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

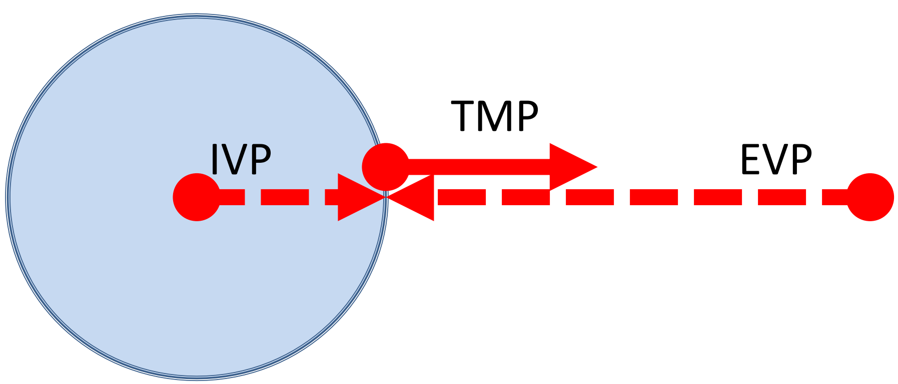
1-Hemodynamic concept of venous drainage

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)

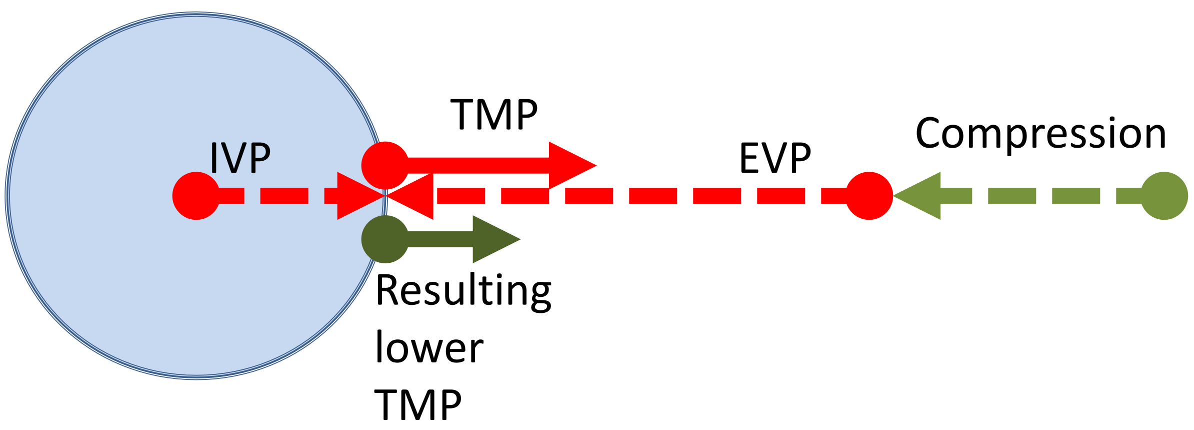
HEMODYNAMIC CORRECTION OF TMP EXECSS.

TMP = IVP-EVP

DECREASE IVP by :

COMPESSION

Increasing physiological EVP with external ARTIFICIAL means

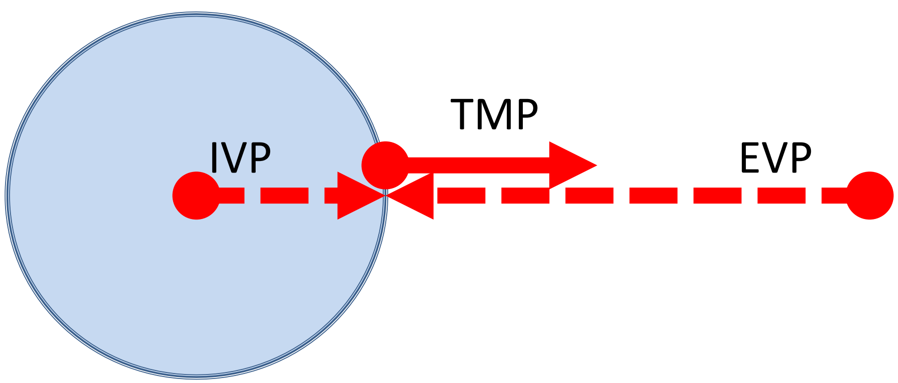


TRANS-MURAL PRESSURE (TMP)

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

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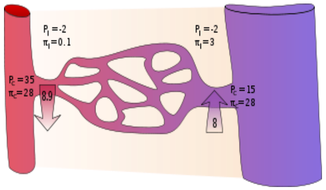
EVP is the static pressure made of:

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)

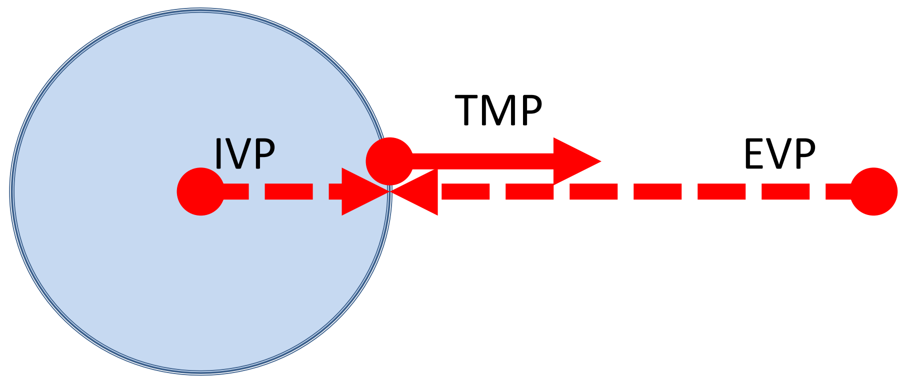
TRANS-MURAL PRESSURE (TMP)

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 :

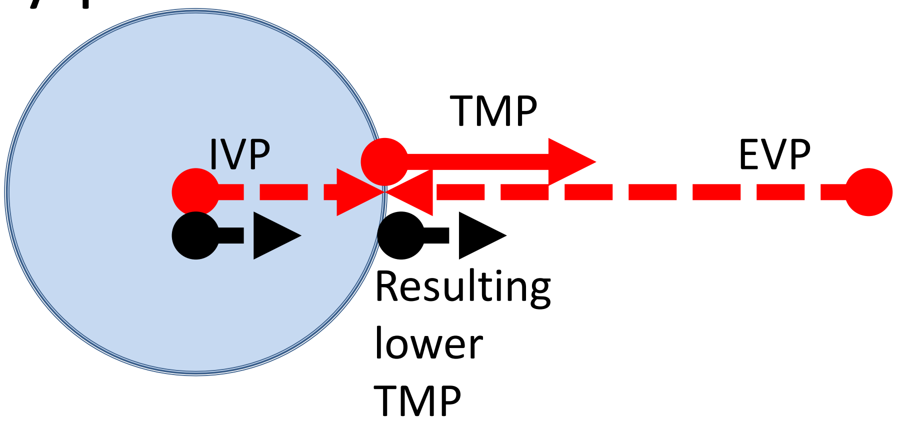
1- Gravitational Pressure(GP) Decrease and/or

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



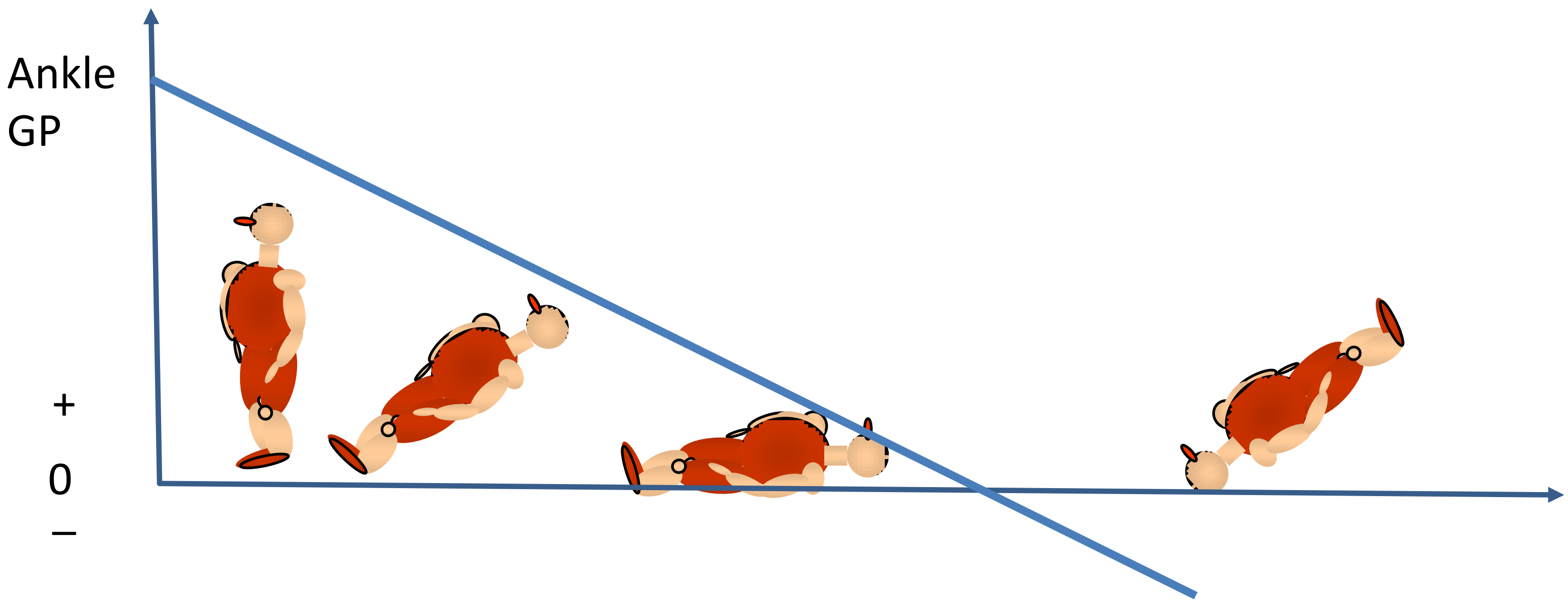
TRANS-MURAL PRESSURE (TMP)

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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DECREASE IVP by :

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TRANS-MURAL PRESSURE (TMP)

HEMODYNAMIC CORRECTION OF TMP EXECSS.

TMP = IVP-EVP

COMPESSION

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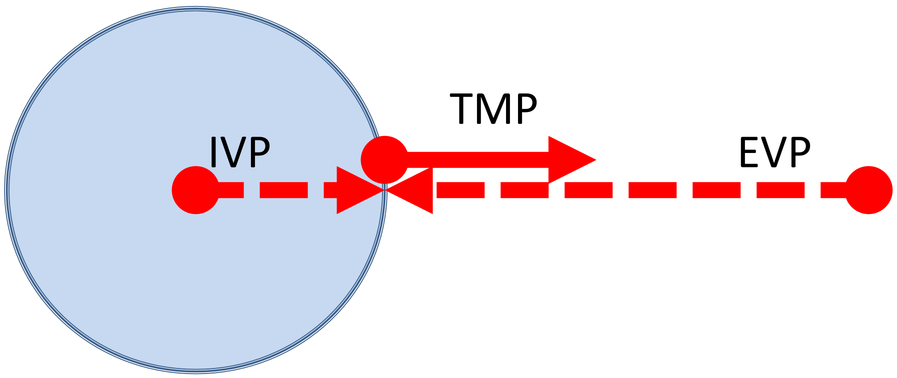
TMP = IVP-EVP

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



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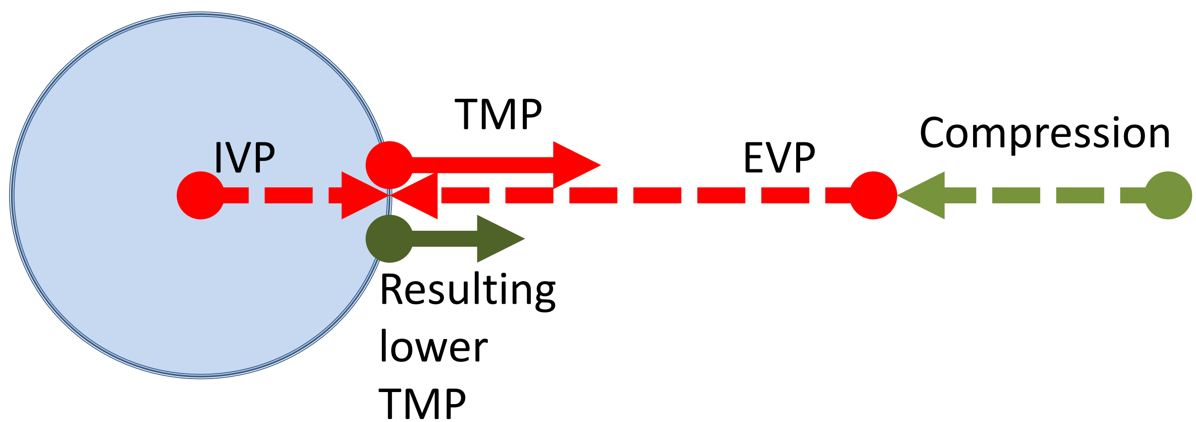
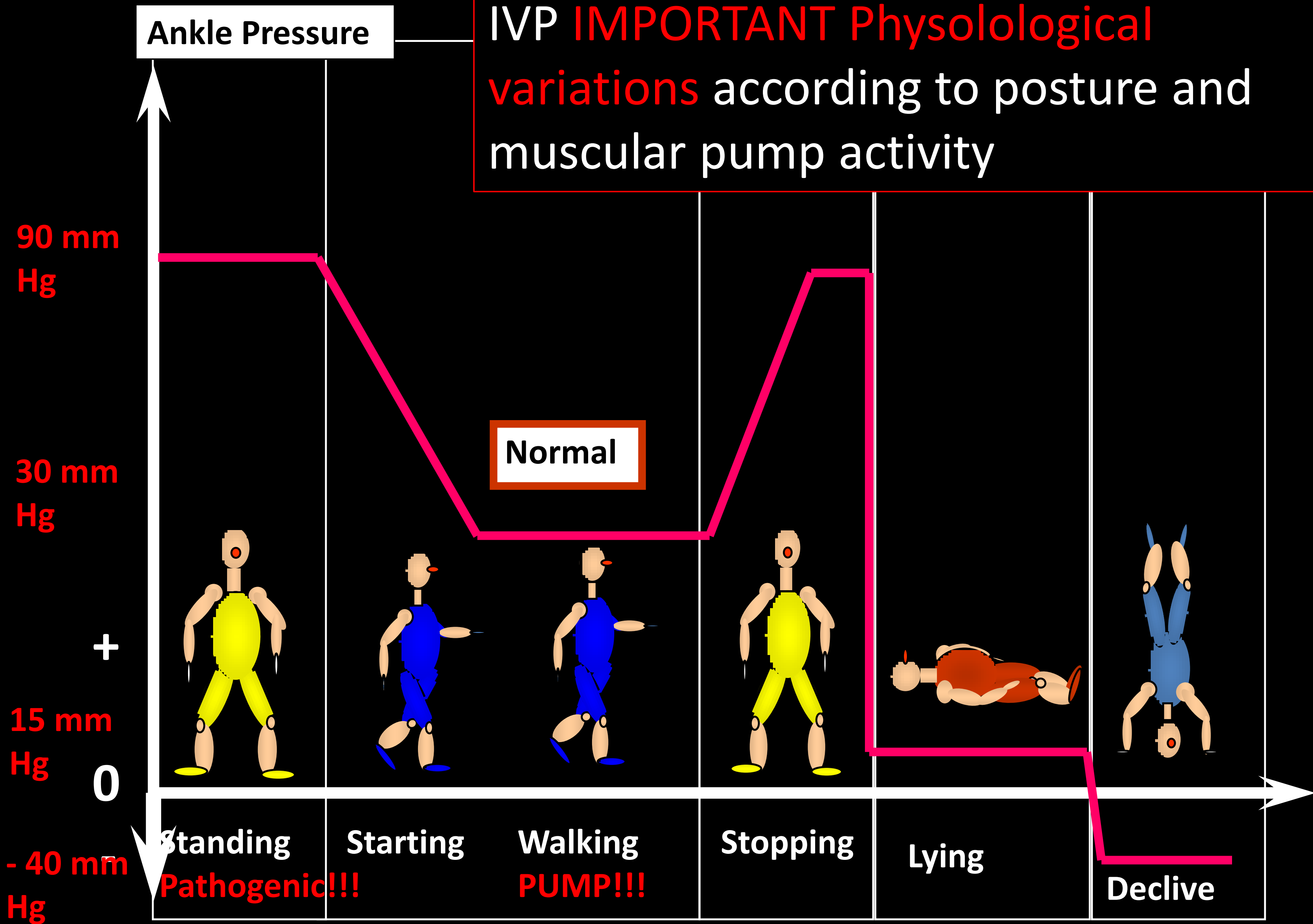
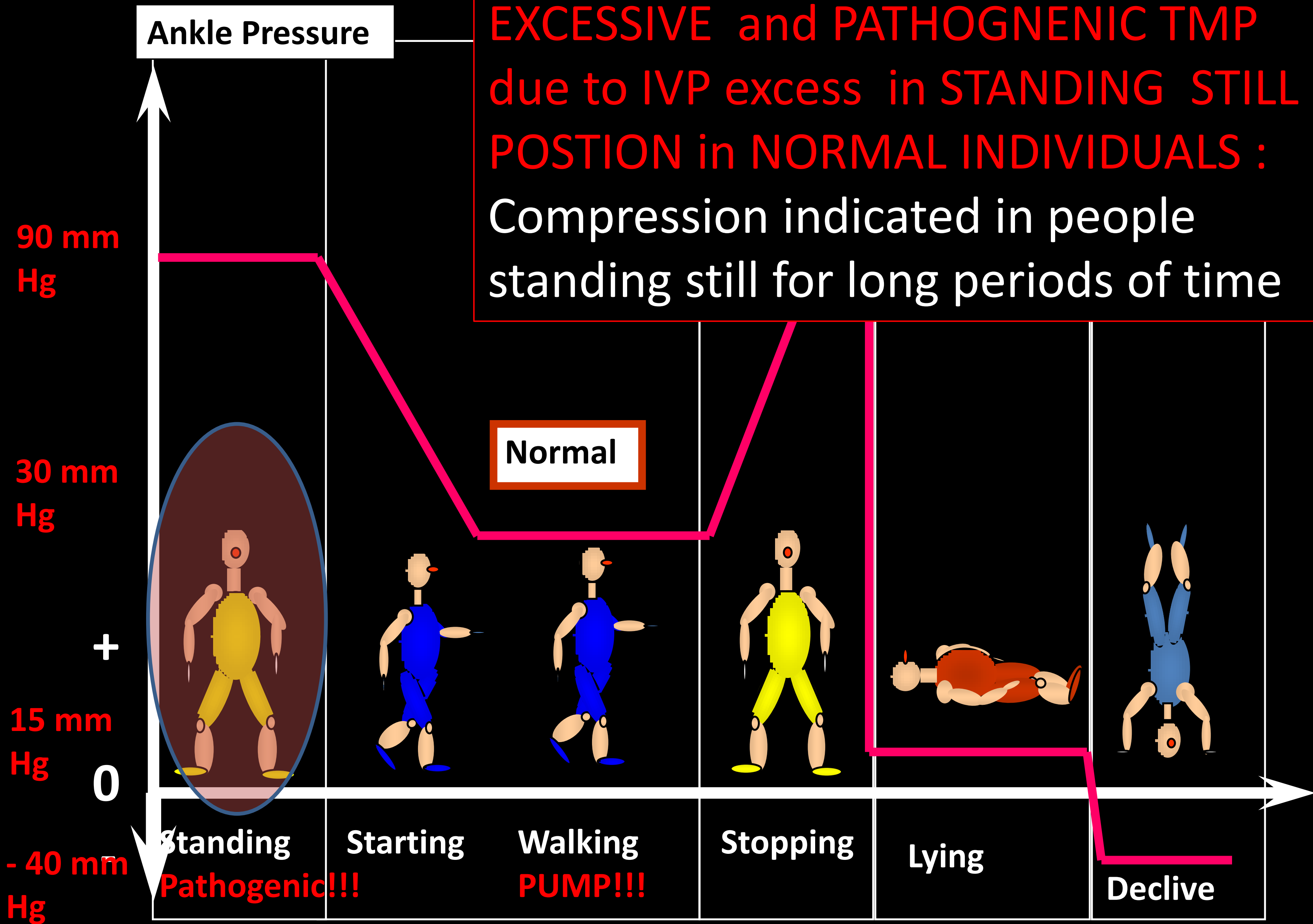


IVP IMPORTANT Physolological variations according to posture and muscular pump activity



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



Oedema, Varices,Trophiques Changes , Ulcer

When related to venous insufficency

Are caused by a TMP excess

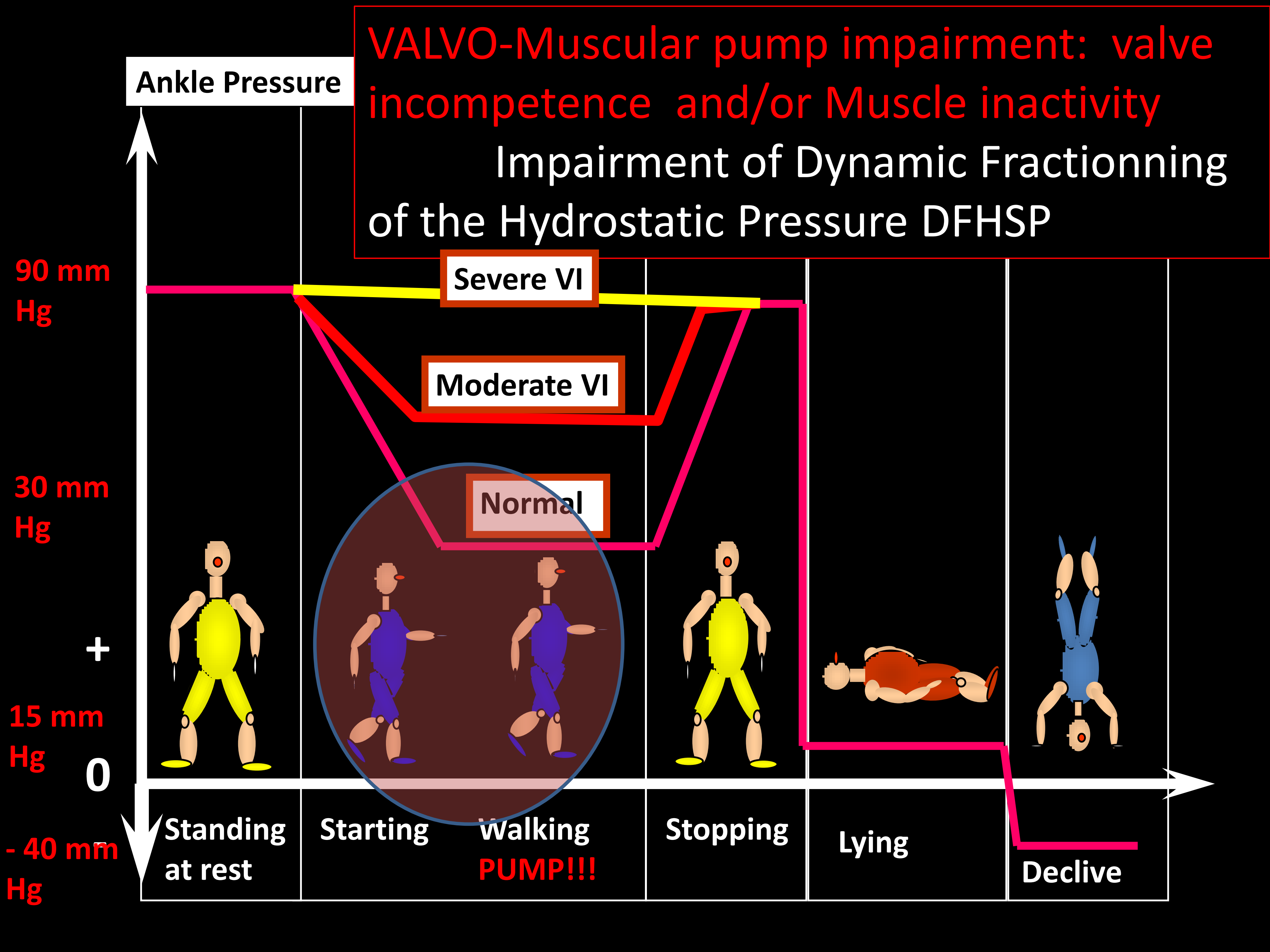
CAUSES FOR TMP EXCESS

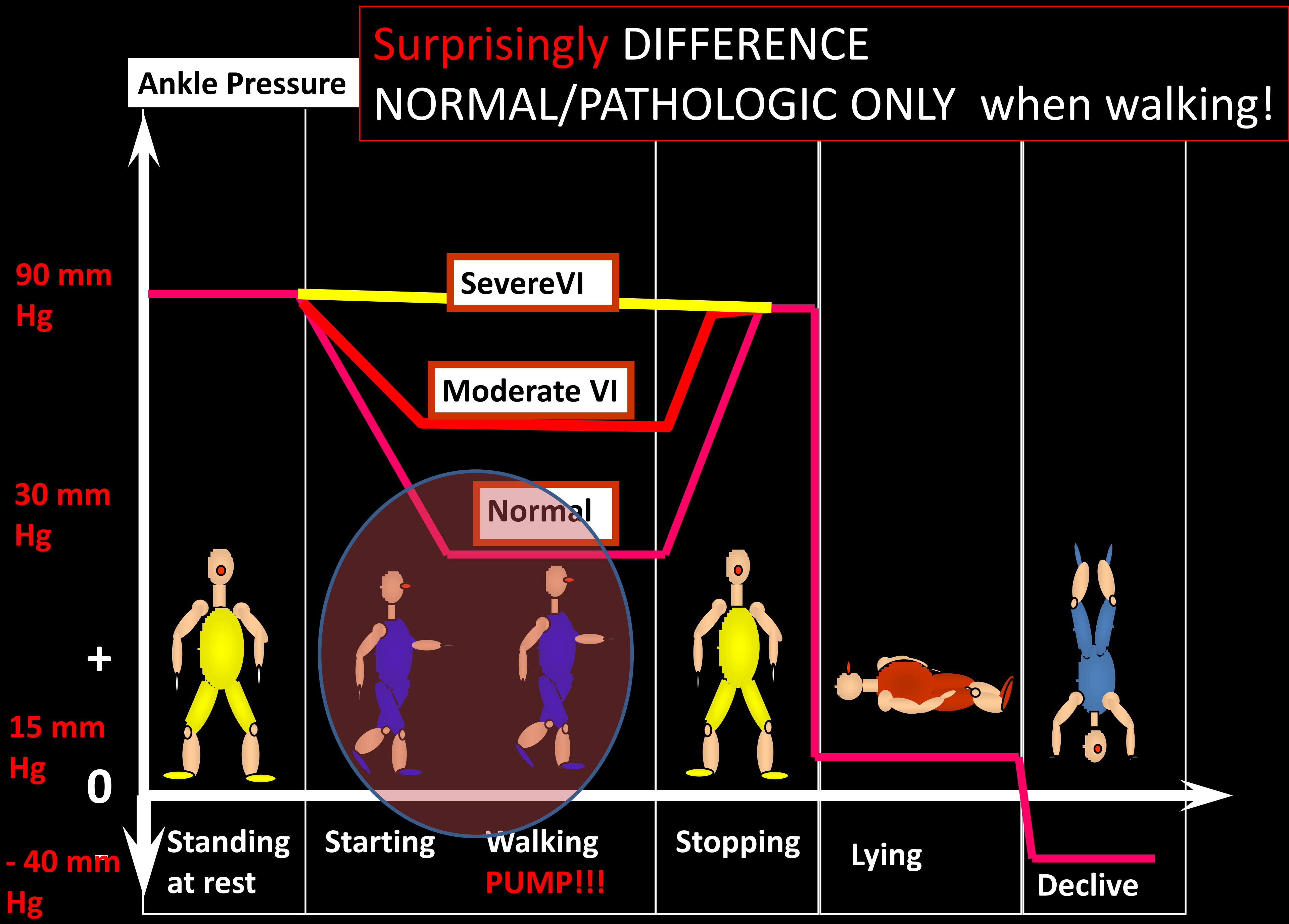
1- VALVULAR INCOMPETENCE and/or Muscle inactivity

Impairment of Dynamic Fractionning of the Hydrostatic Pressure DFHSP

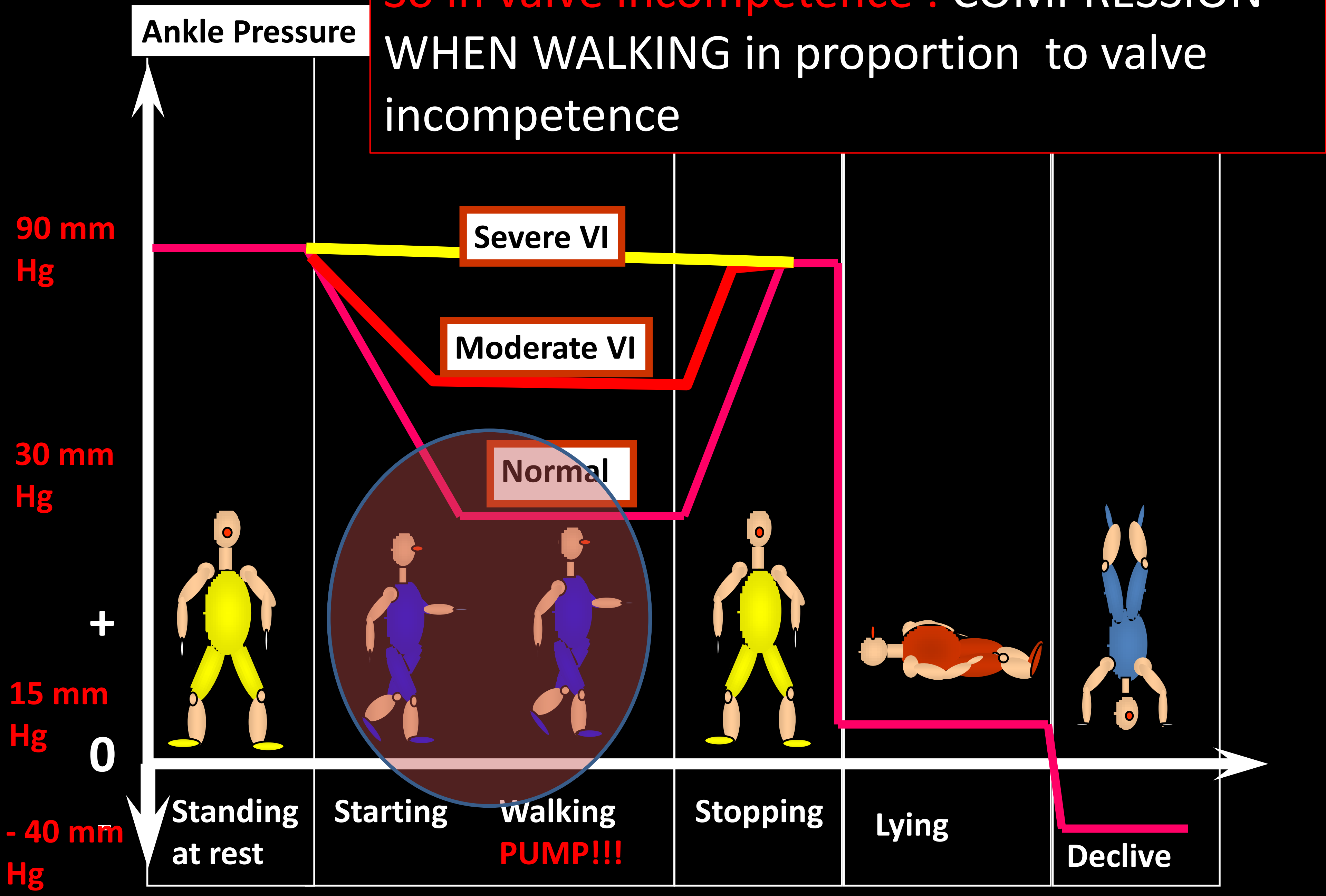
2- OBSTACLE to the FLOW

Excess of RESIUAL PRESSURE

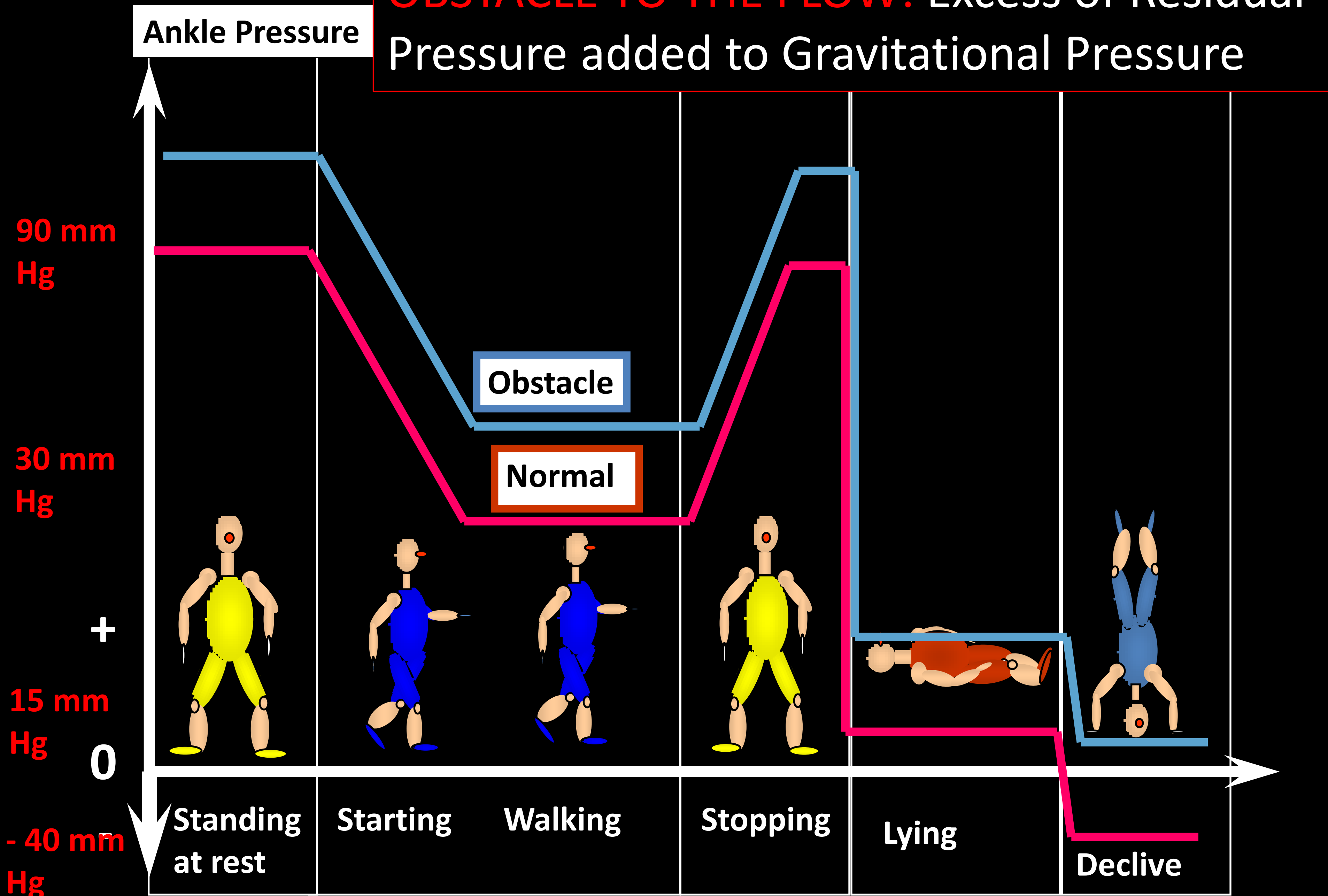

VALVO-Muscular pump impairment: valve incompetence and/or Muscle inactivity
Impairment of Dynamic Fractionning of the Hydrostatic Pressure DFHSP
Ankle Pressure
90 mm Hg
30 mm Hg
+
15 mm Hg
0
- 40 mm Hg
Severe VI
Moderate VI
Normal
Standing at rest
Starting
Walking
PUMP!!!
Stopping
Lying
Declive


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

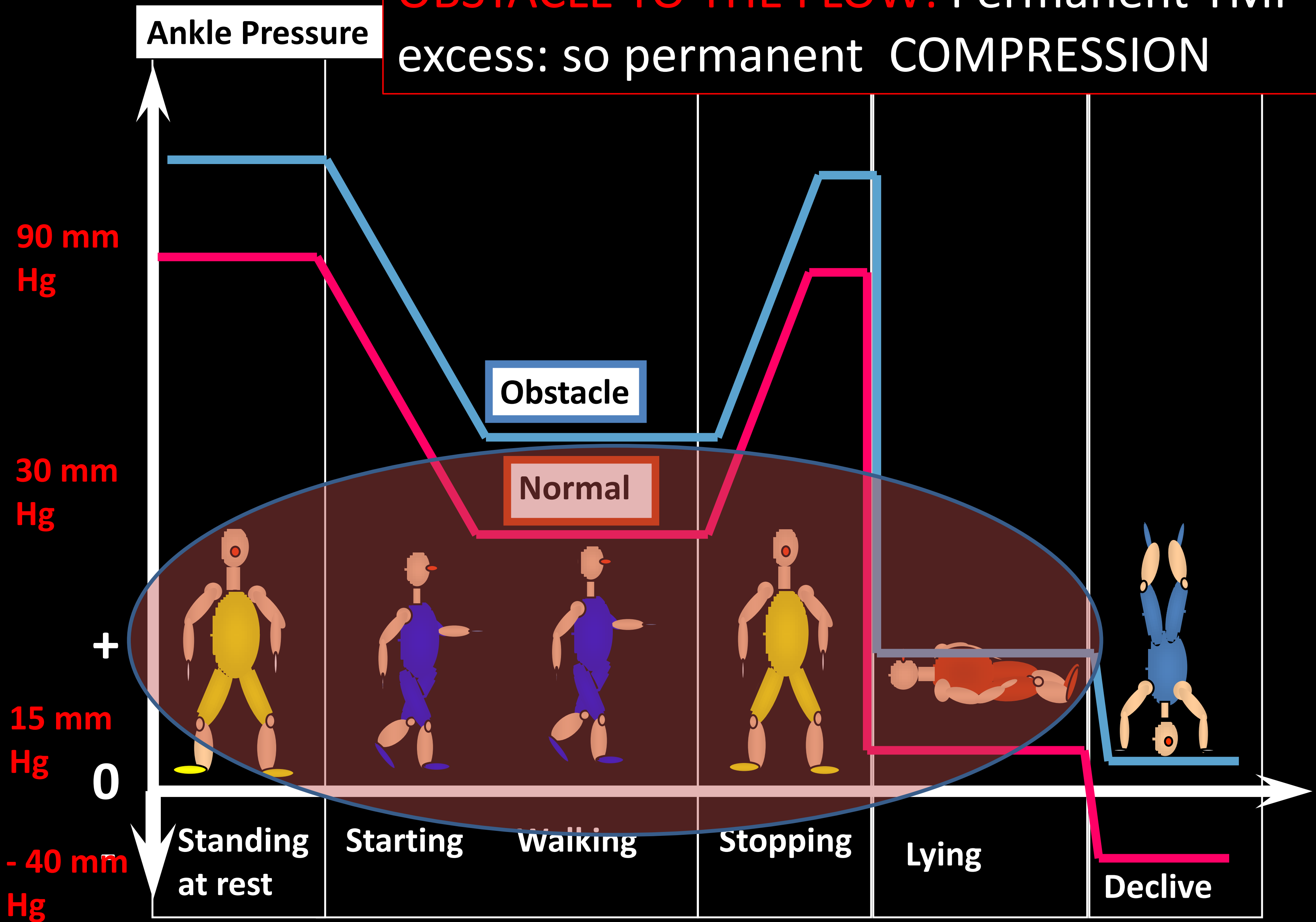
So in valve incompetence : COMPRESSION WHEN WALKING in proportion to valve incompetence



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



OBSTACLE TO THE FLOW: Permanent TMP excess: so permanent COMPRESSION



Expected hemodynamic effects of external leg compression

Venous Trans-Mural-Pressure (TMP)

At the veins level:

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2-Hydrostatic component of the Pressure made of:

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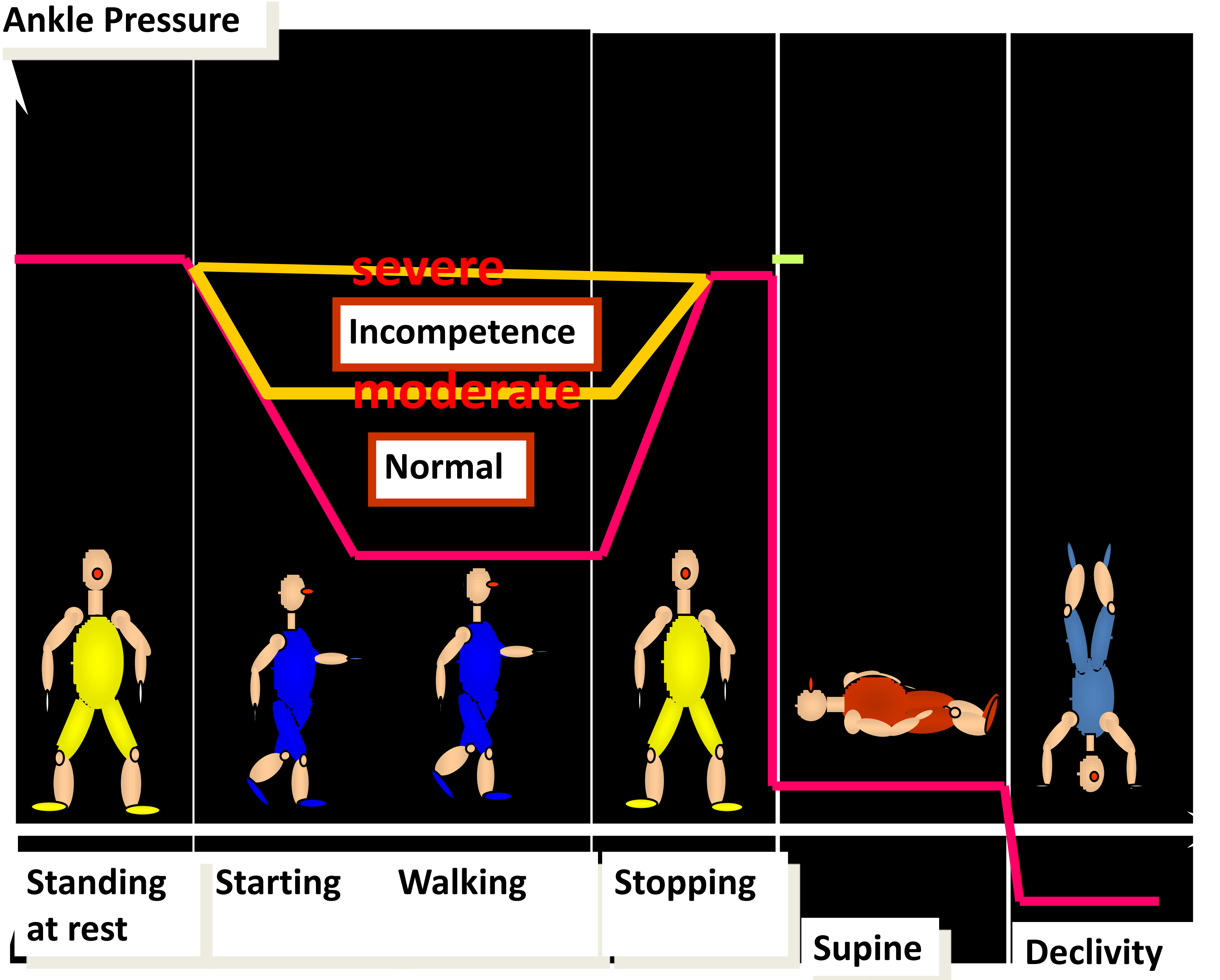
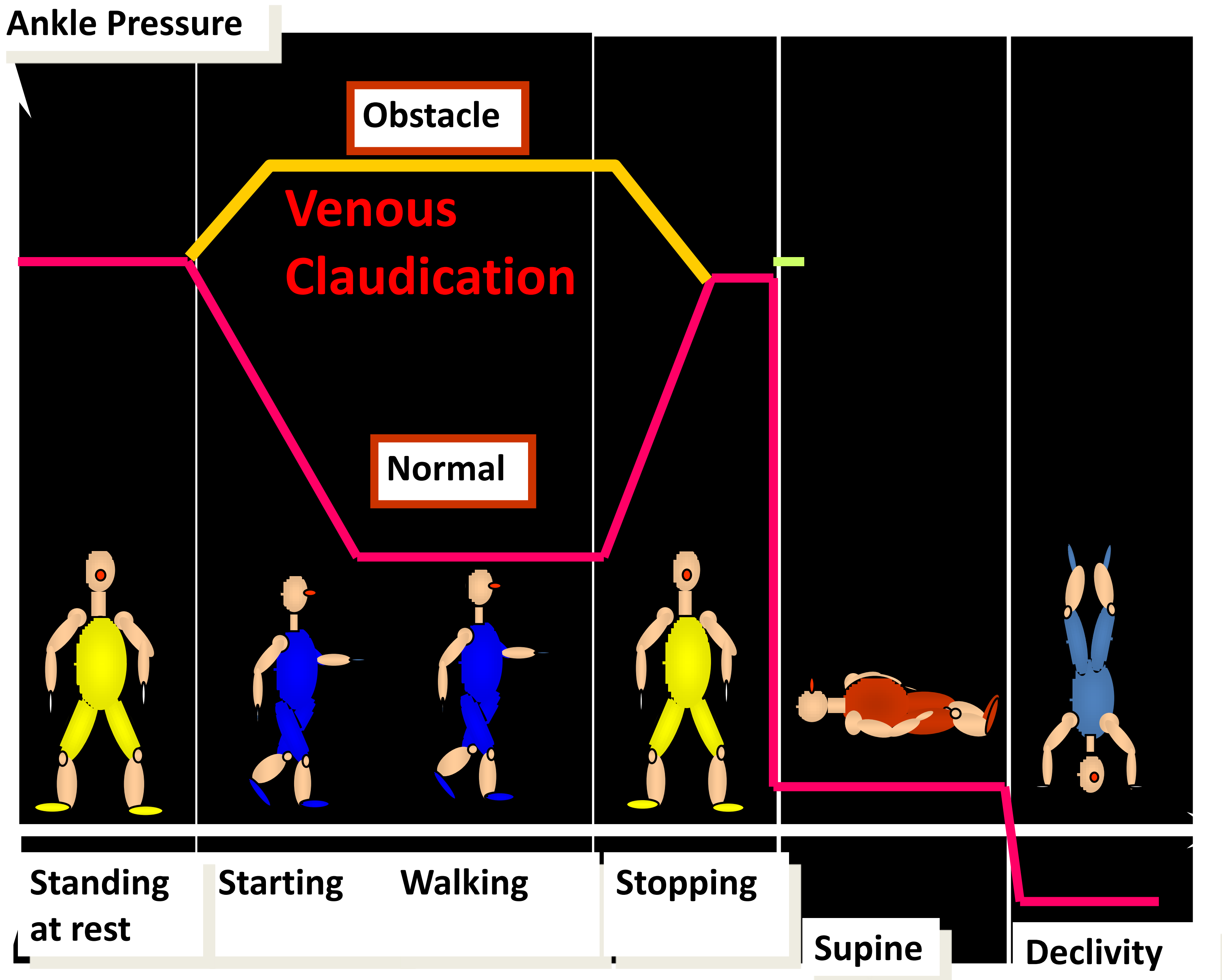


Ankle Pressure
severe
Incompetence
moderate
Normal
Standing
at rest
Starting
Walking
Stopping
Supine
Declivity


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

TRANS-MURAL PRESSURE (TMP)

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1-DECREASE IVP and/or

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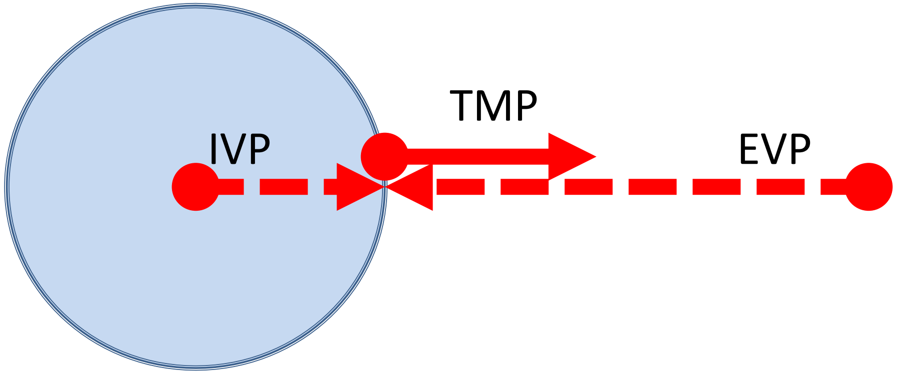

TRANS-MURAL PRESSURE (TMP)

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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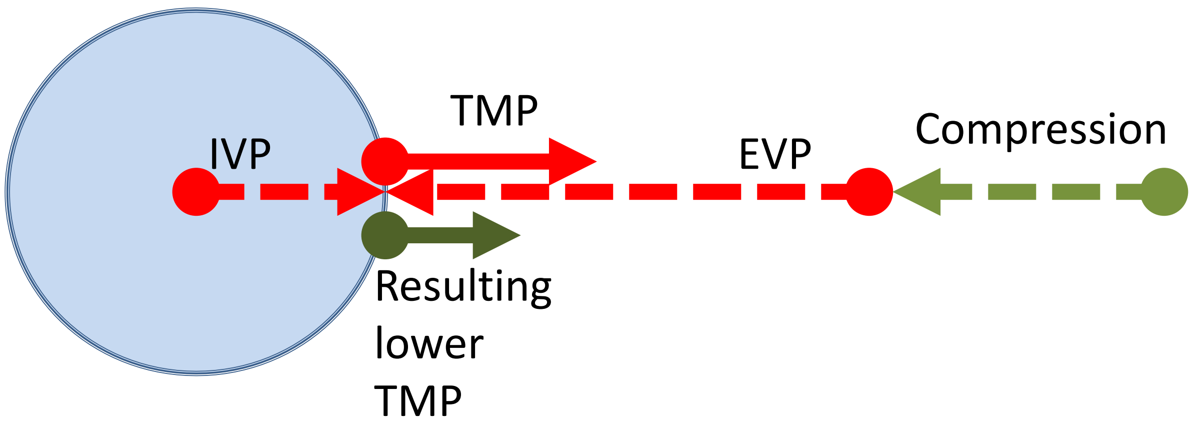
INCREASE EVP by :

COMPESSION

Increasing physiological EVP with external ARTIFICIAL means



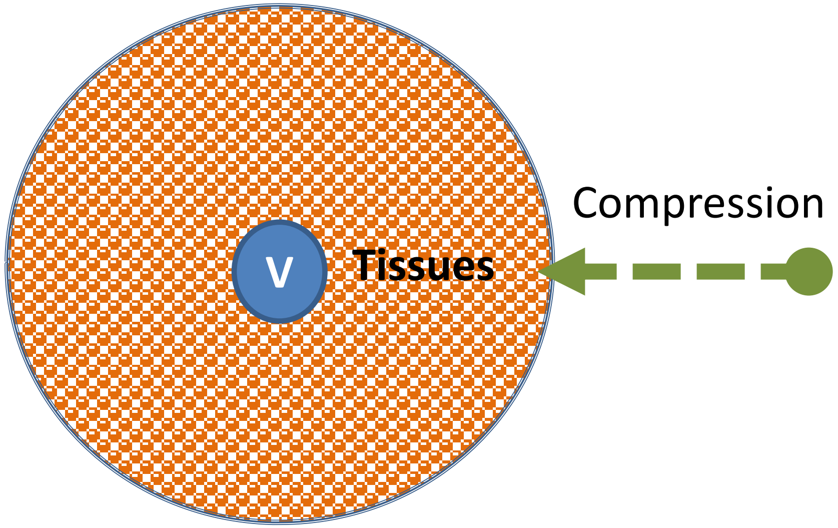
COMPRESSION: DEFINITION

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

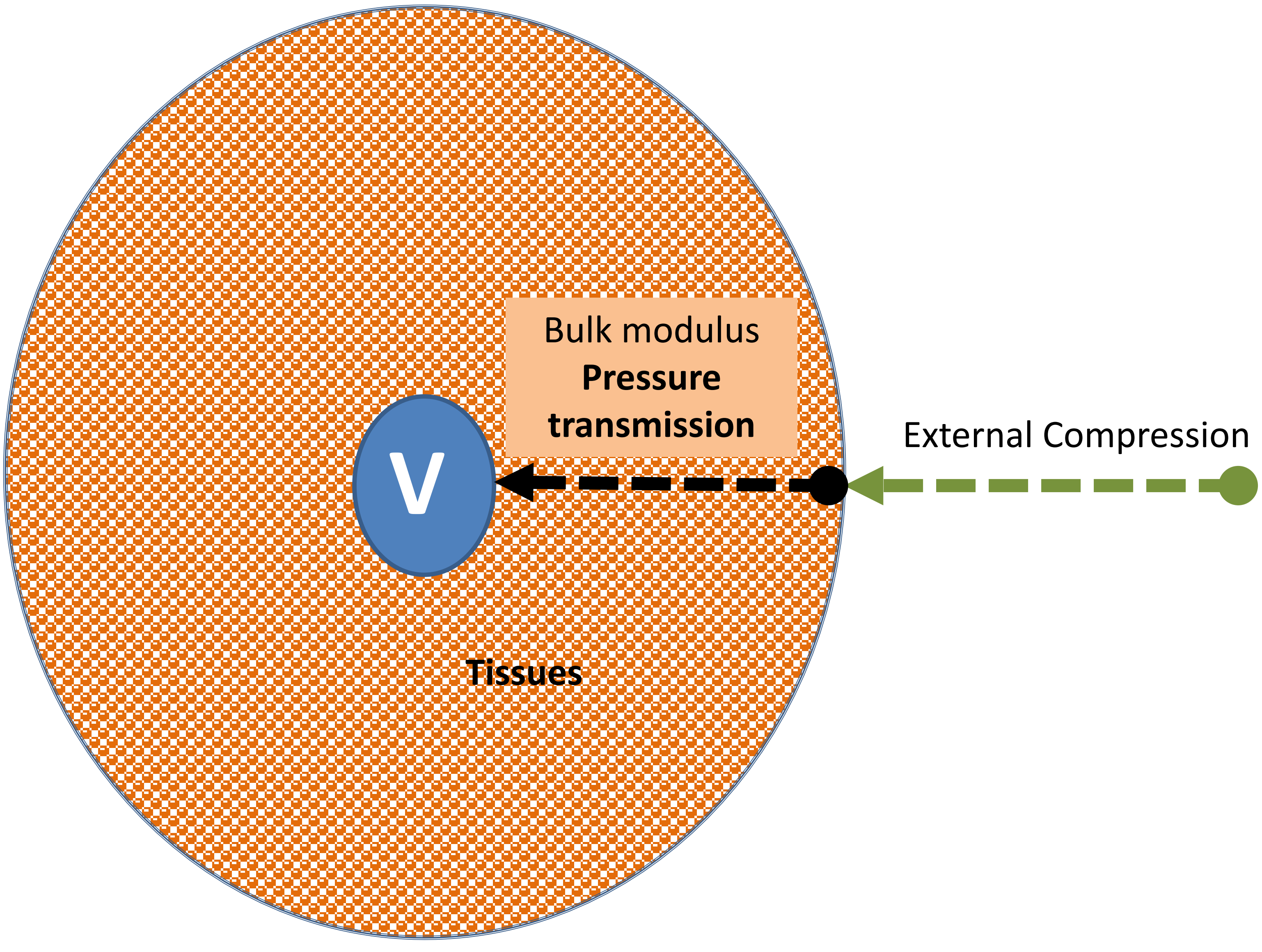
Pressure compression transmitted from surface to depth

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
External Compression
V
Tissues

LEG COMPRESSION FEATURES ACCORDING TO THE PHYSICAL MEANS

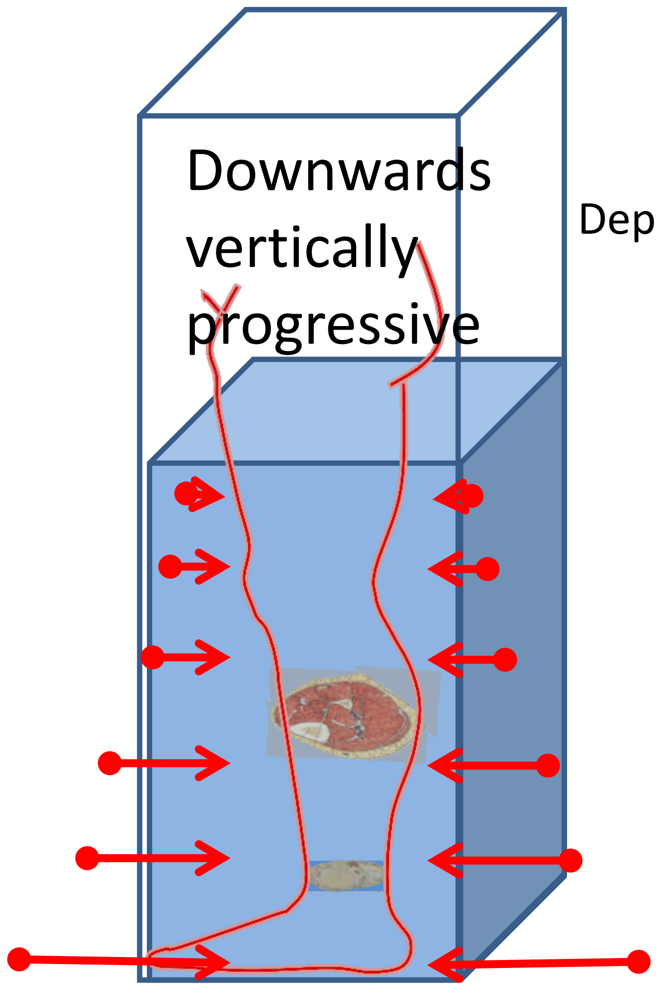
Into liquid immersion (pressure by load): Independent on the leg geometry

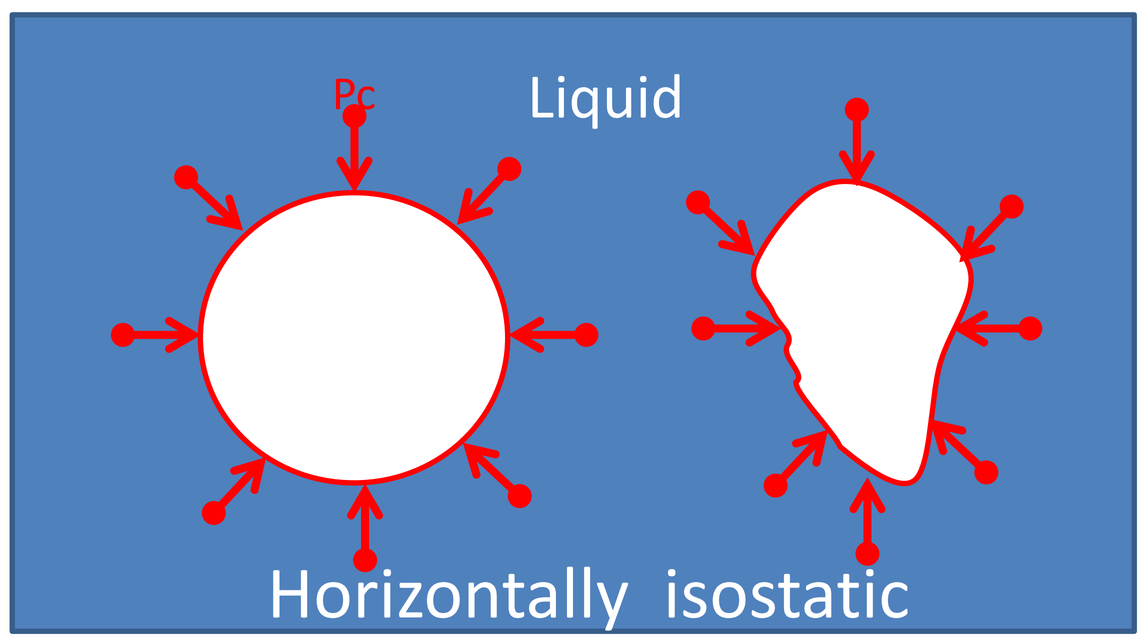
-Horizontally isostatic (uniformly distributed)

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

h = liquid height ρ = liquid density

Dependent of gravitational pressure and liquid density

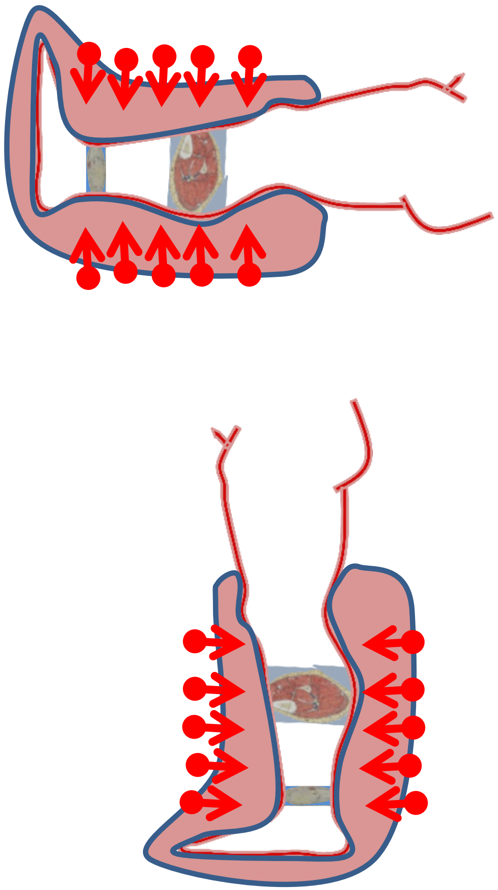


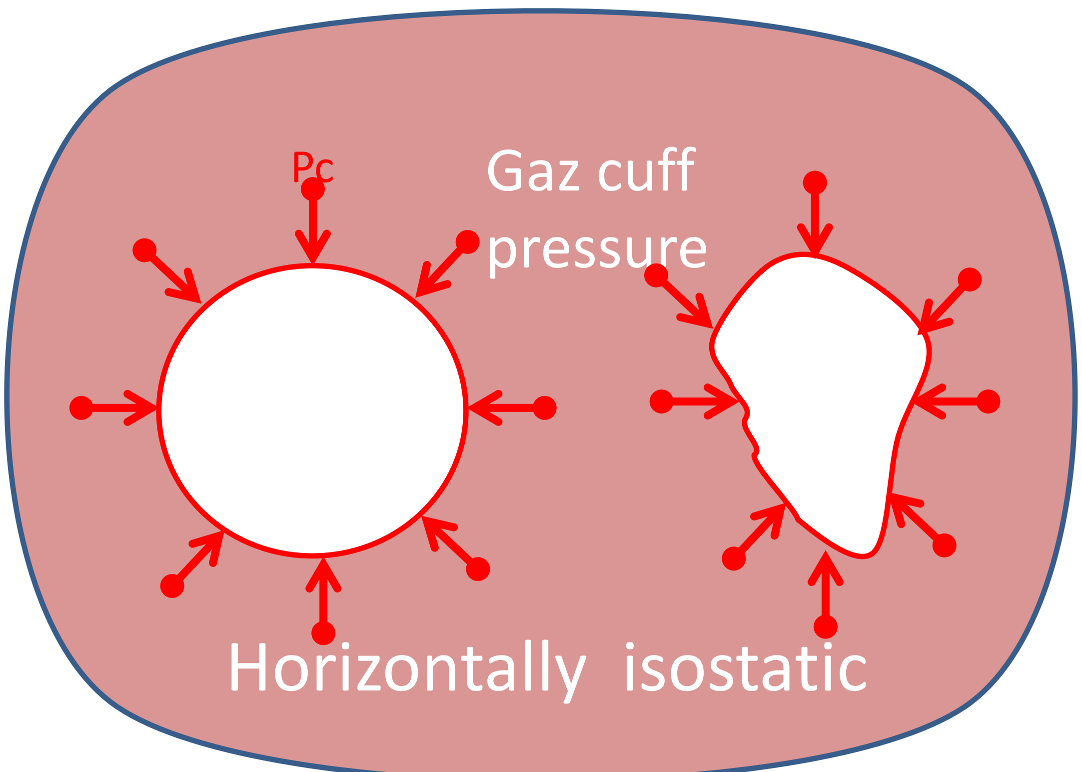


LEG COMPRESSION FEATURES ACCORDING TO THE PHYSICAL MEANS

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

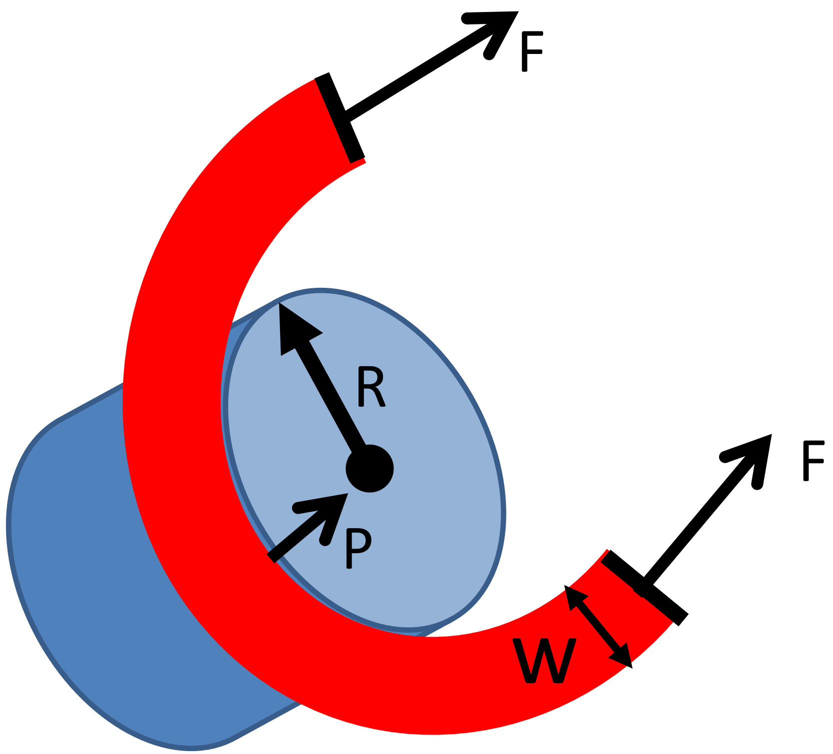
P: hPascal

F: cNewton

w= bandage width

R= cylinder radius

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



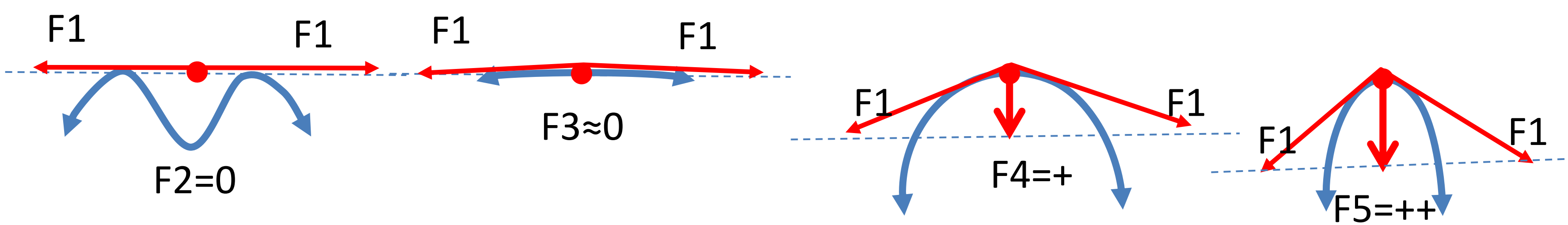
LEG COMPRESSION FEATURES ACCORDING TO THE PHYSICAL MEANS

Bandage compression:

Dependent on the leg circularity

Dependent of bandaging strength

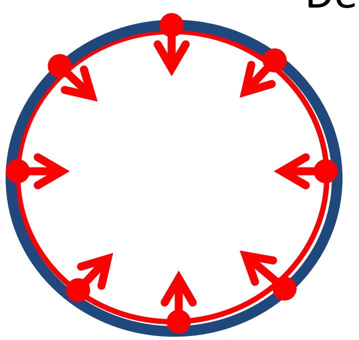
Dependent of leg mid diameter : Starling Law

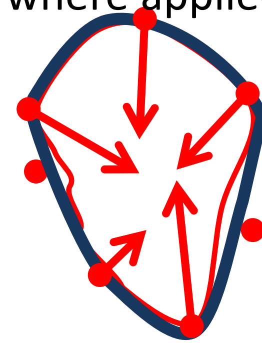


Bandaging (force) strength =F1

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

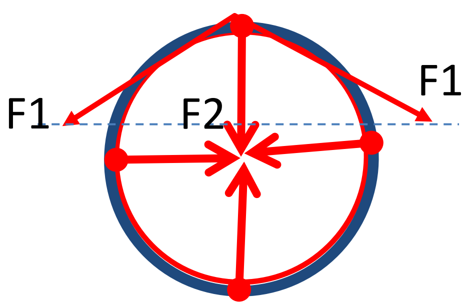
Dependent of leg mid diameter : Starling Law

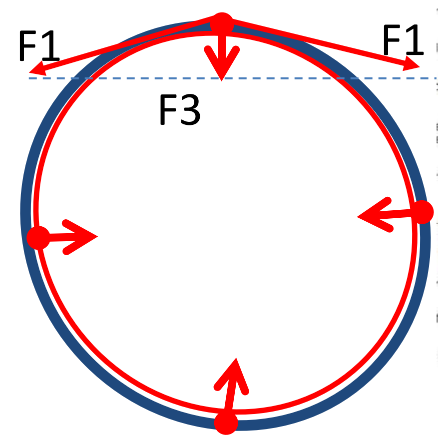
Bandaging (force) strength =F1

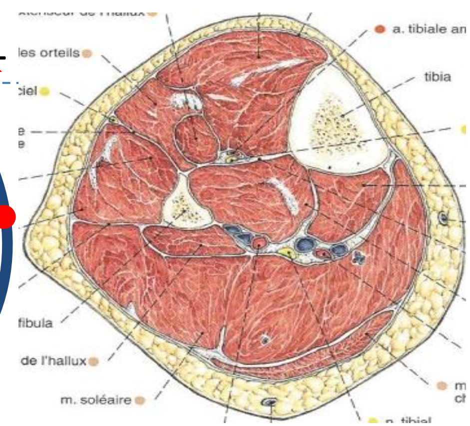
Resulting compression (Force) pressure: F2>F3

Depends on the mid diameter of the leg :

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







Circular :

homogeneous transmitted pressure

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Dependent on the leg circularity
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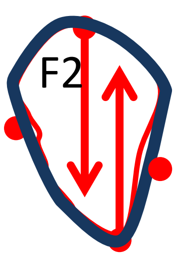
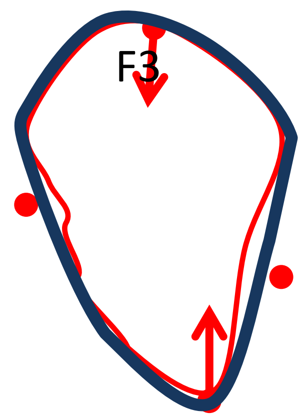
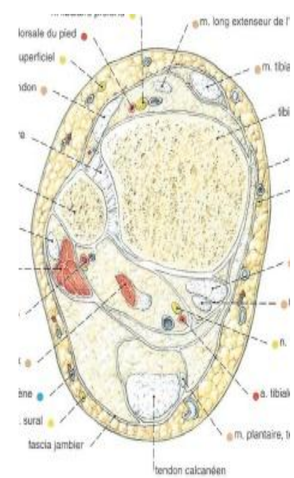






Non Circular :
heterogeneous transmitted pressure
eg ankle

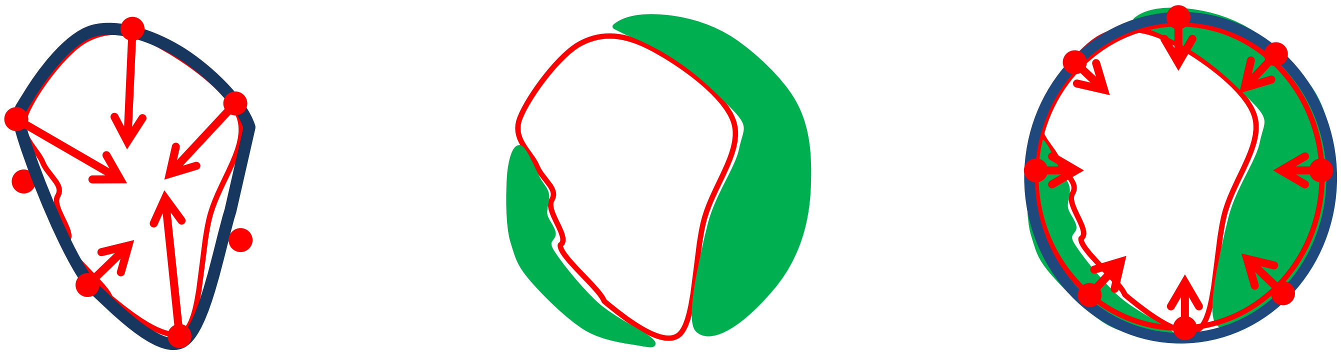
LEG COMPRESSION FEATURES ACCORDING TO THE PHYSICAL MEANS

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:

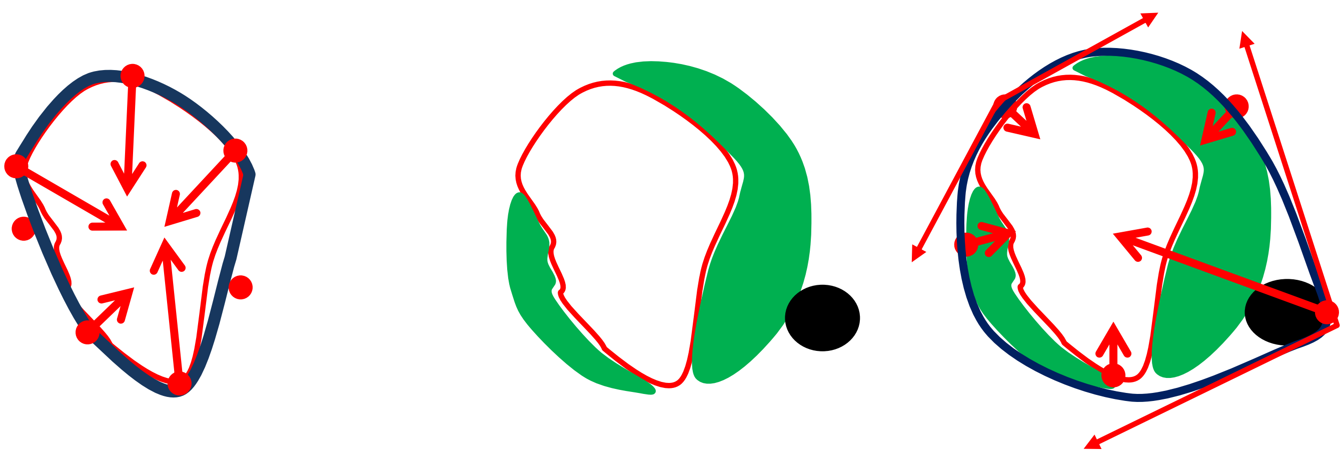
Dependent on the leg circularity

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:

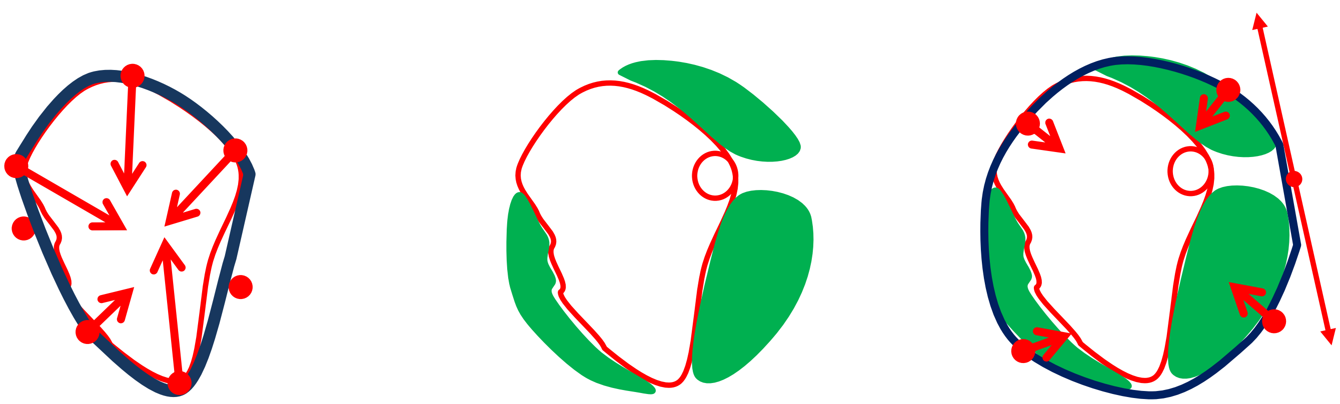
Dependent on the leg circularity

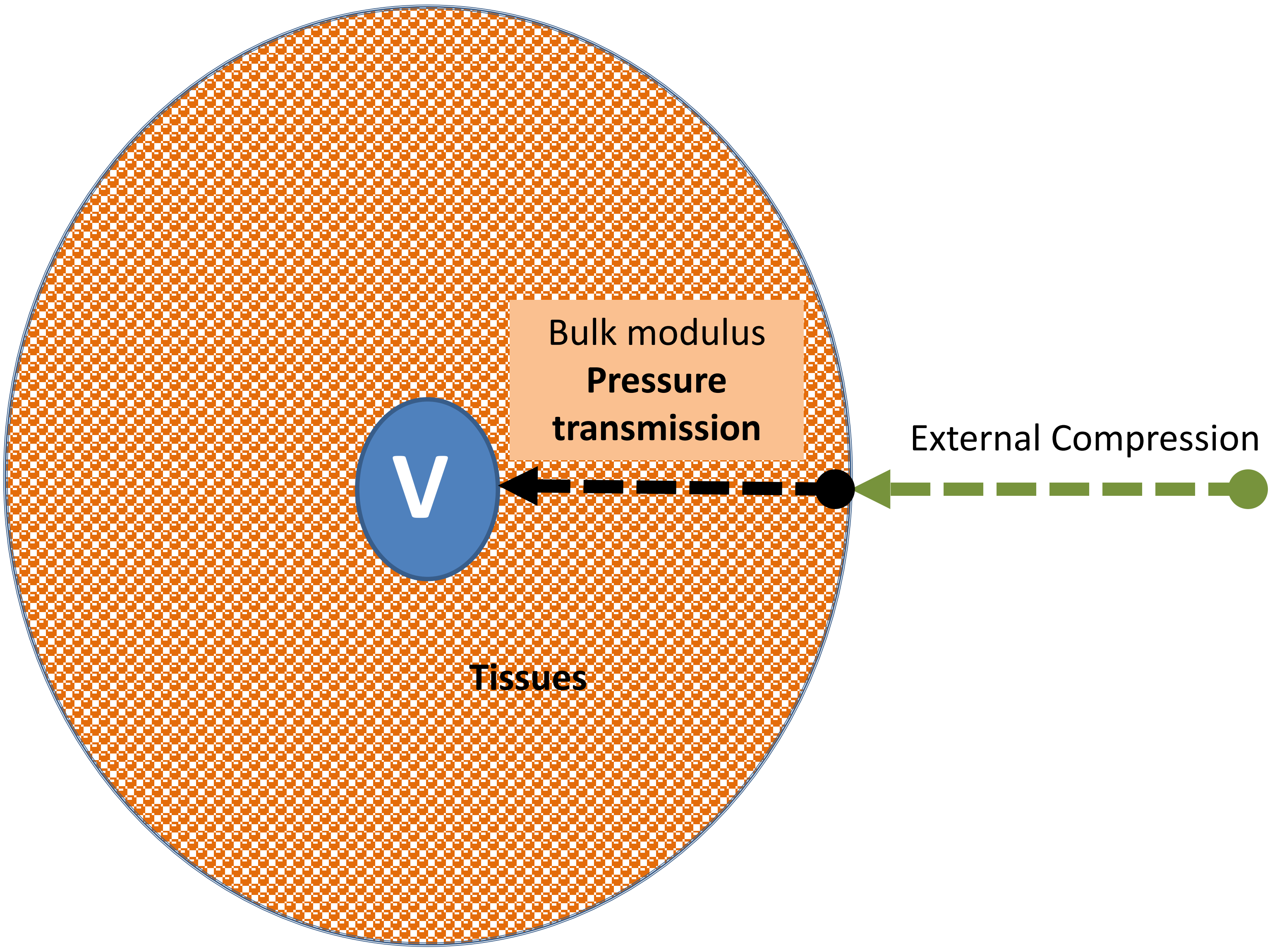
Dependent of bandaging strength

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

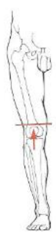
Compressive Pressure value transmitted from surface to depth depends on the elastic and the bulk modulus of the medium :

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

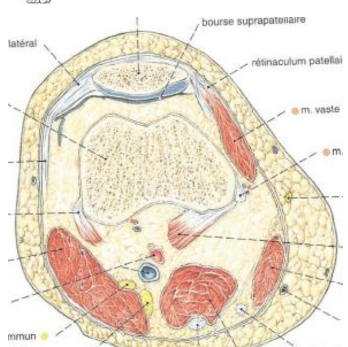
Topography: from thigh down to foot

Posture: Gravitational hydrostatic pressure

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

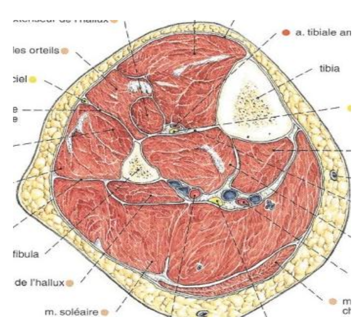


$$K = -V\frac{\partial P}{\partial V}$$



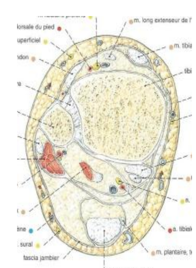
Circumference = 38 cm

Diameter = 12 cm



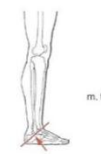
Circumference = 30 cm

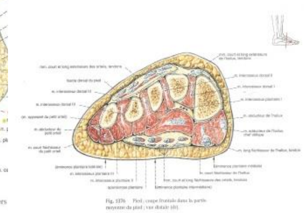
Diameter = 10 cm



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

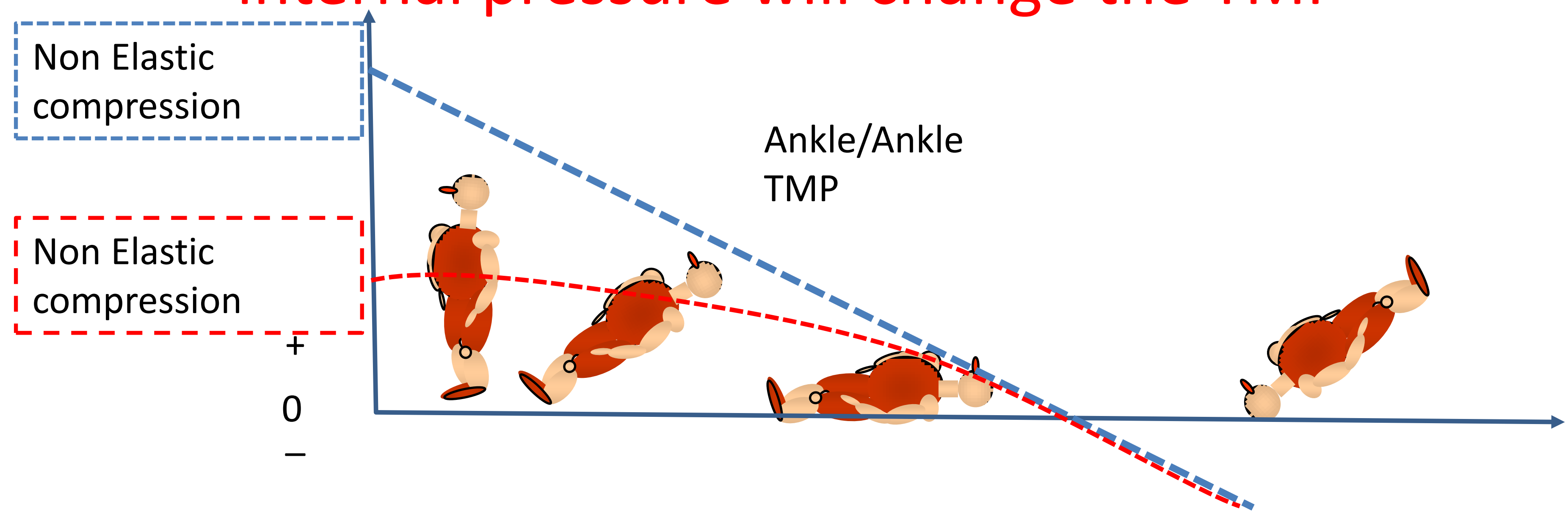
STANDING

WALKING

ANELASTIC NON EXTENSIVE (static)(SUPPORT) BANDAGES

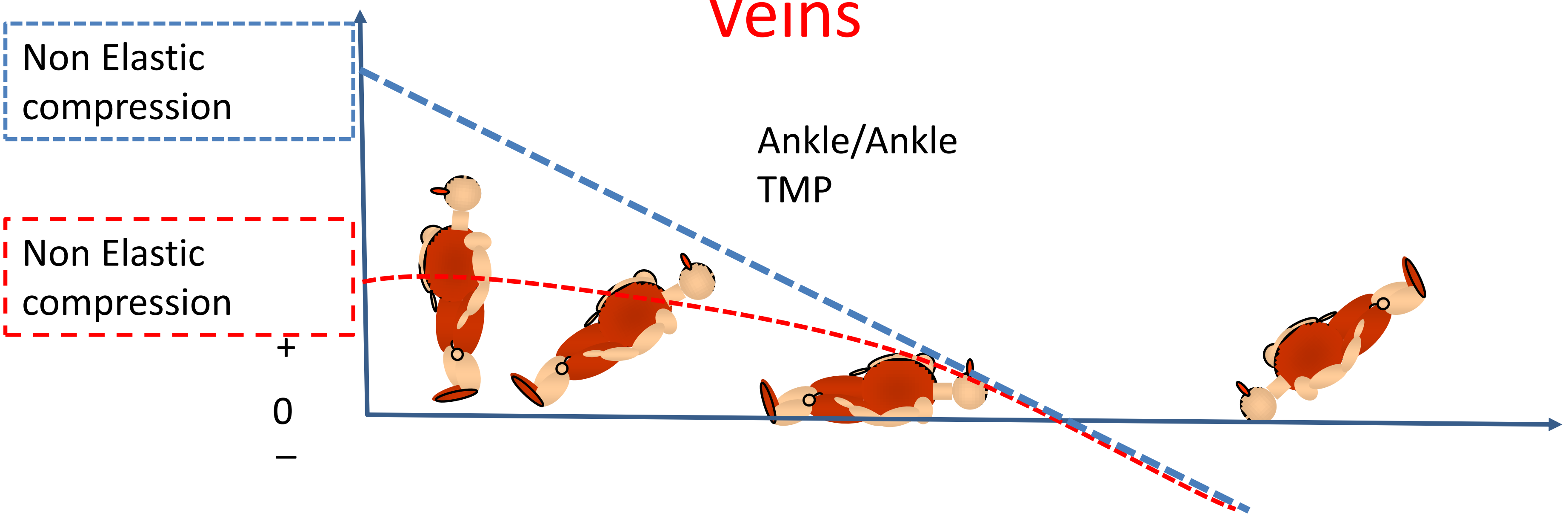
Deliver the FORCE at the moment of bandaging

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

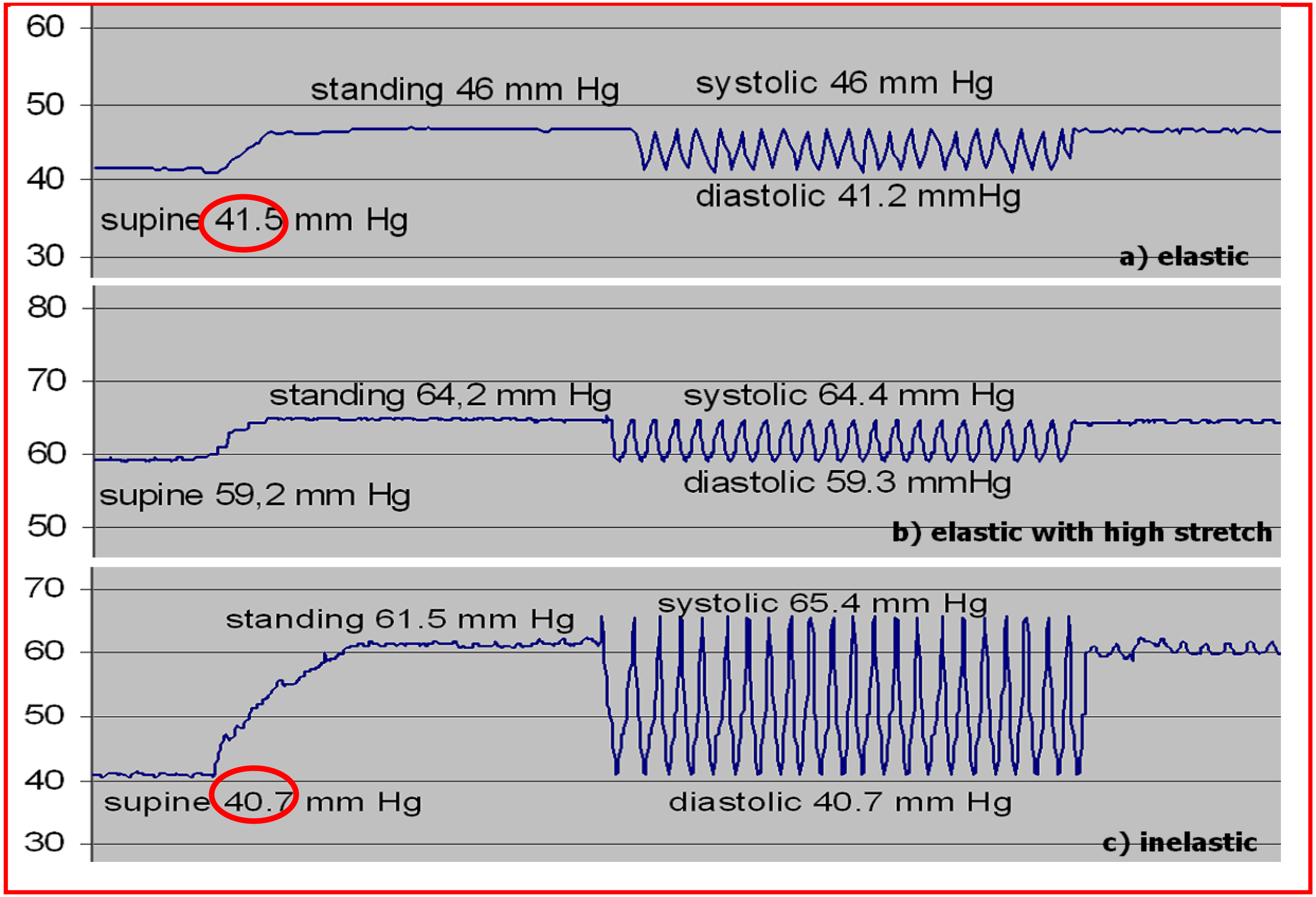


ANELASTIC NON EXTENSIVE NON EXTENSIVE (static)(SUPPORT) BANDAGES Deliver the FORCE at the moment of bandaging

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

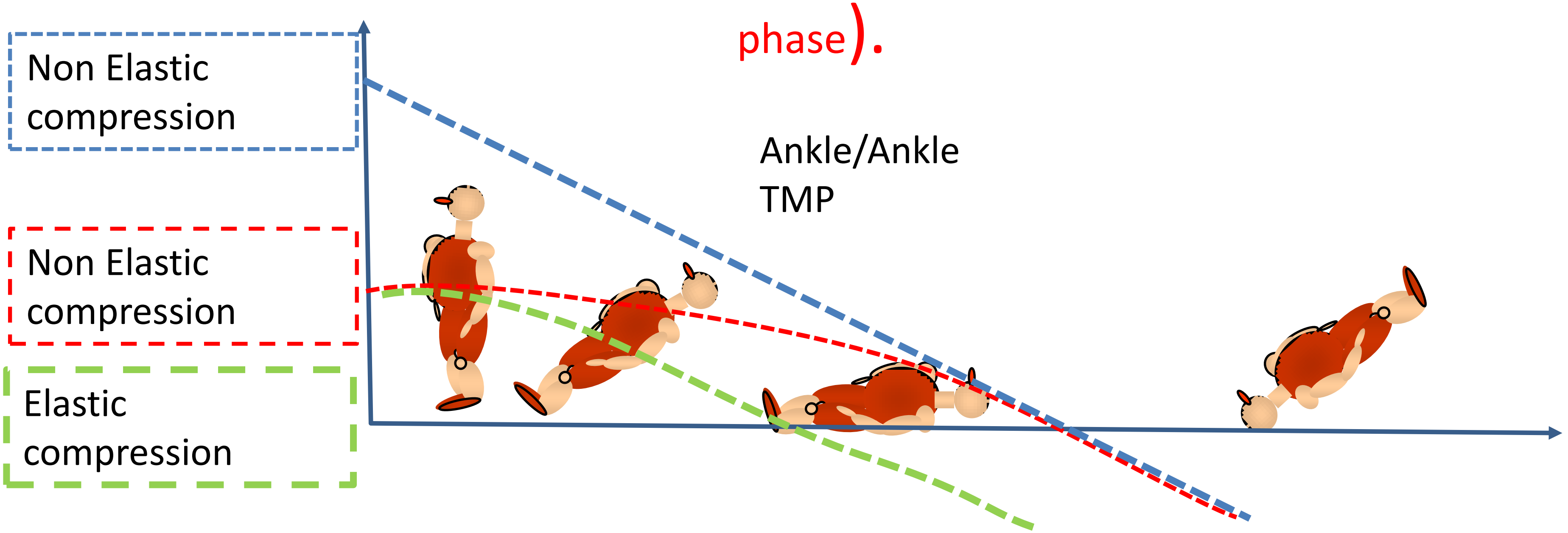
WALKING

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).

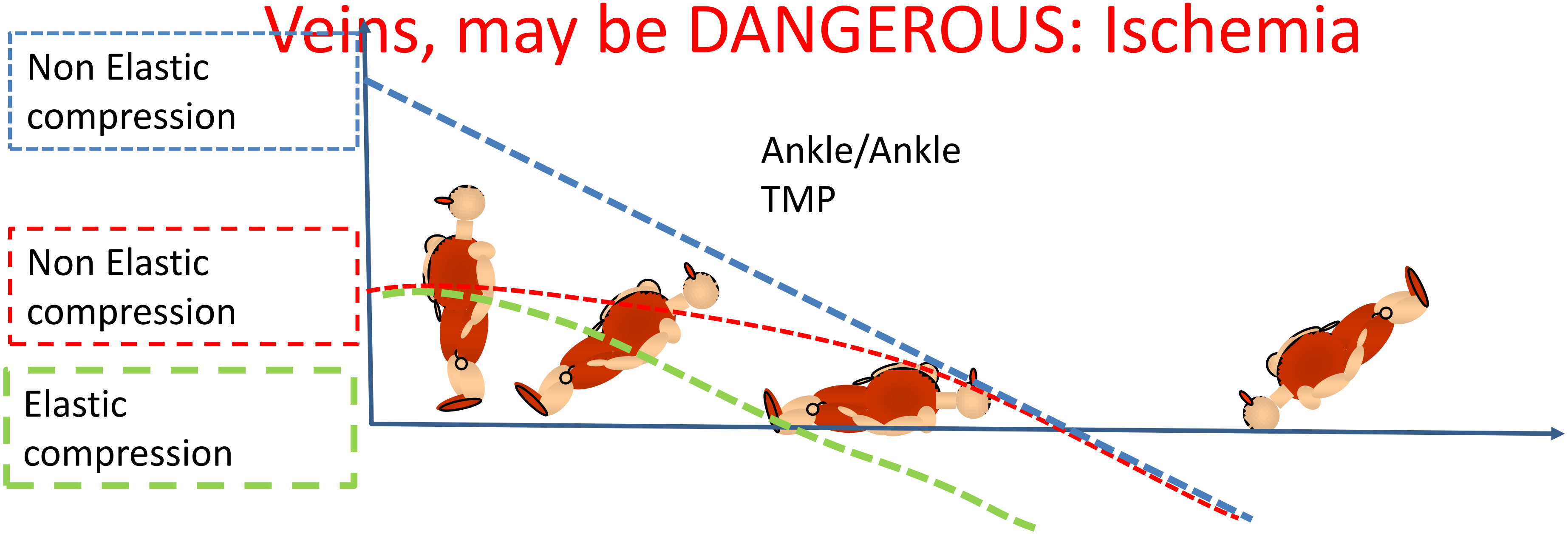


ELASTIC EXTENSIVE BANDAGES

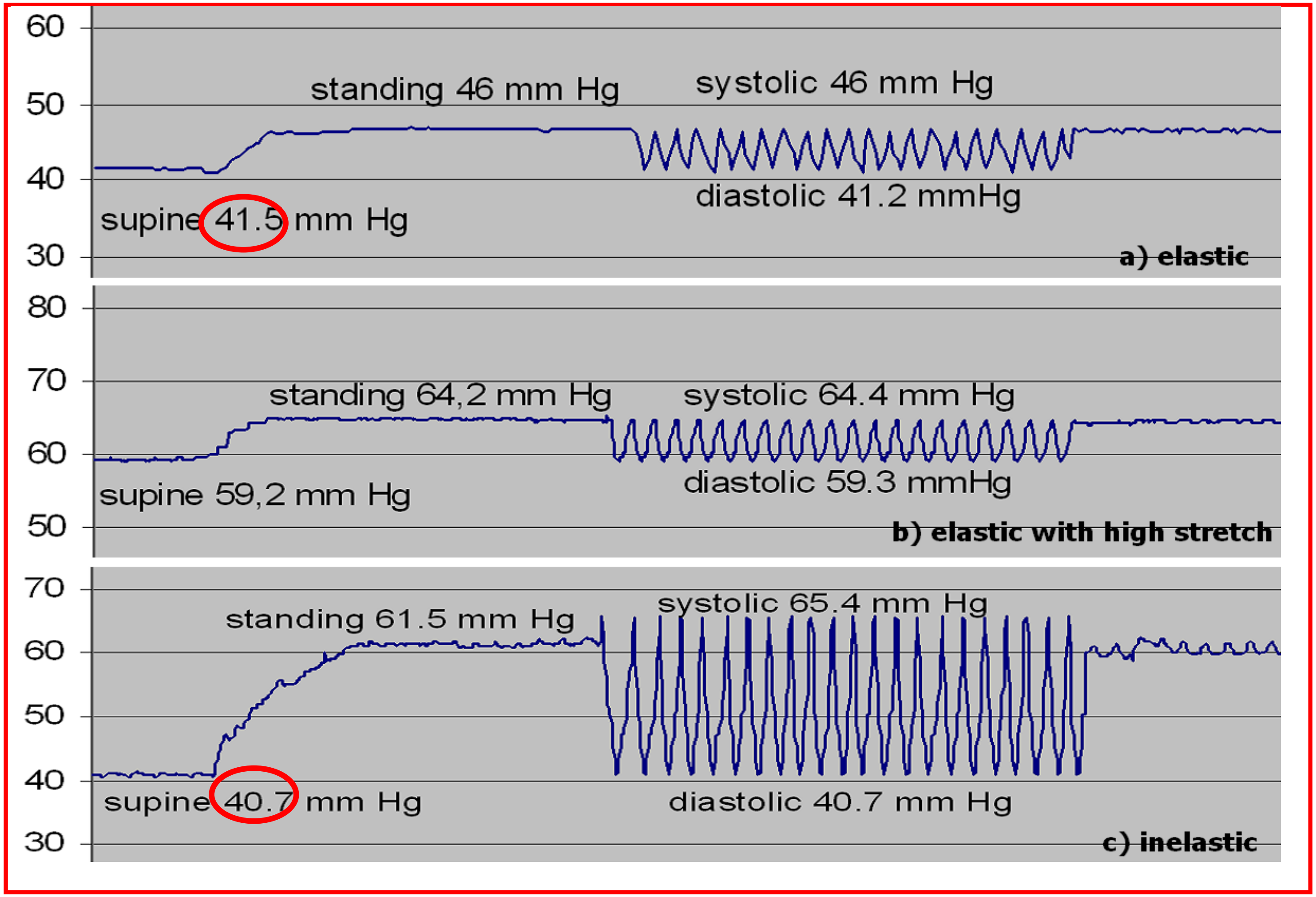
BANDAGES

Deliver the FORCE at the moment of bandaging and LATER

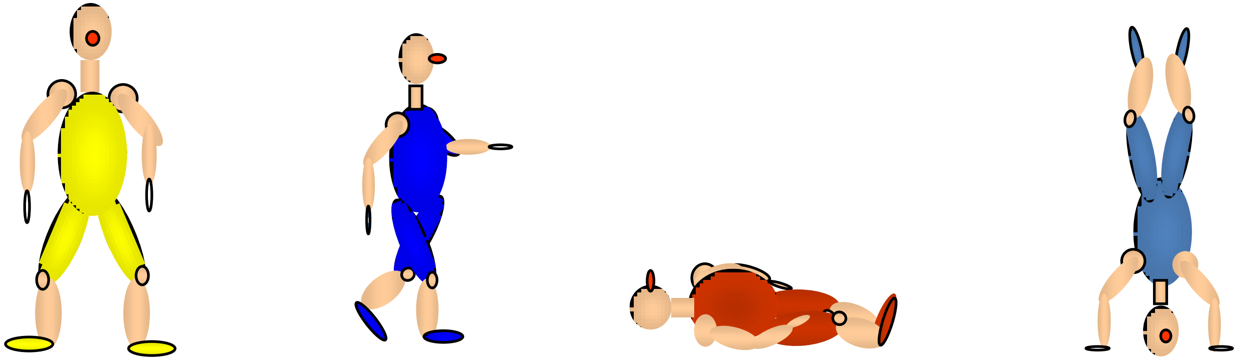
So, the EFFECT on TMP increases when not necessary in Normal and Incompetent Veins, may be DANGEROUS: Ischemia



Sub-bandage pressure (mm Hg)



BANDAGING
Proposals



Normal Individuals

Light elastic compression

Moderate Valve Incompetence

Light/ Moderate elastic compression

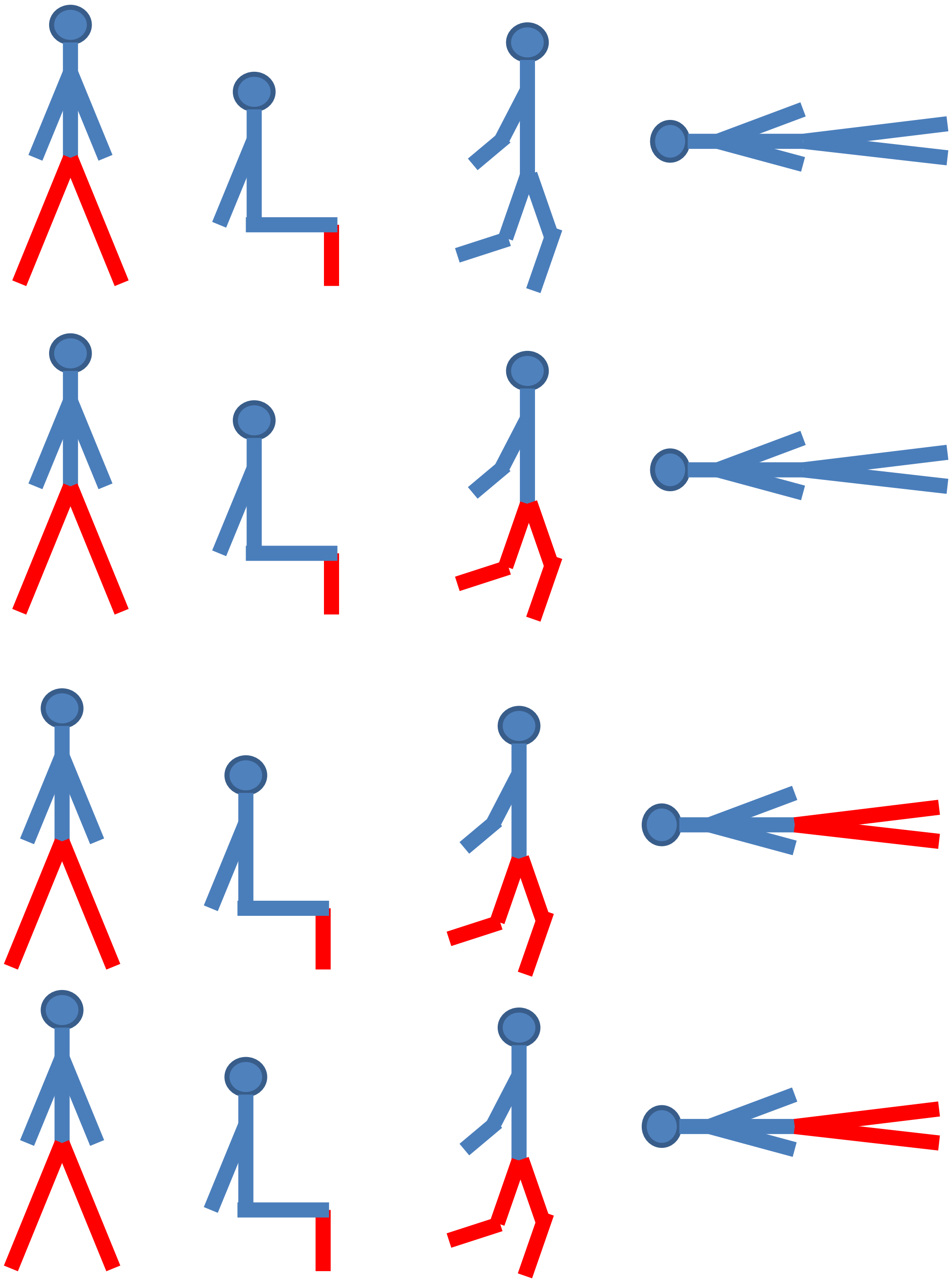
Moderate Venous Obstacle

AV Fistule

Light/ Moderate elastic compression

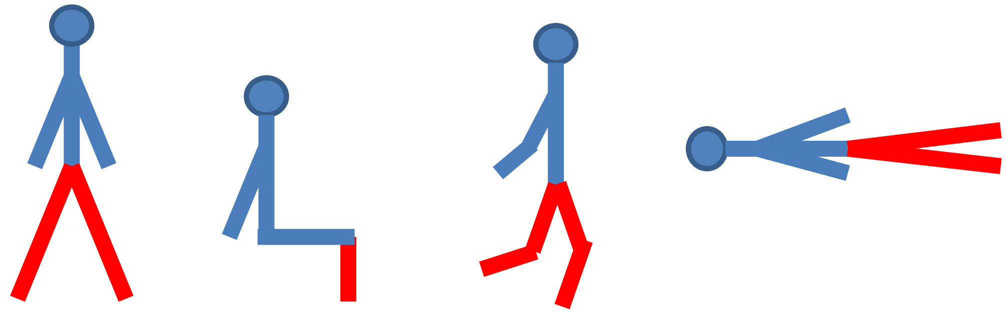
Phlebitis prevention

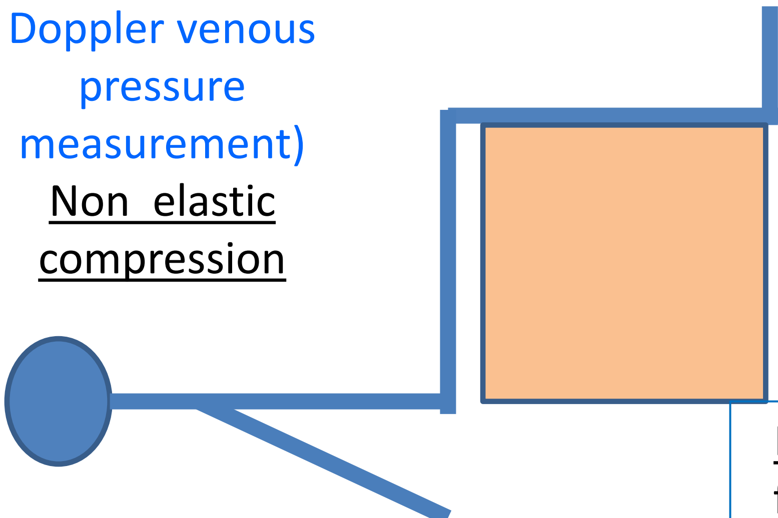
Light elastic compression



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

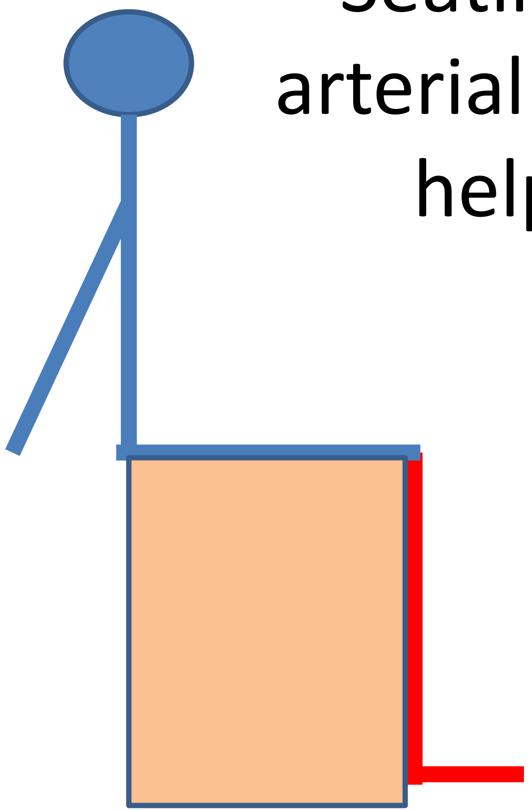
<u>Draining posture</u>
for 2 hours + or -
elastic
compression

Then

Replace elastic
compression by
non elastic
bandage

Check the forefoot
arterial pressure
with Doppler

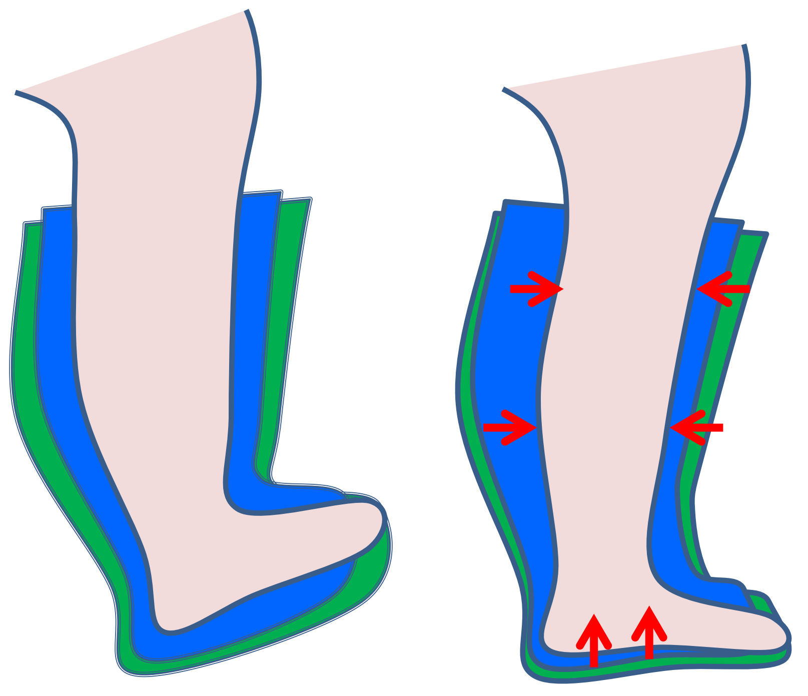
Arteropathy IV th stage :
Thanks to Gravitational Pressure, Seating posture increases foot arterial pressure, relieves pain and helps for gangrene healing



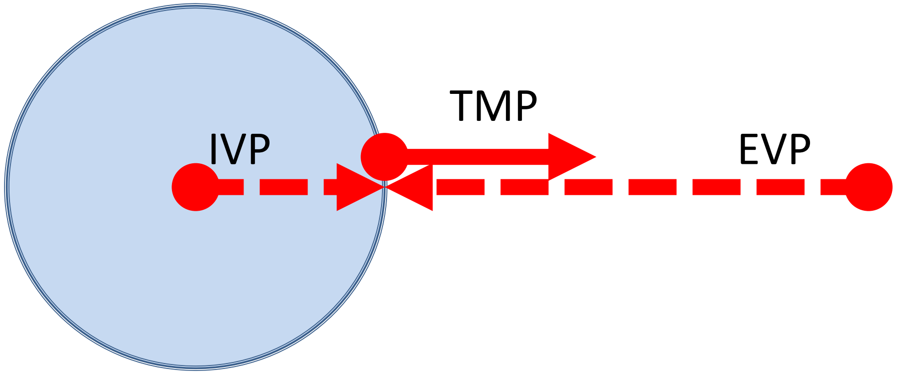
non elastic light bandaging prevents stasis edema

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

The degree of narrowing depends on the body position and the amount of compression pressure.
At the same time the reduction of venous calibre leads to an increase of venous blood flow velocity, demonstrable by measuring the mean transit time to the groin after injection of radio-tracers into a dorsal foot vein and by Doppler and Duplex investigations . Flow VELOCIY Yes but not flow VOLUME

In the upright position, pressures of 70-80 mm Hg are necessary to counteract the standing intravenous pressure and to achieve a reduction of the venous diameter, clearly shown by phlebography (30), Duplex (21,31) and, recently, by MRI (32-34). To compress the femoral vein at thigh level in upright position a minimal pressure of 60 mmHg is required (20). Surprisingly it could be shown that in the prone and in the standing position compression may lead to a more pronounced narrowing of deep than of superficial veins, probably due to a shift of the muscle compartments (32-34).

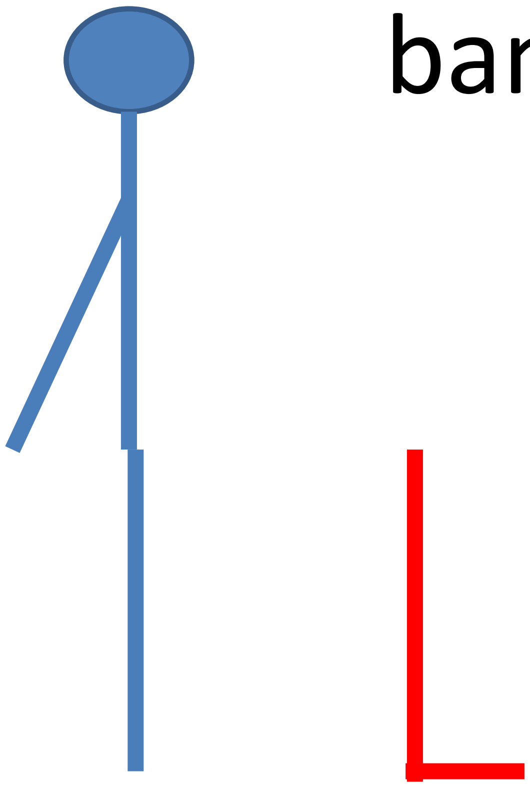
Stiffness in vivo can be assessed by measuring the pressure under a compression product at the B1 point and by calculating a “Static Stiffness Index (SSI)”, subtracting the supine from the standing pressure, (13,14). The B1 point is defined by the transition of the muscular into the tendinous part of the part of the medial gastrocnemius muscle, showing the biggest increase of the leg circumference by dorsiflexion. As a cut-off between elastic and inelastic material a value of 10 was proposed (12). Elastic material is characterized by values lower than 10; inelastic by values higher than 10. Other parameters of stiffness correlating with SSI are the maximal pressure achieved during exercise, pressure peaks, and pressure amplitudes during walking (the difference between systolic and diastolic pressure) (15).

Conclusions (Partsh)
As can be demonstrated in many experimental studies, most of them corresponding to level 1 evidence (Grade A), compression has positive effects on the impaired venous hemodynamic in patients with chronic venous disease causing:

- narrowing of superficial and deep veins, depending on body position and exerted pressure
- an increase of venous blood velocity
- a reduction/abolition of venous reflux
- an improvement/normalization of the venous pumping function and, consequently,
- a reduction/ normalization of ambulatory venous hypertension and an improvement of microcirculation.

Compression is able to counteract the hemodynamic impairment of CVD if the exerted interface pressure is higher than the intravenous pressure. The ideal compression device should therefore exert a low resting pressure (well tolerated at rest and during night time) combined with high standing and working pressure.

Pump like effect bandaging



non elastic light bandaging prevents stasis edema

Check the forefoot arterial pressure

Pressure compression transmitted from surface to depth

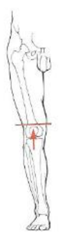
according to COMPRESSIBILITY:

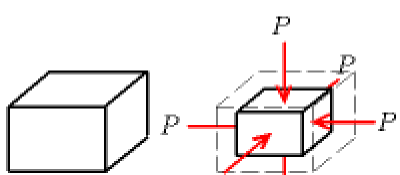
Bulk modulus of leg structures

Bulk Elastic Properties

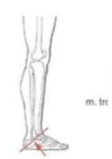
The bulk elastic properties of a material determine the COMPRESSIBILTY how much it will compress under a given amount of external pressure. The ratio of the change in pressure to the fractional volume compression is called the bulk modulus of the material . Therefore, leg content being an anisotropic solid one must use the full generalized Hooke's law.

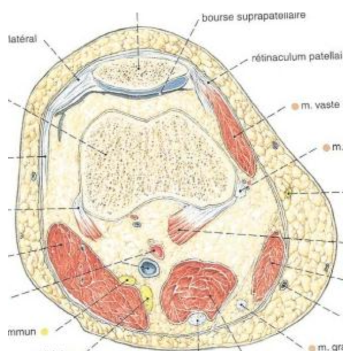
Varies according to the leg level: mid thigh, mid calf, ankle , foot



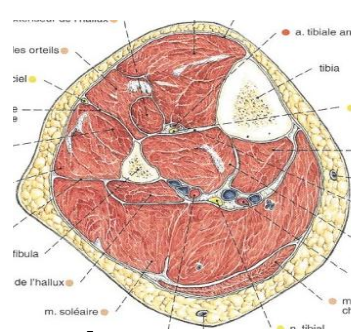


$$K = -V\frac{\partial P}{\partial V}$$

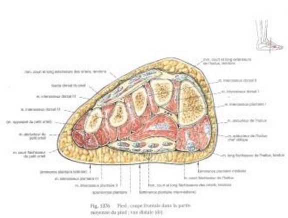




Circumference = 38 cm
Diameter = 12 cm



Circumference = 30 cm
Diameter = 10 cm



Circumference = 19 cm
Diameter = 6 cm

Extensible and non-extensible Leg Compression and *Support* setting (non extensible bandages)

Why? TMP reduction by external pressure enhancement

How? External strain: Water, mercury, air, elastic compression, non elastic bandage compression: different strain features

Sub-compression pressure axial transmission in the leg:

Heterogeneous bulk modulous of the leg components supposed to transmit the superficial compression pressure.

Where?

Superficial location: Foot, ankle, leg, thigh

Effective Depth pressure transmission

Ulcer: why superficial and not « deep »

Necrosis affects only skin in venous insufficiency (except in case of phlegmatia cerulea), in contrast with arterial insufficiency (skin and muscles…)

Expected hemodynamic effects of external leg compression

The magnitude of this pressure transmission from the surface (skin) to the deep structures of the leg depends on their pressure conductance and bulk modulus.

Compression reduces TMP Extra-venous Pressure (EVP) enhancement.
Correction of the venous

How?

External compression Increases the extra-vascular pressure of the skin and the underlying tissues pressure and narrows the veins thanks to TMP decrease because :

TMP = Intra-venous pressure (IVP) – Extra-venous Pressure (EVP)

l strain: Water, mercury, air, elastic compression, non elastic bandage compression: different strain features

Sub-compression pressure axial transmission in the leg:

Heterogeneous bulk modulous of the leg components supposed to transmit the superficial compression pressure.

Where?

Superficial location: Foot, ankle, leg, thigh
Effective Depth pressure transmission

Ulcer: why superficial and not « deep »

Necrosis affects only skin in venous insufficiency (except in case of phlegmatia cerulea), in contrast with arterial insufficiency (skin and muscles…)

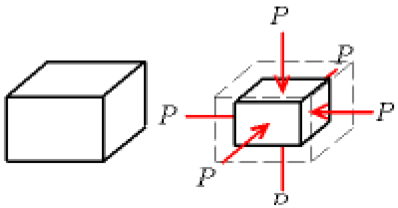
For an anisotropic solid such as wood or paper, these three moduli do not contain enough information to describe its behaviour, and one must use the full generalized Hooke's law.

Bulk Elastic Properties

The bulk elastic properties of a material determine how much it will compress under a given amount of external pressure. The ratio of the change in pressure to the fractional volume compression is called the bulk modulus of the material.

MODULE D'ELASTICITE ISOSTATIC

The **bulk modulus** (*K*) of a substance measures the substance's resistance to uniform compression. It is defined as the pressure increase needed to decrease the volume by a factor of 1/e. Its base unit is the pasc



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

al.[1]

he bulk modulus K>0 can be formally defined by the equation:

where *P* is pressure, *V* is volume, and ∂*P*/∂*V* denotes the partial derivative of pressure with respect to volume. The inverse of the bulk modulus gives a substance's compressibility.

Other moduli describe the material's response (strain) to other kinds of stress: the shear modulus describes the response to shear, and Young's modulus describes the response to linear stress. For a fluid, only the bulk modulus is meaningful. For an anisotropic solid such as wood or paper, these three moduli do not contain enough information to describe its behaviour, and one must use the full generalized Hooke's law.

Pressures of about 40 mmHg at the ankle are widely quoted in the literature for the prevention or treatment of venous leg ulcers, but some authorities recommend values significantly higher than this

Sub-bandage pressure may be calculated using a using a simple formula derived from the Laplace equation as follows;

P = (TN x 4630) / CW

where P = pressure (in mmHg)

T = bandage tension (in kgf)

C = circumference of the limb (in cm)

W = bandage width (in cm)

N = number of layers applied

Sub-bandage pressure is therefore *directly* proportional to bandage tension but *inversely* proportional to the radius of curvature of the limb to which it is applied

The *extensibility* of a bandage, determines the change in length that is produced when the bandage is subjected to an extending force. Extensibility is usually expressed in the form of a percentage which relates the stretched to the unstretched length. It may be measured using a constant rate of traverse machine such as an Instron, which extends the bandage at a predetermined rate whilst recording the tension developed within it. If the construction of the bandage is such that when it is stretched past a given point the textile components prevent further extension, even though the elastomeric fibres may not have reached the limit of their elasticity, *lock out* is said to have occurred.

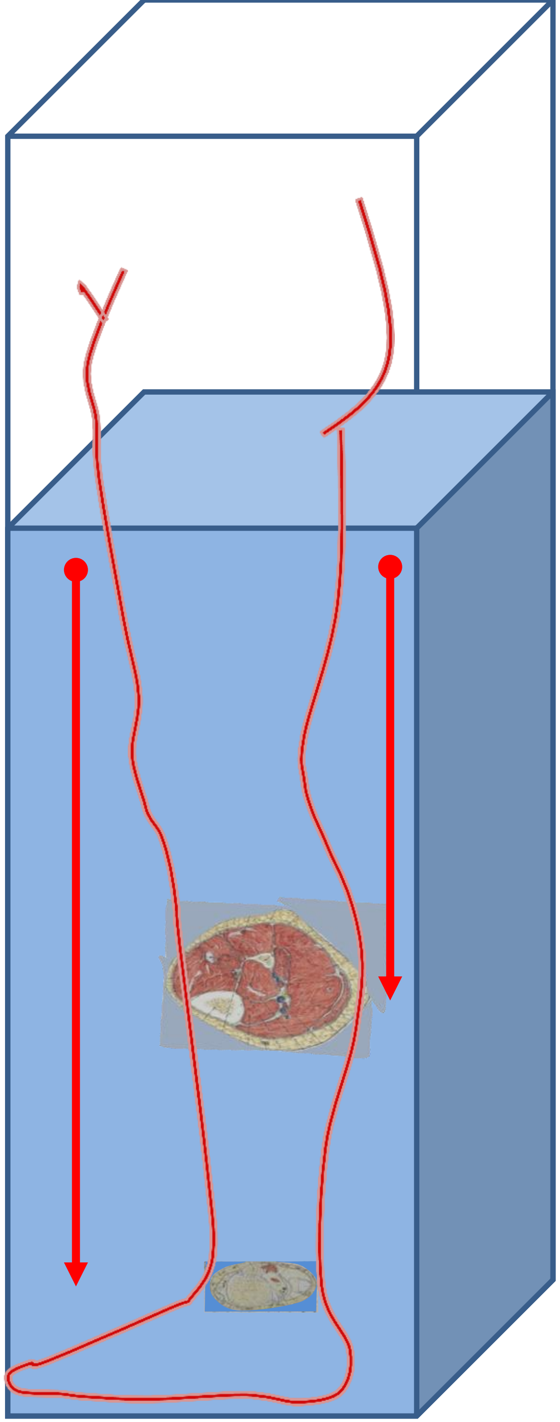
Power or *modulus* determines the force that is required to bring about a specified increase in bandage length. The greater the power, the larger the force that is required.

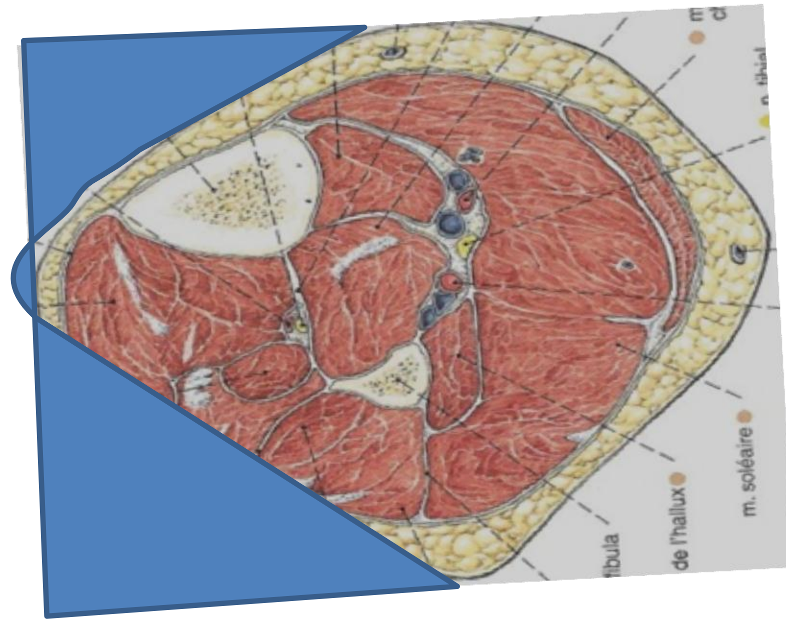
Elasticity determines the ability of bandage subjected to an extending force in the manner described above, to resist any change in length and return to its original length once the applied force has been removed.

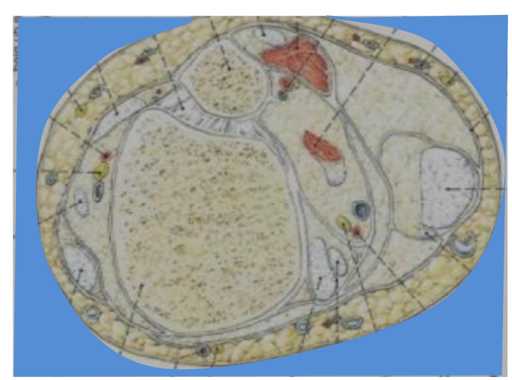
Compression implies the deliberate application of pressure in order to produce a desired clinical effect. It is usually achieved by the use of elasticated stockings or an appropriate bandage, and is most commonly used to control oedema and reduce swelling in the treatment of venous disorders of the leg.

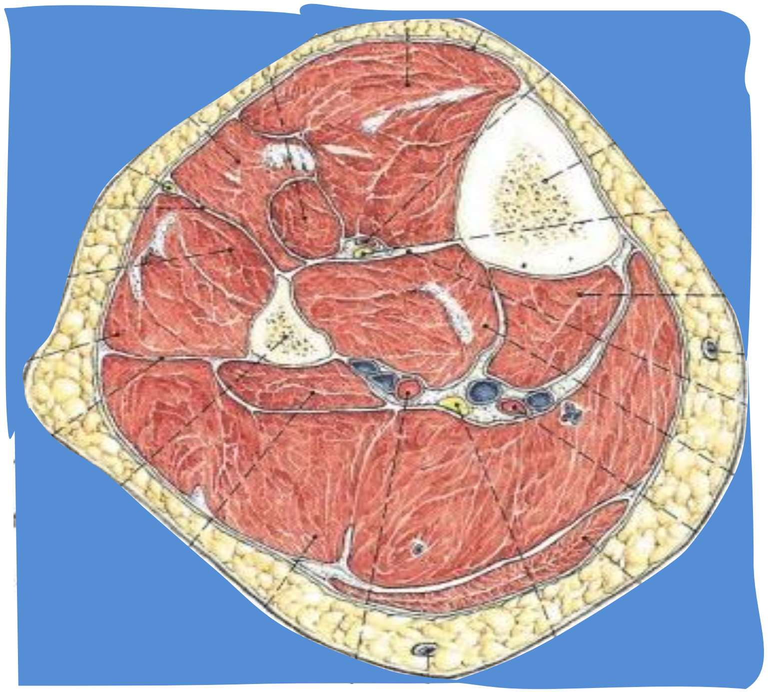
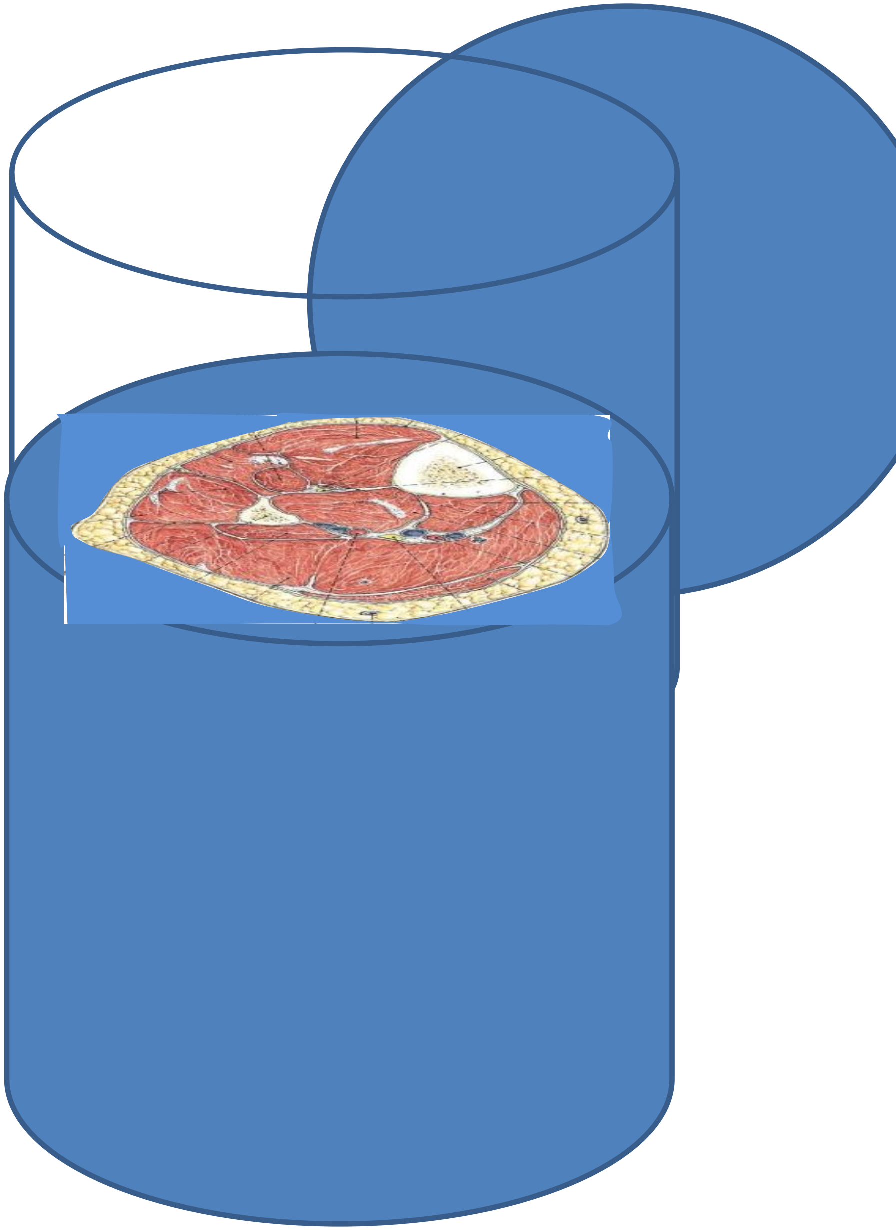
Support may be defined as the retention and control of tissue without the application of compression, and is usually provided to prevent the development of a deformity or a change in shape of a tissue mass due to swelling or sagging. Although non extensible bandages can be used for this purpose, a product with a limited degree of extensibility is generally preferred as it is easier to apply.

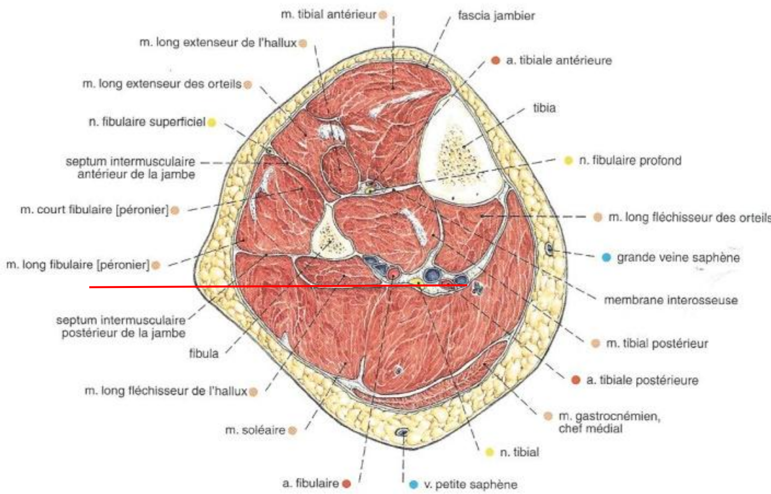
Conformability of a bandage determines its ability to follow the contours of a limb and is governed largely by the density and extensibility of the fabric, the more open and extensible the structure, the more conformable the product is likely to be. As a general rule, knitted bandages tend to be more comfortable than woven ones.

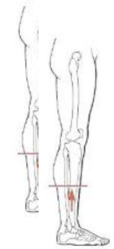



de l'hallux
m. soléaire

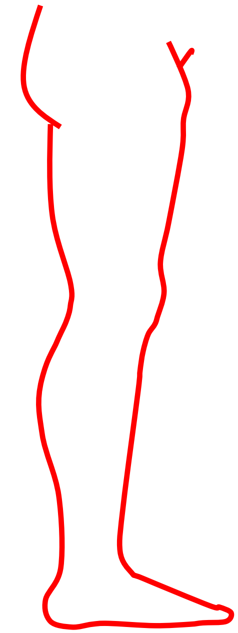






Circumference = 30 cm
Diameter = 10 cm



rsale dans le tiers

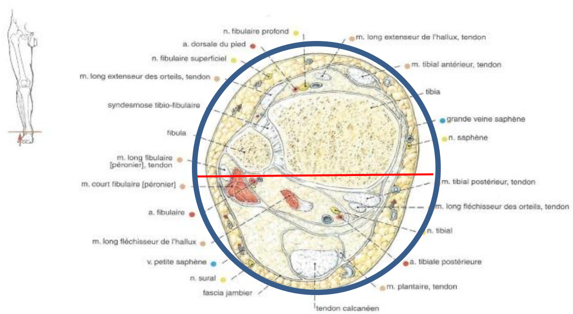
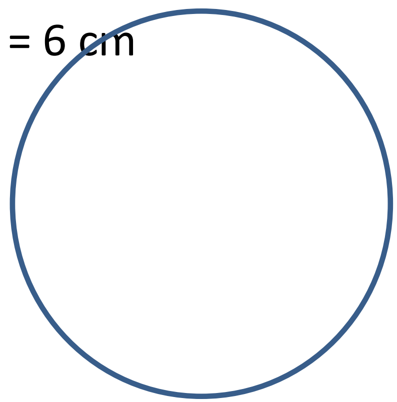


Fig. 1374 Jambe ; coupe transversale juste au-dessus de l'articulation talo-crurale ; vue distale (dr).

Circumference = 19 cm
Diameter = 6 cm



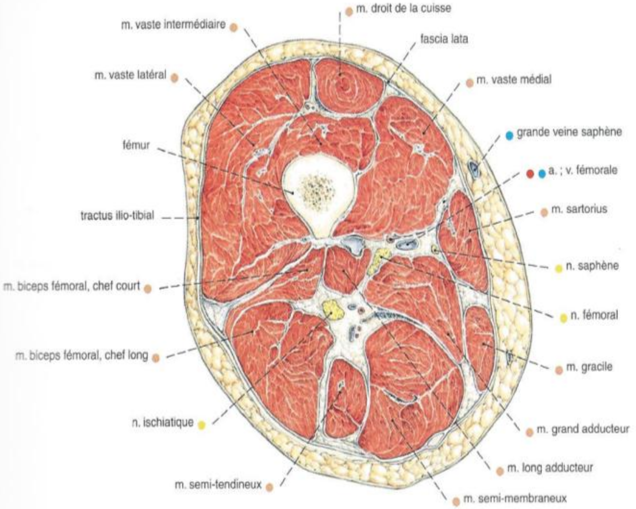
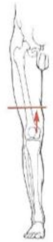
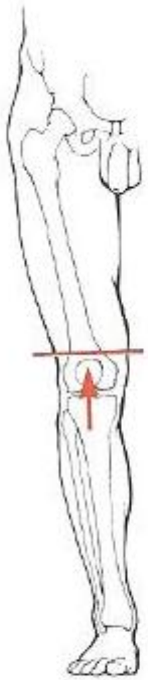


Fig. 1368 Cuisse ; coupe transversale dans la partie moyenne ; vue distale (dr).



Circumference = 49 cm
Diameter = 16 cm

Circumference = 38 cm
Diameter = 12 cm



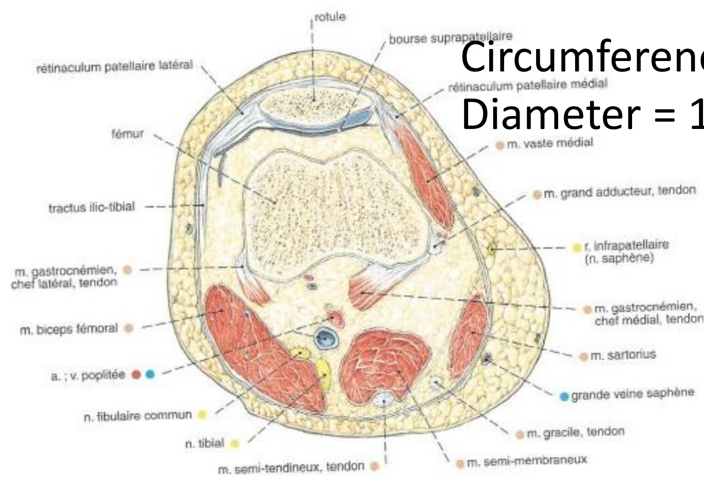


Fig. 1370 Cuisse ; coupe transversale dans le tiers distal et dans la base de la rotule ; vue distale (dr).

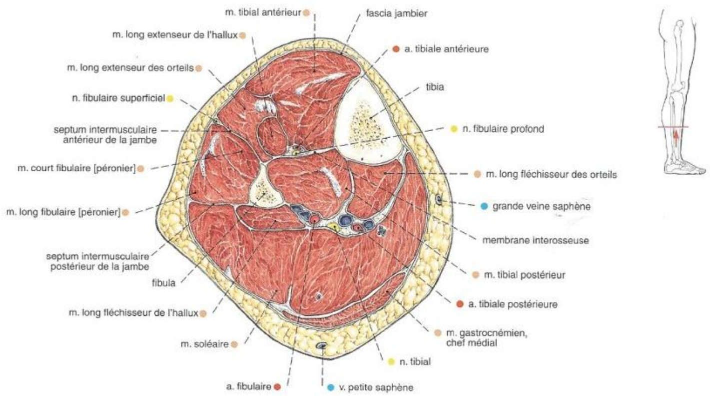


Fig. 1372 Jambe ; coupe transversale dans le tiers moyen ; vue distale (dr).
Comparez avec la fig. 1295.

Circumference = 30 cm
Diameter = 10 cm

Circumference = 19 cm
Diameter = 6 cm

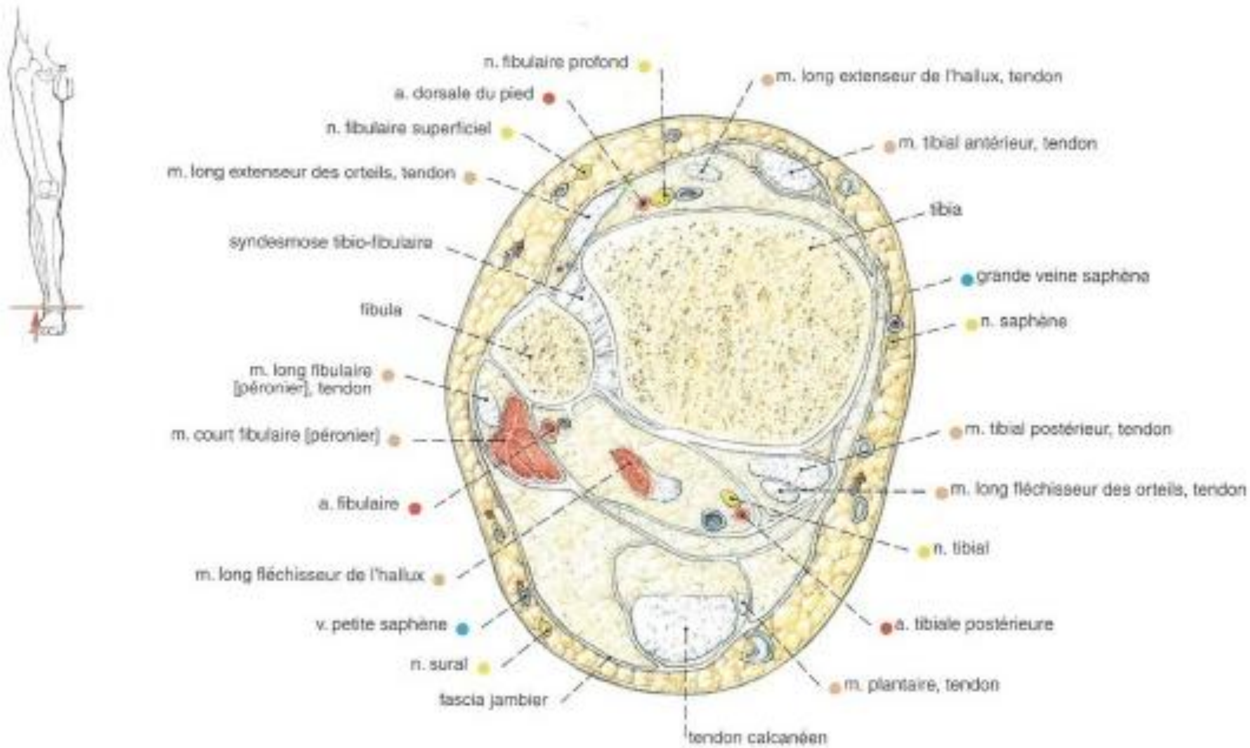


Fig. 1374 Jambe ; coupe transversale juste au-dessus de l'articulation talo-crurale ; vue distale (dr).

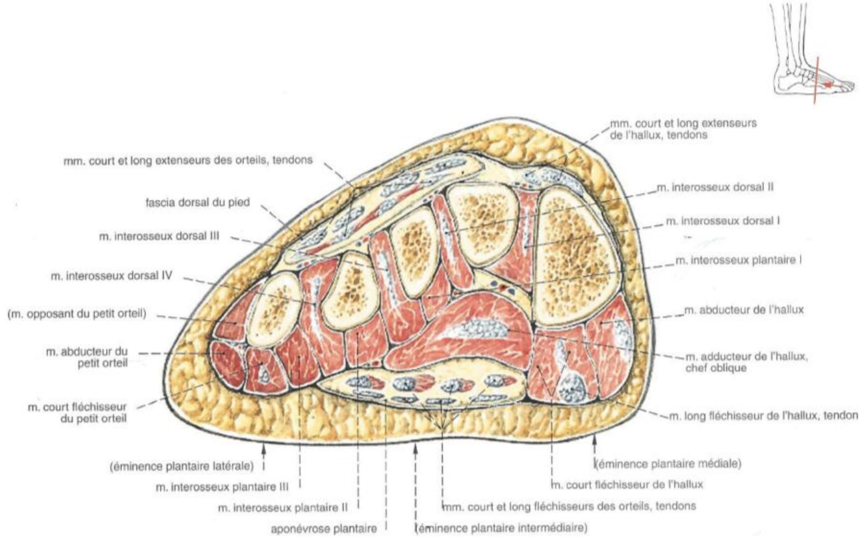


Fig. 1376 Pied ; coupe frontale dans la partie moyenne du pied ; vue distale (dr).

urs

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Compression reduces TMP Extra-venous Pressure (EVP) enhancement.
Correction of the venous

How? External compression Increases the extra-vascular pressure of the skin and the underlying tissues pressure and narrows the veins thanks to TMP decrease because :

TMP = Intra-venous pressure (IVP) – Extra-venous Pressure (EVP)

l strain: Water, mercury, air, elastic compression, non elastic bandage compression: different strain features

Sub-compression pressure axial transmission in the leg:

Heterogeneous bulk modulous of the leg components supposed to transmit the superficial compression pressure.

Where?

Superficial location: Foot, ankle, leg, thigh
Effective Depth pressure transmission

Ulcer: why superficial and not « deep »

Necrosis affects only skin in venous insufficiency (except in case of phlegmatia cerulea), in contrast with arterial insufficiency (skin and muscles…)

Three factors affect the movement of water be-tween body water compartments.
The previous chapter took a brief look at the factors which influence thedistribution of water between compartments. These factors are hydrostaticpressure, osmotic pressure and membrane characteristics.

Hydrostatic pressure

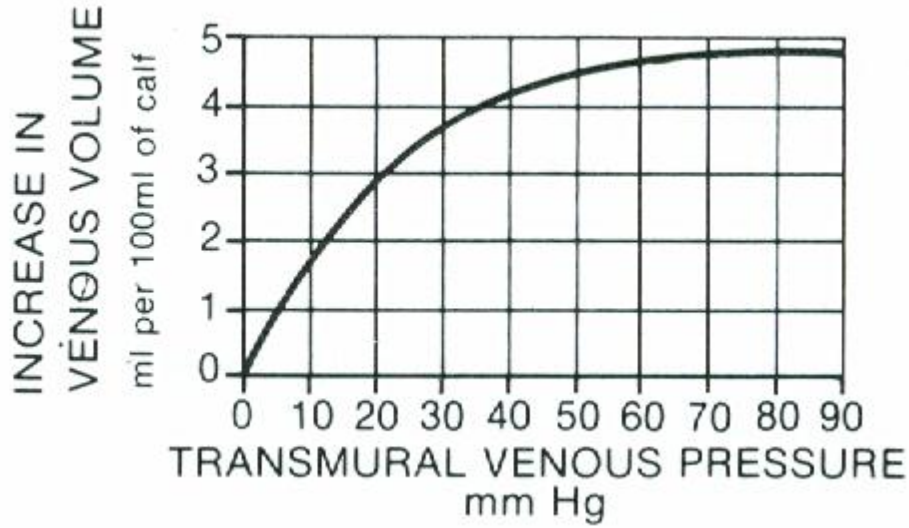
is a force generated by water. Hydrostatic pres-sure pushes water out of a compartment.

Osmotic pressure

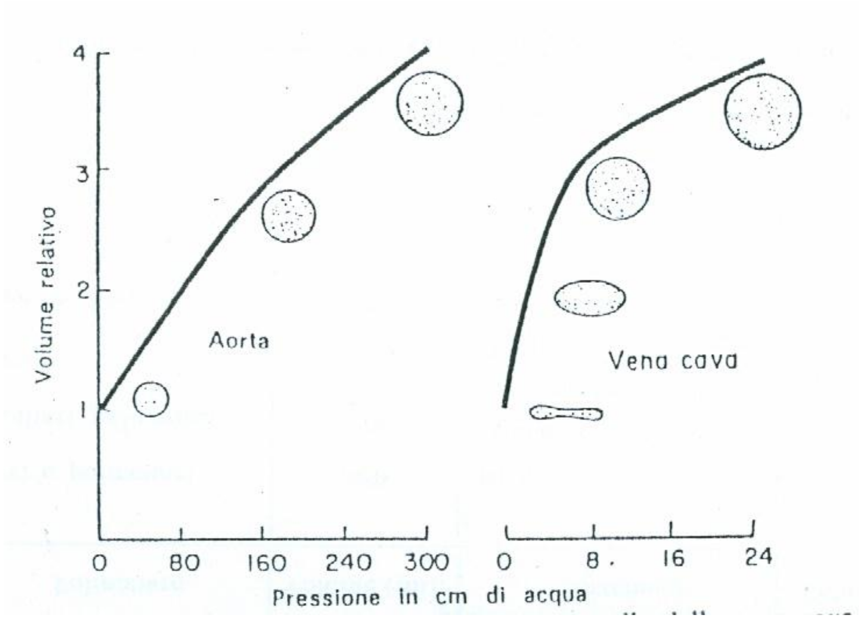
is a force exerted by solutes. Osmotic pressure draws water into a compartment. This force is dependent only on the concentra-tion of particles (osmolality) in solution.

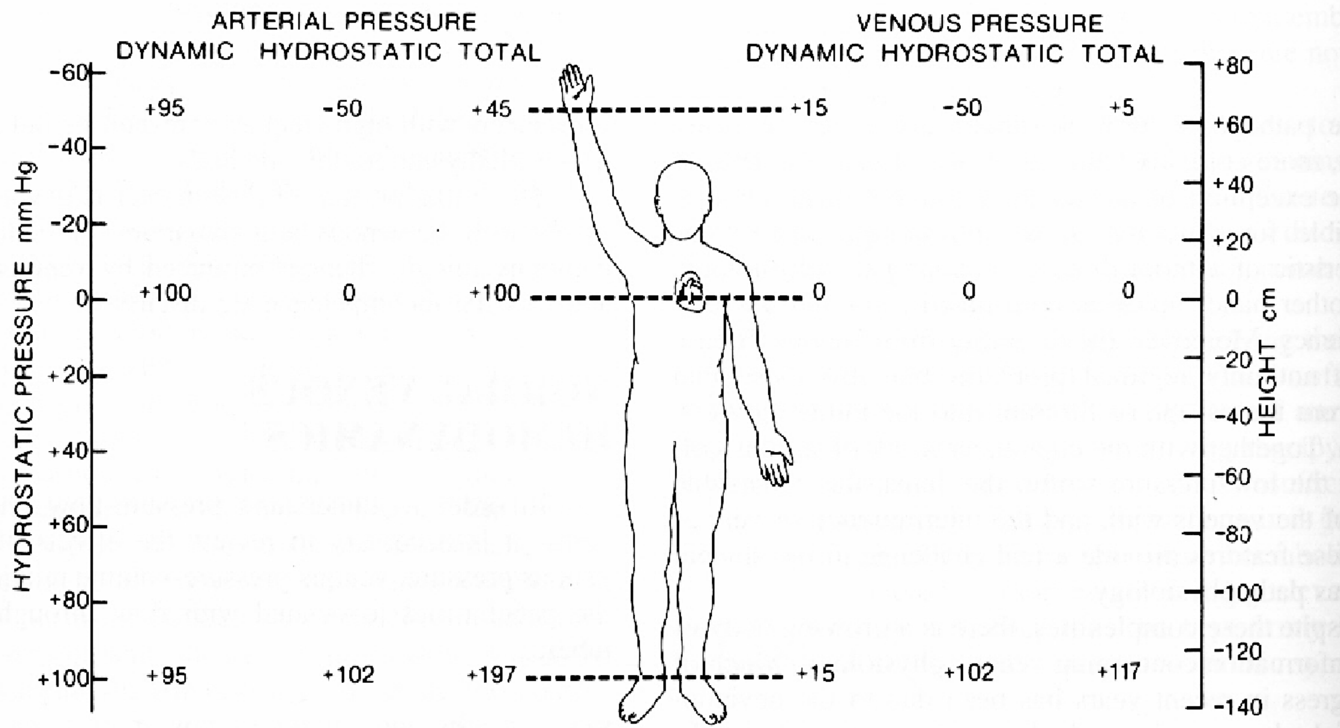
Membrane characteristics

affect the ability of water and solute to move between compartments.
This chapter focuses on how these factors are incorporated into Starling'slaw. Starling's law governs fluid shifts between compartments and can be used to understand all fluid accumulations, including peripheral edema, pleural effusions and ascites.


INCREASE IN VENOUS VOLUME
ml per 100ml of calf
0
1
2
3
4
5
0 10 20 30 40 50 60 70 80 90
TRANSMURAL VENOUS PRESSURE
mm Hg

$E = P + gh + 1/2v2 = cost$





ARTERIAL PRESSURE
DYNAMIC HYDROSTATIC TOTAL
VENOUS PRESSURE
DYNAMIC HYDROSTATIC TOTAL
+95 -50 +45
+15 -50 +5
+100 0 +100
0 0 0
+95 +102 +197
+15 +102 +117
HYDROSTATIC PRESSURE mm Hg
-60 -40 -20 0 +20 +40 +60 +80 +100
HEIGHT cm
+80 +60 +40 +20 0 -20 -40 -60 -80 -100 -120 -140

Expected hemodynamic effects of external leg compression

Hemodynamics can be defined as the physical factors that govern blood flow

Solid mechanics is the branch of mechanics, physics, and mathematics that concerns the behavior of solid matter under external action

Static compression
One the

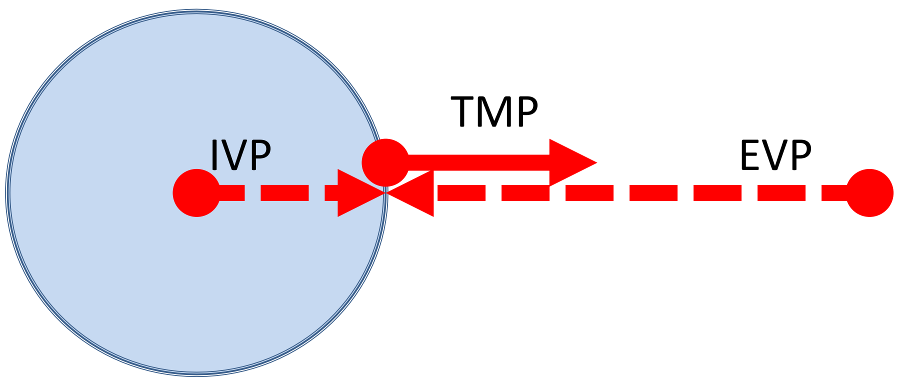
$$Pressure\ (mmHg) = \frac{Tension\ (Kfg) \times n \times 4620}{Circumference\ (cm) \times Bandage\ width\ (cm)}$$

Venous Trans-Mural-Pressure (TMP) excess is responsible for tissue drainage impairment (pain, edema, trophic changes, ulcer) and vein dilatation.

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

COMPRESSION reduces TMP by increasing EVP



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:

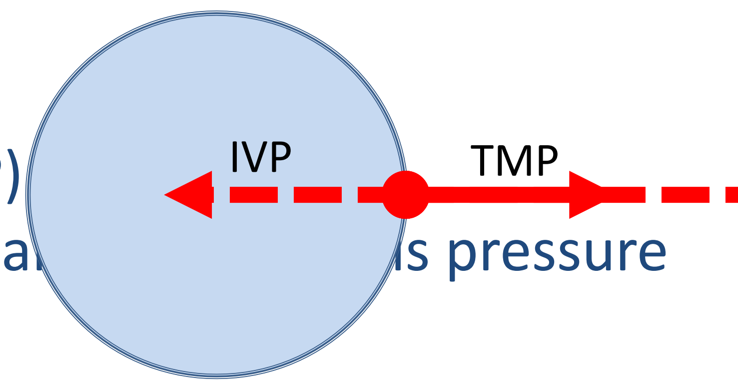
a-Residual pressure resulting of the arterial pressure throughout the microcirculation resistance, and

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

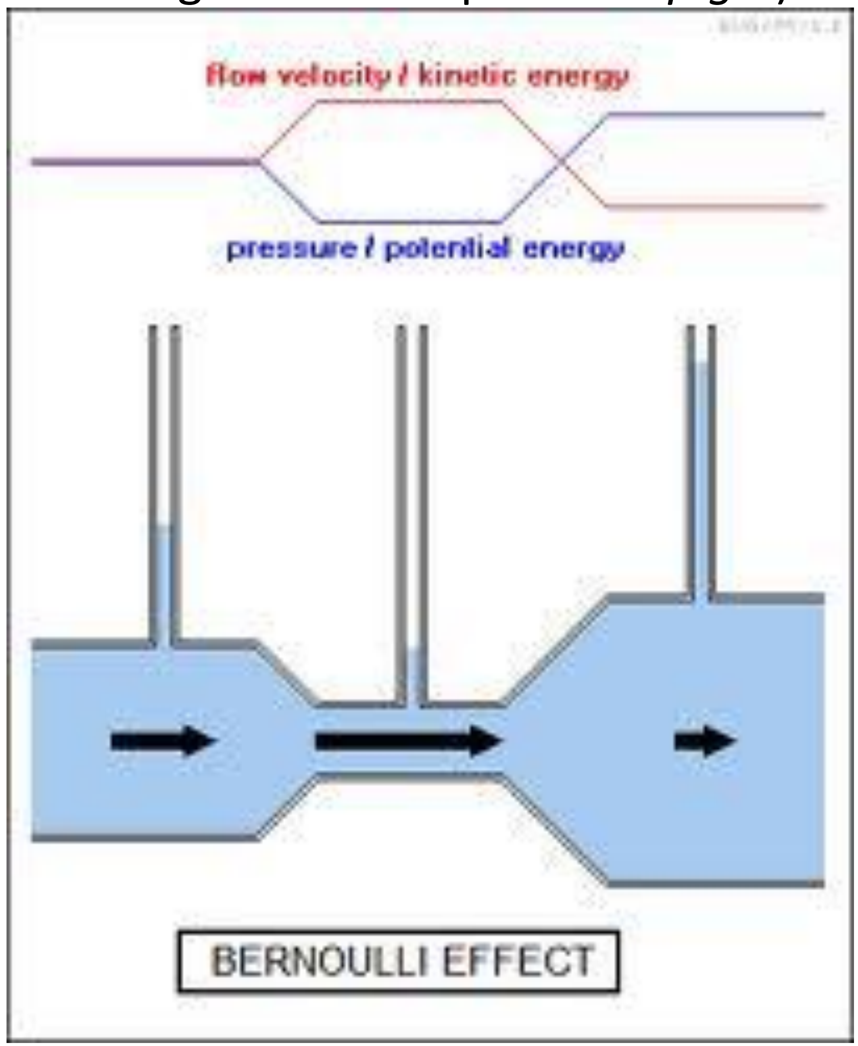
EVP is the static pressure made of:

1-Atmospheric pressure (AtP)

2-Muscles , interstitial fluids a… s pressure (TP)



Thus an increase in the speed of the fluid occurs proportionately with an increase in both its dynamic pressure and kinetic energy, and a decrease in its static pressure andpotential energy. If the fluid is flowing out of a reservoir the sum of all forms of energy is the same on all streamlines because in a reservoir the energy per unit volume (the sum of pressure and gravitational potential $\rho\ g\ h$) is the same everywhere.[4].



$$\frac{1}{2}\rho v^2 + \rho g z + P$$

COMPRESSION: DEFINITION

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

Hemodynamics can be defined as the physical factors that govern blood flow.
These are the same physical factors that govern the flow of any fluid,
and are based on a fundamental law of physics, namely Ohm's Law,
which states that:
current (I) equals the voltage difference (ΔV) divided by resistance (R).
In relating Ohm's Law to fluid flow,
the voltage difference is the **pressure difference** (ΔP;
sometimes called **driving pressure**, **perfusion pressure**, or **pressure gradient**),
the resistance is
the resistance to flow (R) offered by the blood vessel and its interactions with the flowing blood, and the current is the blood flow (F).
This hemodynamic relationship can be summarized by: $F = \frac{\Delta P}{R} = \frac{(P_A - P_V)}{R}$

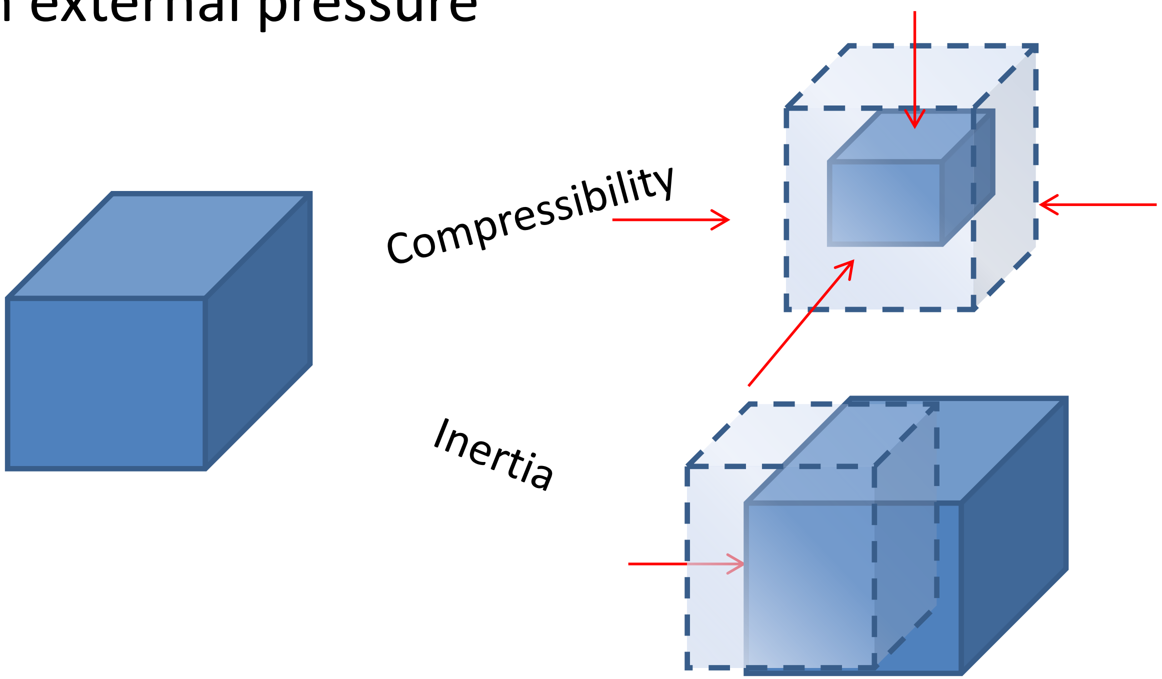
For the flow of blood in a blood vessel, the ΔP is
the pressure difference between any two points along a given length of the vessel.
When describing the flow of blood for an organ,
the pressure difference is generally expressed as
the difference between the arterial pressure (P_A) and venous pressure (P_V).
For example, the blood flow for the kidney is determined
by the renal artery pressure, renal vein pressure, and renal vascular resistance.

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

Elastic Properties (Bulk modulus): compressibility

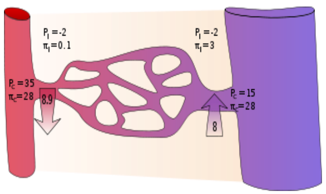
how much a material will compress under a given amount of external pressure

Inertia Properties: a material will resist in its motion under a given external pressure



Expected hemodynamic effects of external leg compression

Venous Trans-Mural-Pressure (TMP)



At the venous end of the capillaries:

IVP is made of: : ρ g h + HDP + Osmotic plasma pressure (OPP)

EVP is made of: TP + AtP + Osmotic Interstitium pressure (OIP)

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

b-Muscular pump pressure

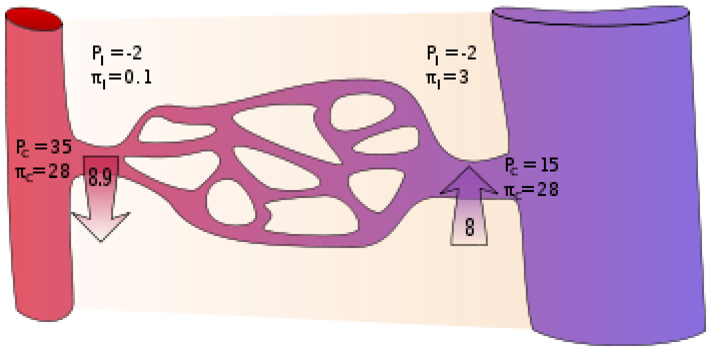
Venous Trans-Mural-Pressure (TMP)

At the venous end of the capillaries:

Starling equation

- $([P_c - P_i] - \sigma[\pi_c - \pi_i])$ is the net driving force,
- K_f is the proportionality constant, and
- J_v is the net fluid movement between compartments

$$J_v = K_f([P_c - P_i] - \sigma[\pi_c - \pi_i])$$



According to Starling's equation, the movement of fluid depends on six variables:
Capillary hydrostatic pressure (P_c), Interstitial hydrostatic pressure (P_i)
Capillary oncotic pressure (π_c),Interstitial oncotic pressure (π_i)
Filtration coefficient (K_f): constant of proportionality regarding the capillary permeability (product of capillary surface area and capillary hydraulic conductance).
Reflection coefficient (σ) Corrects the ineffectiveness of some of the oncotic pressure gradient(0 up to 1).

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