COMPRESSION

Hemodynamic Rational
XII CHIVA meeting
Hannover May 2012

Claude Franceschi

COMPRESSION

Positive clinical effects in venous and lymphatic diseases are today indisputable

BUT

COMPRESSION

Pathophysiological Interpretation

Techniques

Indications

Are still today disputed

Leg COMPRESSION

1-Hemodynamic concept of venous drainage

2-Hemodynamic effects of compression

3-Means and compression techniques features and their specific hemodynamic effects

4-Proposals for rational hemodynamic compression

Leg COMPRESSION

Positive clinical effects

By the mean of drainage improvement in :

- Edema Volume reduction
- Ulcer and wounds healing
- Pain relieve

in

- Venous insufficiency
- Lymphatic insufficiency

By the mean of stasis reduction in:

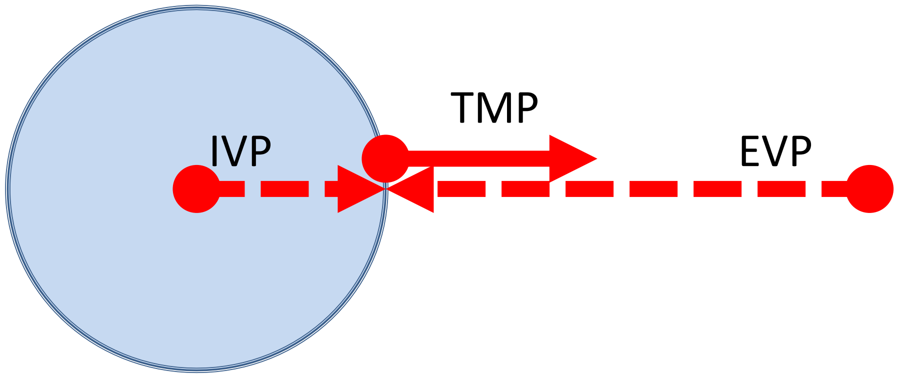
- Phlebitis treatment and prevention

1-Hemodynamic concept of venous drainage

Hemodynamics can be defined as:
the physical factors that govern blood flow which are the same physical factors that govern the flow of any fluid, and are based on a fundamental law of physics.

TRANS-MURAL PRESSURE (TMP) is the hemodynamic key point of the venous drainage because it determines the transfer of fluids and their components from the tissue into the venous bed.

VENOUS DISEASE?
Just THINK TMP!



TRANS-MURAL PRESSURE (TMP)

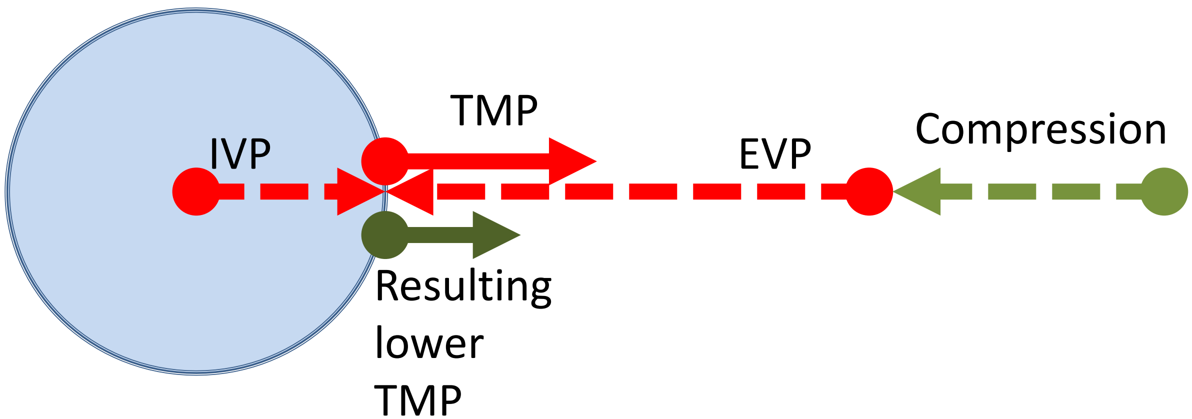
HEMODYNAMIC CORRECTION OF TMP EXECSS.

TMP = IVP-EVP

DECREASE IVP by :

COMPESSION

Increasing physiological EVP with external ARTIFICIAL means

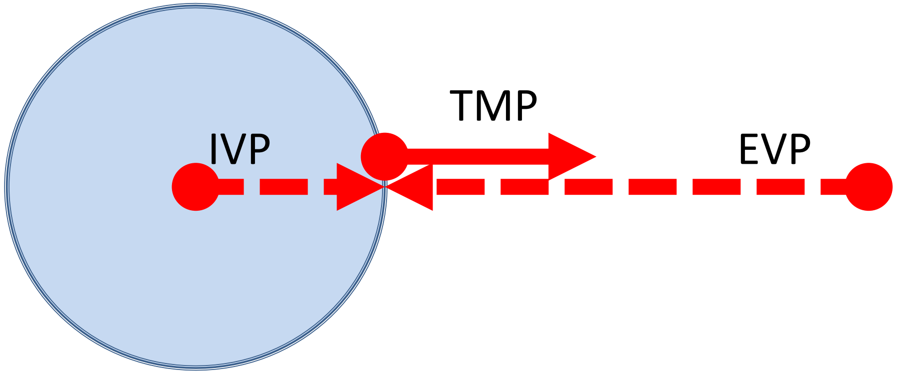


TRANS-MURAL PRESSURE (TMP)

Is the resulting static pressure from the opposite Extra-venous (EVP) and Intra-venous (IVP) static (potential) pressures against:

- the wall of the veins and
- venous end of the capillaries.

TMP = IVP-EVP



TRANS-MURAL PRESSURE (TMP)

At the veins level:

IVP is a venous Static Pressure made of :

1-Gravitational pressure: ρ g h (h = liquid height ρ = liquid density g = gravitational acceleration).

2-Static component of the Pressure made of:

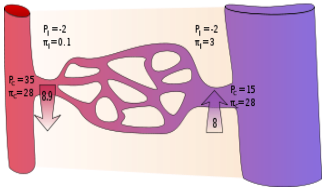
a-Residual pressure resulting of the arterial pressure throughout the microcirculation resistance, and

b-Muscular pump pressure produced by the valvo-muscular pump.

EVP is the static pressure made of:

1-Atmospheric pressure (AtP)

2-Muscles , interstitial fluids and aponeurosis pressure (TP)



TRANS-MURAL PRESSURE (TMP)

At the level of the venous end of the capillaries :

IVP is a venous Static Pressure made of :

)

VENOUS IVP + Osmotic plasma pressure (OPP)

VENOUS EVP + Osmotic Interstitium pressure (OIP)

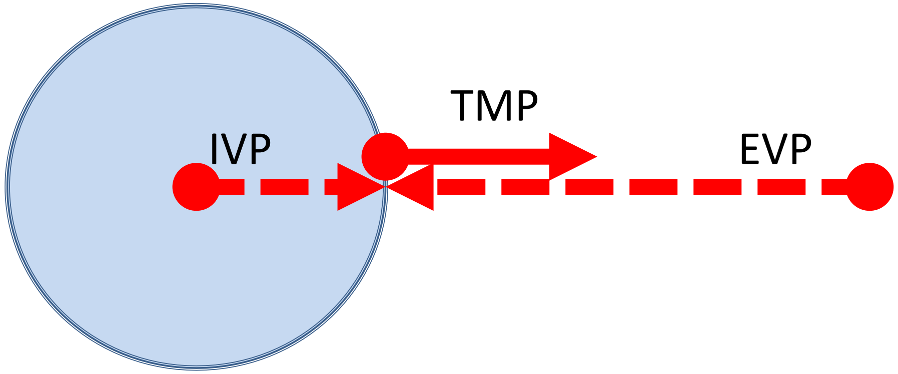
TRANS-MURAL PRESSURE (TMP)

HEMODYNAMIC CORRECTION OF TMP EXECSS.

TMP = IVP-EVP

1-DECREASE IVP and/or

2-INCREASE EVP



TRANS-MURAL PRESSURE (TMP)

HEMODYNAMIC CORRECTION OF TMP EXECSS.

TMP = IVP-EVP

DECREASE IVP by :

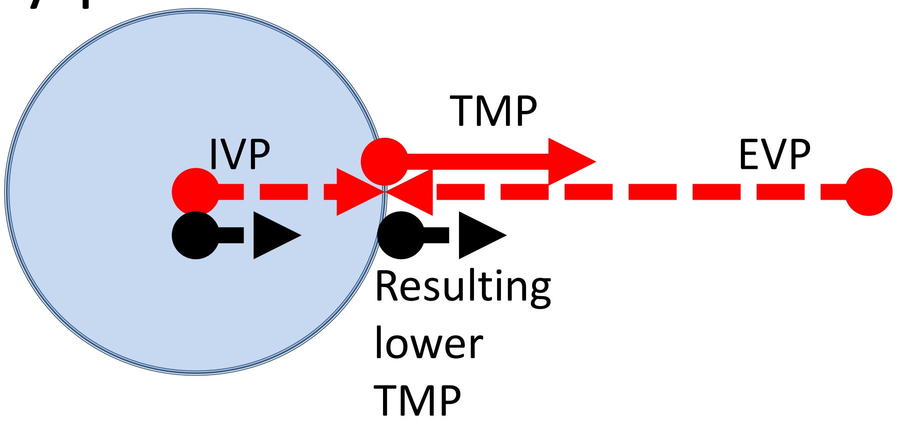
1- Gravitational Pressure(GP) Decrease and/or

2 - If Valve incompetence:

a-Incompetent Valve repair or new valve

b-Closed shunts disconnection + Column fractionning (CHIVA)

3 – if obstacle: By-pass or liberation

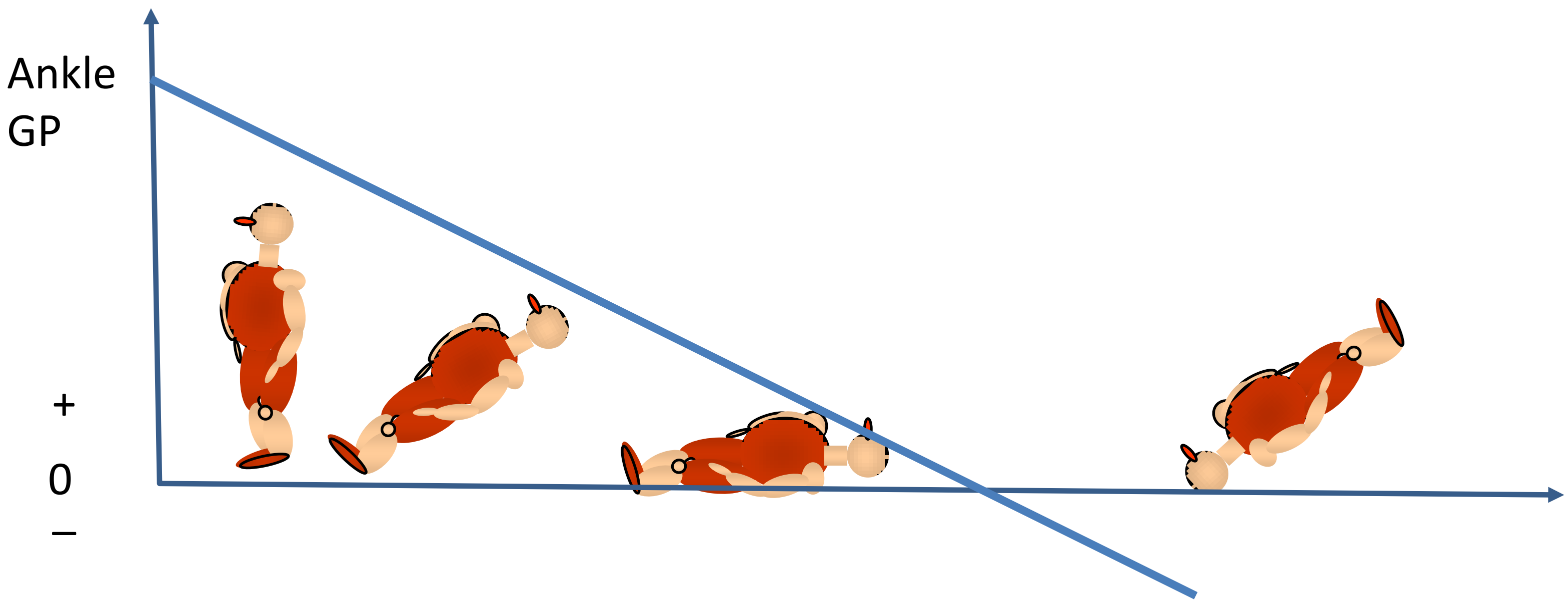


TRANS-MURAL PRESSURE (TMP)
HEMODYNAMIC CORRECTION OF TMP EXECSS.

TMP = IVP-EVP

DECREASE IVP :

1- Decrease Gravitational Pressure: POSTURAL TREATMENT: The more the foot is elevated, the less the Gravitational Pressure (GP)



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TRANS-MURAL PRESSURE (TMP)

HEMODYNAMIC CORRECTION OF TMP EXECSS.

TMP = IVP-EVP

DECREASE IVP by :

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TRANS-MURAL PRESSURE (TMP)

HEMODYNAMIC CORRECTION OF TMP EXECSS.

TMP = IVP-EVP

COMPESSION

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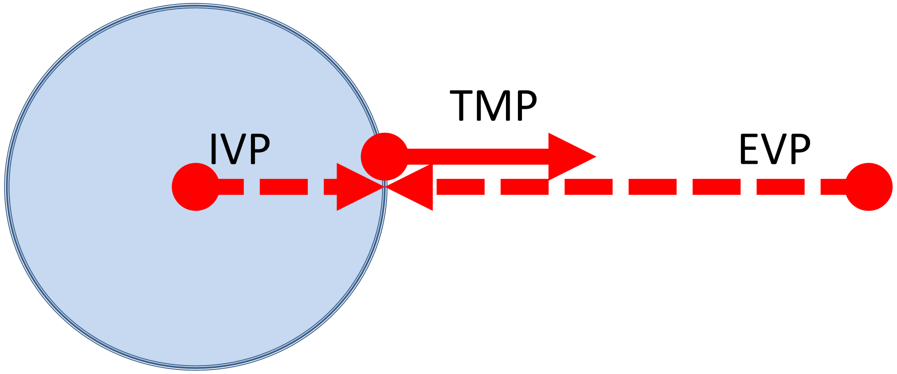
TMP = IVP-EVP

Decrease the TMP by the mean of Increasing physiological EVP with external ARTIFICIAL means



TRANS-MURAL PRESSURE (TMP)

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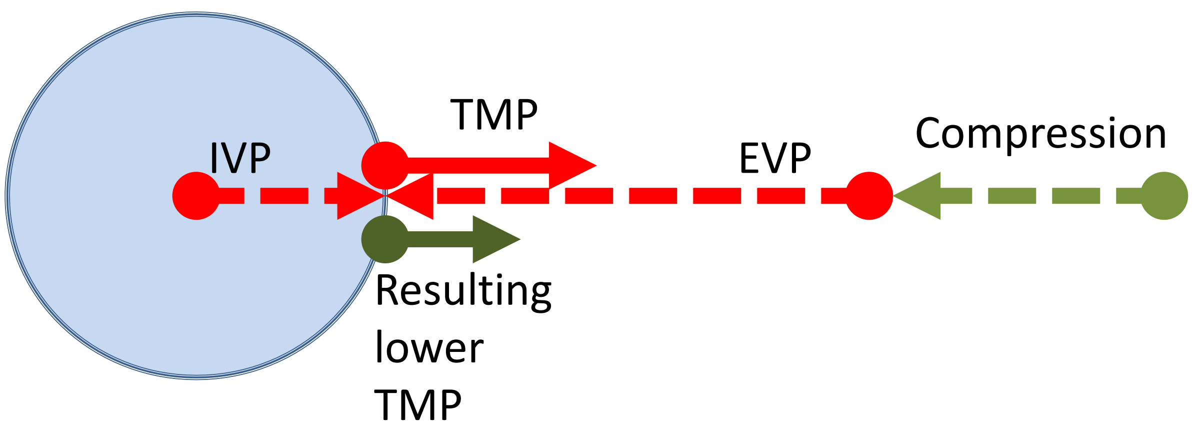
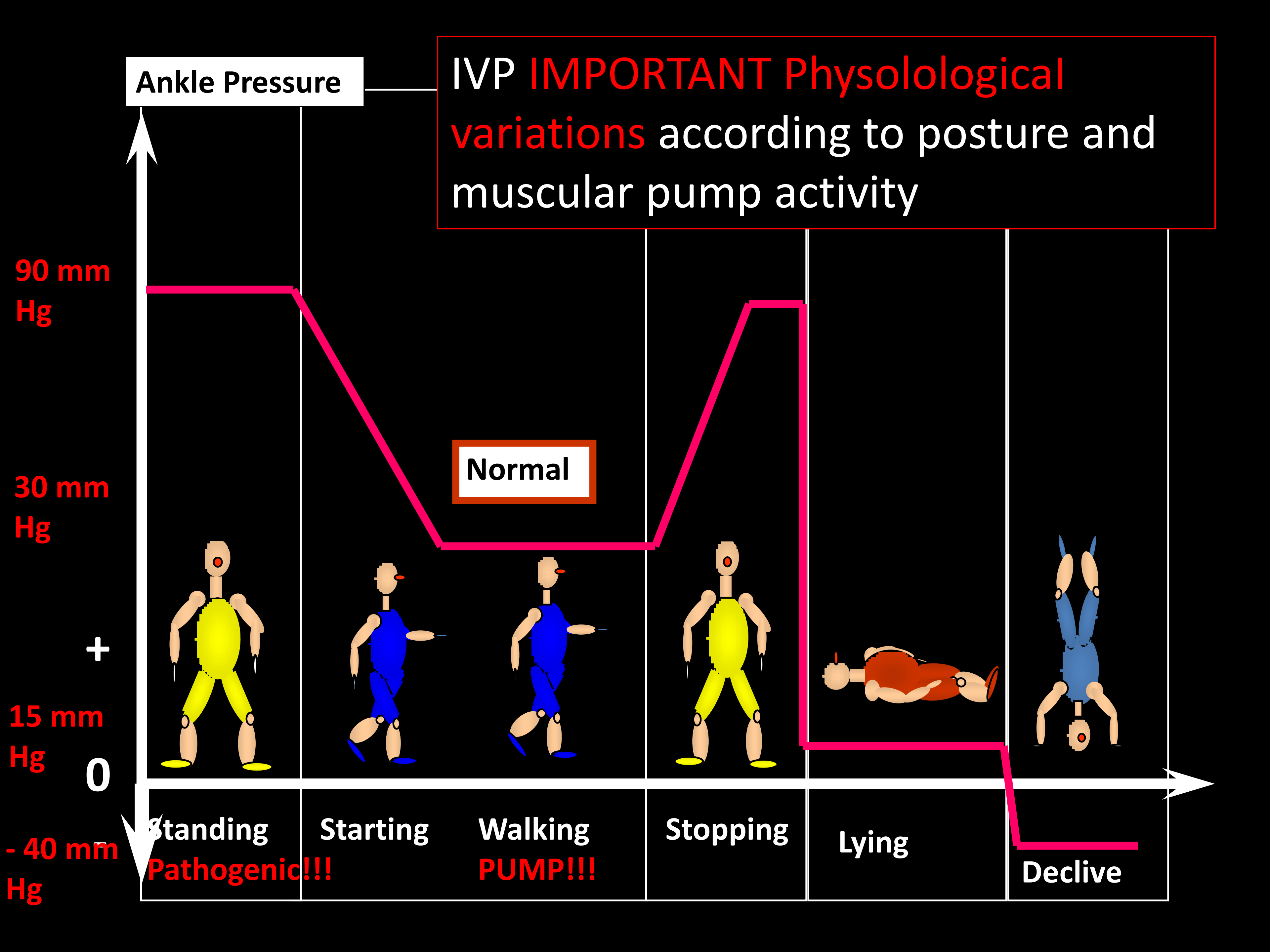
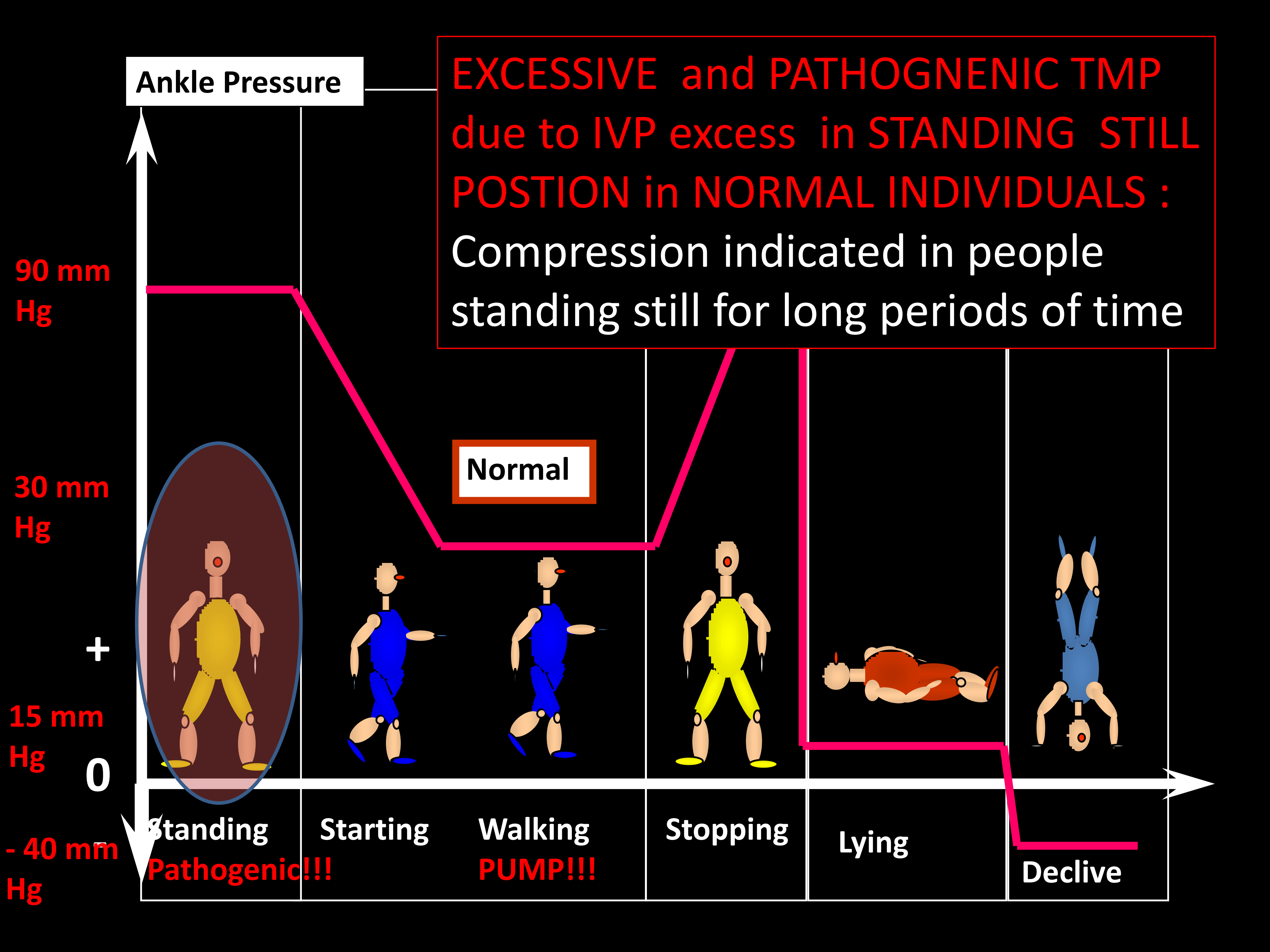
DECREASE IVP by :

COMPESSION

Increasing physiological EVP with external ARTIFICIAL means




IVP IMPORTANT Physolological variations according to posture and muscular pump activity
Ankle Pressure
90 mm Hg
30 mm Hg
+
15 mm Hg
0
- 40 mm Hg
-
Normal
Standing
Pathogenic!!!
Starting
Walking
PUMP!!!
Stopping
Lying
Declive


Ankle Pressure
EXCESSIVE and PATHOGNENIC TMP due to IVP excess in STANDING STILL POSTION in NORMAL INDIVIDUALS :
Compression indicated in people standing still for long periods of time
90 mm Hg
30 mm Hg
Normal
+
15 mm Hg
0
- 40 mm Hg
Standing
Pathogenic!!!
Starting
Walking
PUMP!!!
Stopping
Lying
Declive

Oedema, Varices,Trophiques Changes , Ulcer

When related to venous insufficency

Are caused by a TMP excess

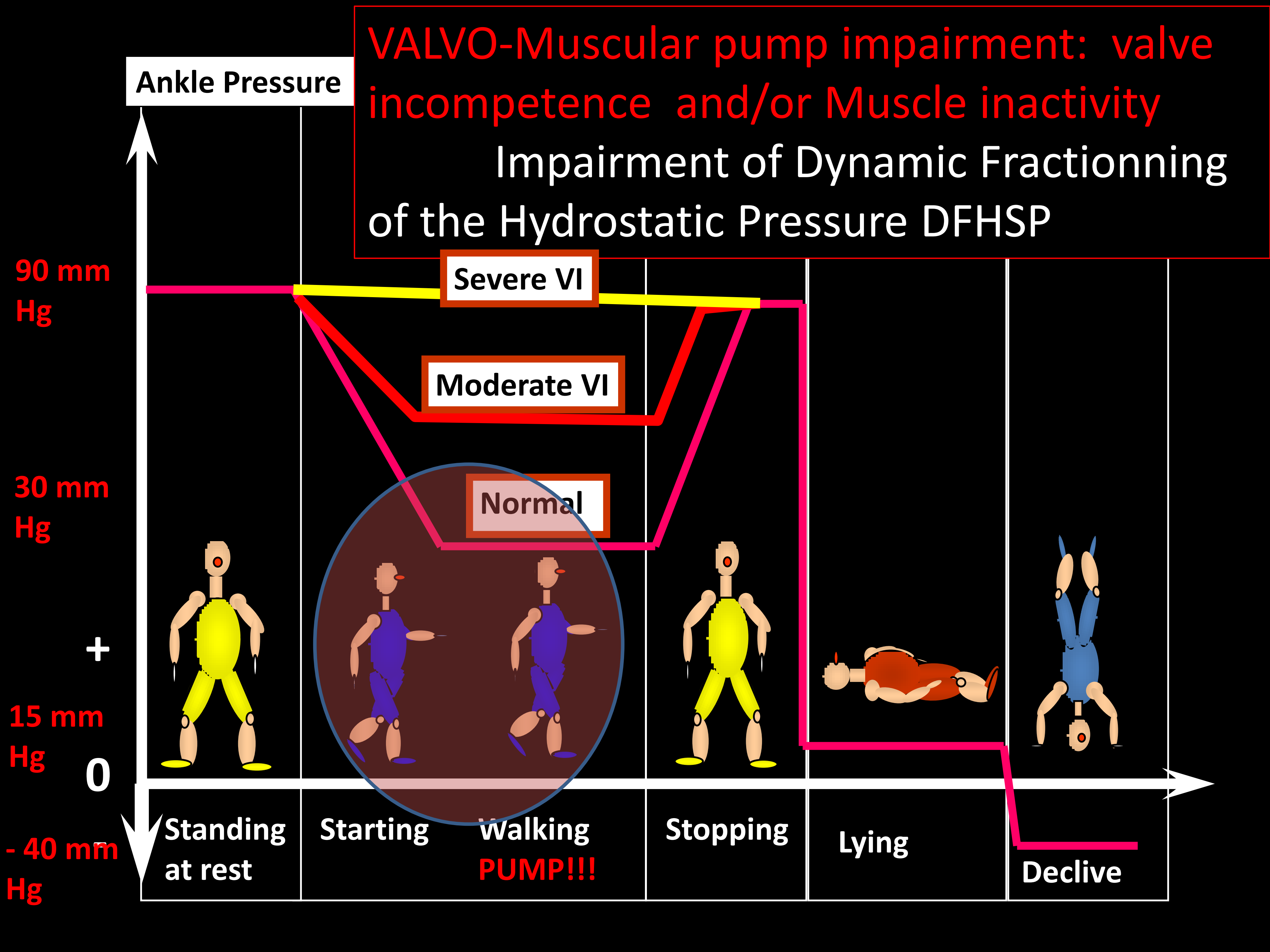
CAUSES FOR TMP EXCESS

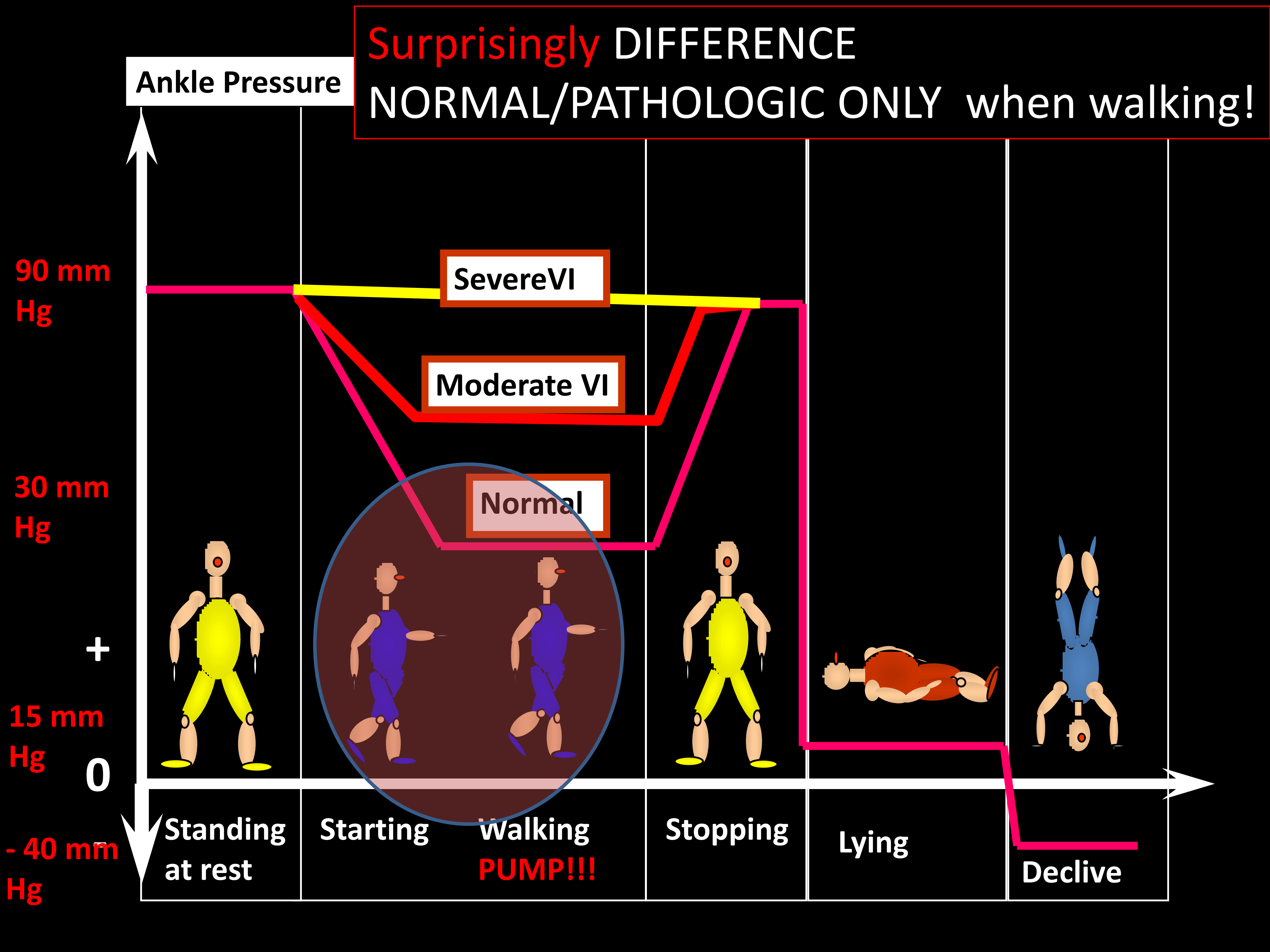
1- VALVULAR INCOMPETENCE and/or Muscle inactivity

Impairment of Dynamic Fractionning of the Hydrostatic Pressure DFHSP

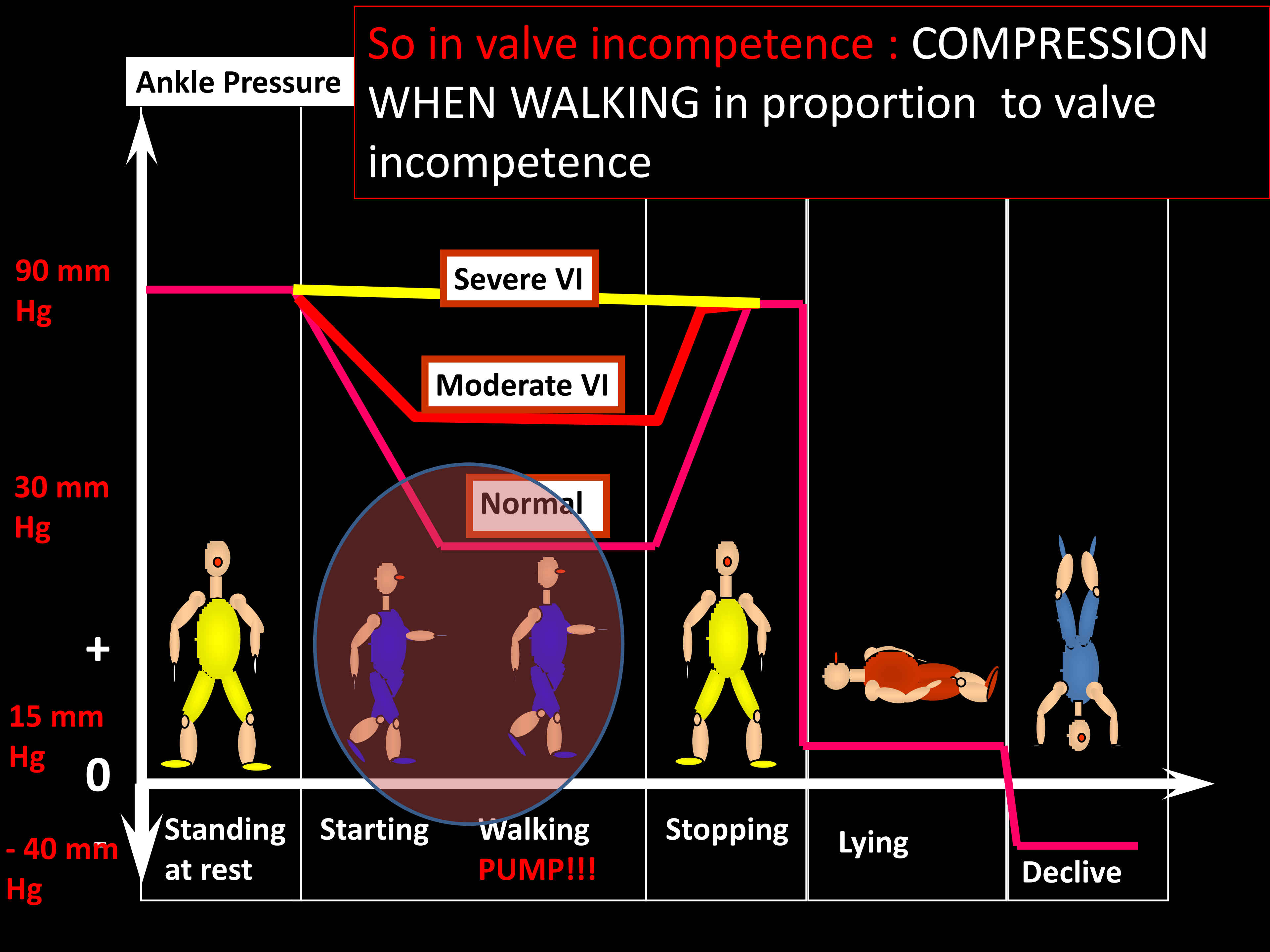
2- OBSTACLE to the FLOW

Excess of RESIUAL PRESSURE

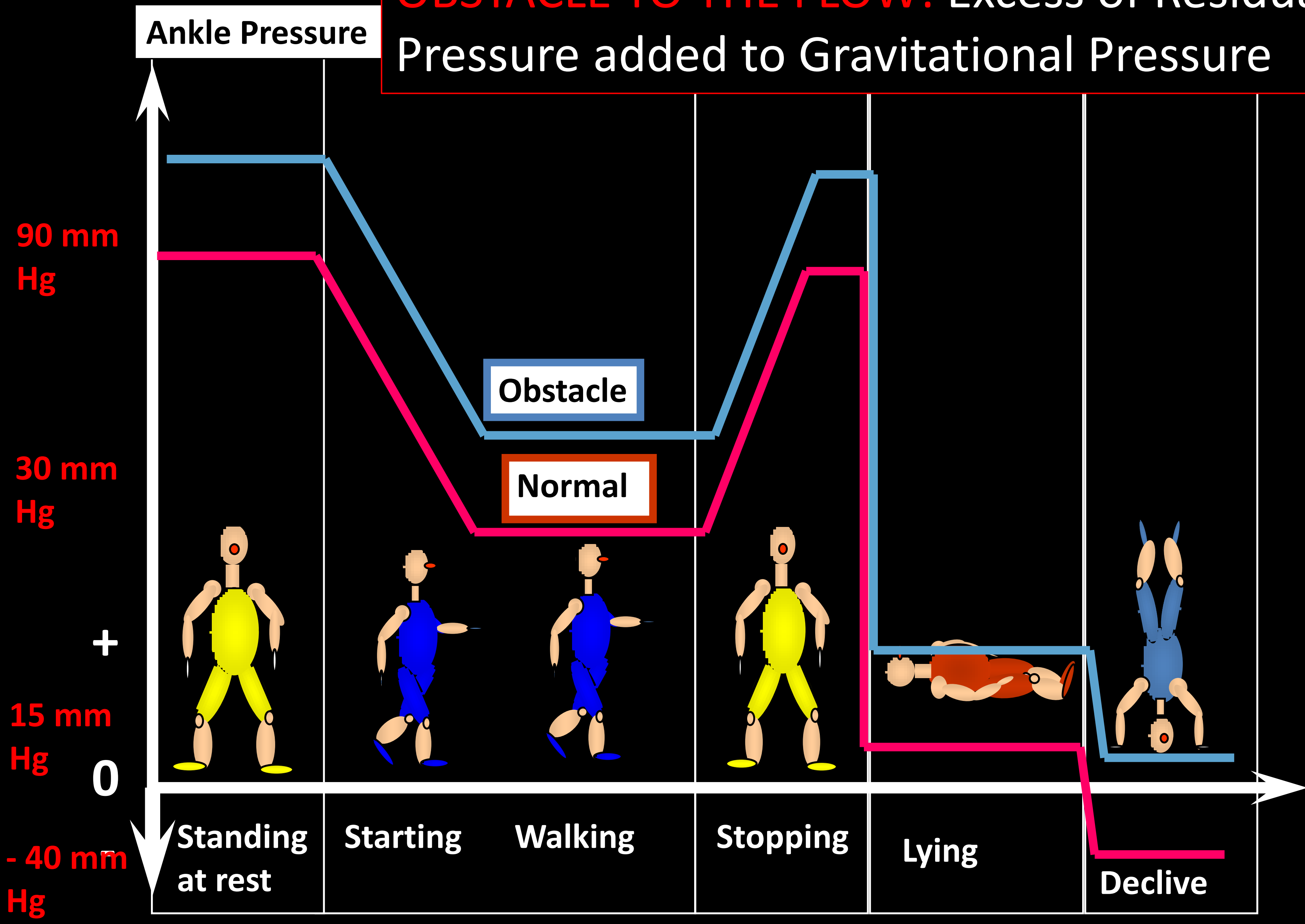

VALVO-Muscular pump impairment: valve incompetence and/or Muscle inactivity
Impairment of Dynamic Fractionning of the Hydrostatic Pressure DFHSP
Ankle Pressure
90 mm Hg
30 mm Hg
+
15 mm Hg
0
- 40 mm Hg
Severe VI
Moderate VI
Normal
Standing at rest
Starting
Walking
PUMP!!!
Stopping
Lying
Declive

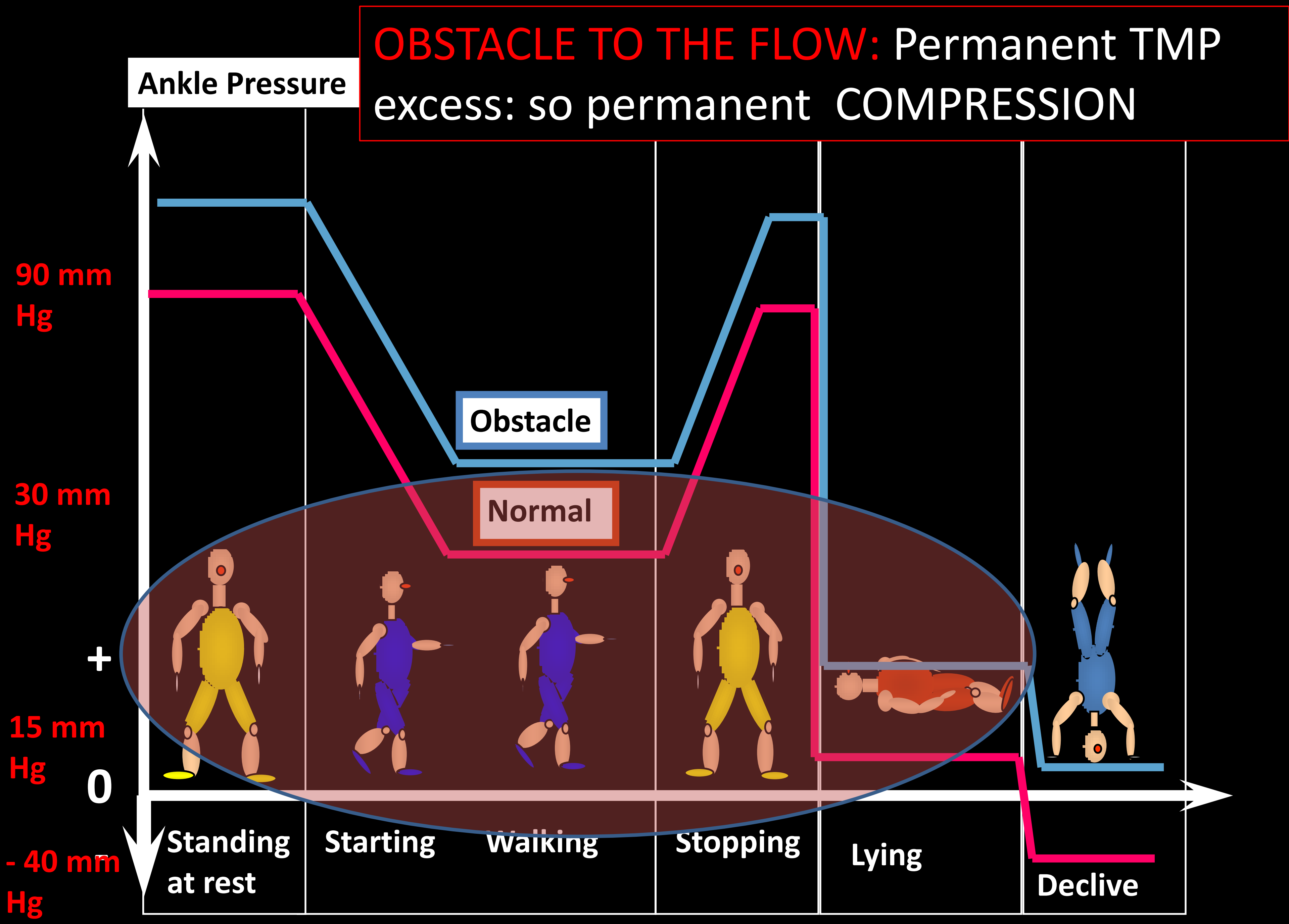


Surprisingly DIFFERENCE
NORMAL/PATHOLOGIC ONLY when walking!
Ankle Pressure
90 mm Hg
30 mm Hg
+
15 mm Hg
0
- 40 mm Hg
SevereVI
Moderate VI
Normal
Standing at rest
Starting
Walking
PUMP!!!
Stopping
Lying
Declive


So in valve incompetence : COMPRESSION WHEN WALKING in proportion to valve incompetence
Ankle Pressure
90 mm Hg
30 mm Hg
+
15 mm Hg
0
- 40 mm Hg
Severe VI
Moderate VI
Normal
Standing at rest
Starting
Walking
PUMP!!!
Stopping
Lying
Declive

OBSTACLE TO THE FLOW: Excess of Residual Pressure added to Gravitational Pressure





OBSTACLE TO THE FLOW: Permanent TMP excess: so permanent COMPRESSION
Ankle Pressure
90 mm Hg
30 mm Hg
+
15 mm Hg
0
- 40 mm Hg
Obstacle
Normal
Standing at rest
Starting
Walking
Stopping
Lying
Declive

Expected hemodynamic effects of external leg compression

Venous Trans-Mural-Pressure (TMP)

At the veins level:

IVP is a venous Hydrostatic pressure made of :

1-Gravitational pressure: ρ g h (h = liquid height ρ = liquid density g = gravitational acceleration).

2-Hydrostatic component of the Pressure made of:

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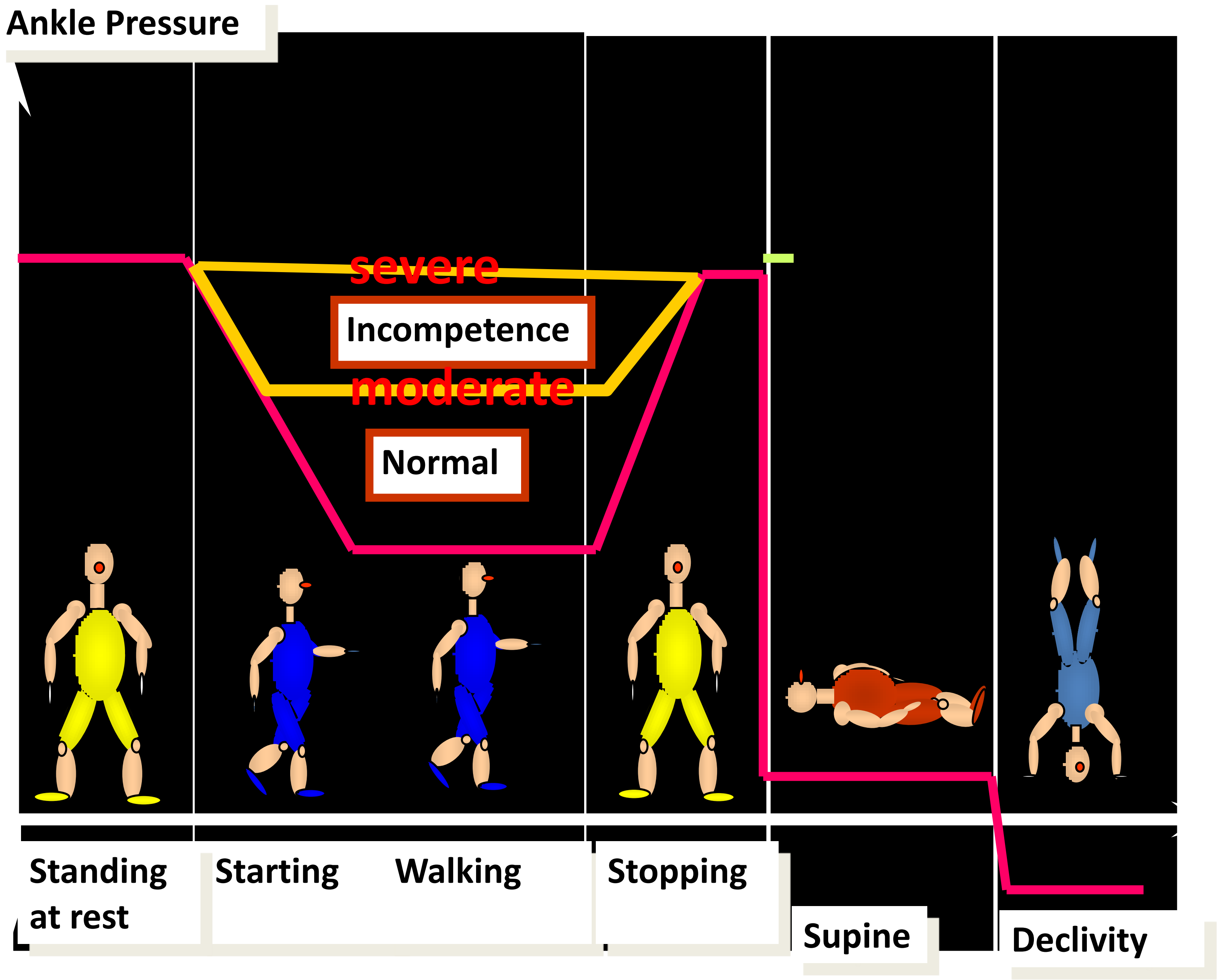
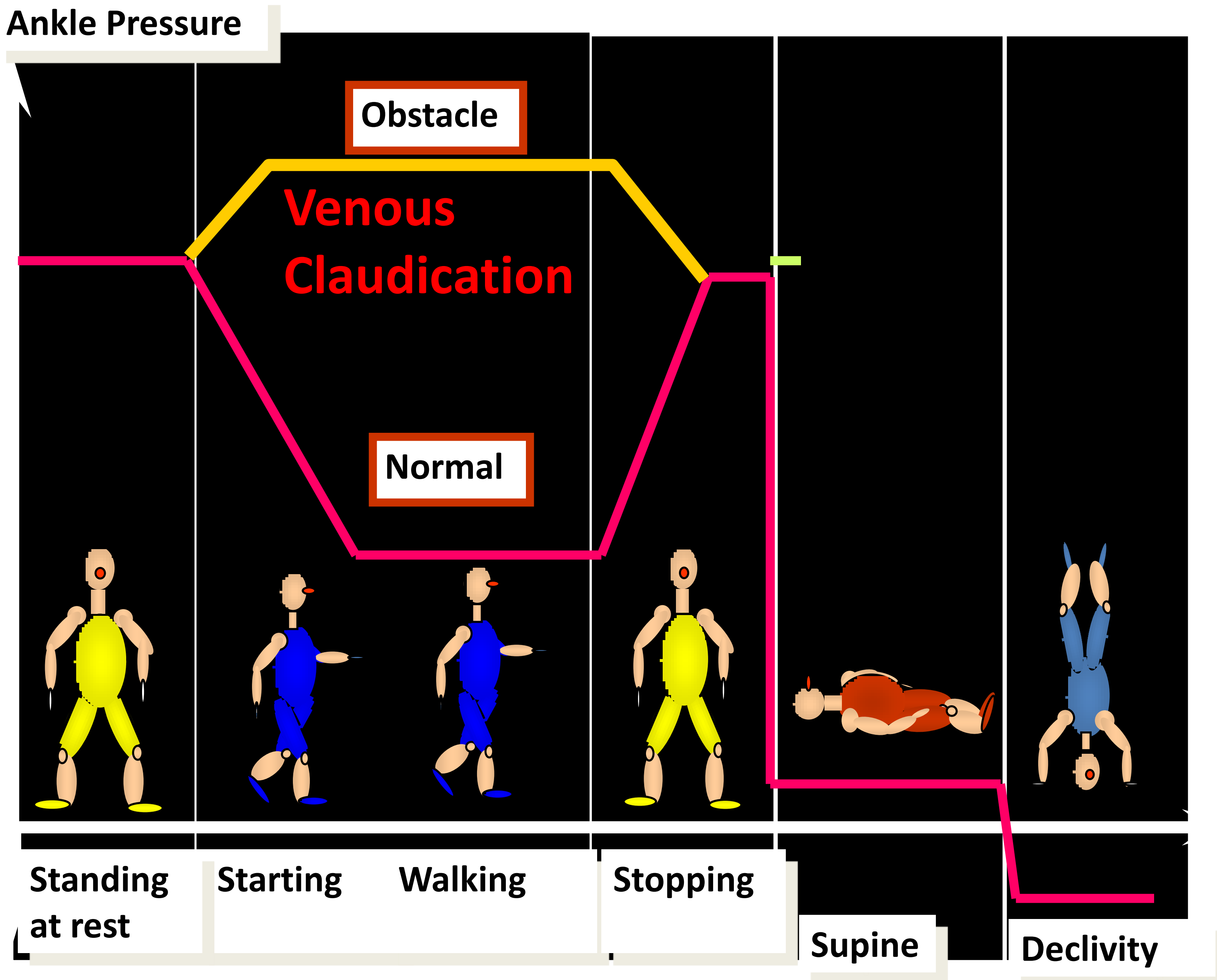


Ankle Pressure
severe
Incompetence
moderate
Normal
Standing at rest
Starting
Walking
Stopping
Supine
Declivity


Ankle Pressure
Obstacle
Venous
Claudication
Normal
Standing
at rest
Starting
Walking
Stopping
Supine
Declivity

TRANS-MURAL PRESSURE (TMP)

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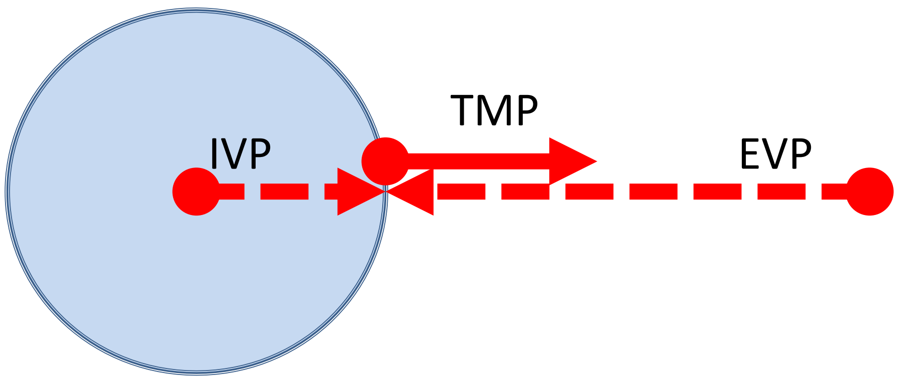

TRANS-MURAL PRESSURE (TMP)

HEMODYNAMIC CORRECTION OF TMP EXECSS.

TMP = IVP-EVP

INCREASE EVP

WHEN?

1-When EVP is too low

2-When IVP is too high

TRANS-MURAL PRESSURE (TMP)

HEMODYNAMIC CORRECTION OF TMP EXECSS.

TMP = IVP-EVP

INCREASE EVP

WHEN?

1-When EVP is too low: Too low ath.P (altitude, Plane)

TRANS-MURAL PRESSURE (TMP)

HEMODYNAMIC CORRECTION OF TMP EXECSS.

TMP = IVP-EVP

INCREASE EVP

WHEN?

2-When IVP is too high:

-Valve incompetence and/or

- Obstacle to the flow

NOT reductible or only partially reduced by hemodynamic treatments previously explained

TRANS-MURAL PRESSURE (TMP)

HEMODYNAMIC CORRECTION OF TMP EXECSS.

TMP = IVP-EVP

INCREASE EVP

HOW?

TRANS-MURAL PRESSURE (TMP)

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INCREASE EVP by :

COMPESSION

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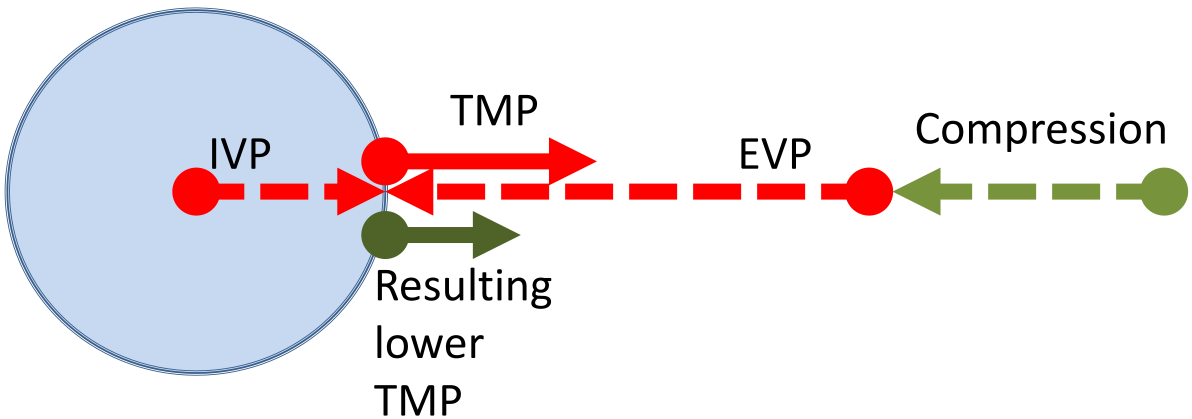


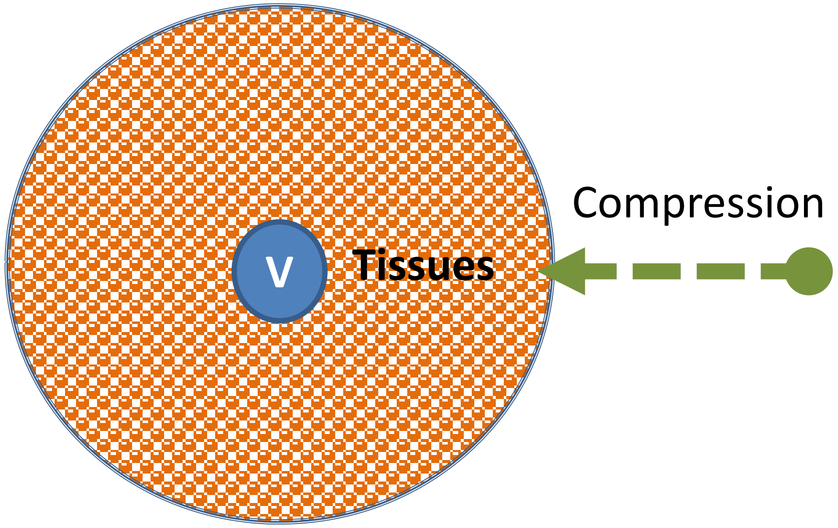
COMPRESSION: DEFINITION

Pressure resulting from action-reaction at the interface (contact) of 2 bodies

Expected hemodynamic effects of external leg compression

External Compression reduces TMP by increasing the static components of the EVP at both levels: Veins and venous end of the capillaries

EVP



LEG COMPRESSION RATIONNAL

Pressure compression exerted against the leg surface

Homogeneous (isostatic) or Heterogeneous (heterostatic)

according to :

Compression technique

Leg geometry

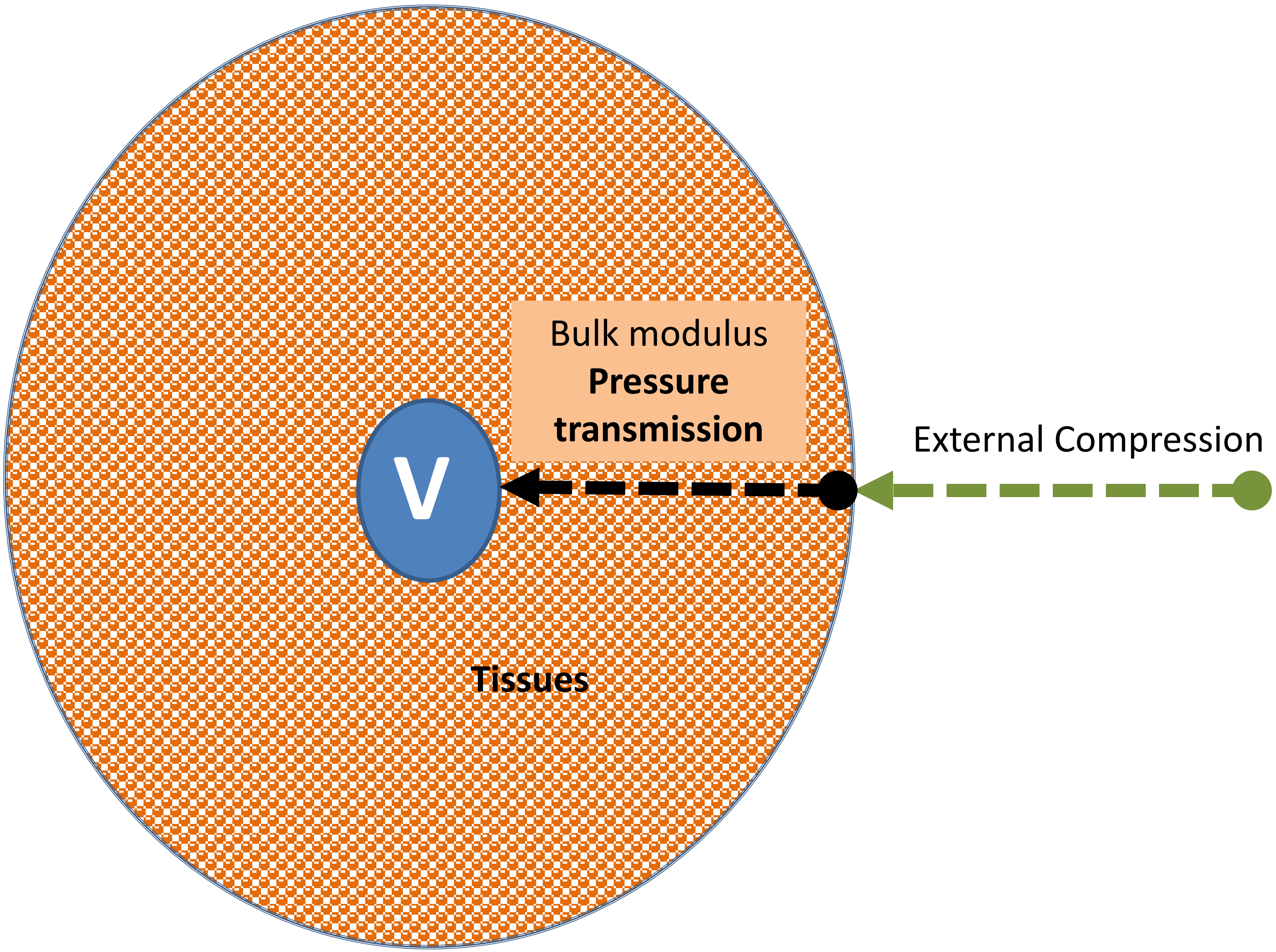
Pressure compression transmitted from surface to depth

according to:

Bulk modulus of leg structures

Euler–Cauchy stress principle

Continuum mechanics deals with deformable bodies. The stresses considered in continuum mechanics are only those produced during the application of external forces and the consequent deformation of the body


Bulk modulus
Pressure transmission
V
External Compression
Tissues

LEG COMPRESSION FEATURES ACCORDING TO THE PHYSICAL MEANS

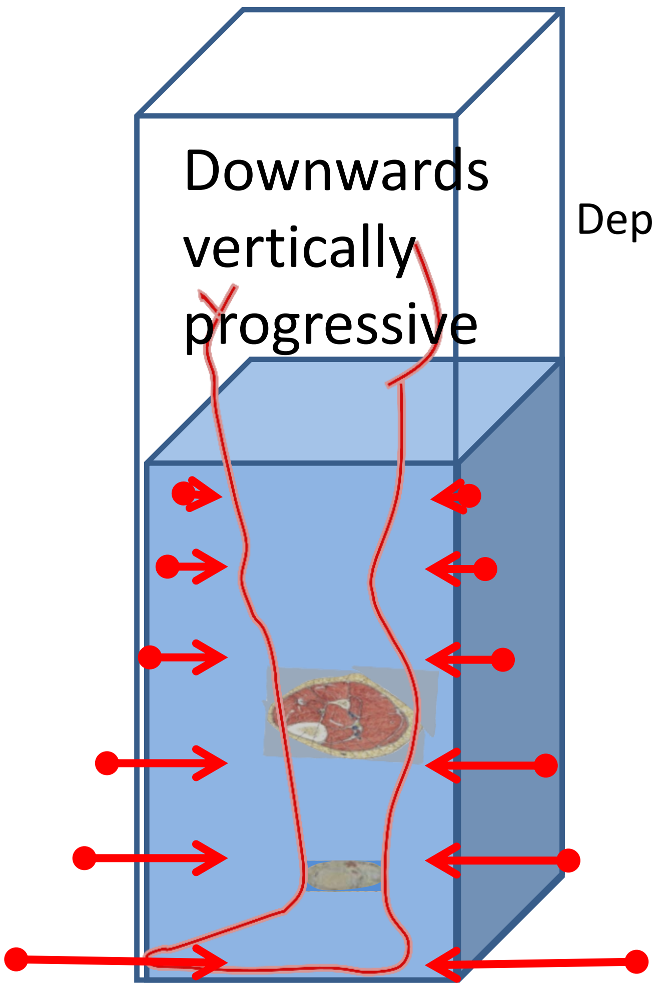
Into liquid immersion (pressure by load):
Independent on the leg geometry

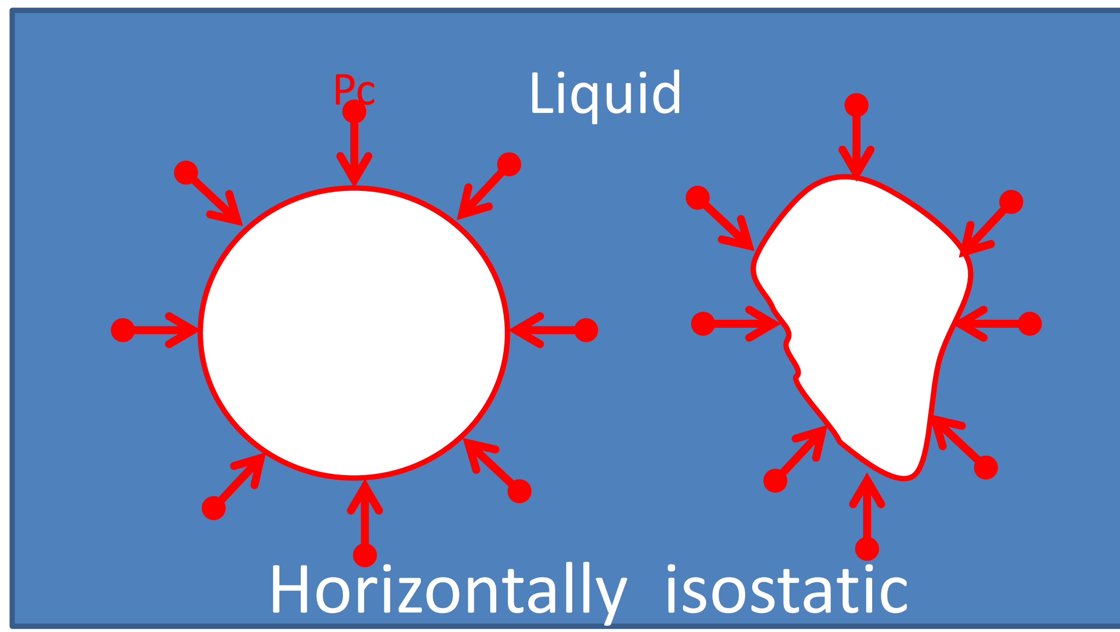
-Horizontally isostatic (uniformly distributed)

-Vertically downwards progressive (linearly distributed($Pc = \rho gh$)

h = liquid height ρ = liquid density

Dependent of gravitational pressure and liquid density

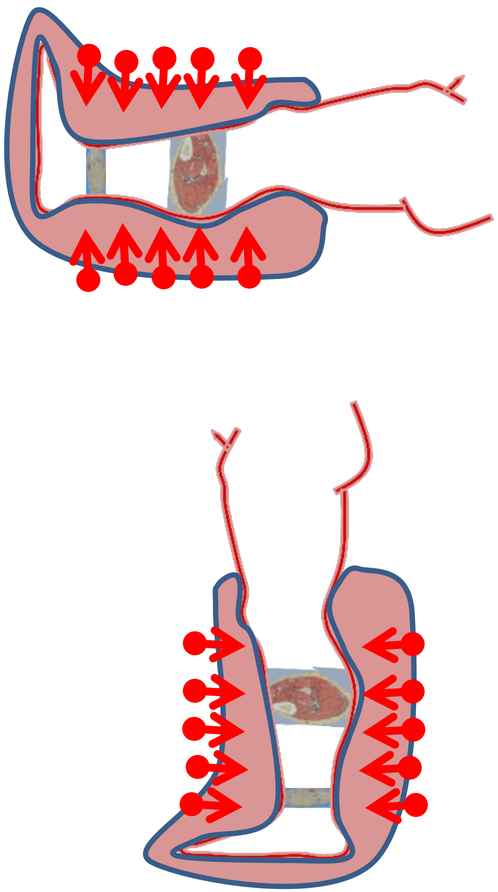


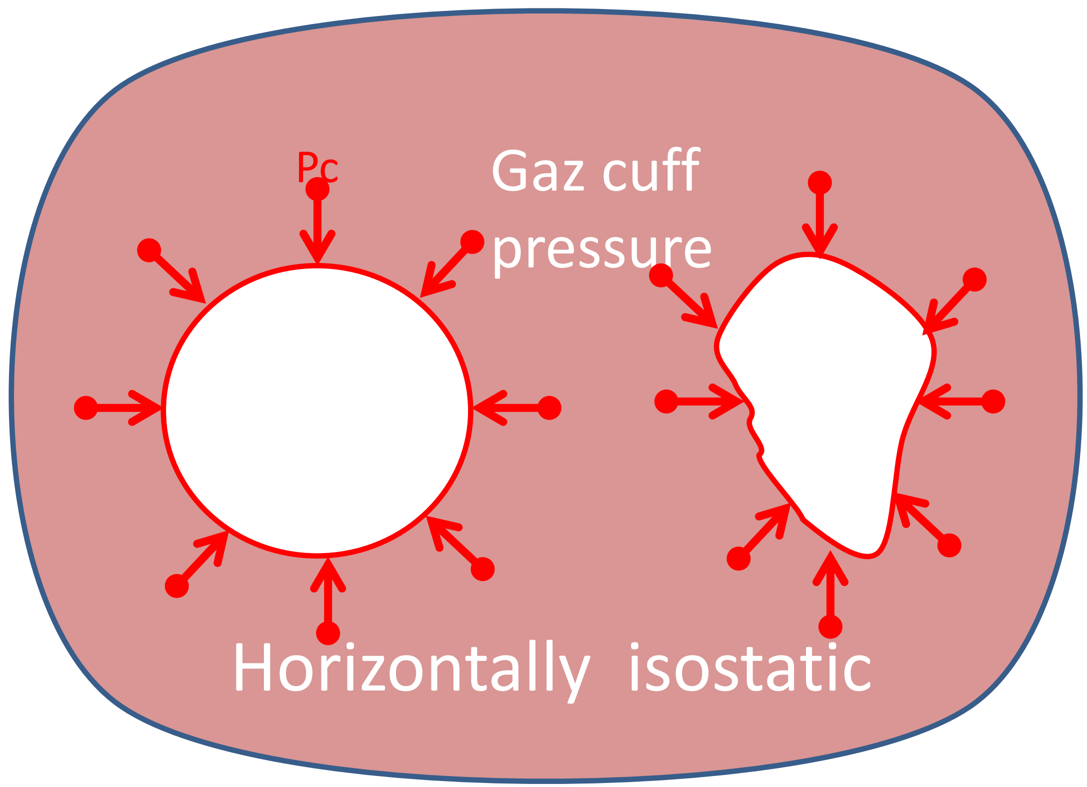


LEG COMPRESSION FEATURES ACCORDING TO THE PHYSICAL MEANS

Pneumatic compression (pressure by fluid density):
Independent on the leg geometry : uniformly distributed.

-Horizontally isostatic
-Vertically isostatic
Dependent of the inflation pressure
Independent of gravitational pressure and density





LEG COMPRESSION FEATURES ACCORDING TO THE PHYSICAL MEANS

Pressure compression Pc exerted against the leg surface:

Bandage compression: LAPLACE'S LAW

Pressure = F/wR = F/R when b=1cm

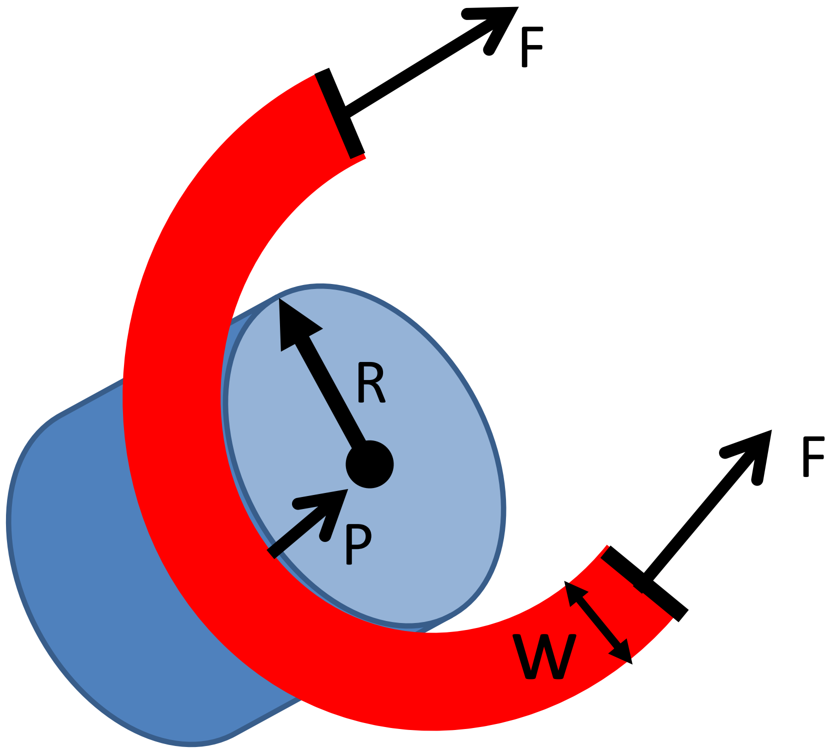
P: hPascal

F: cNewton

w= bandage width

R= cylinder radius

1mmHg = 1,333 hPa = 1,359 cm water depth = 0,00131 atm



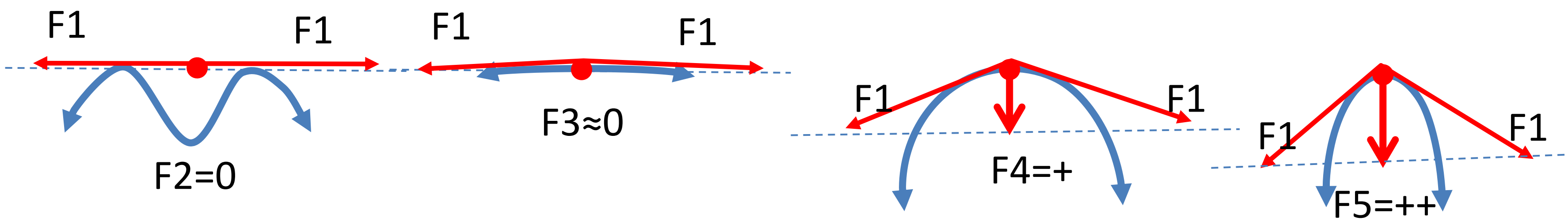
LEG COMPRESSION FEATURES ACCORDING TO THE PHYSICAL MEANS

Bandage compression:

Dependent on the leg circularity

Dependent of bandaging strength

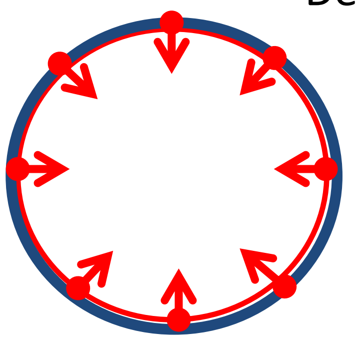
Dependent of leg mid diameter : Starling Law



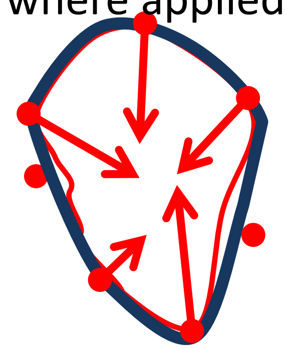
Bandaging (force) strength =F1

Resulting compression (Force) pressure: F5>F4>F3>F2

Depends on the arc angle where applied



Circular :
homogeneous transmitted pressure



Non Circular :
heterogeneous transmitted pressure

LEG COMPRESSION FEATURES ACCORDING TO THE PHYSICAL MEANS

Bandage compression:

Dependent on the leg circularity

Dependent of bandaging strength

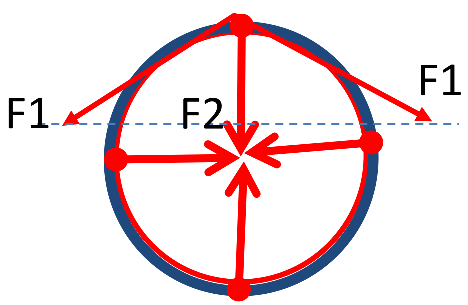
Dependent of leg mid diameter : Starling Law

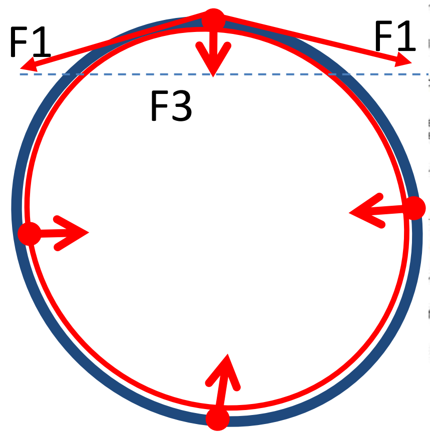
Bandaging (force) strength =F1

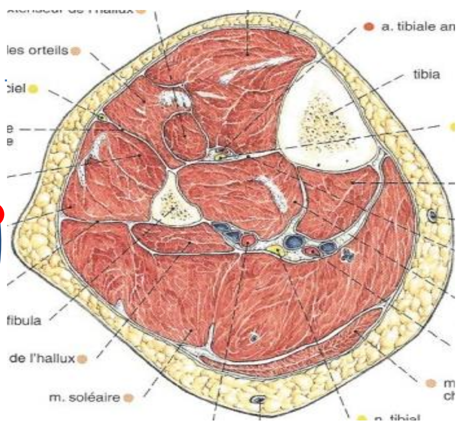
Resulting compression (Force) pressure: F2>F3

Depends on the mid diameter of the leg :

$$\text{Resulting P} = \frac{\text{Bandaging Force}}{\text{mid Leg Radius}}$$







Circular :

homogeneous transmitted pressure

LEG COMPRESSION FEATURES ACCORDING TO THE PHYSICAL MEANS

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Dependent on the leg circularity

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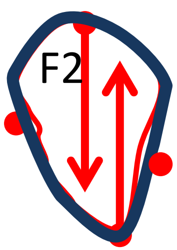
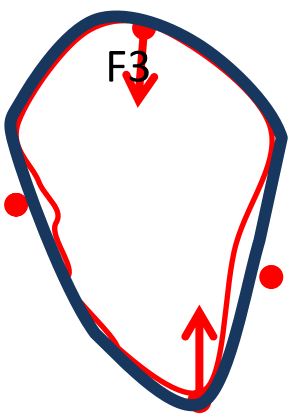
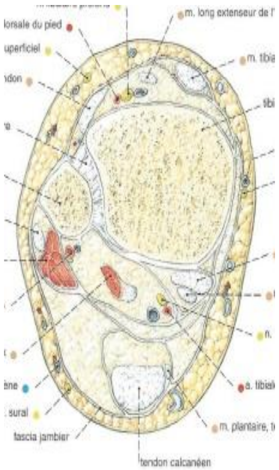






Non Circular :
heterogeneous transmitted pressure
eg ankle

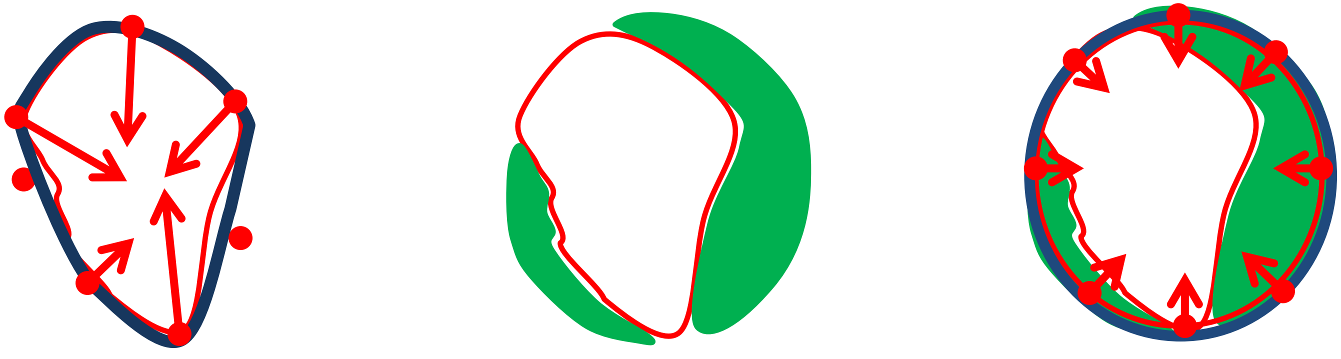
LEG COMPRESSION FEATURES ACCORDING TO THE PHYSICAL MEANS

Bandage compression:

- Dependent on the leg circularity
- Dependent of bandaging strength
- Dependent of leg mid diameter : Starling Law

For more homogenous compression:

Circularization of the leg with additional dressing

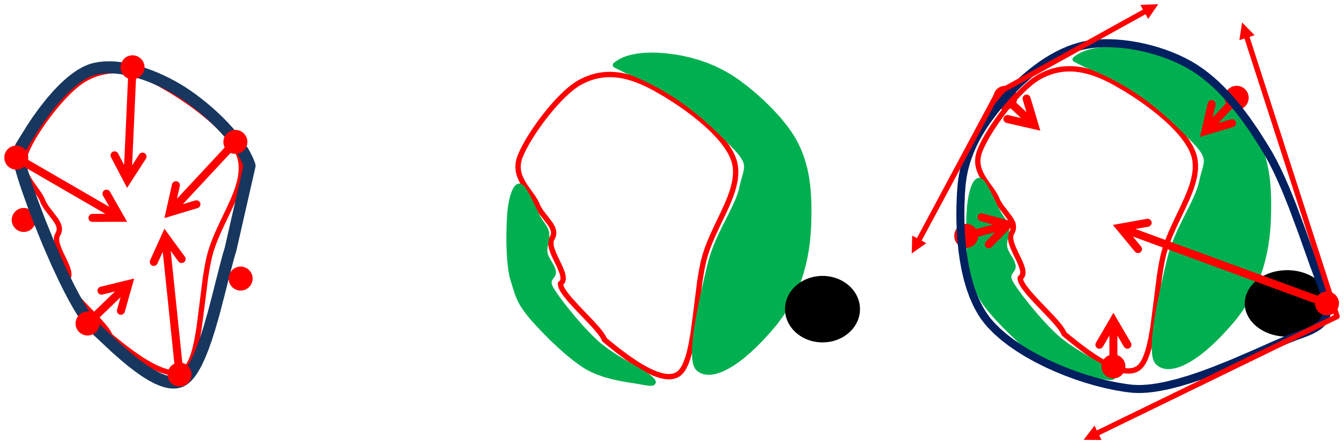


LEG COMPRESSION HEMODYNAMIC EFFECTS AND PHYSIOLOGICAL CONSEQUENCES

Bandage compression:

- Dependent on the leg circularity
- Dependent of bandaging strength
- Dependent of leg mid diameter : Starling Law

For more wanted heterogeneous compression:
Addition of small angle arc material



LEG COMPRESSION HEMODYNAMIC EFFECTS AND PHYSIOLOGICAL CONSEQUENCES

Bandage compression:

Dependent on the leg circularity

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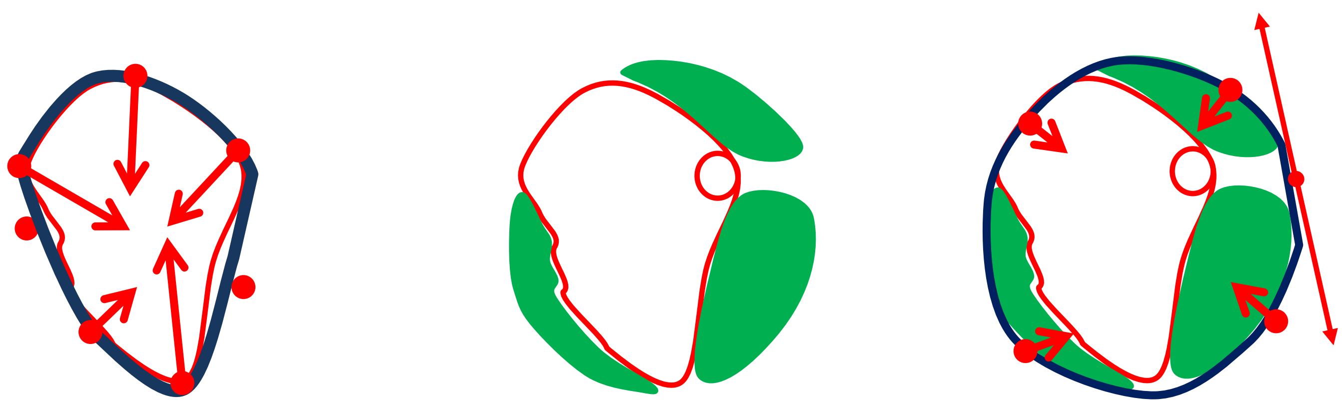
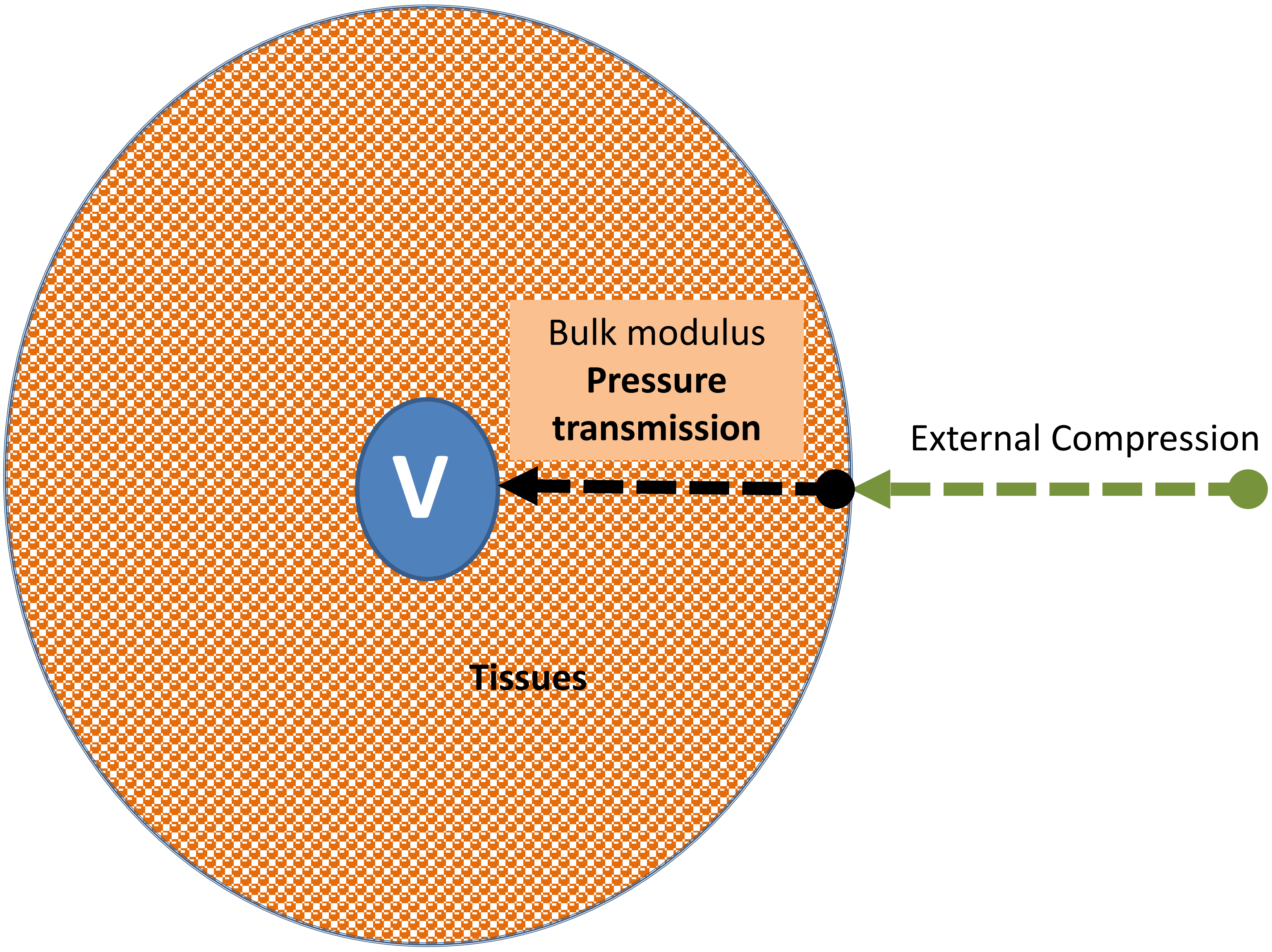
Dependent of leg mid diameter : Starling Law

For more wanted heterogeneous compression:

Unwanted local compression ie pedal or tibial arteries pathway




Bulk modulus
Pressure transmission
External Compression
V
Tissues

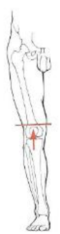
Compressive Pressure value transmitted from surface to depth depends on the elastic and the bulk modulus of the medium :

Leg components are basically heterogonous so that Elastic and Inertia Properties varies according to:

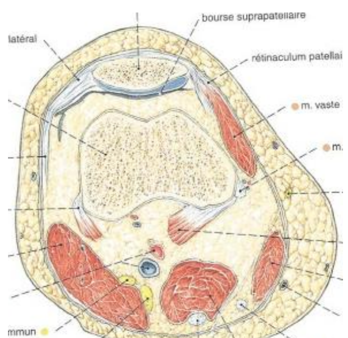
Topography: from thigh down to foot

Posture: Gravitational hydrostatic pressure

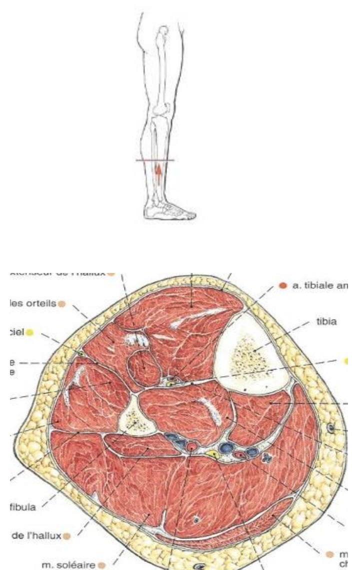
Movement: muscle volume and compressibility how much a material will compress under a given amount of external pressure



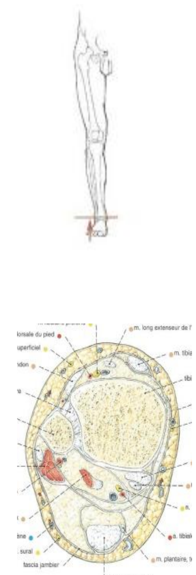
$$K = -V\frac{\partial P}{\partial V}$$



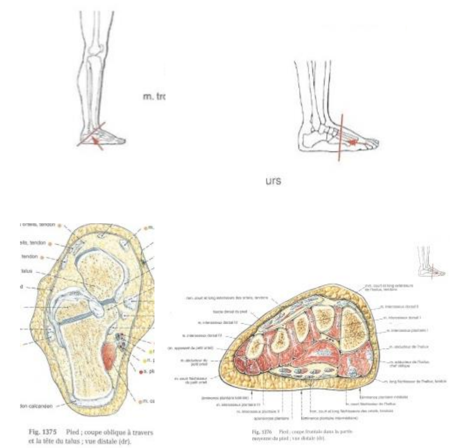
Circumference = 38 cm
Diameter = 12 cm



Circumference = 30 cm
Diameter = 10 cm



Circumference = 19 cm
Diameter = 6 cm



BANDAGE FEATURES

Extensibility : stretched length/unstretched length percentage. The stretching length limit is called "lock out"

Power (strength): force required to achieve a determinate elongation although "power" is an inadequate physical term.

Elasticity: ability to resist elongation then return to its original length once the applied force has been removed.

Compression : leg superficial pressure resulting from the bandage.

Support : no compressive bandage designed to prevent change in shape and volume the leg. Although support bandage is theoretically non extensible, a limited degree of extensibility is generally preferred as it is easier to apply.

Conformability : ability to follow the contours of a limb provided by multidimensional extensibility..

Stiffness of a compression device is defined as the pressure increase induced by an increase in leg circumference of 1 cm (8) and represents the relationship between its resting and working pressures. Based on stiffness compression materials are differentiated in "elastic" and "inelastic"

BANDAGE EFFECTS
TMP REDUCTION
Venous blood flow is not increased but its velocity is increased and its volume (stasis) is reduced , as prevention for phlebitis.

BANDAGE Efficacy/SAFETY

Compression effects on arterial circulation:

Doppler at the fore-foot:

1st intermetarsal space in lying position

Anelastic (NON EXTENSIVE) (SUPPORT)

BANDAGES

Effects on TMP

LYING

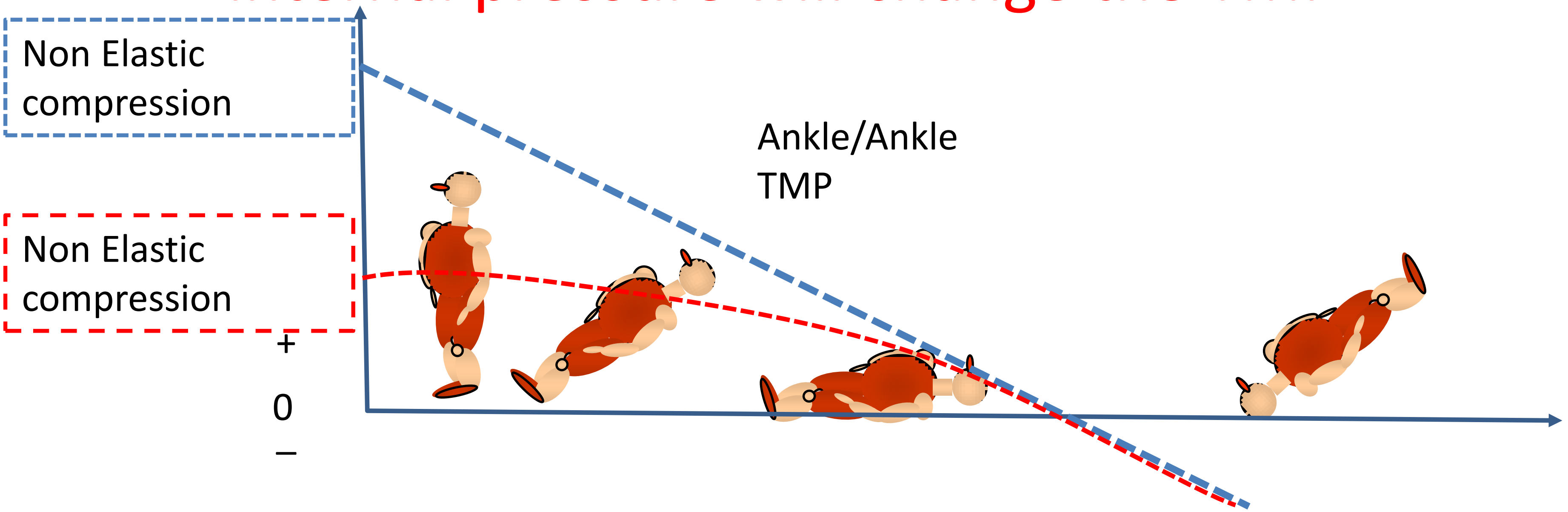
STANDING

WALKING

ANELASTIC NON EXTENSIVE (static)(SUPPORT) BANDAGES

Deliver the FORCE at the moment of bandaging

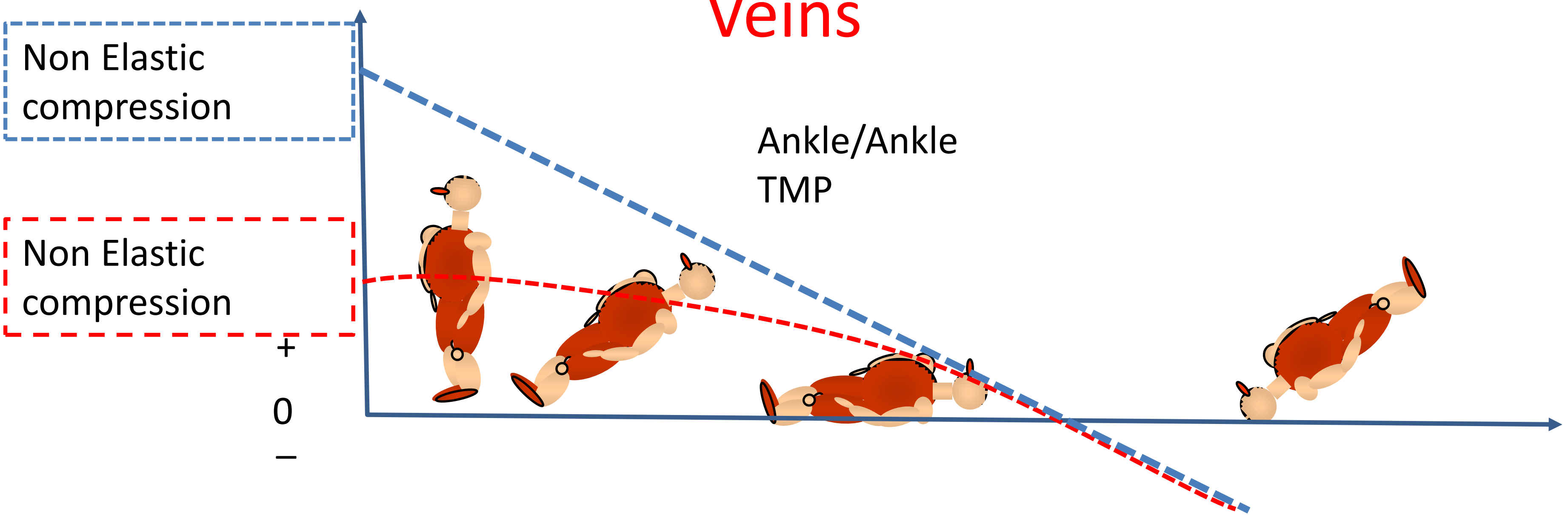
All the force/pressure is stored by the leg so that , only variations of leg and vessels internal pressure will change the TMP



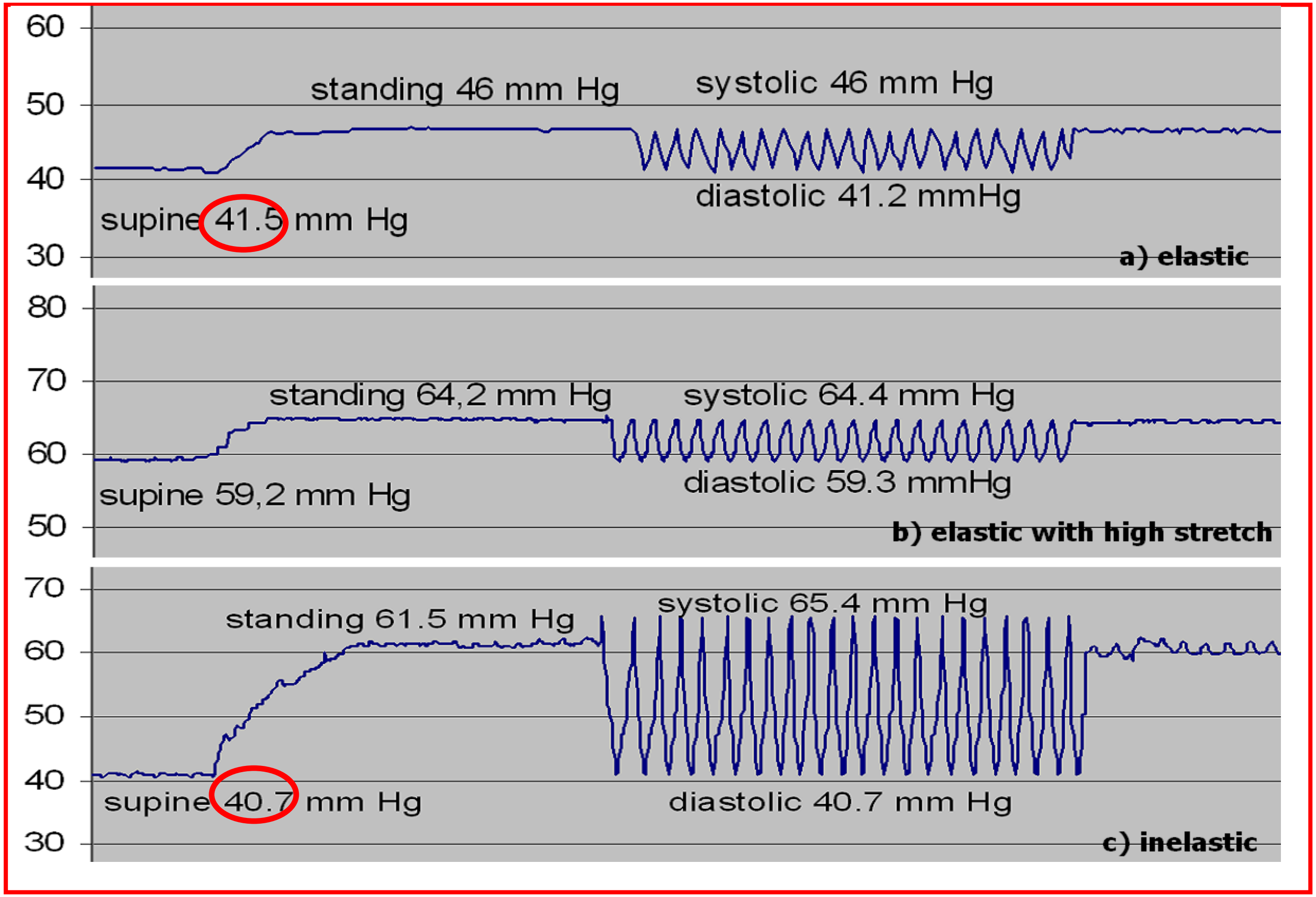
ANELASTIC NON EXTENSIVE NON EXTENSIVE (static)(SUPPORT) BANDAGES

Deliver the FORCE at the moment of bandaging

So ONLY when necessary according to the posture In Normal and Incompetent Veins



Sub-bandage pressure (mm Hg)



ELASTIC (EXTENSIVE)BANDAGES

Effects on TMP

LYING

STANDING

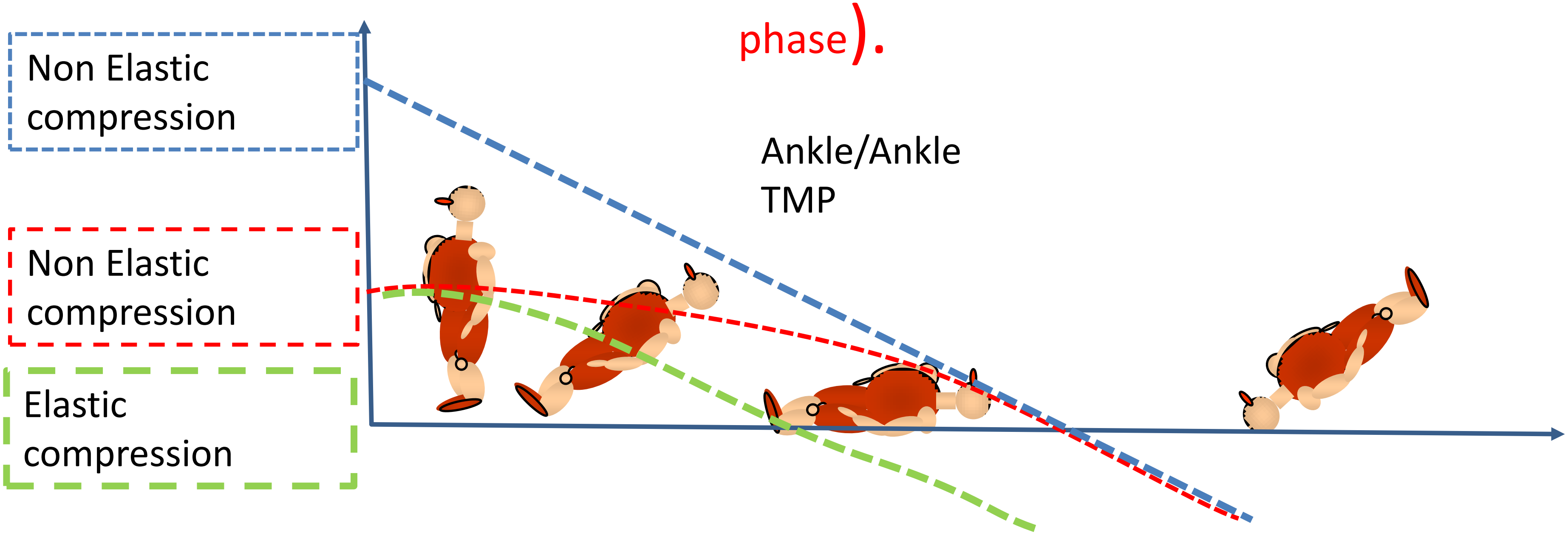
WALKING

EXTENSIVE BANDAGES

BANDAGES

Deliver the FORCE at the moment of bandaging and LATER

All the force/pressure is stored by BOTH the leg and the bandage (potential force : Hooks hysteresis phase).

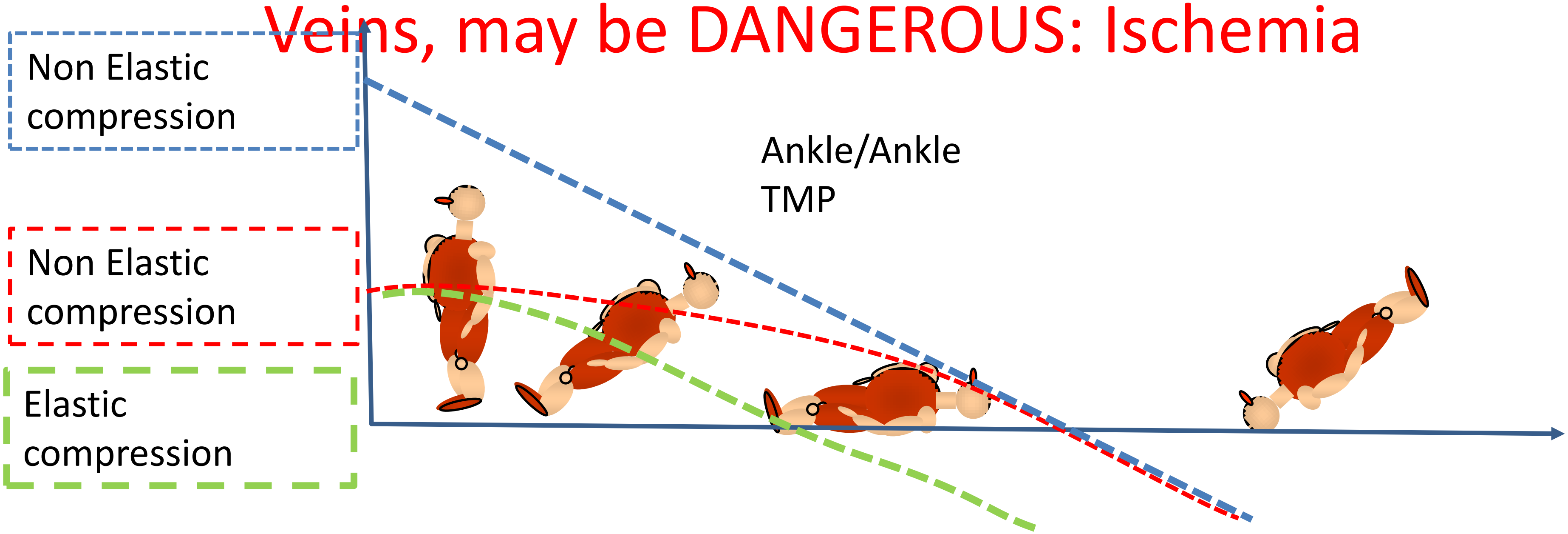


ELASTIC EXTENSIVE BANDAGES

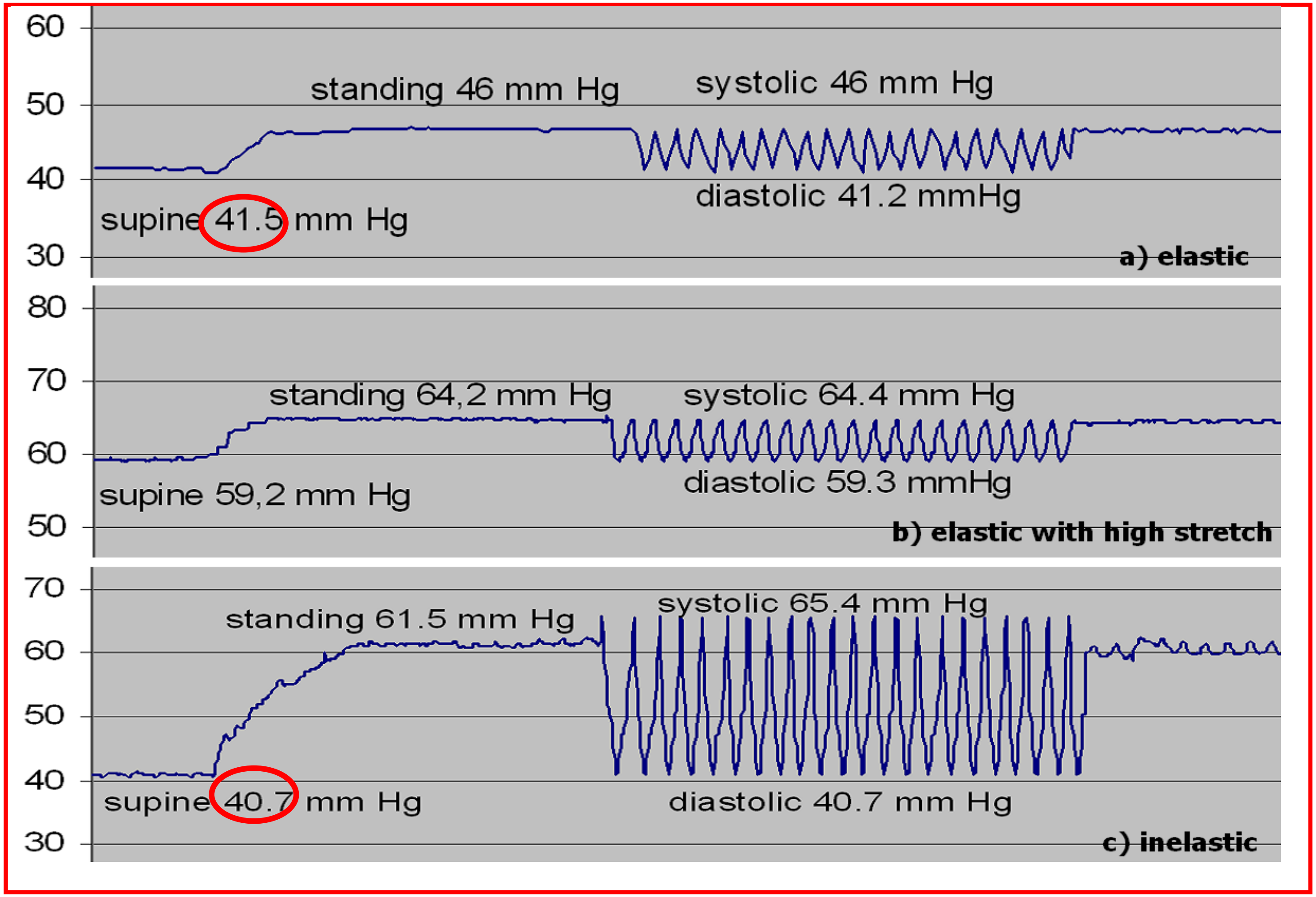
BANDAGES

Deliver the FORCE at the moment of bandaging and LATER

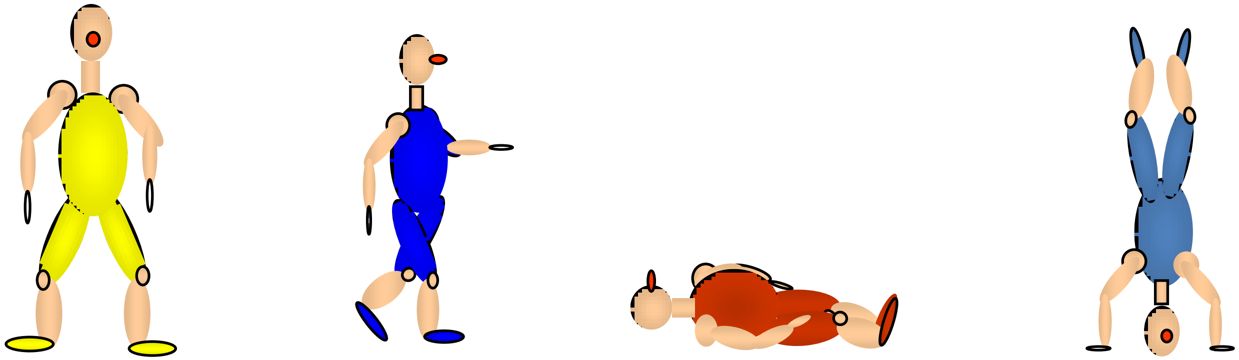
So, the EFFECT on TMP increases when not necessary in Normal and Incompetent Veins, may be DANGEROUS: Ischemia



Sub-bandage pressure (mm Hg)



BANDAGING
Proposals

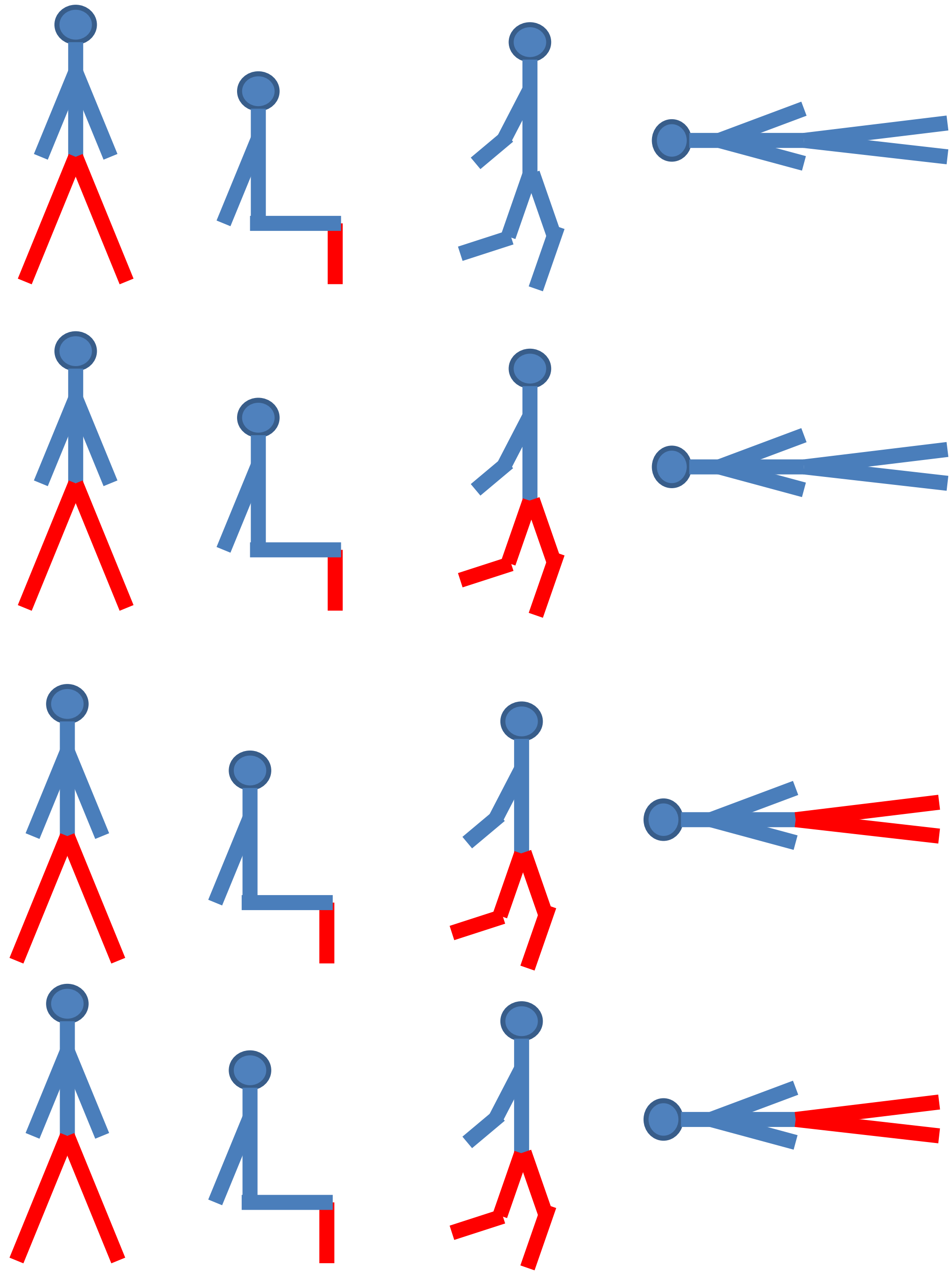


Normal Individuals
Light elastic compression

Moderate Valve Incompetence
Light/ Moderate elastic compression

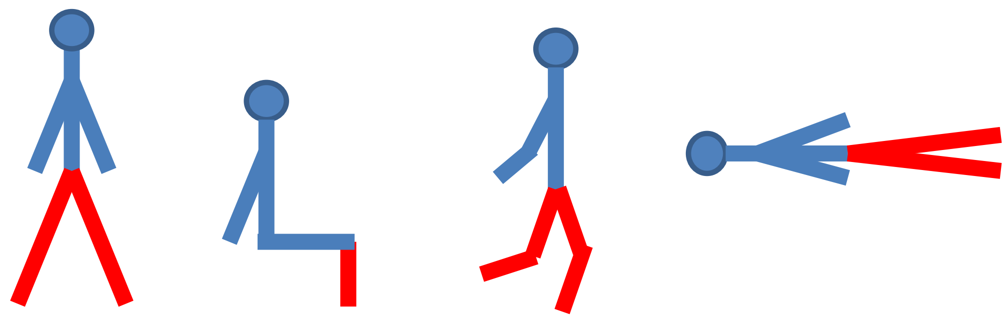
Moderate Venous Obstacle
AV Fistule
Light/ Moderate elastic compression

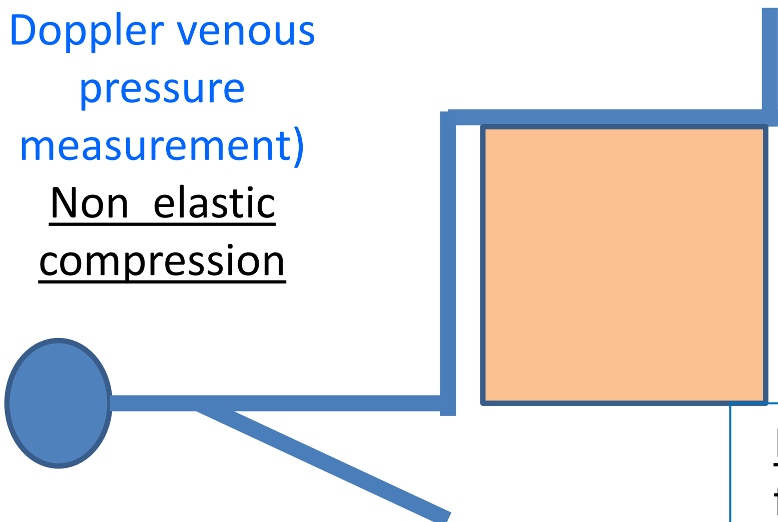
Phlebitis prevention
Light elastic compression



Sever venous incompetence and/or Importante Obstacle and/or AV Fistule (Doppler venous pressure measurement)

<u>Non elastic compression</u>





NON ELASTIC COMPRESSION permits a STRONGER COMPRESSION
so MORE EFFICIENT and
LESS DANGEROUS THAN ELASTIC

PROCEDURE

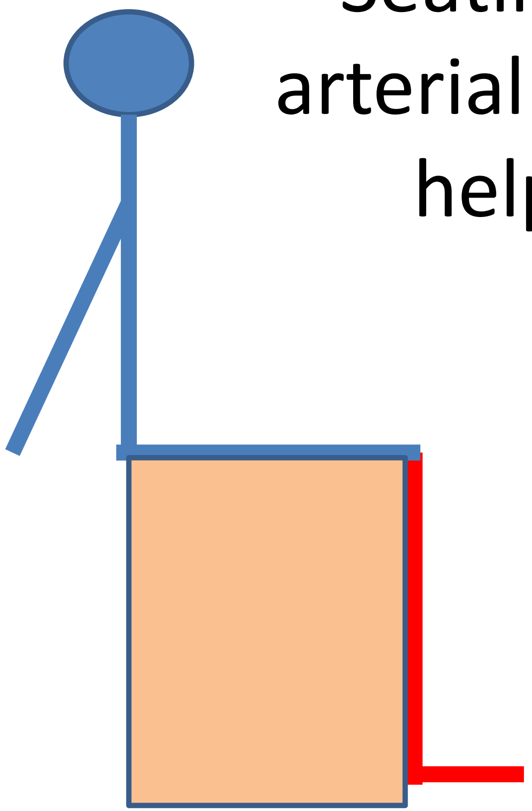
<u>Draining posture</u> for 2 hours + or - elastic compression

Then

Replace elastic compression by non elastic bandage

Check the forefoot arterial pressure with Doppler

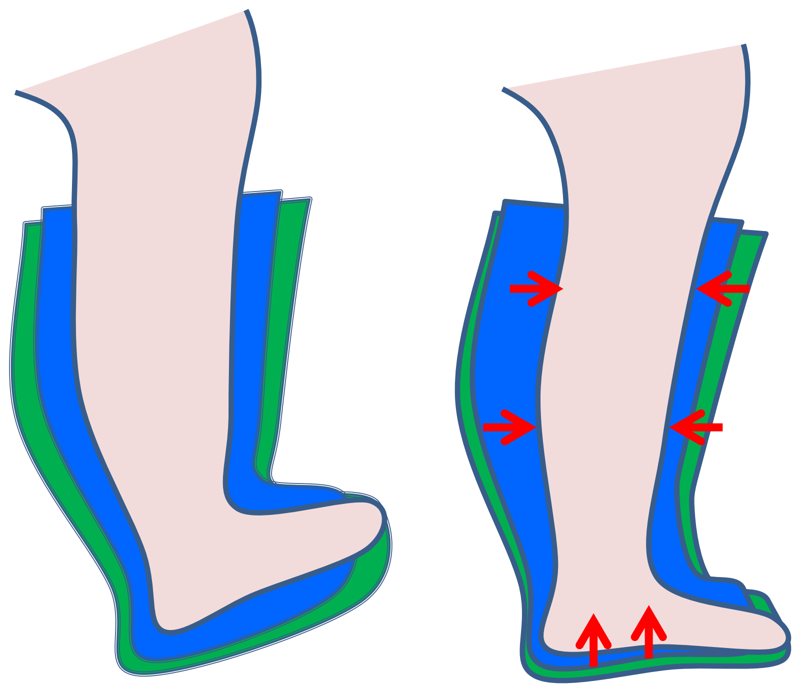
Arteropathy IV th stage : Thanks to Gravitational Pressure, Seating posture increases foot arterial pressure, relieves pain and helps for gangrene healing



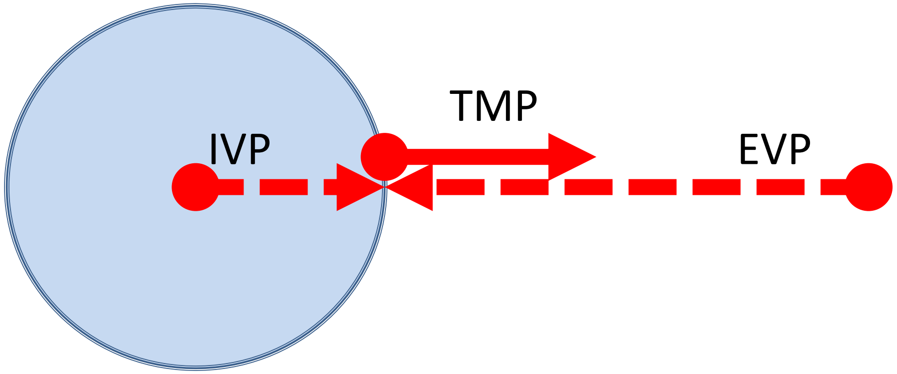
non elastic light bandaging prevents stasis edema

Check the forefoot arterial pressure with Doppler

Extra Systolic Calf Pump
Non elastic air/fluid bag beneath non elastic compression when walking



VENOUS DISEASE?
Just THINK TMP!



For the diagnosis,
and for the treatment