Erasmus MC
Universitair Medisch Centrum Rotterdam

Clinical importance of stiffness

Prof. dr. H.A. Martino Neumann

Department of Dermatology

Erasmus MC

Rotterdam

ICC Copenhagen May 17, 2013

Chronic venous disease

- CVD characterized by venous hypertension
- Balance between Input and Output

In- and Output

- **Input:**
  - **Venous volume (capacity of the veins)**
  - **Venous filling index (reflux)**

In- and Output

- Input:
  - Venous volume (capacity of the veins)
  - Venous filling index (reflux)

- Output:
  - Venous return (pump function)

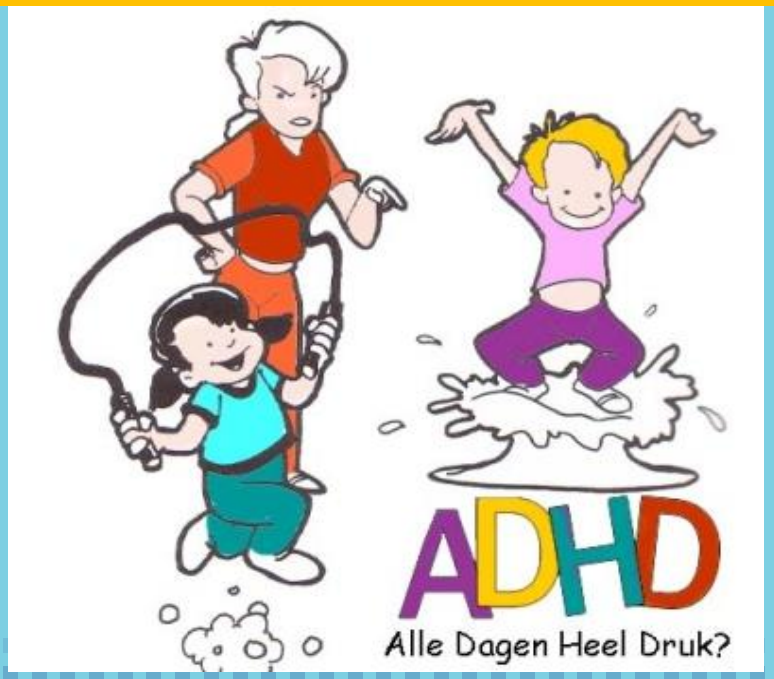
The balance of venous function

- Venous volume
- Pump function

} → Pressure

+

=



Compression in Phlebology

- A certain pressure pursued by a device (e.g. Medical Elastic Compression Stocking) on the lower extremity

- Normally expressed as interface pressure

  depending on Laplace low

- This pressure is conducted to deeper structures (subcutaneous tissue / muscles / veins, etc)

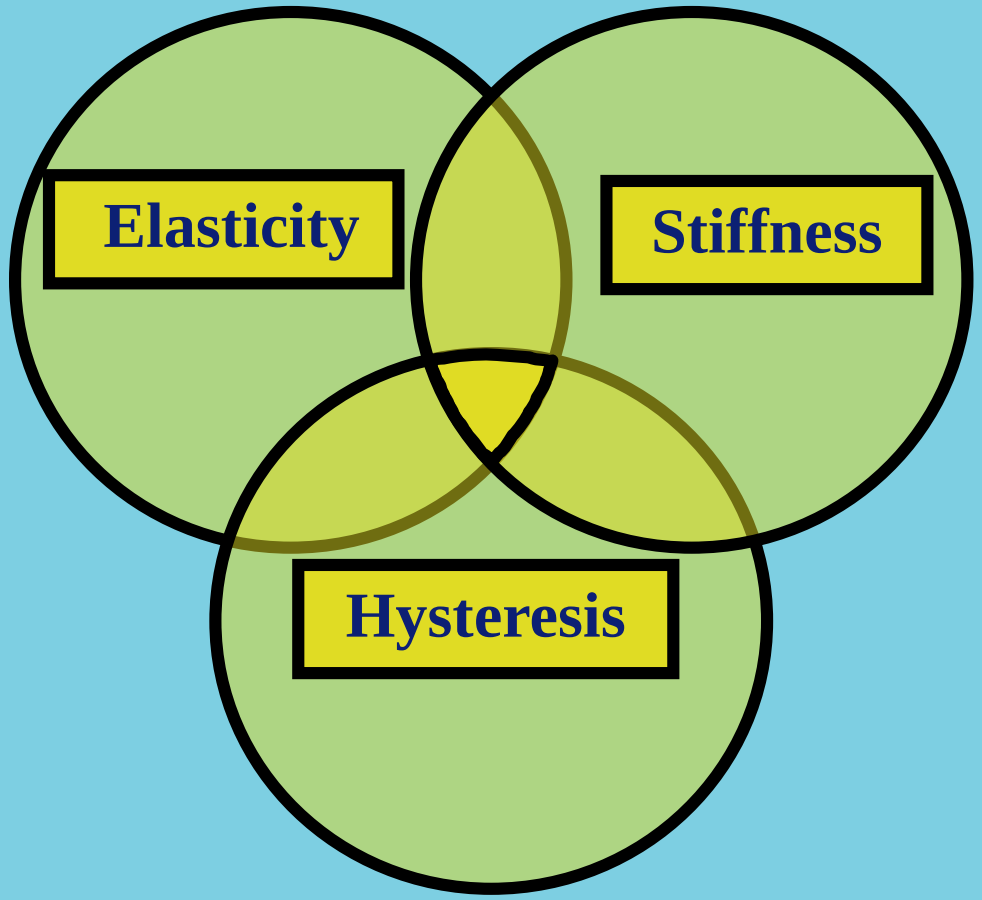
  depending on Pascal low

From experience to evidence

Compression therapy

- **Pressure and stiffness**
  - Stockings versus bandages
    - Flat knitted versus round knitted stockings

Characteristics of Compression Therapy



Elasticity

- Natural or synthetic rubber

- Elasticity is the capacity of material / fabric to return to its original dimension and shape after it has been stretched / elongated.

- Laplace's law: $T = P \times R$

Elasticity coefficient / stiffness

Stiffness = Elasticity coefficient

CEN definition: normal tension at B + 1 cm

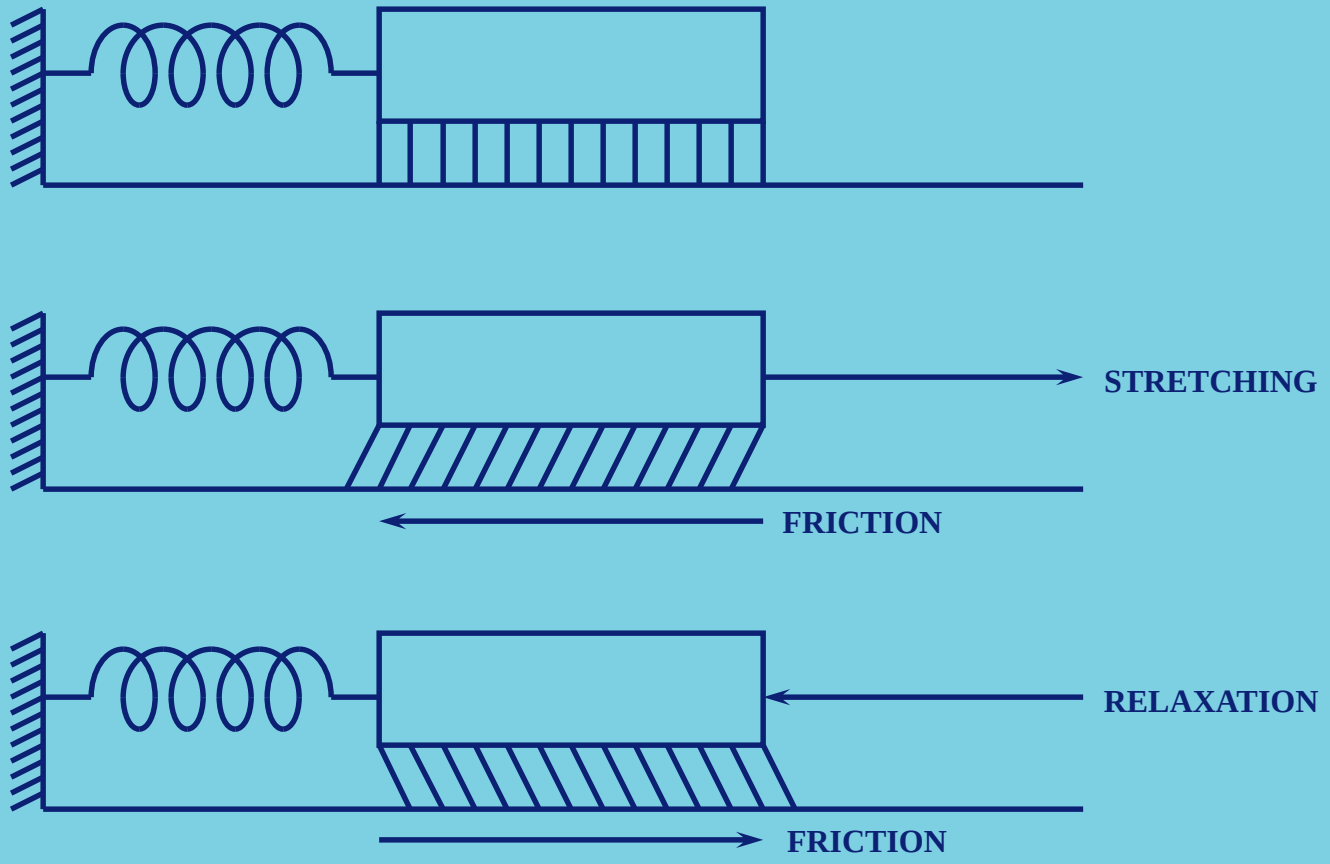
Increase in pressure due to the elastic material

measured in static condition

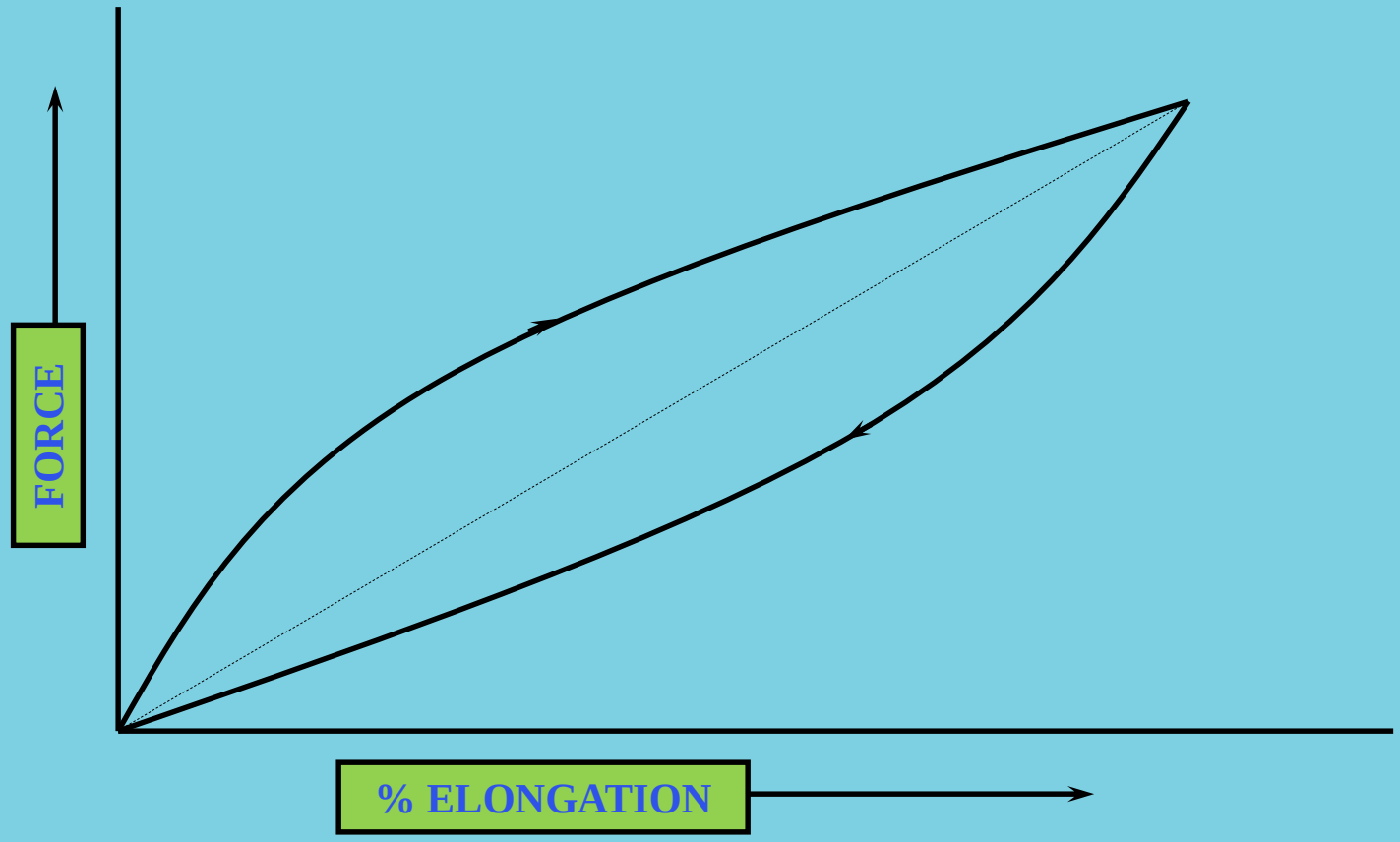
Hysteresis

- Greek; legging
- Characteristic of material
- Result of internal friction

Hysteresis



Force - Elongation curve I



Force - Elongation curve II

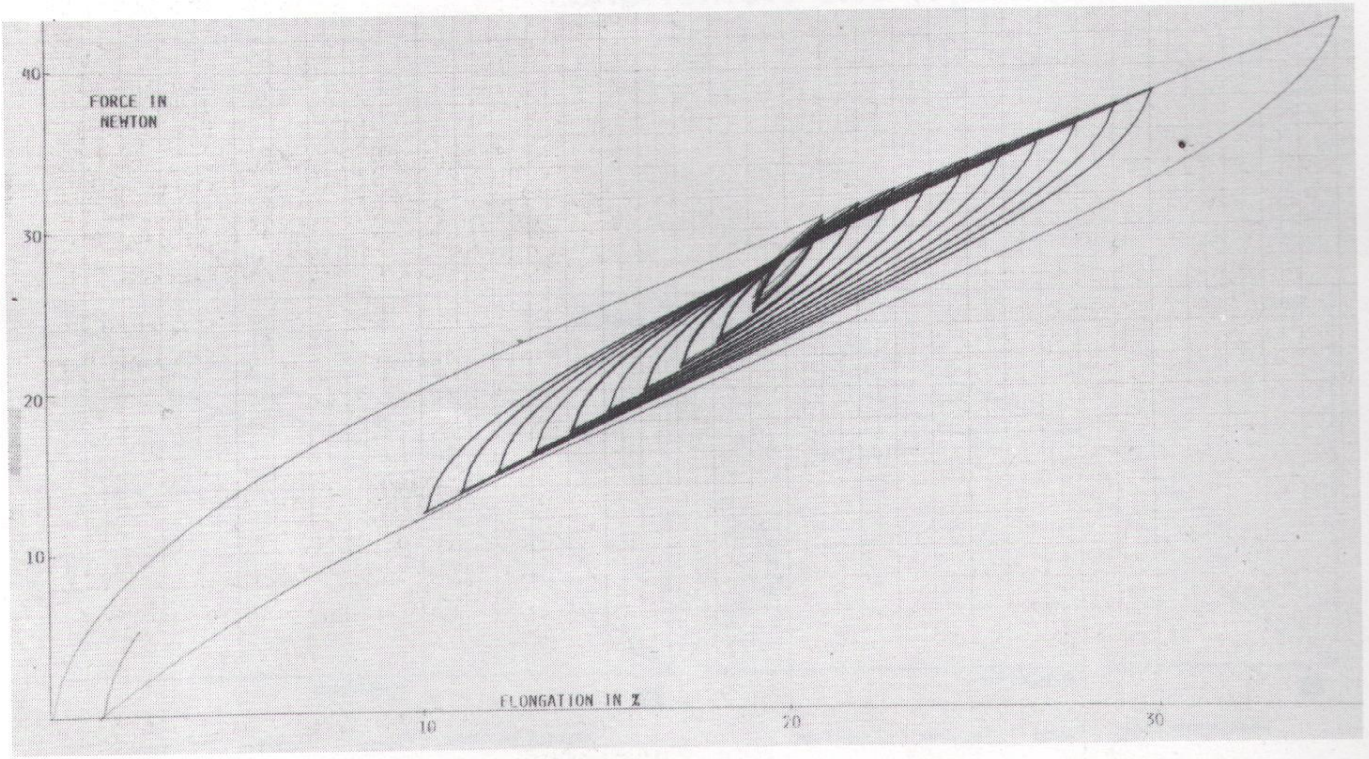


Fig. 3: Force Elongation Curve of Elastic Knitwear. The elongation increments are progressively made larger. The steepness of the initially small cycle is diminished with the increased amplitude.

Ref: Stolk R. A quick pressure determining device for medical stockings based on the determination of the counterpressure of air-filled leg segments. Swiss Med 10. 1988; 91-96.

Dynamic Stiffness Index (DSI)

1. Healthy volunteers walking on a treadmill
2. Analyzing the movement
3. Mimic the leg volume changes in a model
4. Calculate the DSI

Circumference changes

Length (L) measured from the floor in cm	Leg circumference in cm with			MDF – MPF in cm
	Foot at right angles to the leg	Foot in maximal dorsal flexion (MDF)	Foot in maximal plantar flexion (MPF)	
L = 16	22.9	23.1	22.8	+ 0.3
L = 18	23.9	24.1	23.6	+ 0.5
L = 20	25.5	25.7	24.9	+ 0.8
L = 22	27.4	27.6	27.1	+ 0.5
L = 24	30.3	30.9	29.7	+ 1.2
L = 26	**33.4**	**33.9**	**32.1**	**+ 1.8**
L = 28	35.2	35.9	34.8	+ 1.1
L = 30	37.7	38.3	37.5	+ 0.8
L = 32	39.1	39.7	39.1	+ 0.6
L = 34	40.5	40.8	40.5	+ 0.3
L = 36	40.4	40.2	40.4	– 0.2
L = 38	39.8	39.6	40.0	– 0.4
L = 40	37.7	37.6	37.6	0.0
L = 42	35.5	35.5	35.7	– 0.2

Variatie in DSI

Type of MECS	Minimum DSI	Maximum DSI	Mean DSI	±SD
Class II round-knitted (n=6)	12.6	28.1	16.5	5.7
Class II flat-knitted (n=7)	14.9	25.7	20.2	3.5
Class III round-knitted (n=3)	15.9	28.6	21.0	6.7
Class III flat-knitted (n=3)	18.0	25.7	21.6	3.9

MECS & DSI

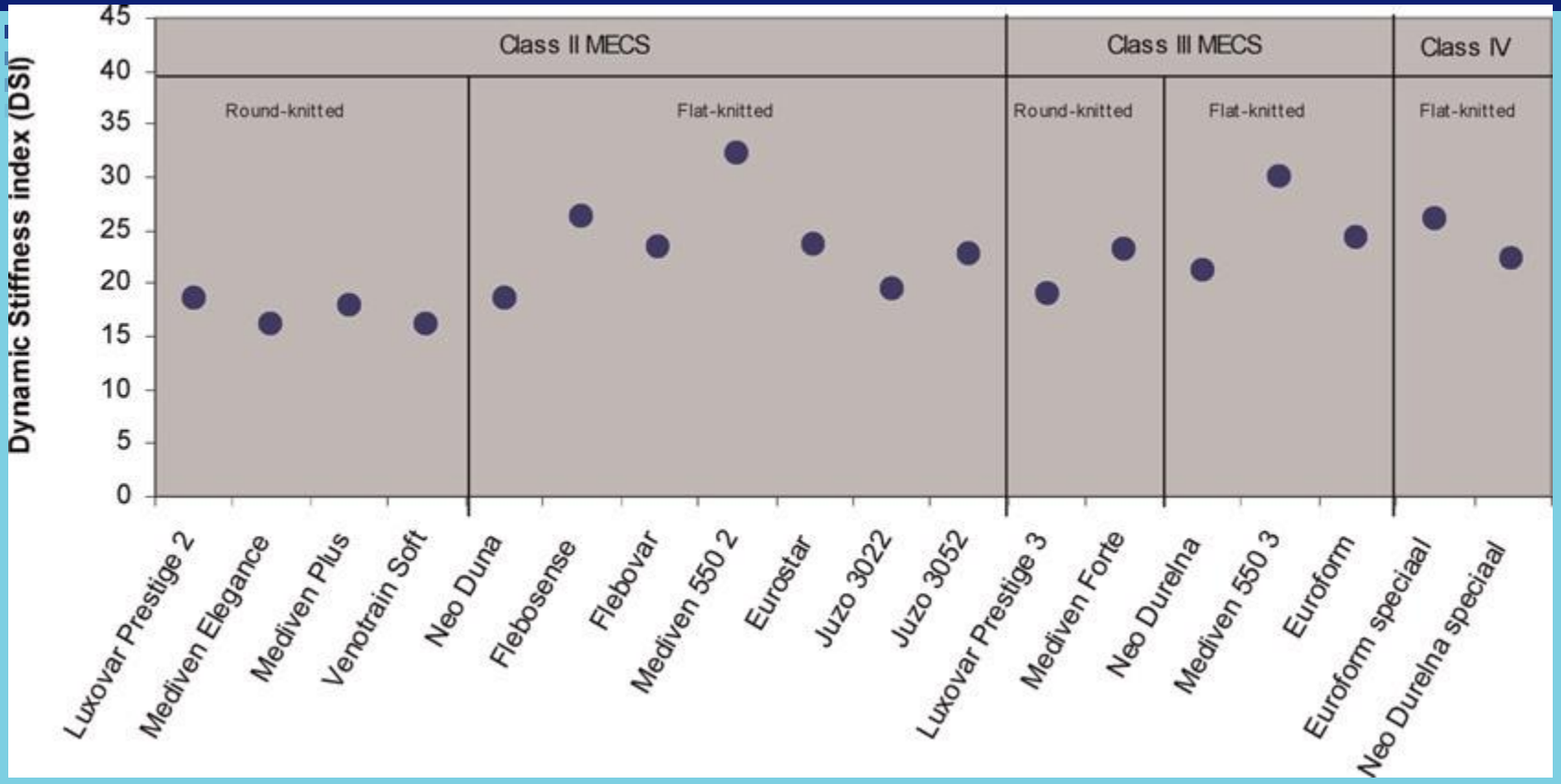


Figure 6 Distribution of dynamic stiffness index of 18 different brands of class II, class III MECS. Each dot represents one MECS

MECS & DSI

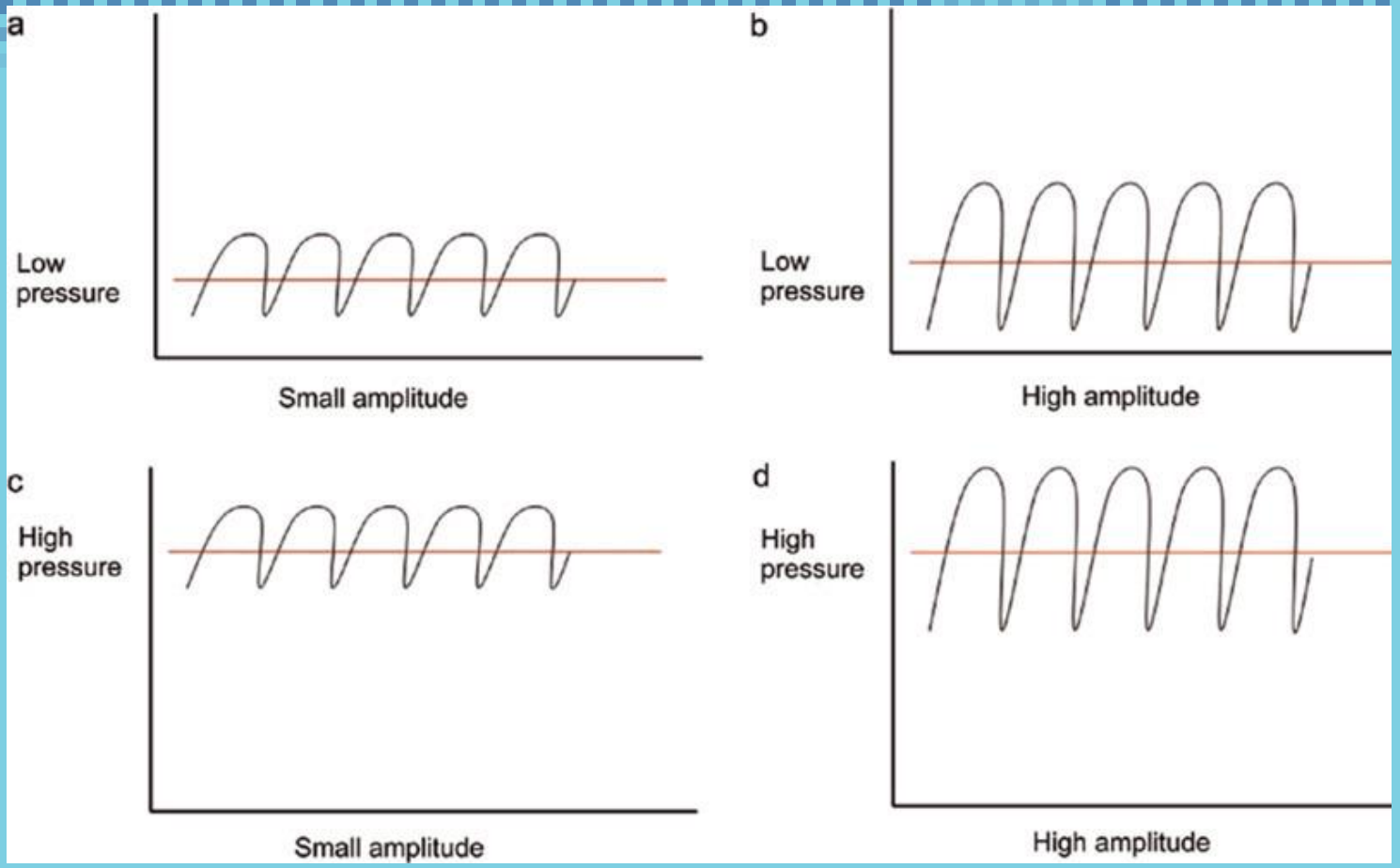
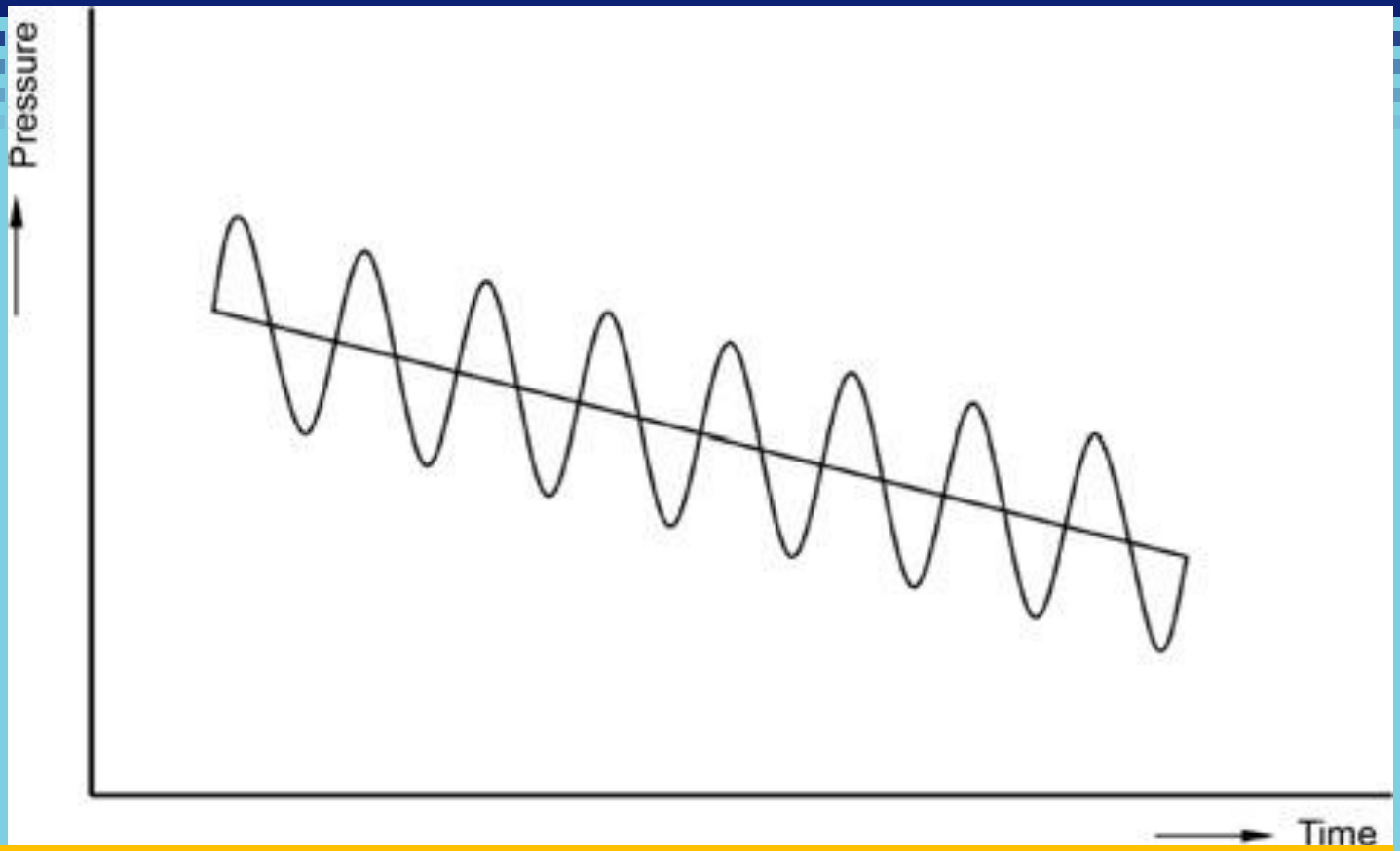


Figure 7 Four types of registration curves: (a) MECS with low compression and low DSI; (b) MECS with low compression and high DSI; (c) MECS with high compression and low DST; (d) MECS with high compression and high DSI

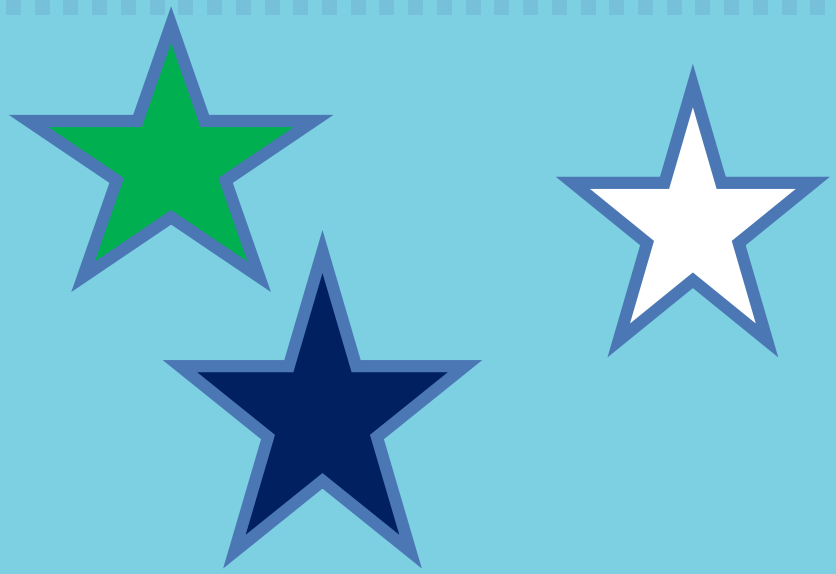
MECS & DSI



Example of a stocking that shows a decrease in pressure and continuous pressure pulsations (dynamic stiffness index) during the day

The players in the field

- Compression
- Hysteresis
- Venous return



The relation between pressure, slope and venous function

Conclusions I

The active behavior of the MECH during normal walking differed considerably from its passive behavior

DSI

We defined the Dynamic Stiffness Index (DSI) as a important characteristic of compression therapy and specially for the MECH based on the dynamic pressure profile

Elasticity and DSI

Insertion of non-elastic materials into the MECH covering overlying the expanding muscles increased the DSI. This may increase the therapeutic effect of the MECH

Influence of elasticiy on DSI

	Circumference variation of the MCH in cm	Pressure changes in the air-filled drum in mmHg	Calculated DSI in mm Hg / cm
Exp.#150 MCH without non-elastic material	2.82 % x 25.0 cm = 0.70 cm	From 10.8 to 51.2 mm Hg, this is 40.4 mm Hg	40.4 / 0.70 = 58 mm Hg / cm
Exp.#151 MCH with non- elastic material	2.75 % x 25.0 cm = 0.69 cm	From 1.5 to 57.3 mm Hg, this is 55.8 mm Hg	55.8 / 0.69 = 81 mm Hg / cm

Conclusions II

1. The type of knitwear defines the efficacy of MECS
2. The DSI defines the quality of compression expressed as interface pressure: Laplace low
3. The composition of the tissue defines the final effect *in* the leg:

   Pascal low
4. Optimize of venous functions depends on all 3 points