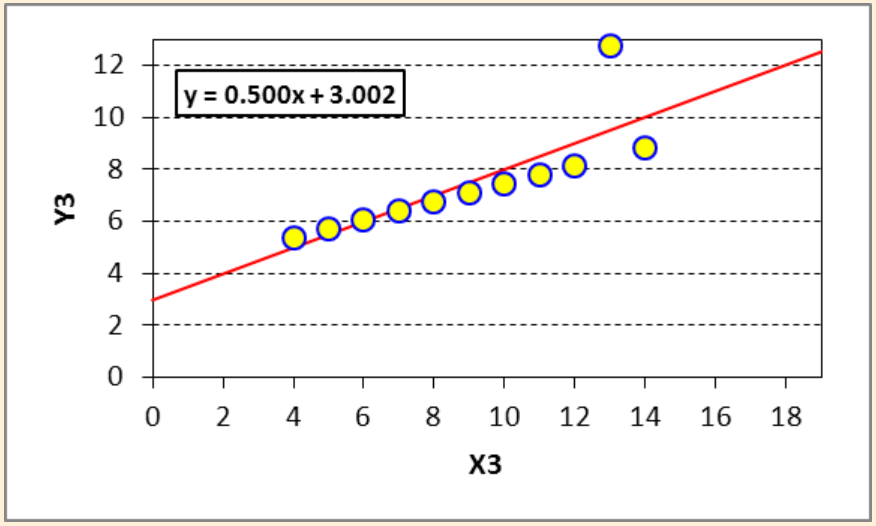
Methods

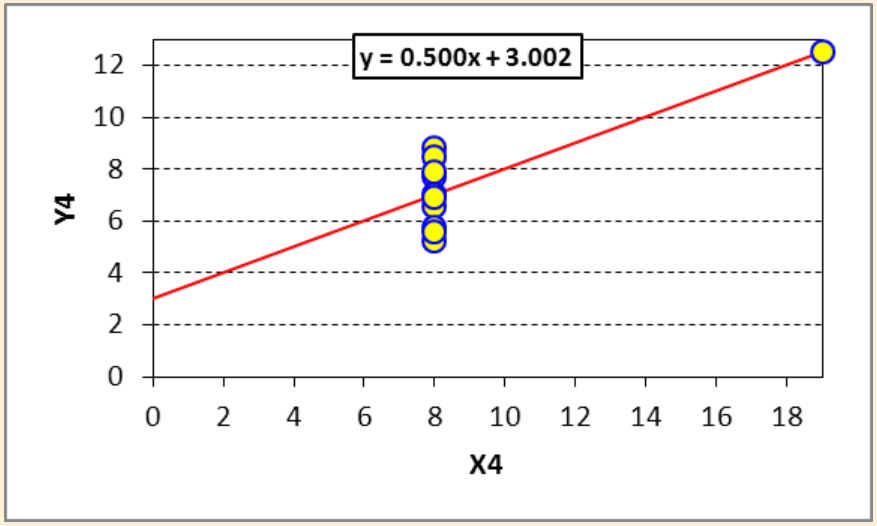
- Francis Anscombe, Princeton professor and statistician
- Anscombe Quartet
  - X_{mean} = 9.00, var_x = 11.0
  - y_{mean} = 7.50, var_y = 4.1
  - Correlation between *x*-*y* = 0.816
  - Linear regression: $y = 0.500\,x + 3.00$
- Importance of graphing and the effect of outliers on statistical properties

N


y = 0.500x + 3.000
Y1
X1
0
2
4
6
8
10
12
14
16
18


y = 0.500x + 3.001
Y2
X2
0
2
4
6
8
10
12
14
16
18


y = 0.500x + 3.002
Y3
X3
0
2
4
6
8
10
12
14
16
18


y = 0.500x + 3.002
Y4
X4
0
2
4
6
8
10
12
14
16
18

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NASA Wallops Island Flight Facility

Virginia Smart Road

Locked-wheel skid tester

Grip Tester (fixed slip)

Dynatest HFT (fixed slip)

Dynamic Friction Tester

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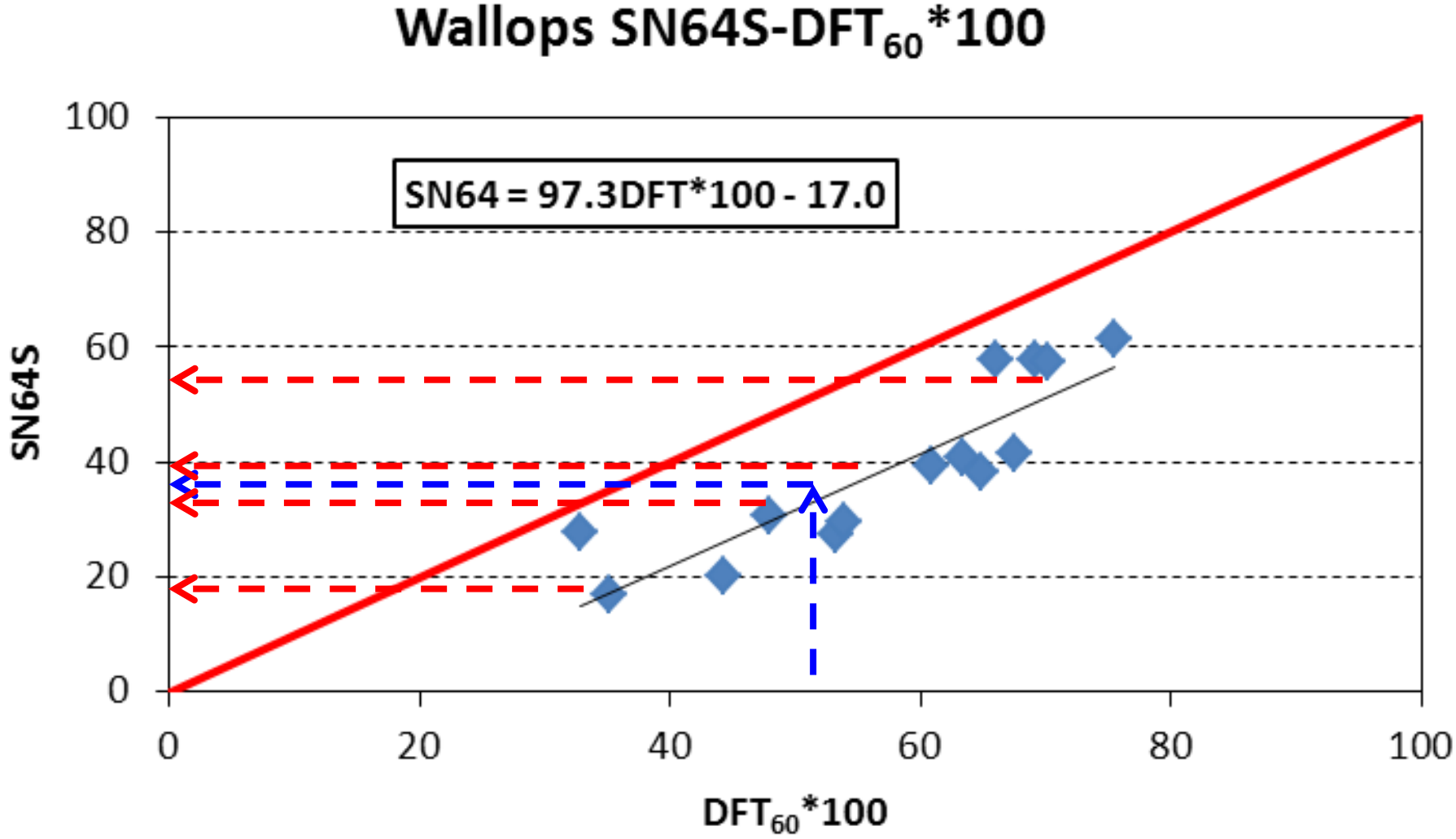
Example 1:


Wallops SN64S-DFT60*100
SN64 = 97.3DFT*100 - 17.0
SN64S
DFT60*100
0
20
40
60
80
100

Example 1: For 4&8 runs

- **Variances:** $s_1^2 = 5.181, s_2^2 = 5.94, \text{and } s_D^2 = 70.144$

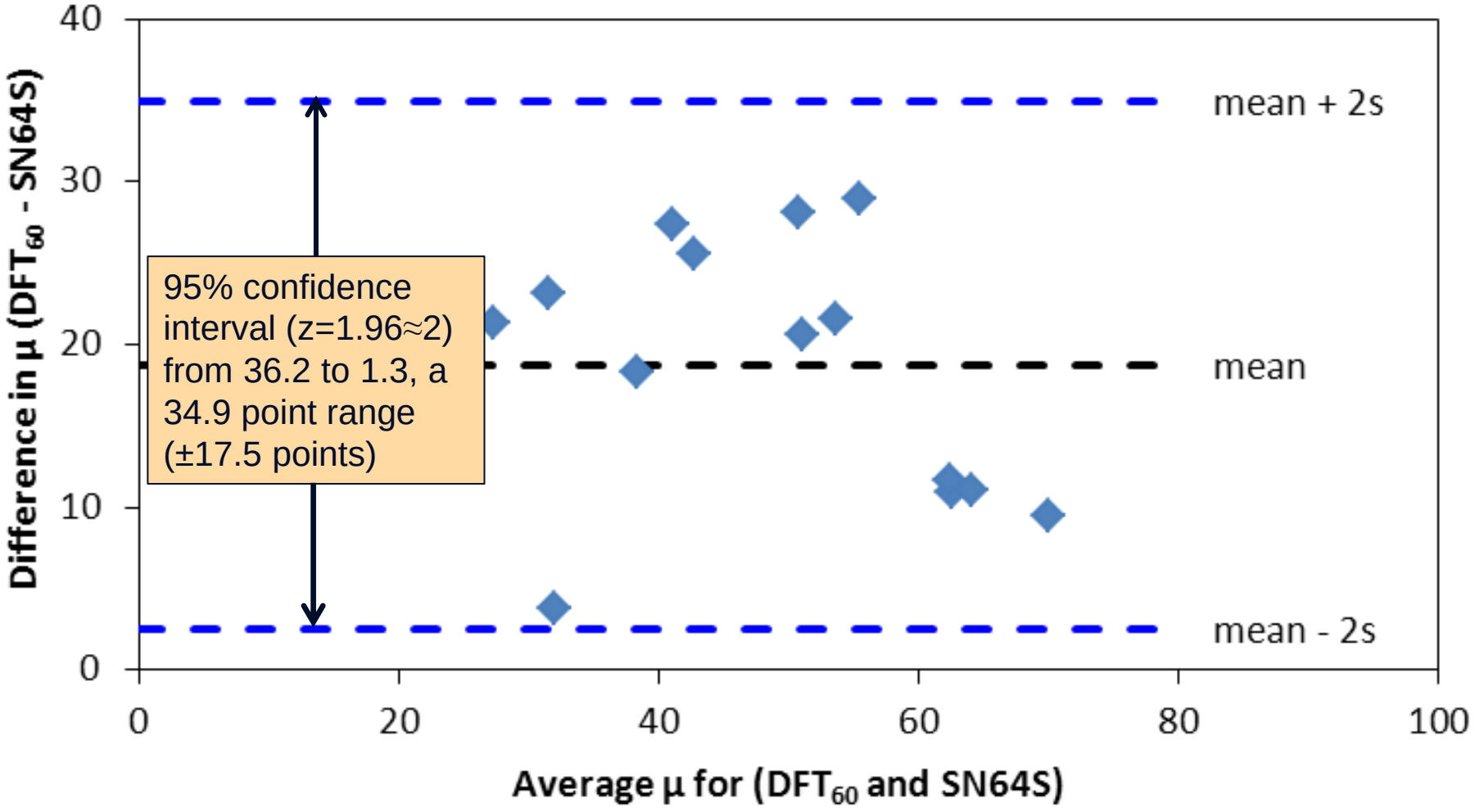
$$f_1 = 3/4, f_2 = 7/8$$

- **Combined effects:**

$$s_c = \sqrt{70.144 + \frac{3}{4} \times 5.181 + \frac{7}{8} \times 5.94} = 8.9$$

- **LOA: ±17.5, range 34.9 points**
- **Repeatability, $r_{1DFT_{60}}$ = 6.3 & r_{2SN64S} = 6.8**

Example 1:


Difference in μ (DFT60 - SN64S)
Average μ for (DFT60 and SN64S)
mean + 2s
mean
mean - 2s
95% confidence interval (z=1.96≈2) from 36.2 to 1.3, a 34.9 point range (±17.5 points)
0
10
20
30
40
0
20
40
60
80
100

Example 2: Different Agreements

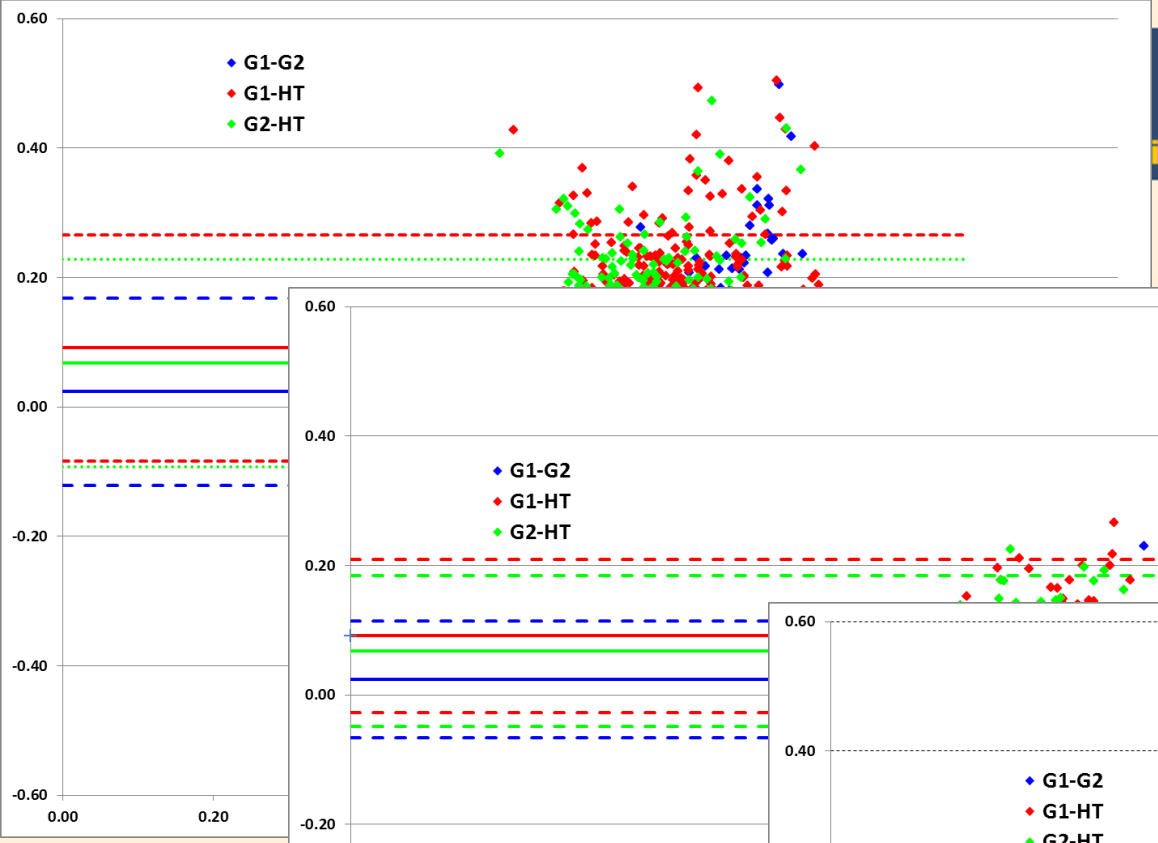
- **Three fixed-slip devices:**
  - **GT1 = Grip Tester 1,**
  - **GT2 = Grip Tester 2 and,**
  - **HFT = Dynatest HFT.**
- **Three speeds (25, 40, and 55 mph)**
- **Three water film thickness (0.25, 0.5, and 1.0 mm)**
- **Same wheelpath and 6% grade**

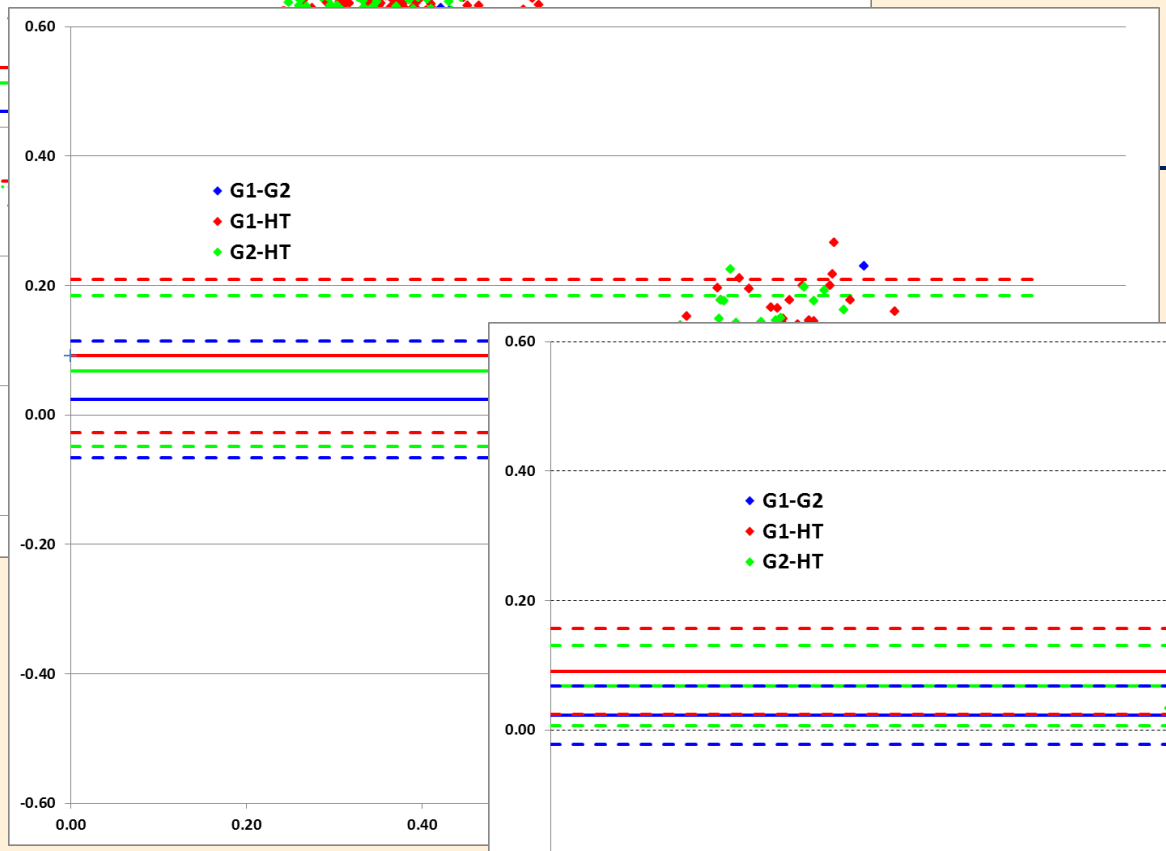

Testing same wheel path

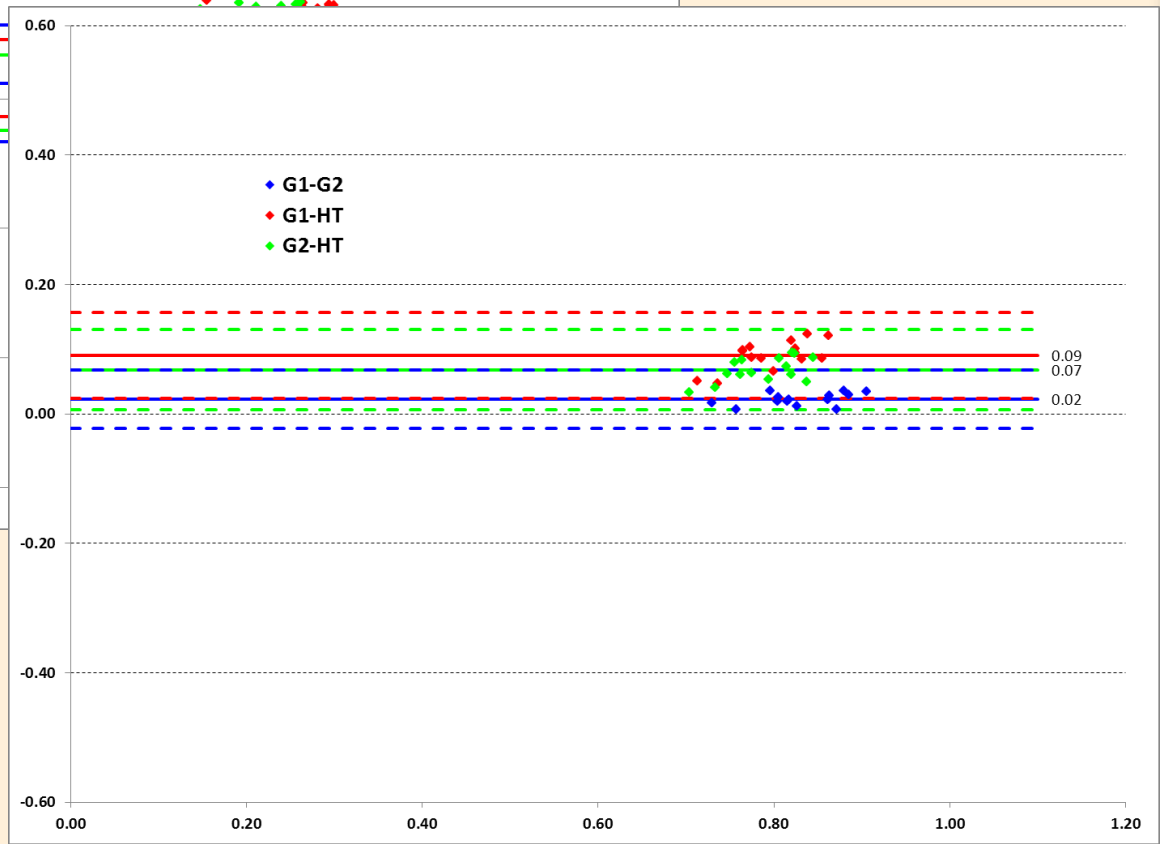
Example 2

Effects of speed change between units			
	40 mph		
DOWNHILL	GT1-GT2	GT1-HFT	GT2-HFT
Limits of Agreement: 3 feet	0.14	0.17	0.16
Limits of Agreement: 30 feet	0.09	0.12	0.12
Limits of Agreement: 300 feet	0.05	0.07	0.06
UPHILL			
Limits of Agreement: 3 feet	0.20	0.19	0.19
Limits of Agreement: 30 feet	0.12	0.14	0.12
Limits of Agreement: 300 feet	0.05	0.07	0.07

Effects of speed change between units			
	40 mph		
DOWNHILL	GT1-GT2	GT1-HFT	GT2-HFT
Repeatability factor $r_{1:}$	0.04	0.04	0.04
Repeatability factor $r_{2:}$	0.04	0.06	0.06
Limits of Agreement: 300 feet	0.05	0.07	0.06
UPHILL			
Repeatability factor $r_{1:}$	0.05	0.05	0.04
Repeatability factor $r_{2:}$	0.04	0.07	0.07
Limits of Agreement: 300 feet	0.05	0.07	0.07

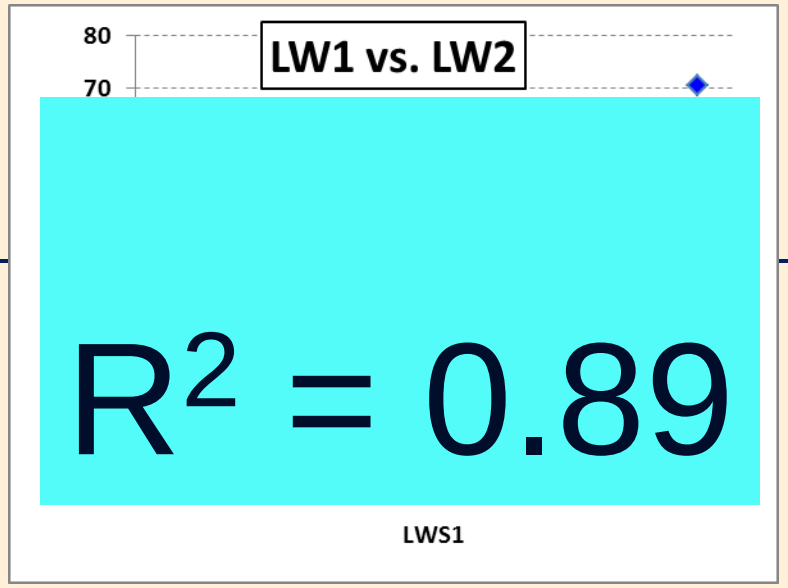

G1-G2
G1-HT
G2-HT
0.60
0.40
0.20
0.00
-0.20
-0.40
-0.60
0.00
0.20

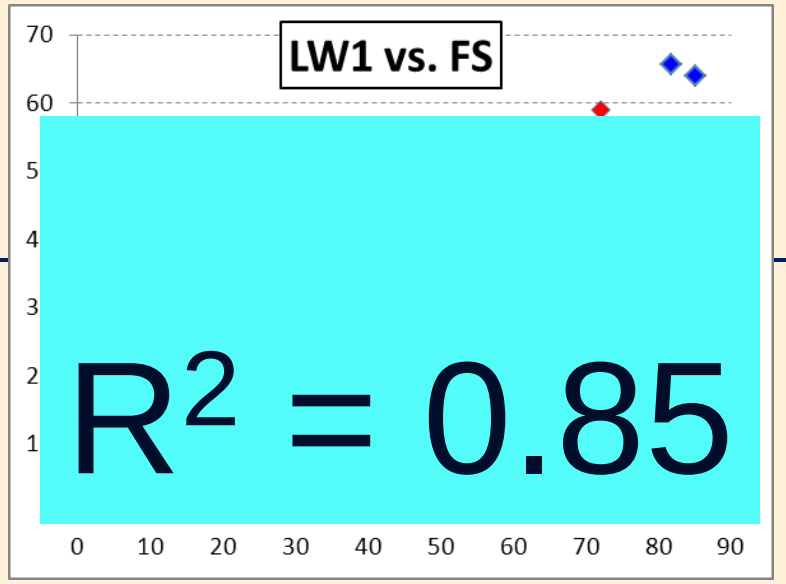

G1-G2
G1-HT
G2-HT
0.60
0.40
0.20
0.00
-0.20
-0.40
-0.60
0.00
0.20
0.40


G1-G2
G1-HT
G2-HT
0.09
0.07
0.02
0.60
0.40
0.20
0.00
-0.20
-0.40
-0.60
0.00
0.20
0.40
0.60
0.80
1.00
1.20

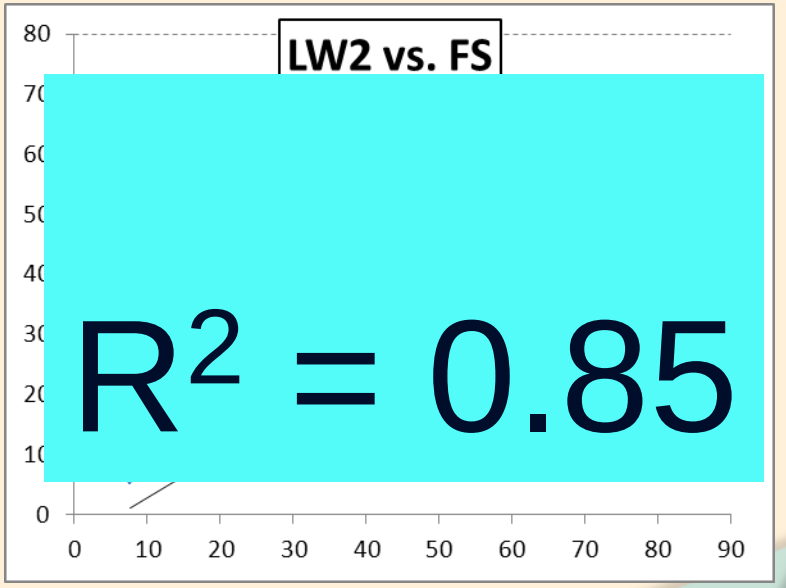
Example 3

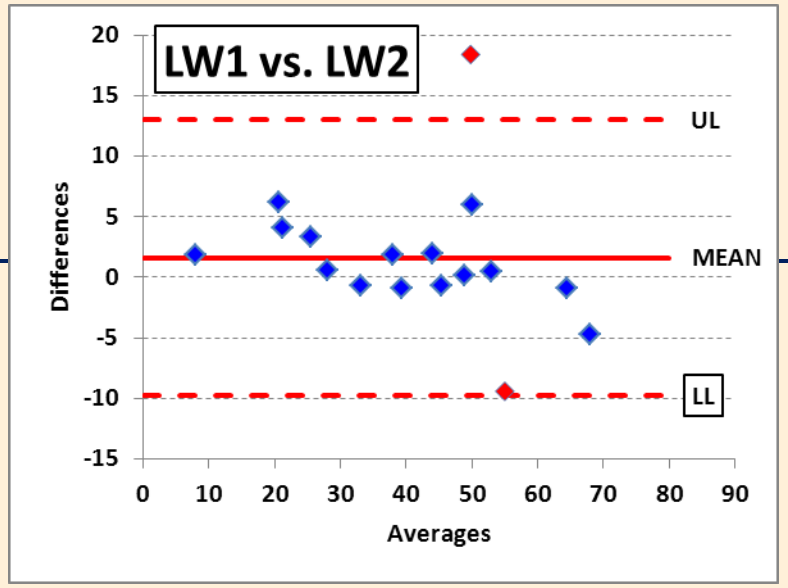
- Two locked-wheel skid testers and one fixed-slip device
  - LWS1
  - LWS2
  - FS
- Average data only (no repeatability)
- LOA effect on statistical inferences

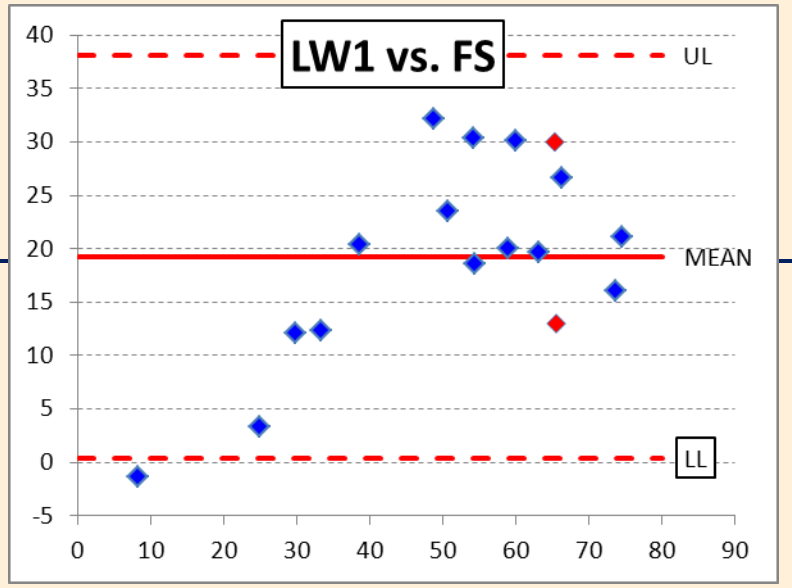




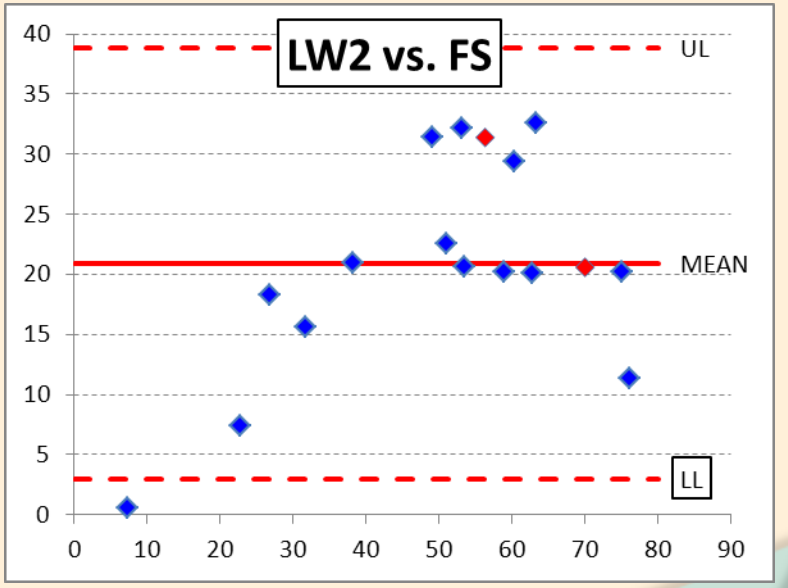
- **Analysis based on averages**
- **Good correlations**
- **Two outliers**

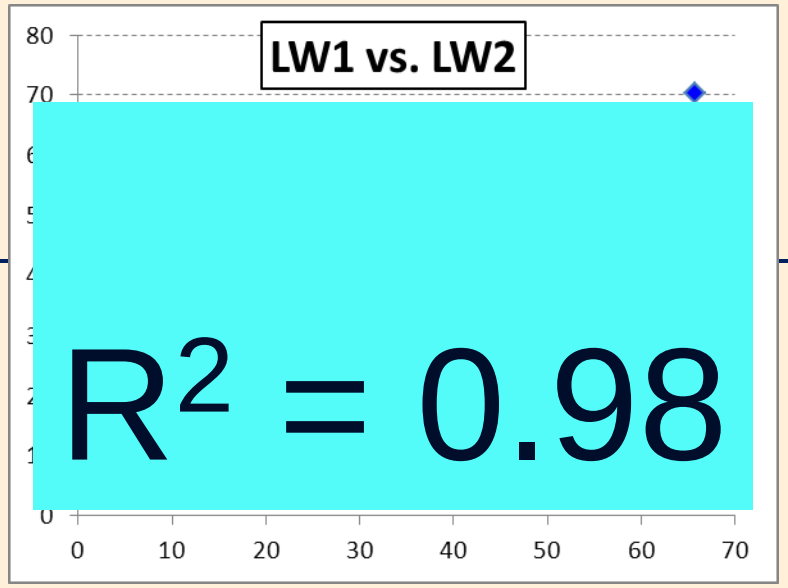


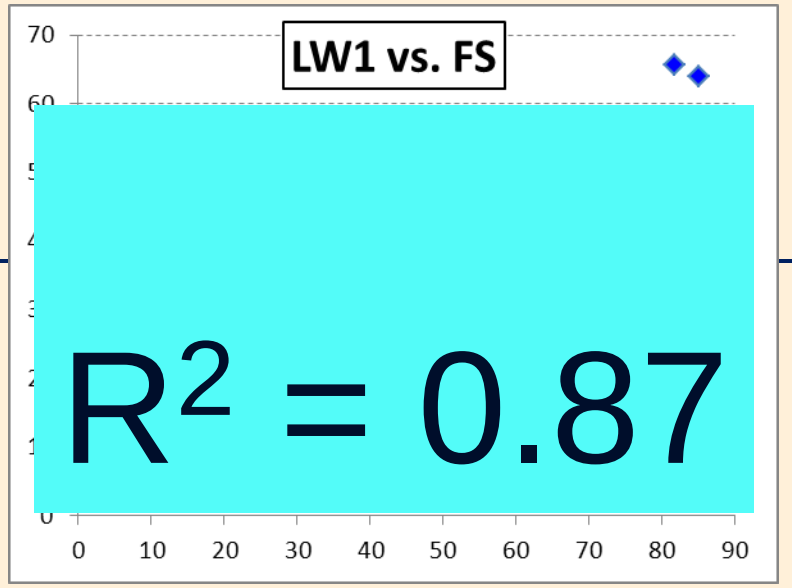




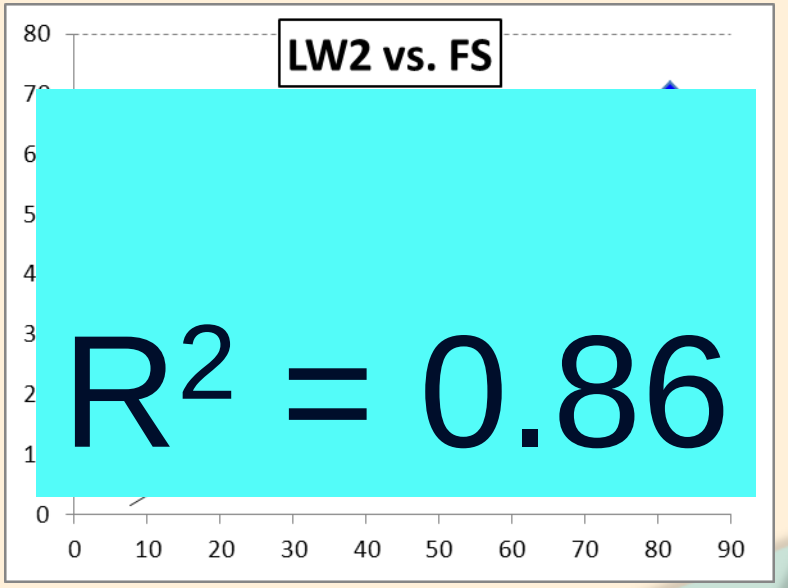
- **Plotting average vs. differences (LOA)**
- **LWS1-LWS2: 22.8**
- **LWS1-FS: 37.7**
- **LWS2-FS: 35.8**

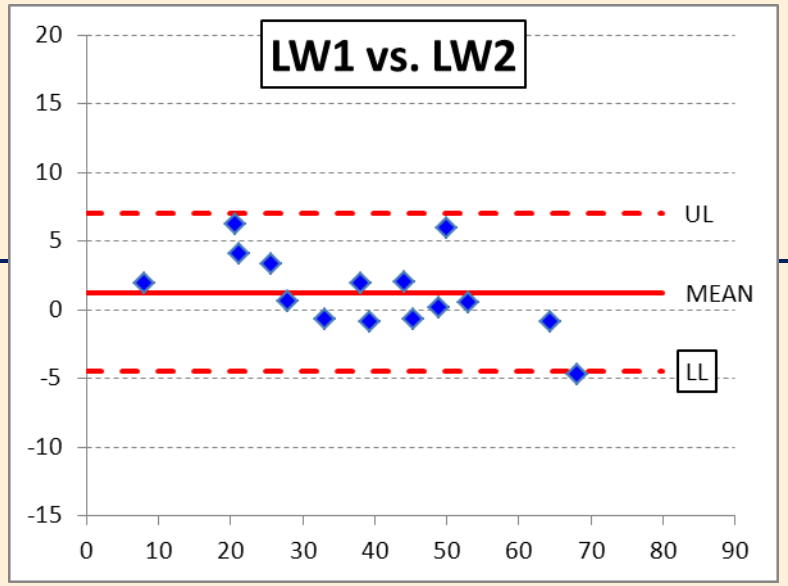


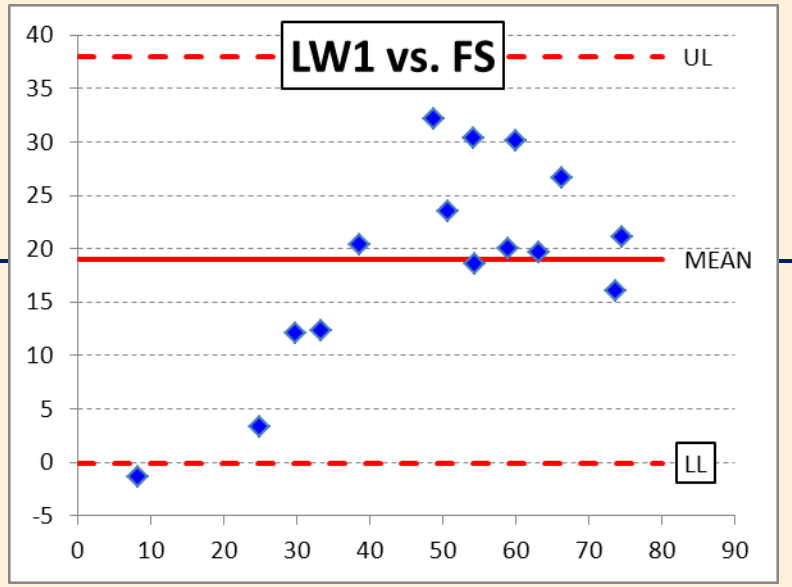




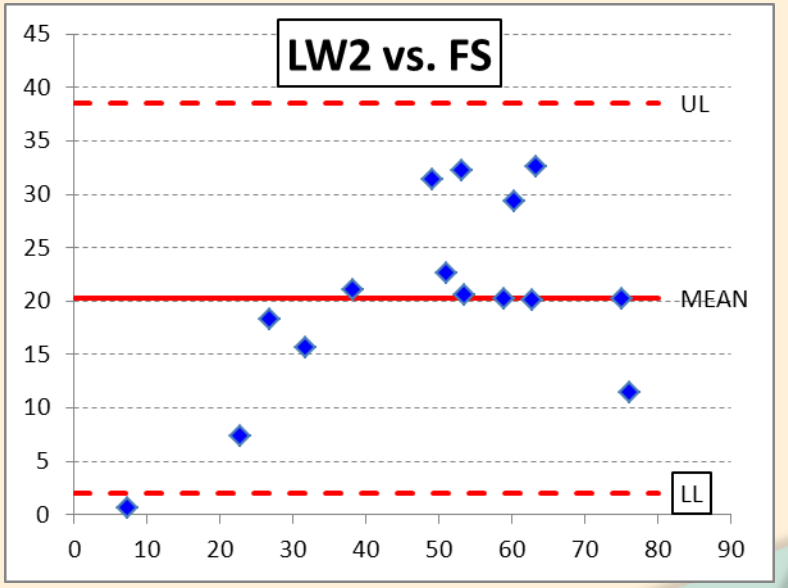
- **Removing the outliers**
- **Better correlation for LWS1 and LWS2, the other two, minimal effect**







- **Limits of Agreement**
- **LWS1-LWS2: 11.5 (22.8)**
- **LWS1-FS: 38.1 (37.7)**
- **LWS2-FS: 36.5 (35.8)**



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- Proposed a method to compare the repeatability and a new alternative for the reproducibility factor, known as the Limits of Agreement
- More research is proposed to explain the effect of the factors that introduce variability and for accountability
- Important to check for normality
- Use of correlation is inappropriate!


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