Limb Volume Assessments Based on Circumference Measurements: Possibilities and Limitations

Dr. Harvey N. Mayrovitz
College Medical Sciences
Nova SE University
Ft. Lauderdale FL
mayrovit@nova.edu

Basics of the Method
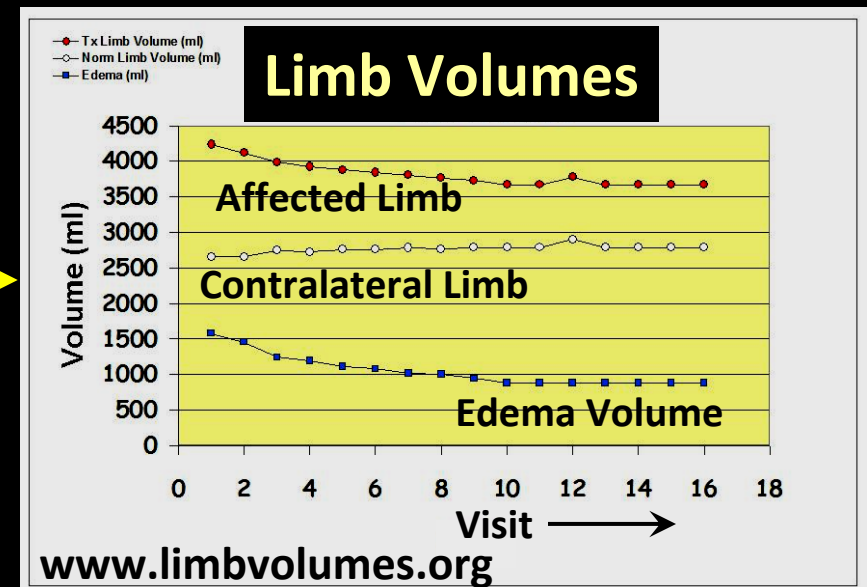
Limb Volume from Girth Measures

Automated

Circumferences @ 4-12 cm intervals

Manual

Geometric Model or Algorithm

Truncated Cone Model (Frustum)

Limb Volumes

- Tx Limb Volume (ml)
- Norm Limb Volume (ml)
- Edema (ml)

Affected Limb

Contralateral Limb

Edema Volume

Volume (ml): 0, 500, 1000, 1500, 2000, 2500, 3000, 3500, 4000, 4500

Visit ⟶: 0, 2, 4, 6, 8, 10, 12, 14, 16, 18

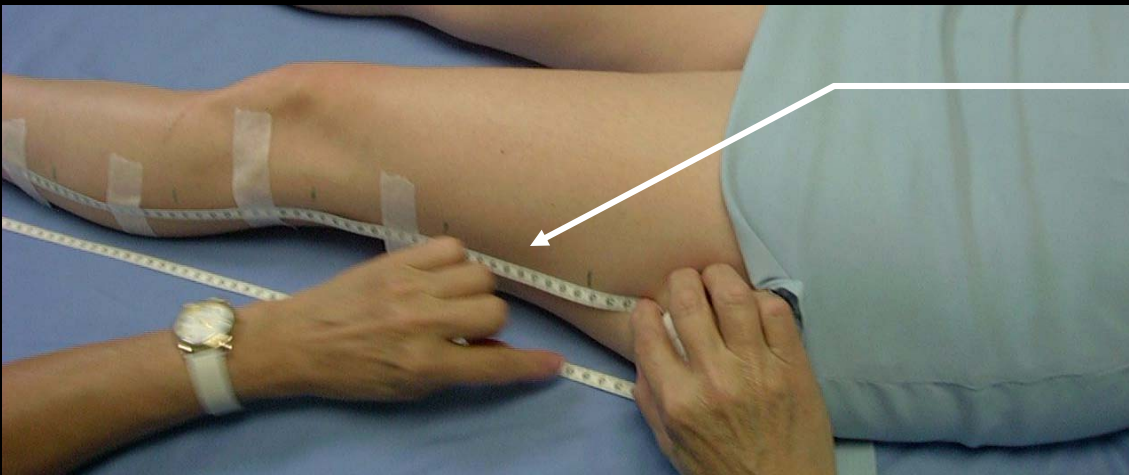**www.limbvolumes.org**

Dr HN Mayrovitz

Measurement Issues Requiring Careful Attention

Minimizing Method Error

Mark in Relation To FLAT Surface

NOT along limb

Source of large Follow-up error

Dr HN Mayrovitz
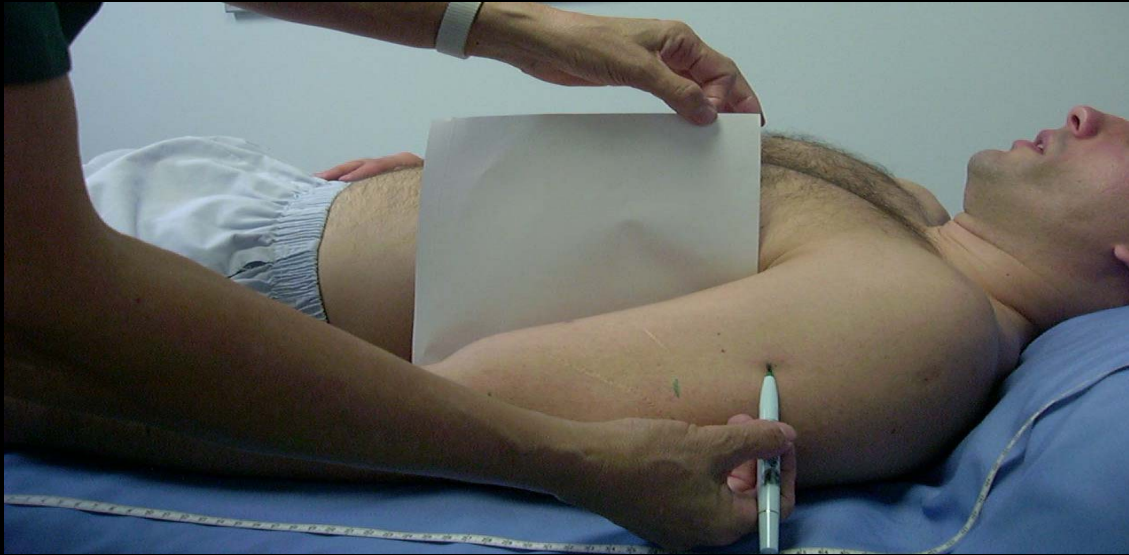
Minimizing Method Error

Ankle at 90º

**Start Point
Mid-malleolus
L = 0 cm**

- **Measure with tape 90º to limb length**
- **Overlap tape with interval mark in middle.**
- **Pull to fixed tension**

Dr HN Mayrovitz

Minimizing Method Error

Highest arm girth at axillary crease. Stiff paper at axilla determines level
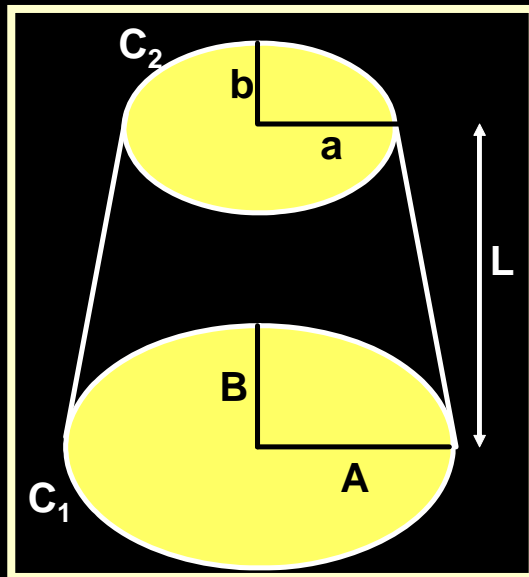

Similar procedure used at groin Girths higher than these are angled and are inaccurate

Dr HN Mayrovitz

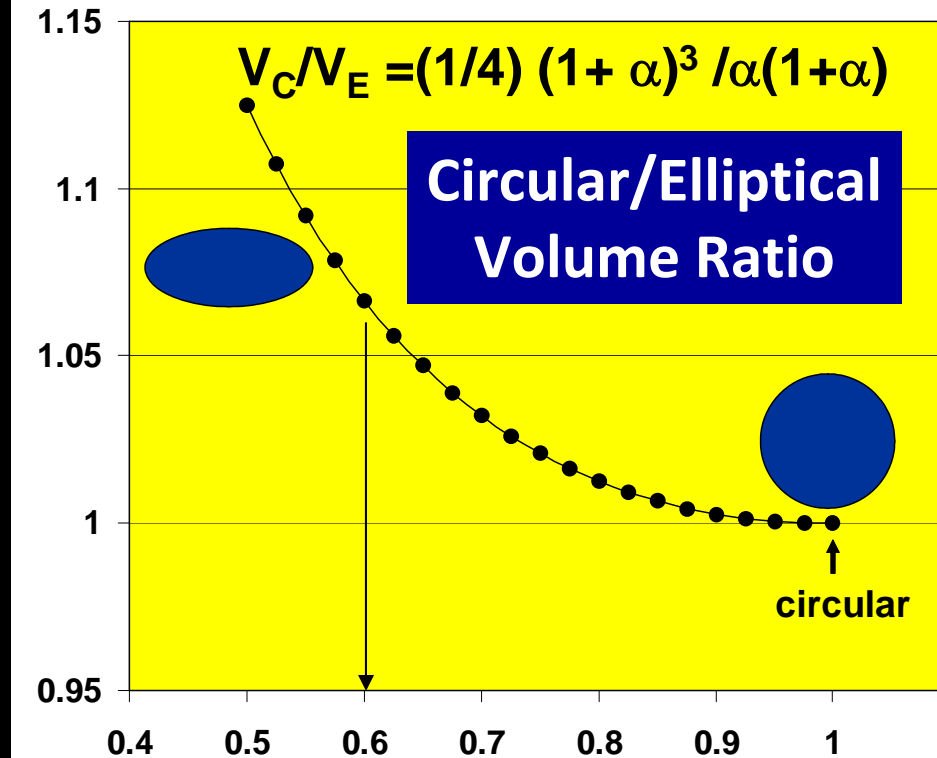# Calculation Algorithm Issues

What if limb is not fully circular?

Effect of Degree of Eccentricity

General Frustum Calculation Model

$$V = \frac{\pi L (A^2 B - a^2 b)}{3(A-a)}$$

$$V_C/V_E = (1/4)(1+\alpha)^3 / \alpha(1+\alpha)$$

Circular to elliptical volume ratio (V_C / V_E)

Circular/Elliptical Volume Ratio

circular

α = ratio of smaller to larger dimension

<5% difference for ratios > ≈ 0.6
So OK for most Arms & Legs
BUT <u>Not</u> OK for Hands or Feet

Dr HN Mayrovitz

How to Deal with Hands and Feet?

Metric Measurements

Hand (60)
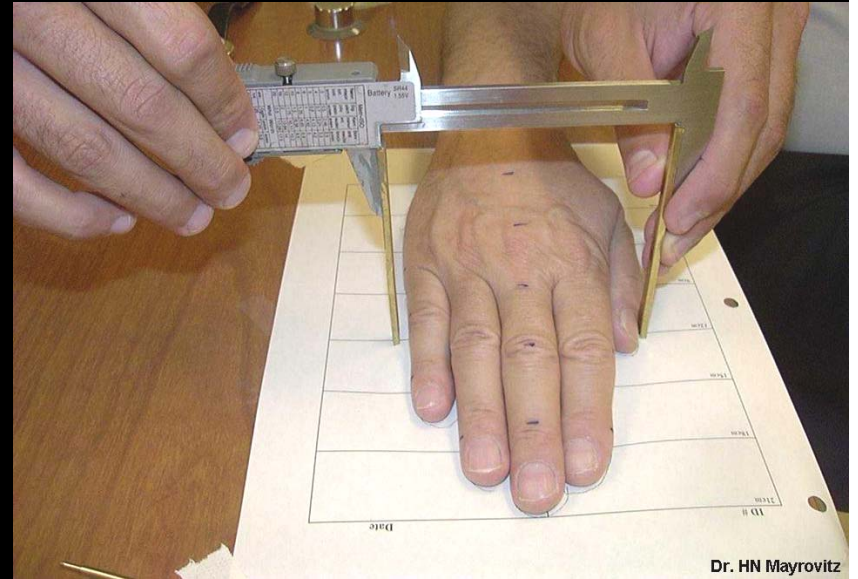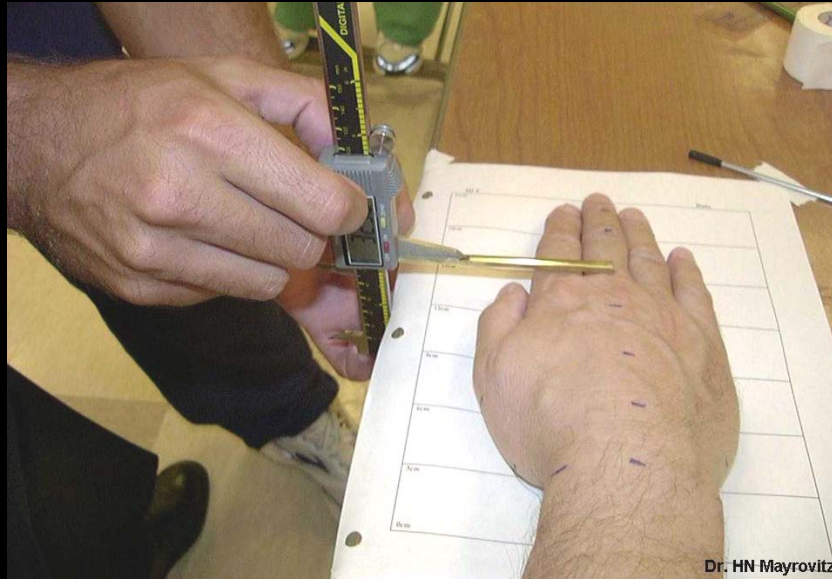
Foot (60)
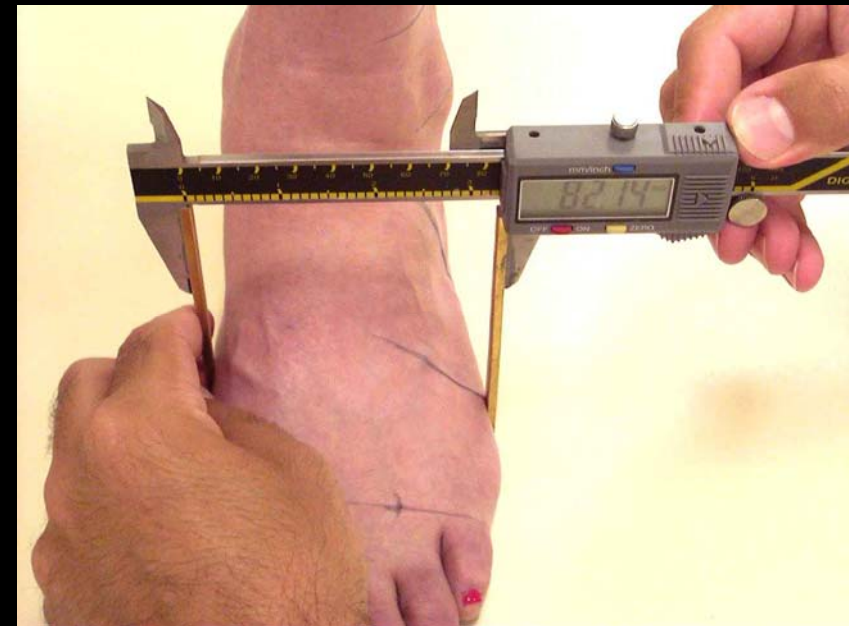
Dr. HN Mayrovitz

Dr HN Mayrovitz

Water Displacement Volumes

Displaced H₂O in recovery container

Dr. HN Mayrovitz

HGD

Dr HN Mayrovitz

Analytical Comparisons:
Metric vs. H$_2$O

Standardized Metric Measurements → **Volume by Computerized Algorithm**

Hands and Feet N=60 each

Volume by Water Displacement → **Compare by Regression and Limits of Agreement (LOA)**

Dr HN Mayrovitz

Algorithm vs. Water Displacement

$V_M = 1.00 V_W + 1.67$ ml

$R^2 = 0.931$; $p < 0.001$

N = 60 Feet

Feet

Volume by Algorithm (ml)

Volume by water displacement (V_w, ml)

Dr HN Mayrovitz
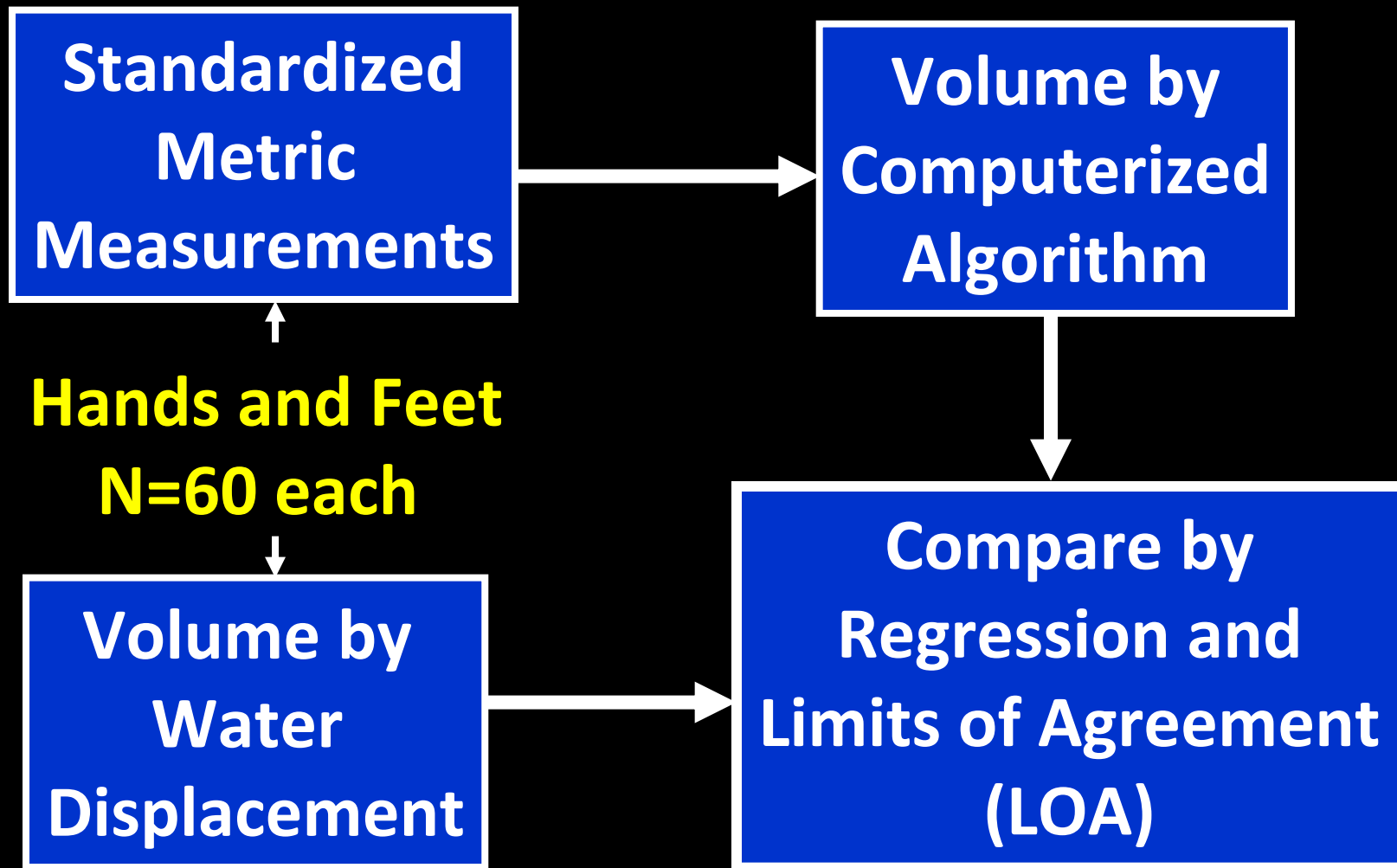
Algorithm vs. Water Displacement

Volume by Algorithm (V_M, ml)

800
700
600
500
400
300
200
100
0

Hands

$V_M = 1.02V_W - 12.2$ ml

$r^2 = 0.985$, $p < 0.001$

N=60 Hands

Line of Identity

Volume by Water Displacement (V_W, ml)

0 100 200 300 400 500 600 700 800

Dr HN Mayrovitz
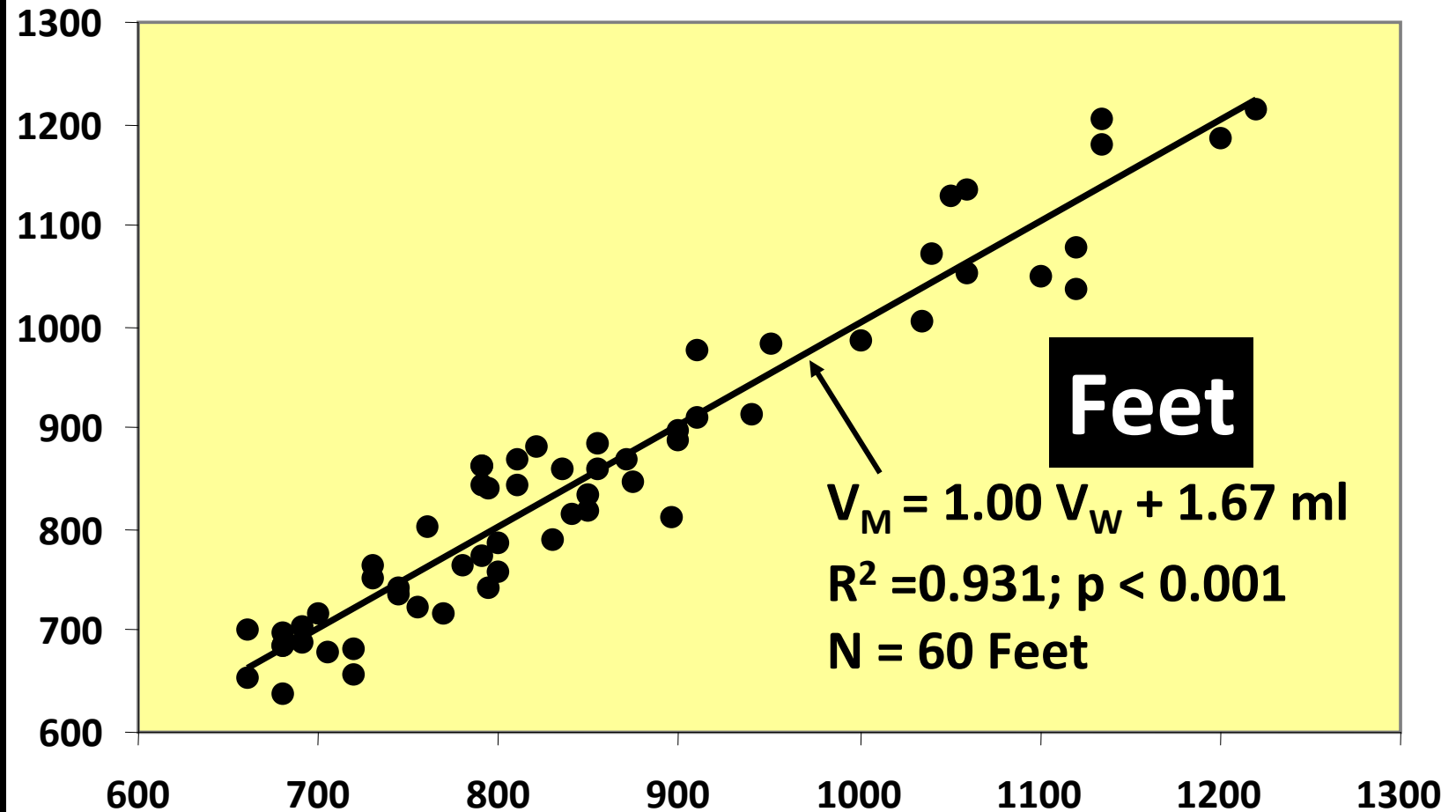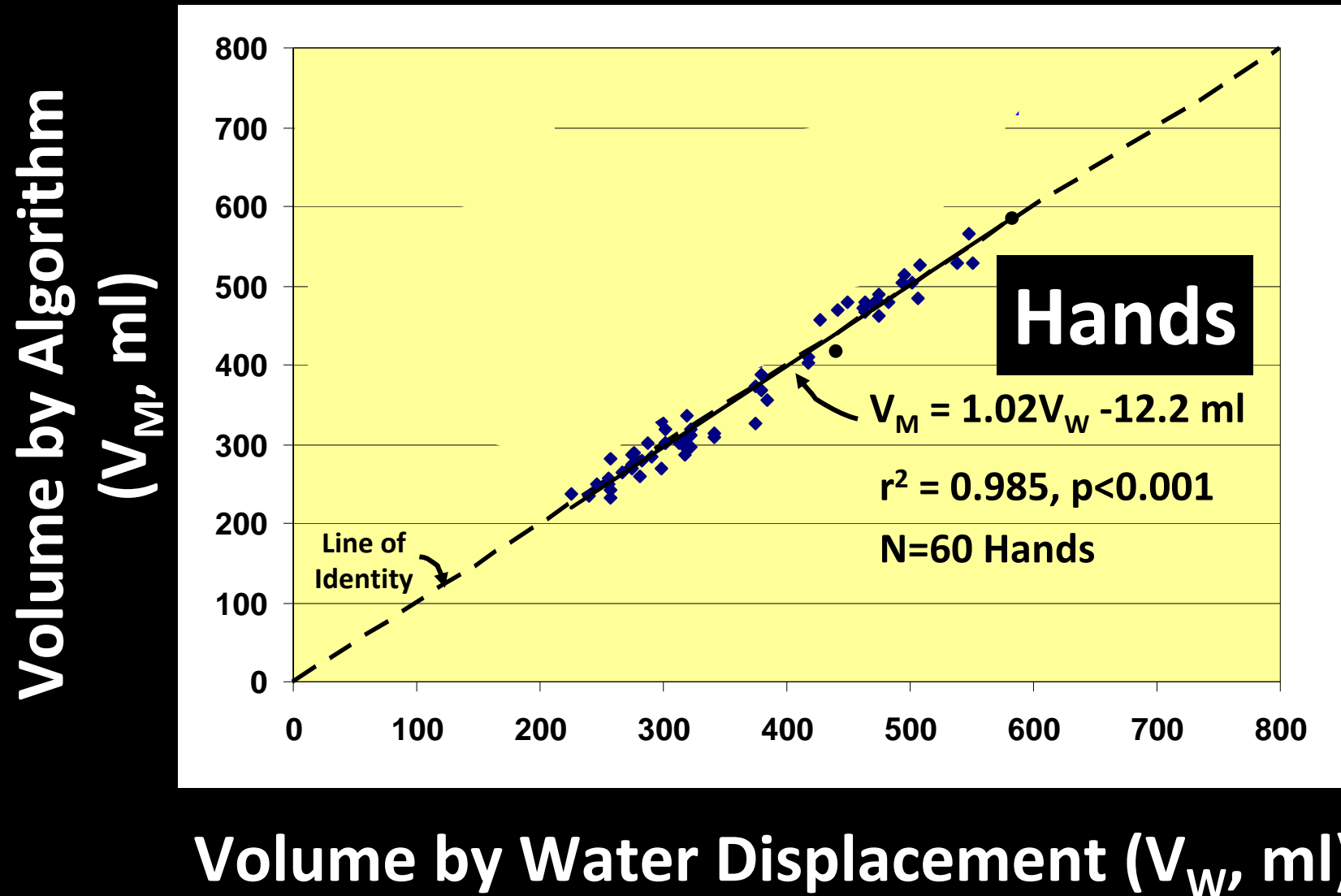
Limits of Agreement (%)

Percent Difference $(V_W - V_M) / V_W$ %

HANDS

Mean Volume $(V_W + V_M)/2$ in ml

	Difference	LOA	95% CI
$(V_W-V_M)/V_W$ (%)	$-0.9 \pm 4.9\%$	$\pm 9.8\%$	+11.2 to -12.9

Dr HN Mayrovitz

Limits of Agreement (%)

FEET

Percent Difference $(V_w - V_m)/V_w$ %

Mean volume $(V_w + V_m)/2$ in ml
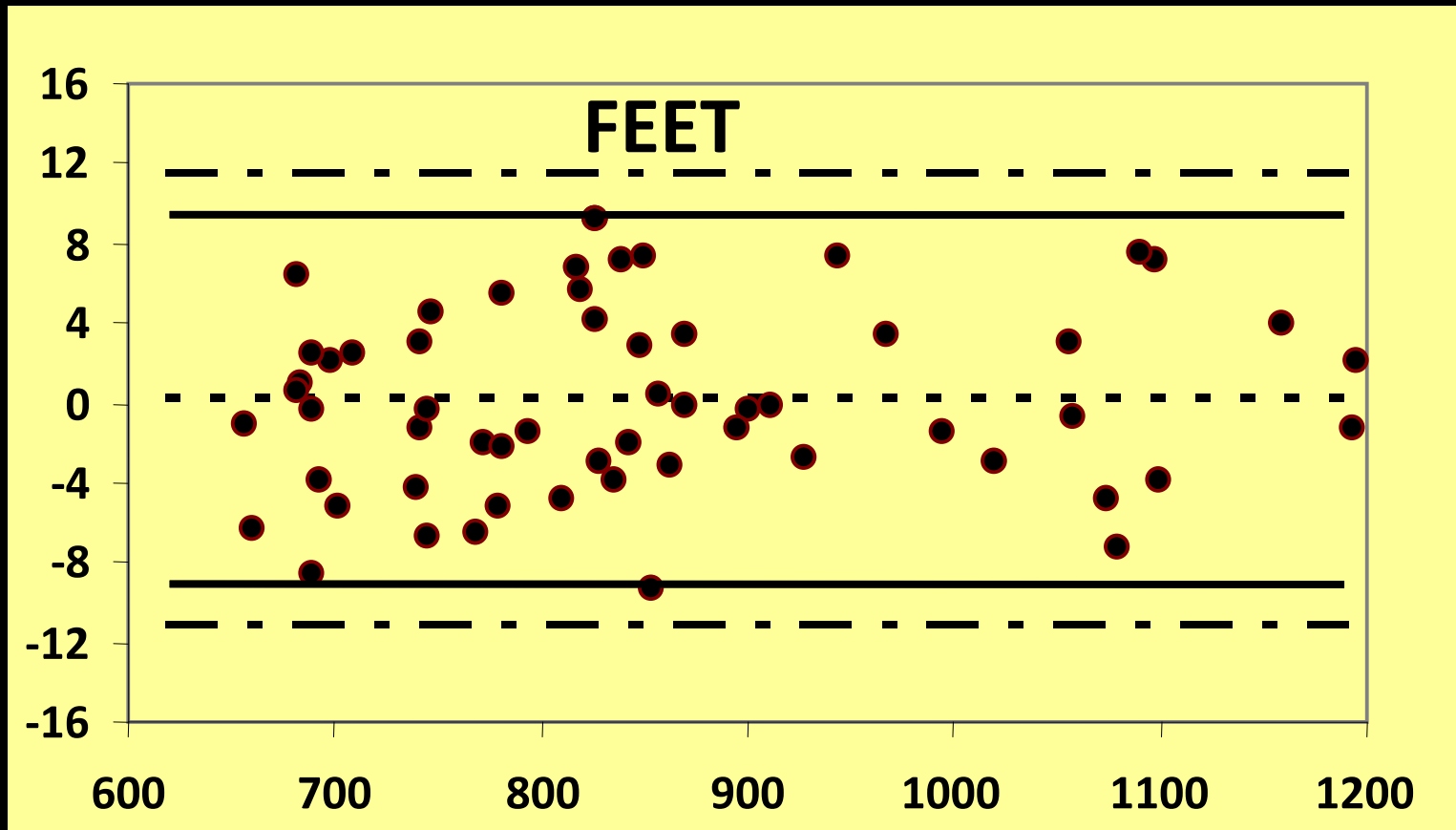
	Difference	LOA	95% CI
$(V_M-V_w)/V_w$ (%)	0.21 ± 4.64	± 9.28	+11.6 to -11.2

Dr HN Mayrovitz

Manual or Automated?

$

Space

Pt. Mobility

Pt. Flexibility

Time

Measurer

Limb Volumes in Liters

	Automated	Manual	%Diff
Legs N=142	7.16 ± 0.17**	6.90 ± 0.17	4.14 ± 0.54
Arms N=42	2.70 ± 0.09**	2.53 ± 0.09	6.97 ± 1.18

- **Small (but significant) difference between volumes Automated → slightly larger absolute volumes**

BUT: No significant difference in Edema volumes

LEGS (N = 32 Pairs) Percentage Edema		ARMS (N = 24 Pairs) Percentage Edema	
Automated	Tape Measure	Automated	Tape Measure
14.2 ± 3.5	15.4 ± 4.4	19.5 ± 4.7	19.8 ± 4.6

Dr HN Mayrovitz

What segment length? Compare 4 vs. 8 vs. 12 cm

Leg Volumes (N = 140) and Reductions with Treatment based on Different Segment Lengths

Segment Length	Volume (ml)		Volume Reduction	
	Pre Treat	Post Treat	ml	%
4 cm	6658 ± 2491	5453 ± 1954	1204 ± 775	17.6 ± 7.0
8 cm	6681±2511	5477 ± 1969	1205 ± 803	17.5 ± 7.2
12 cm	6762±2560	5570 ± 2013	1248 ± 823	17.9 ± 7.3

Insignificant difference between segment lengths

Dr HN Mayrovitz

How to take into account the "Control" limb?

If no change in contralateral "control" limb then need only measure it once

Limb Volumes

Tx

- Tx Limb Volume (ml)
- Norm Limb Volume (ml)
- Edema (ml)

Affected Limb

Contralateral Limb

Edema Volume

Volume (ml): 0, 500, 1000, 1500, 2000, 2500, 3000, 3500, 4000, 4500

Visit: 0, 2, 4, 6, 8, 10, 12, 14, 16, 18

www.limbvolumes.org
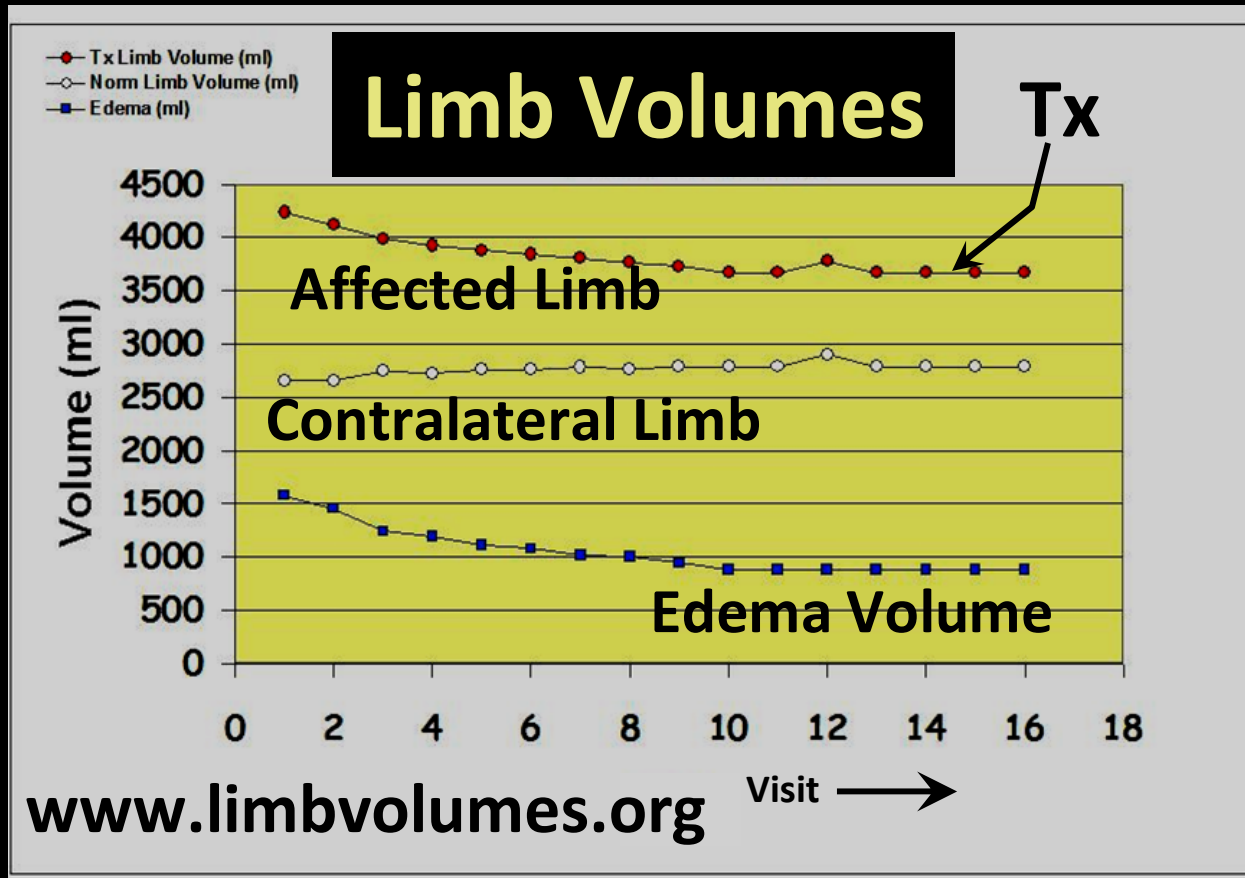
BUT Control limb DOES CHANGE! Need to measure both limbs to track changes and outcomes!

Edema Volume = 100* (Affected – Control)/Control

Dr HN Mayrovitz

Research Study Outcomes		Reduction in Edema volume (%)	
	Pre-Tx Edema Volume (liters)	Based on pre and post tx control limb values	Based on only pre tx control limb values
Arms (40)	0.94 ± 0.54	39 ± 26 →	49 ± 31
Legs (75)	2.3 ± 0.2	47 ± 35 →	60 ± 37

Using only pre-treatment control limb value severely overestimated outcomes

Dr HN Mayrovitz

Conclusions

- Use of girth measurements to obtain limb volumes can be a useful and reliable method to assess changes in edema and lymphedema over time

- Its accuracy and reliability depend on careful attention to detail in the measurement process

- Its utility and versatility is enhanced via the use of a suitable calculation algorithm that appropriately takes into account hand or foot volumes

- Most studies indicate this volume method compares well with other methods including H_2O displacement but the various methods are not interchangeable.

Dr HN Mayrovitz

My sincere thanks to Dr. Gyozo Szolnoky for his heroic efforts on my behalf!