

# EWMA 2019

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OTHER COLLABORATORS:



## Ejection Fraction of calf pump assessed by strain gauge plethysmography

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DISCLOSURE

no conflict of interest

# Ejection Fraction

% blood expelled from the lower leg by physical exercise  
(walking in the daily life)

# Ejection Fraction

non invasive assessment of EF

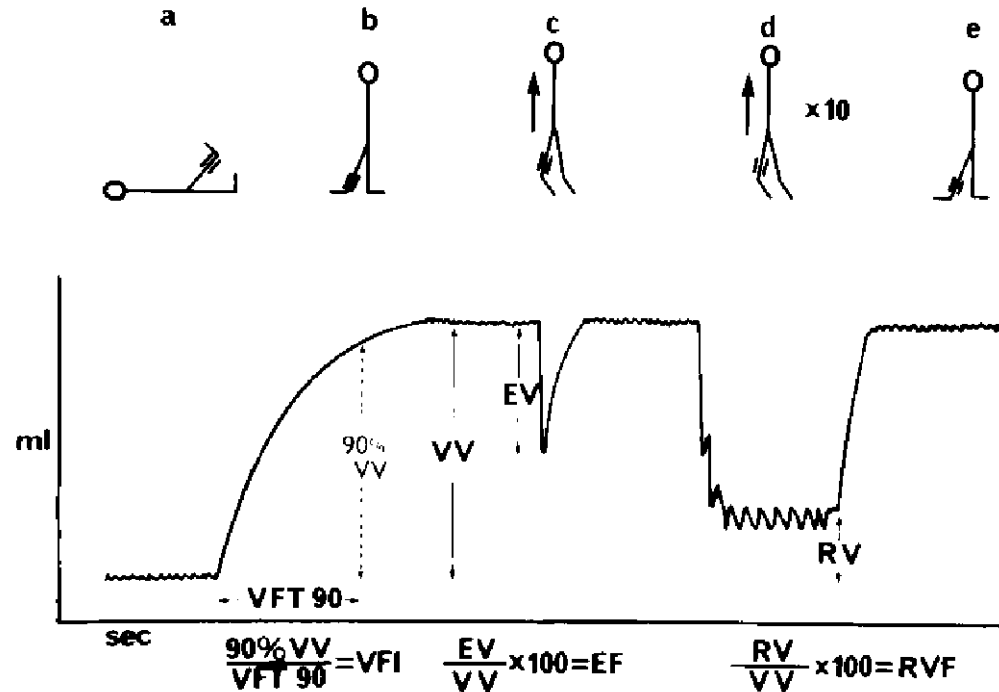
- water plethysmography (foot)
- air plethysmography
- strain gauge plethysmography

# non invasive assessment of hemodynamic parameters

## Air Plethysmography

Air Plethysmography: the best test to assess venous reflux in patients with venous incompetence

general agreement among different authors on the accuracy and reproducibility of venous filling index to assess the global venous reflux

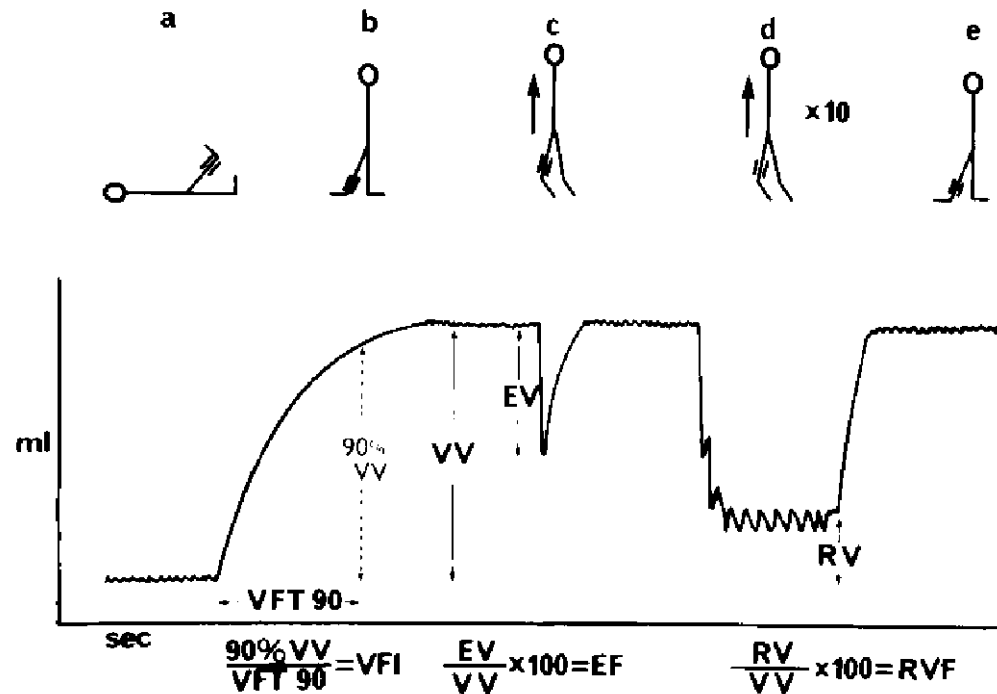


# non invasive assessment of hemodynamic parameters

## Air Plethysmography

Concerning ejection fraction Air Plethysmography seems to be less reliable, both in discriminating between:

- normal subjects and patients with vein disease
- different degrees of venous insufficiency



# non invasive assessment of hemodynamic parameters

## EJECTION FRACTION by Air Plethysmography

additional critical points when we want to differentiate between different compression devices:

- plethysmographic air chamber must be placed over the bandage to measure EV and EF directly over the pumping segment.
- measurement of these parameters will be influenced by the reduction of the basic volume under compression taking place in the region of the calf pump

# non invasive assessment of hemodynamic parameters

## EJECTION FRACTION by Strain Gauge Plethysmography

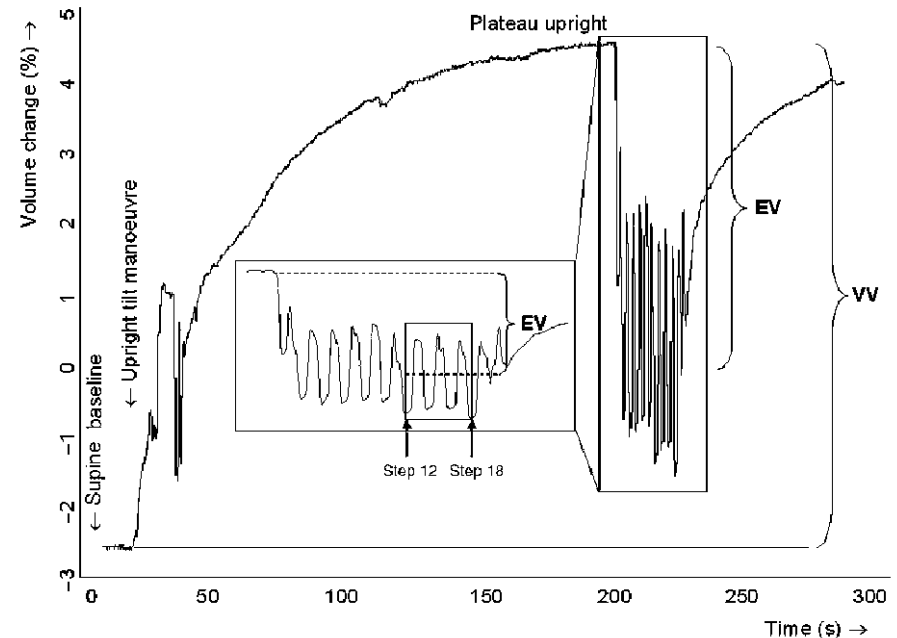
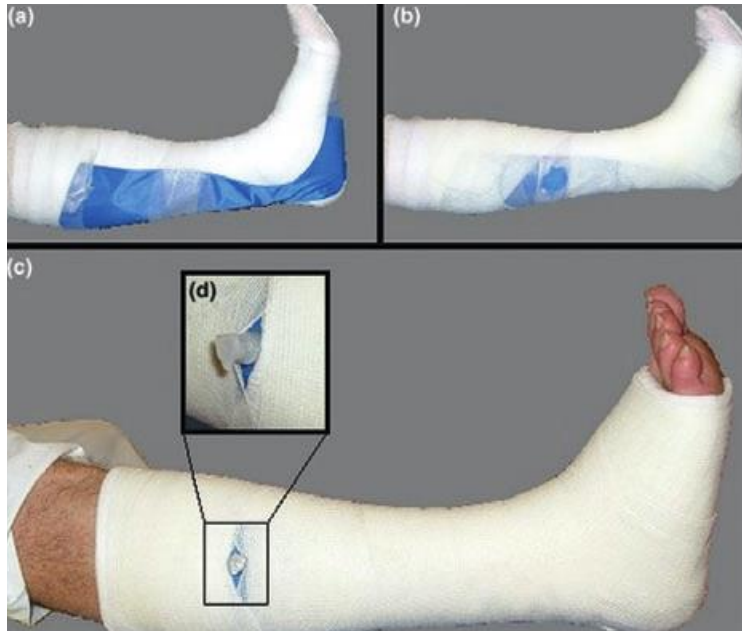
with this method the measuring probe is placed proximally to the bandage directly on the skin; therefore, the measured volume changes reflect changes of the leg and not of the bandage.





# non invasive assessment of hemodynamic parameters

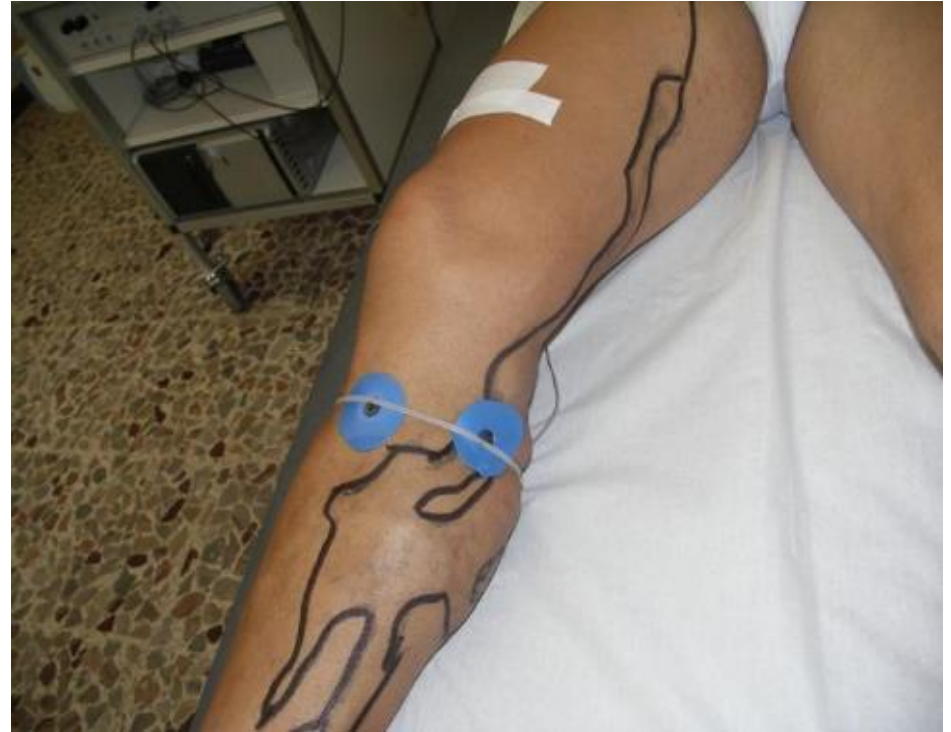
the methodology used in our tests was firstly used by Poelkens under a plaster cast



# Strain Gauge Plethysmography

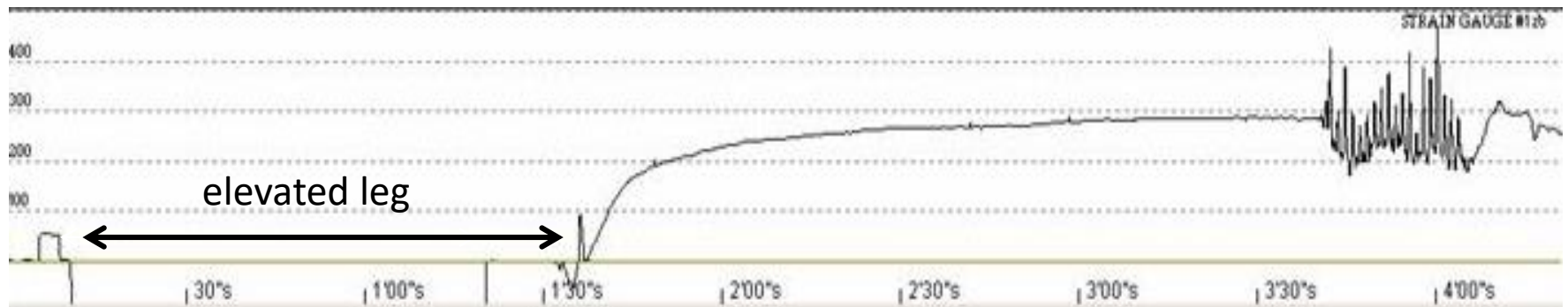
the probe is placed, in the lying position:

- 5 cm distally of the patella
- proximally to the bandage



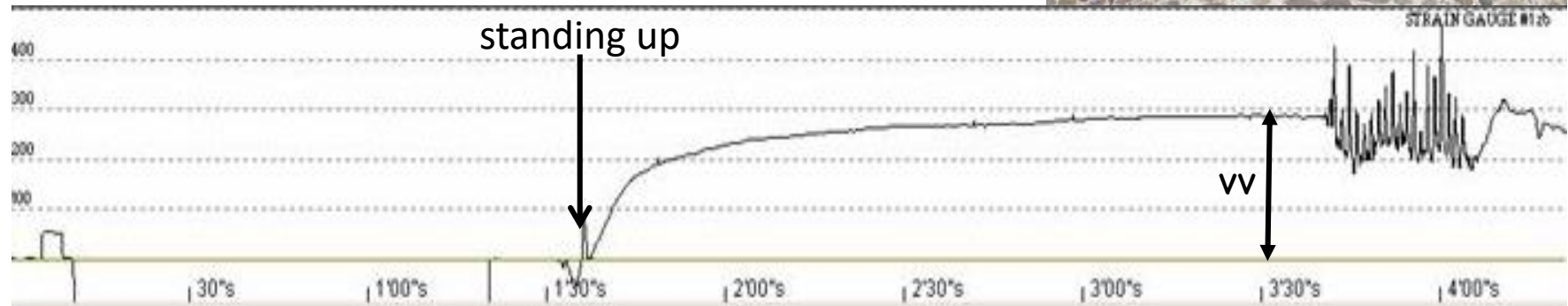
# Strain Gauge Plethysmography

leg is elevated (1') to empty the venous system



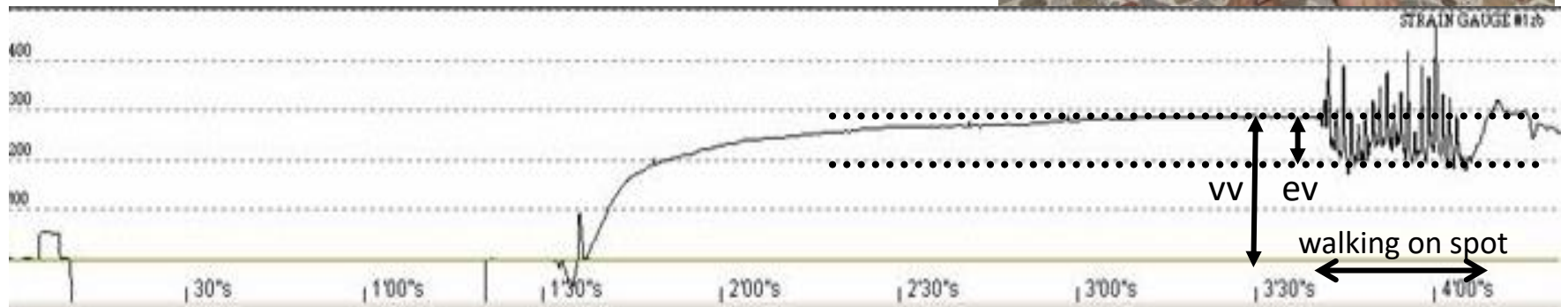
# Strain Gauge Plethysmography

patient in standing position with the weight on the opposite leg (Venous Volume measurement)



# Strain Gauge Plethysmography

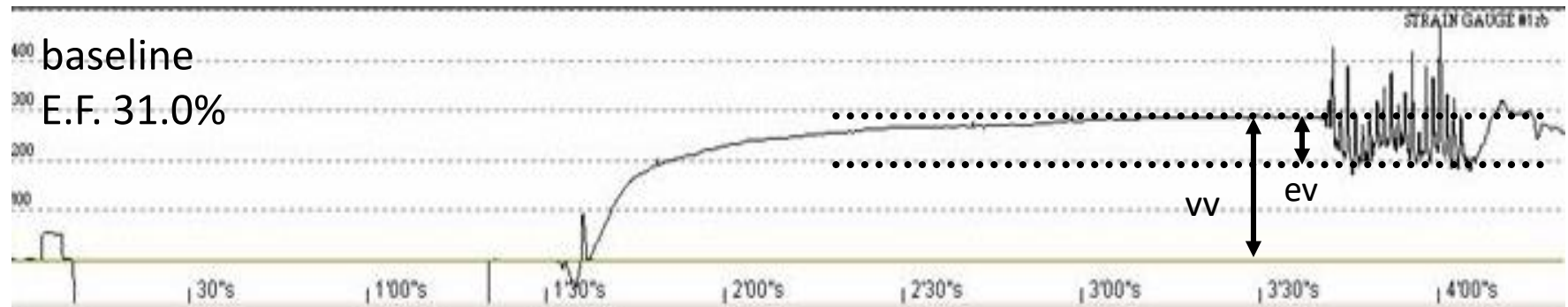
when the tracing is in the steady state: 20 steps in 20 seconds and return to the initial position; (ejection volume measurement)



# Strain Gauge Plethysmography

Ejection Fraction (EF):  $100 \times EV / VV$

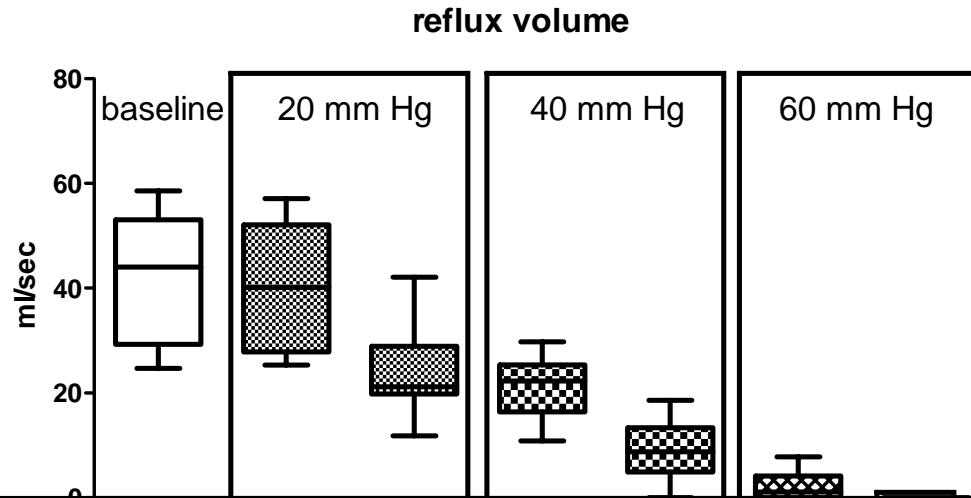
(normal values  $> 60\%$ ; variation coefficient 7.5%)



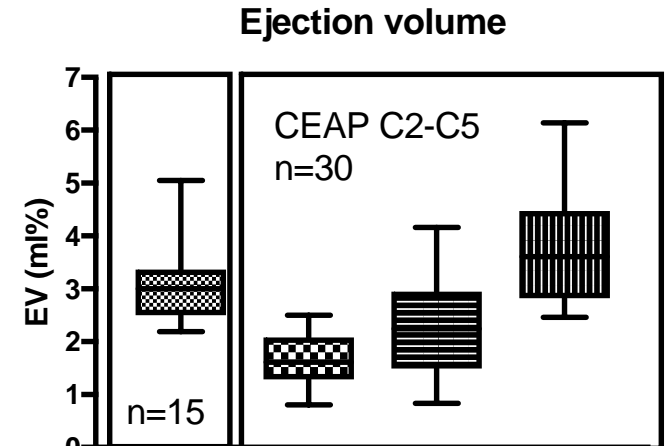
# Ejection Fraction and Strain Gauge Plethysmography

EF improvement by compression is due both to:

- reduction of venous reflux (APG, Duplex)
- increase of ejected volume (SGP)



	baseline	elastic	inelastic	elastic	inelastic	elastic	inelastic
Minimum	24.70	25.30	11.80	10.80	0.0	0.0	0.0
25% Percentile	29.28	27.88	19.80	16.38	4.950	0.0	0.0
Median	44.05	40.15	21.20	22.30	8.800	1.050	0.0
75% Percentile	53.08	52.10	28.93	25.38	13.38	4.150	0.0
Maximum	58.60	57.10	42.10	29.80	18.60	7.800	0.0



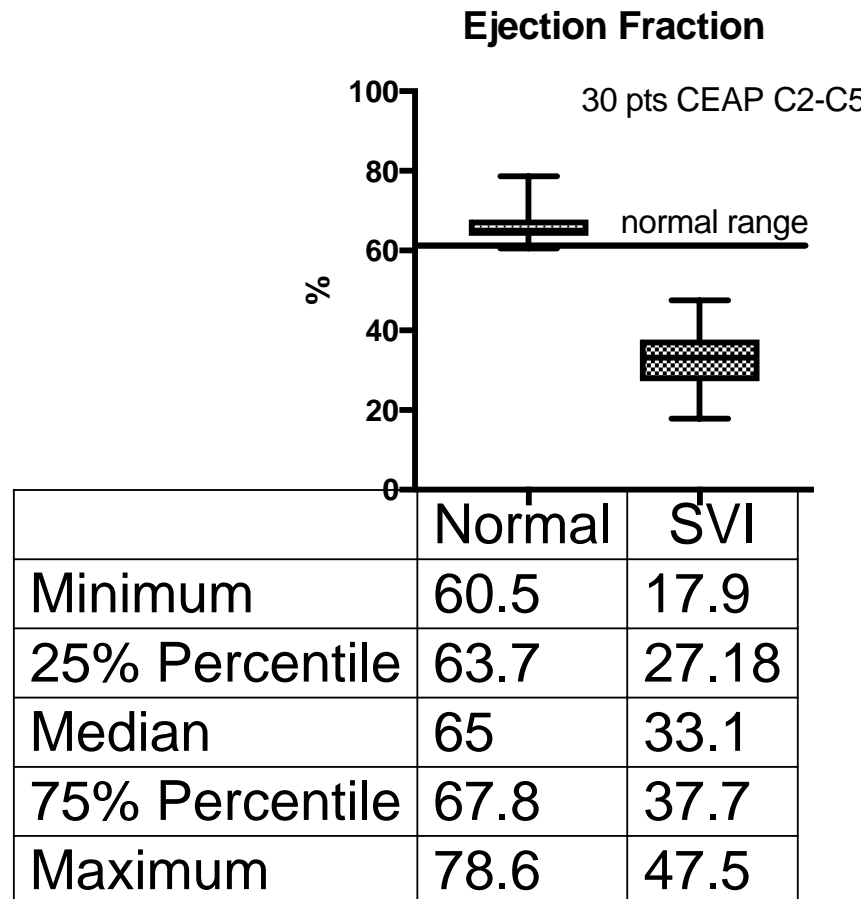
	Normal	no compr	elastic	inelastic
Minimum	2.19	0.8	0.83	2.46
25% Percentile	2.5	1.288	1.493	2.82
Median	3	1.615	2.245	3.61
75% Percentile	3.36	2.08	2.95	4.473
Maximum	5.05	2.5	4.16	6.14



# Ejection Fraction and Strain Gauge Plethysmography

when assessing EF, SGP is able to differentiate between:

- normal subjects and patients with venous insufficiency
- different degrees of venous insufficiency (to some extent)

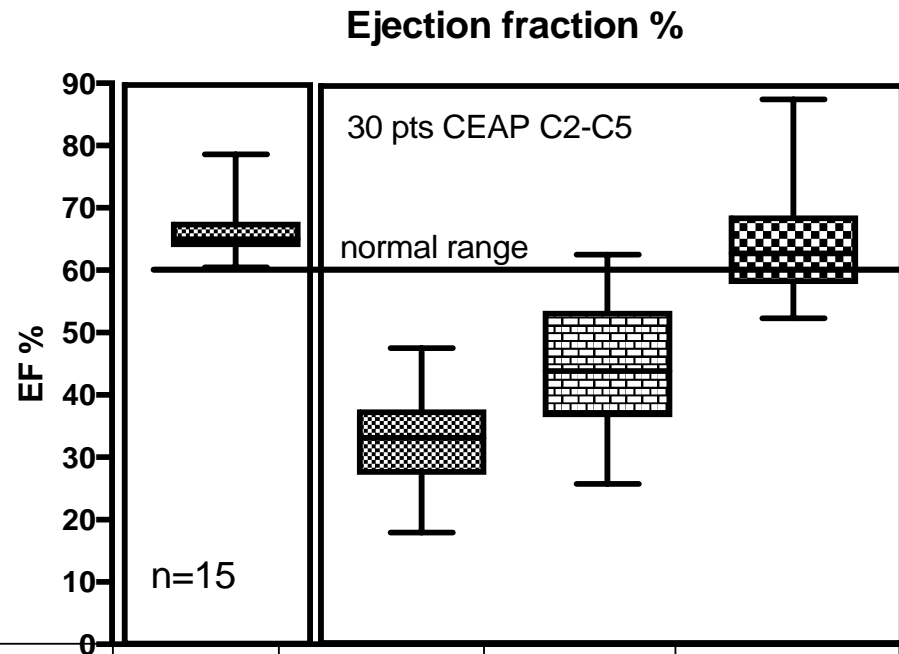




# Ejection Fraction and Strain Gauge Plethysmography

when assessing EF, SGP is able to differentiate between:

- elastic and inelastic bandages even if with some overlapping

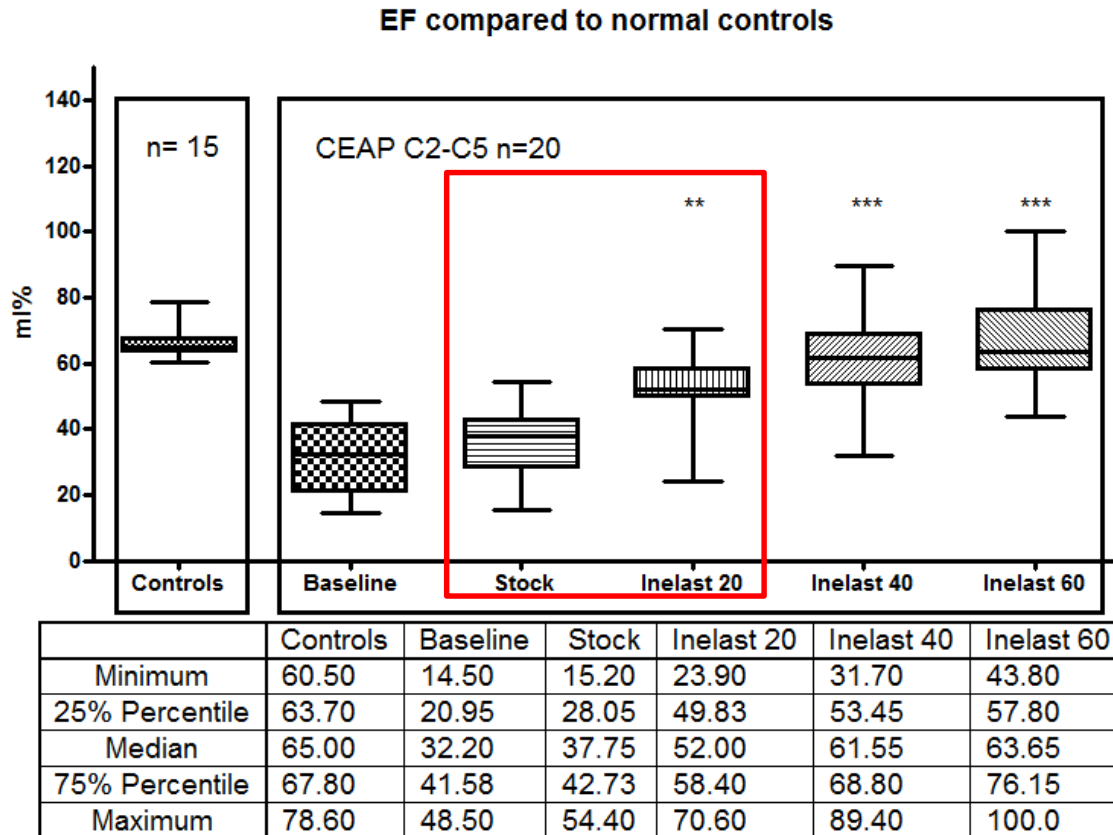


	Normal	no compr	el. band.	inel. band.
Minimum	60.5	17.9	25.7	52.3
25% Percentile	63.7	27.18	36.45	57.75
Median	65	33.1	43.85	62.7
75% Percentile	67.8	37.7	53.53	68.78
Maximum	78.6	47.5	62.5	87.4

# Ejection Fraction and Strain Gauge Plethysmography

when assessing EF, SGP is able to differentiate between:

- elastic stockings and inelastic bandages applied with the same pressure

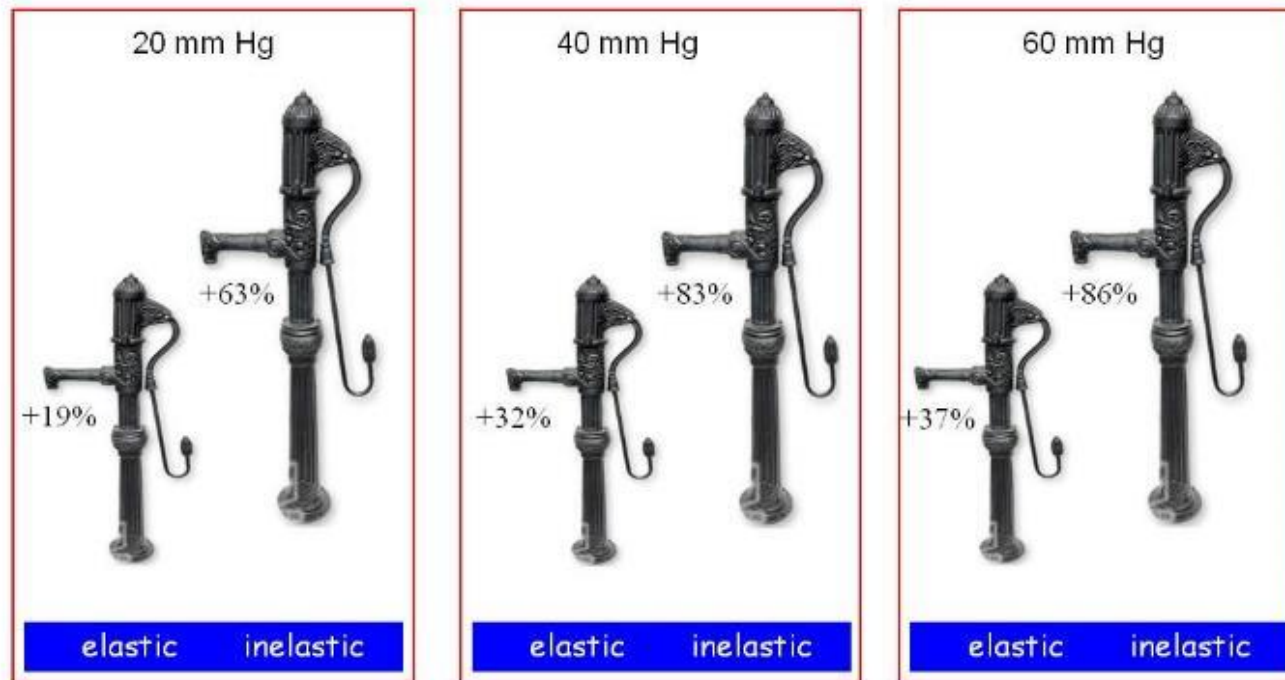


# Ejection Fraction and Strain Gauge Plethysmography

when assessing EF, SGP is able to differentiate between:

- elastic and inelastic material at every pressure ranges

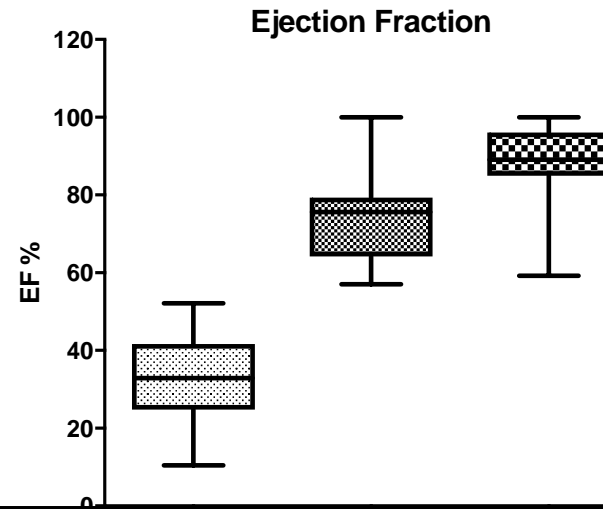
venous pumping function



# Ejection Fraction and Strain Gauge Plethysmography

when assessing EF, SGP is able to differentiate between:

- graduated and progressive pressure profile

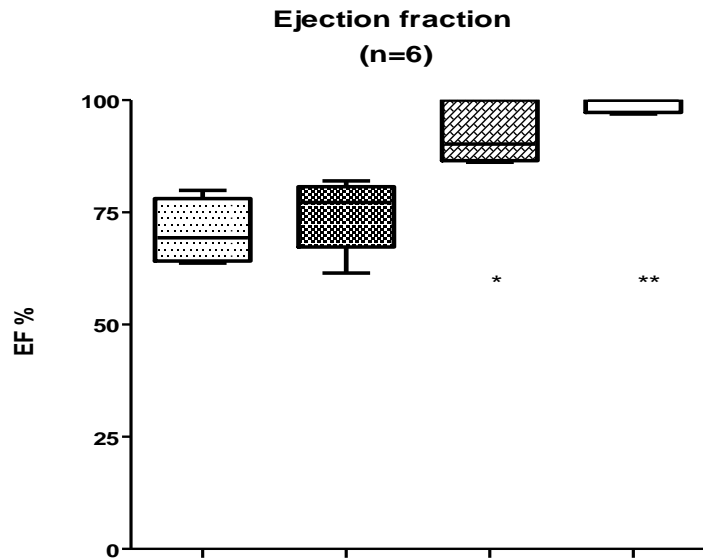


	baseline	GCB	NGCB
Minimum	10.45	57.07	59.20
25% Percentile	24.80	64.18	84.96
Median	32.89	75.59	89.10
75% Percentile	41.64	79.38	96.06
Maximum	52.12	100.0	100.0

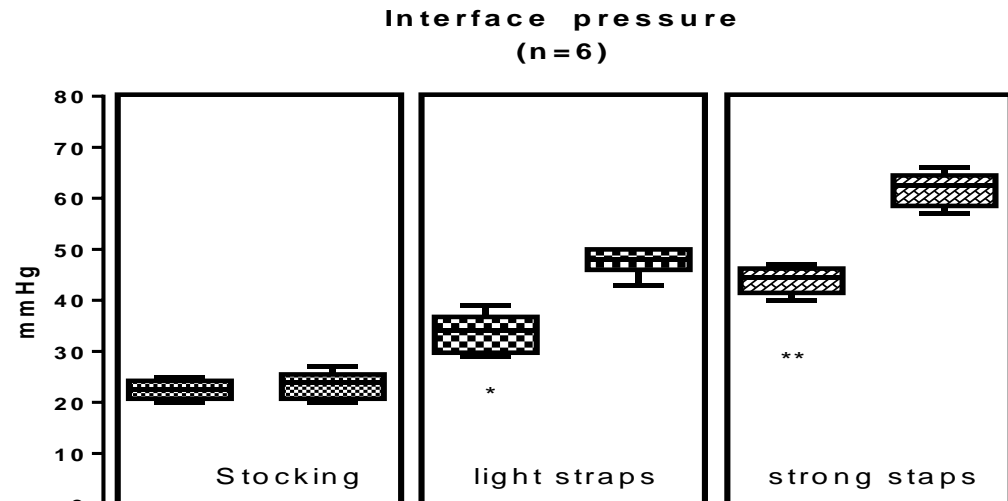
# Ejection Fraction and Strain Gauge Plethysmography

when assessing EF, SGP is able to differentiate between:

- elastic stockings and inelastic wraps on top of elastic stockings in healthy sportsmen



	baseline	stocking	light strap	strong strap
Minimum	63.70	61.50	86.20	96.90
25% Percentile	64.15	67.30	86.55	97.25
Median	69.35	77.20	90.25	100.0
75% Percentile	78.10	80.75	100.0	100.0
Maximum	79.90	82.00	100.0	100.0

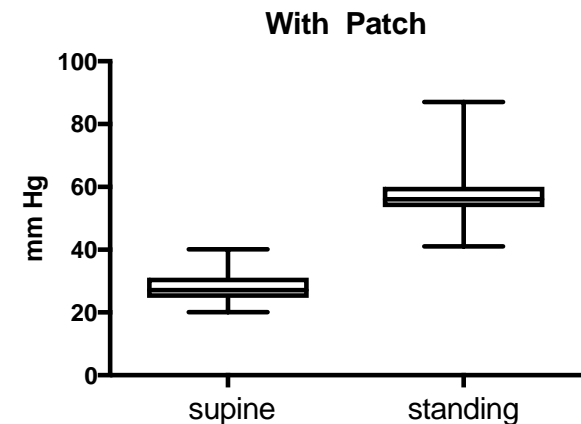
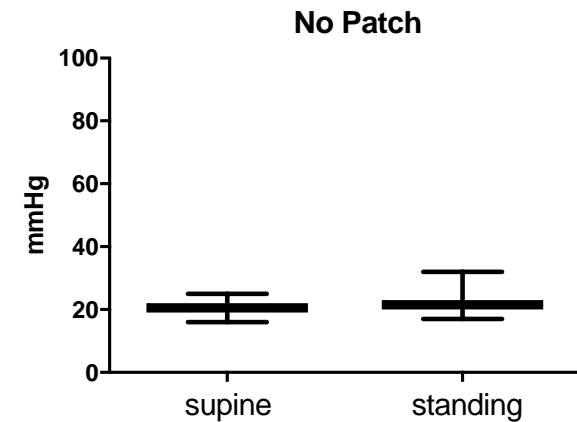


	supine	standing	supine	standing	supine	standing
Minimum	20.00	20.00	29.00	43.00	40.00	57.00
25% Percentile	20.75	20.75	29.75	46.00	41.50	58.50
Median	22.50	24.00	34.00	48.00	44.50	62.50
75% Percentile	24.25	25.50	36.75	50.00	46.25	64.50
Maximum	25.00	27.00	39.00	50.00	47.00	66.00

# Ejection Fraction and Strain Gauge Plethysmography

when assessing EF, SGP is able to differentiate between:

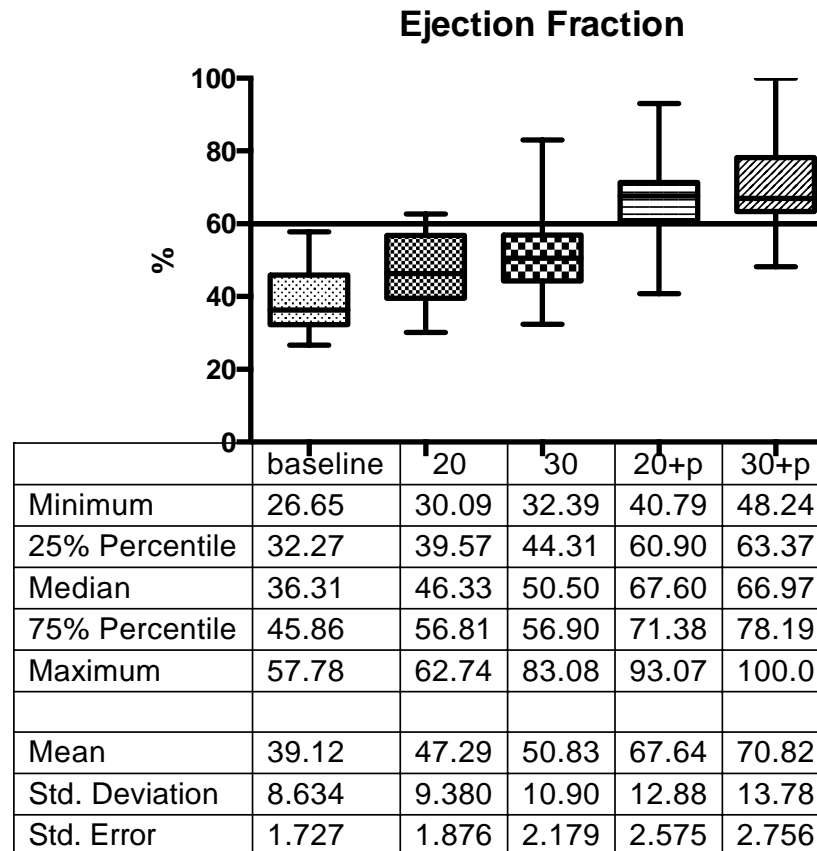
- elastic bandage with or w.o patches making it much stiffer



# Ejection Fraction and Strain Gauge Plethysmography

when assessing EF, SGP is able to differentiate between:

- elastic bandage with or w.o. patches making it much stiffer



# Ejection Fraction and Strain Gauge Plethysmography

when assessing EF, SGP is able to differentiate between:

- elastic bandage and ACW with air pump adjusting pressure to the body position



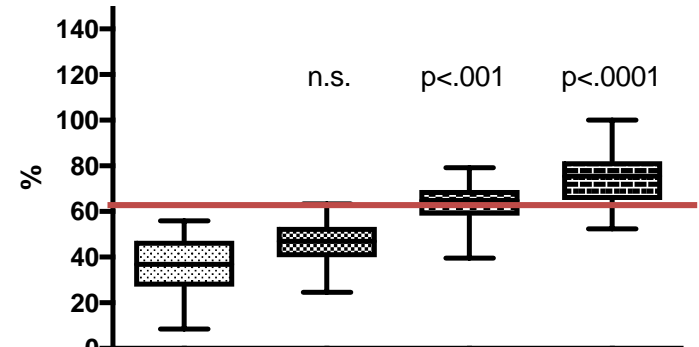


# Ejection Fraction and Strain Gauge Plethysmography

when assessing EF, SGP is able to differentiate between:

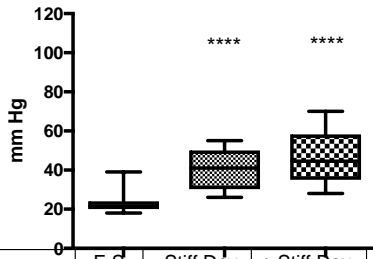
- elastic bandage and ACW with air pump adjusting pressure to the body position

### Ejection Fraction



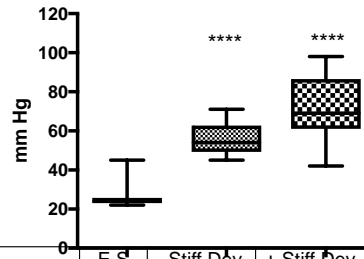
	baseline	E.S	- Stiff Dev.	+ Stiff Dev.
Number of values	16	16	16	16
Minimum	8.41	24.53	39.61	52.48
25% Percentile	27.05	39.89	58.2	65.11
Median	36.76	46.92	64.79	75.5
75% Percentile	47.13	53.25	69.4	82.03
Maximum	55.95	63.33	79.19	100

### diastolic pressure



	E.S	- Stiff Dev.	+ Stiff Dev.
Number of values	16	16	16
Minimum	18	26	28
25% Percentile	20	30.25	35
Median	21.5	41	44.5
75% Percentile	24	50	58.25
Maximum	39	55	70
Mean	23.13	40.44	45.81
Std. Deviation	5.175	9.736	12.92
Std. Error of Mean	1.294	2.434	3.229

### systolic pressure



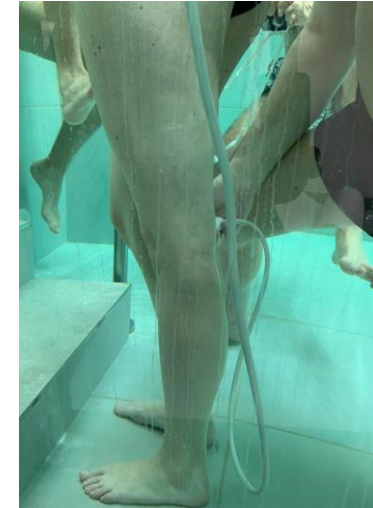
	E.S	- Stiff Dev.	+ Stiff Dev.
Number of values	16	16	16
Minimum	22	45	42
25% Percentile	23	49.25	61
Median	24	54	69
75% Percentile	25.75	62.75	86.5
Maximum	45	71	98
Mean	25.88	56.13	71.5
Std. Deviation	5.632	8.107	16.57
Std. Error of Mean	1.408	2.027	4.143

# UnderWater Strain Gauge Plethysmography

U.W. Pressure

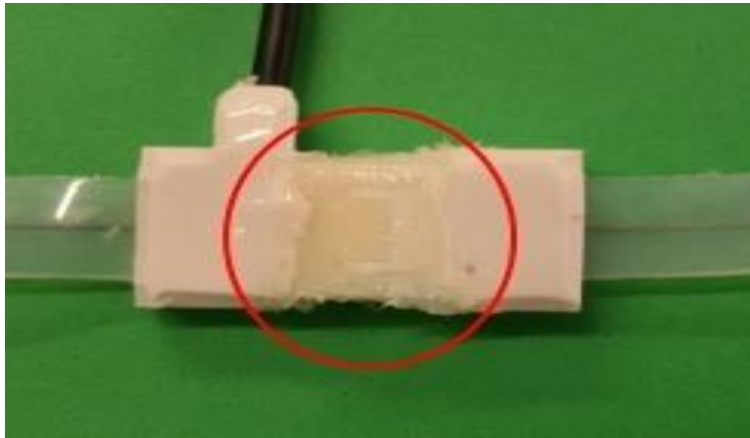


U.W. Duplex for venous hemodynamic research



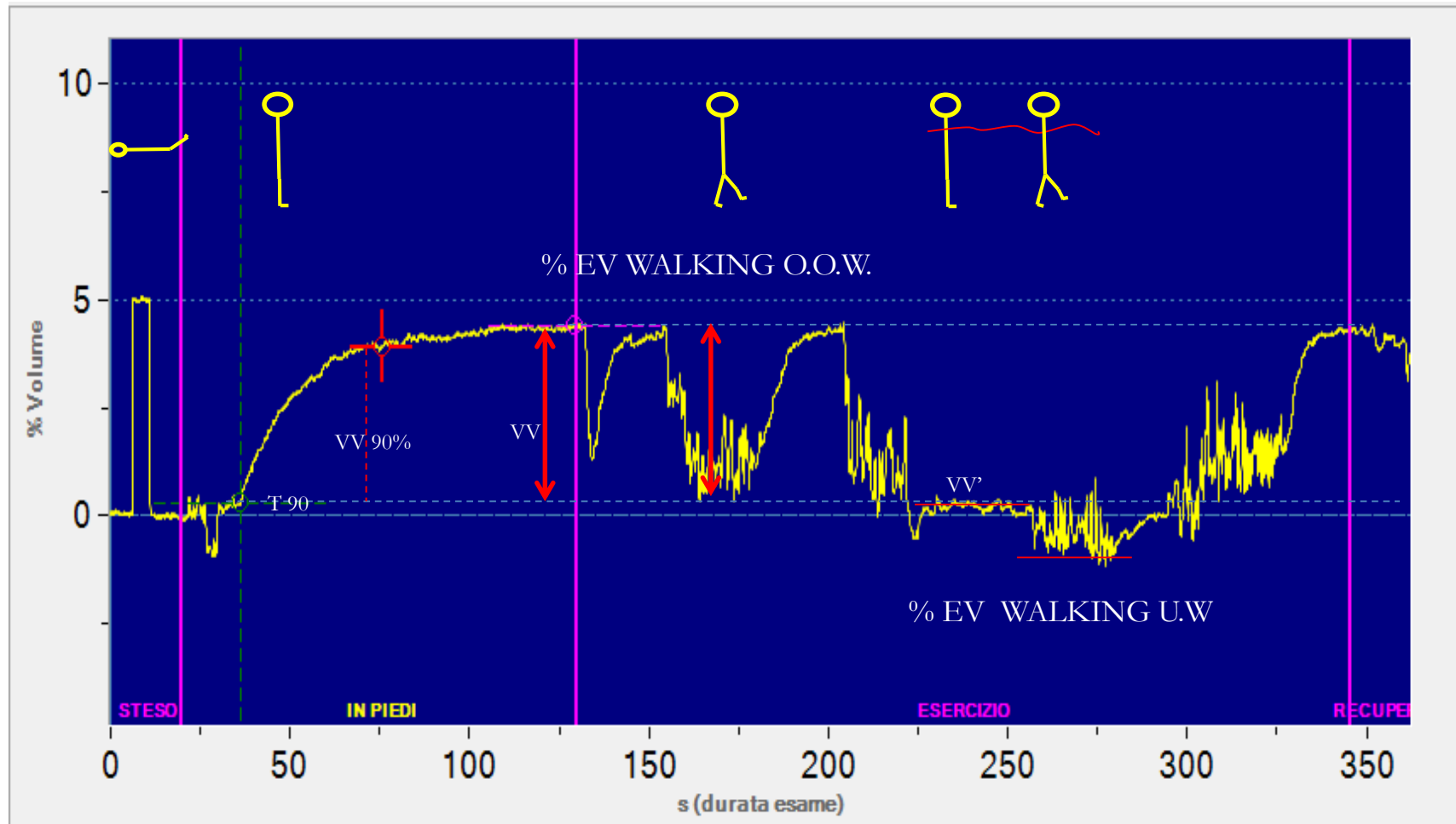
MCS pressure OOW:	26 mm Hg
Water pressure w.o. MCS:	70 mm Hg
Water + MCS:	94 mm Hg

# UnderWater Strain Gauge Plethysmography



On behalf of Underwater Compression Group

# UnderWater Strain Gauge Plethysmography



# CONCLUSIONS

Strain Gauge Plethysmography is able:

- to differentiate normal subjects from patients with venous insufficiency when assessing Ejection Fraction
- to show the improvement of venous hemodynamics by compression therapy
- to differentiate between elastic and inelastic compression and different compression modalities
- to help in finding new data in underwater compression



thank you for your attention

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