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NON-INVASIVE ASSESSMENT OF THE PULMONARY AND SYSTEMIC VASCULAR DISTENSIBILITY AT EXERCISE IN SEDENTARY VS. ATHLETIC SUBJECTS

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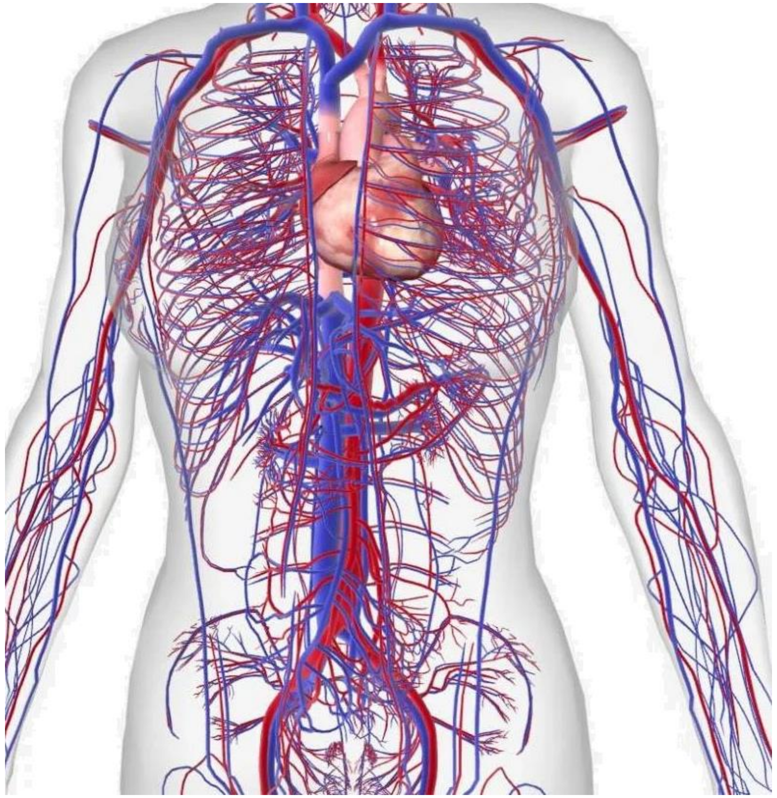

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INTRODUCTION

PULMONARY VS. SYSTEMIC CIRCULATION

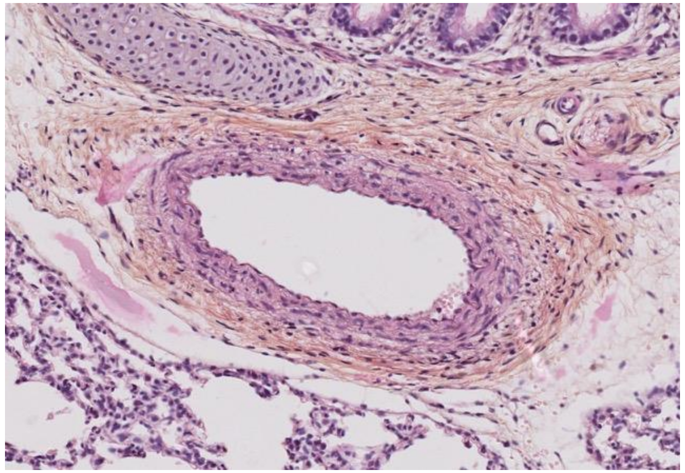
PULMONARY CIRCULATION

Cardiac Output (CO) =

Pulmonary Arterial Pressure (PAP) - - -

± 10 mmHg (PAP-LAP)

PVR = PAP-LAP/CO
= 1/10e SVR (~ 1,6 mmHg)



thin media

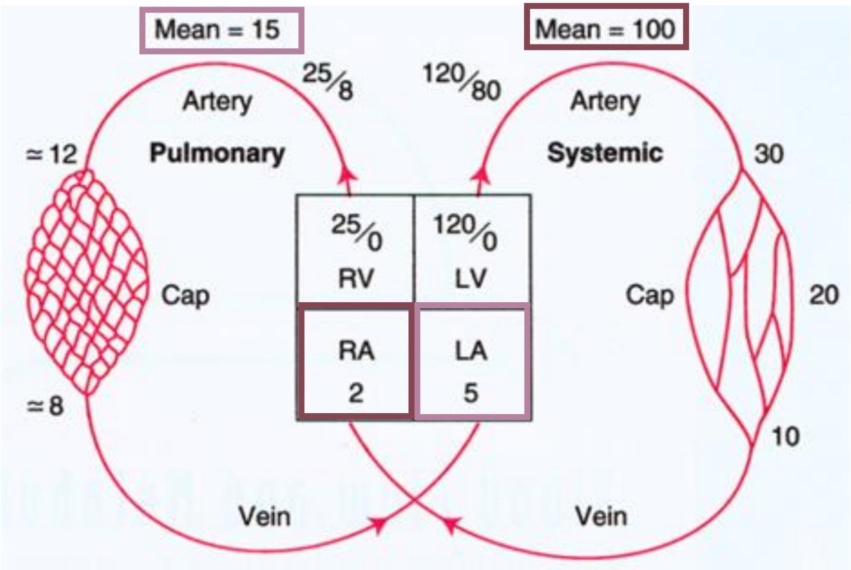
SYSTEMIC CIRCULATION

Cardiac Output (CO) =

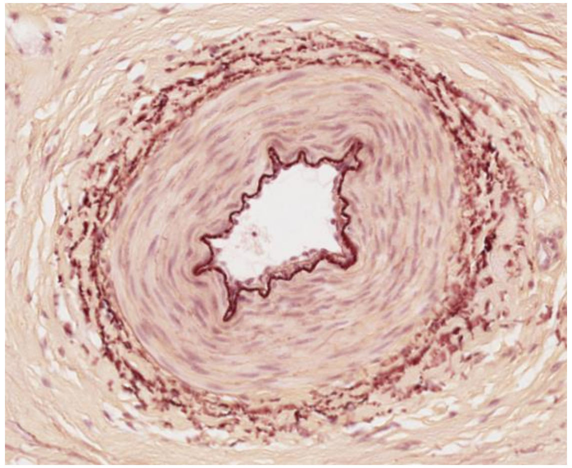
Systemic Arterial Pressure (SAP) ++

± 98 mmHg (SAP- RAP)

SVR = SAP – RAP/CO
= 10x PVR (~16,5 mmHg)



J.B. West



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PVR = pulmonary vascular resistance
PAP = pulmonary arterial pressure
LAP = left atrial pressure

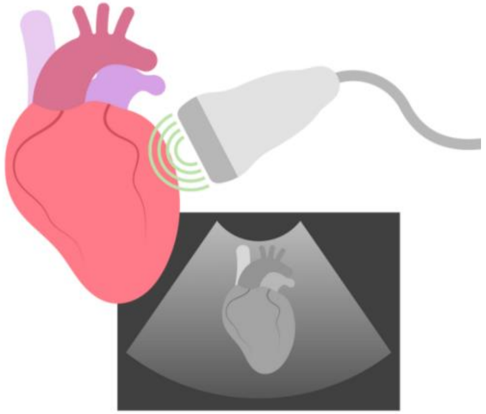
SVR = systolic vascular resistance
SAP = systolic arterial pressure
RAP = right atrial pressure

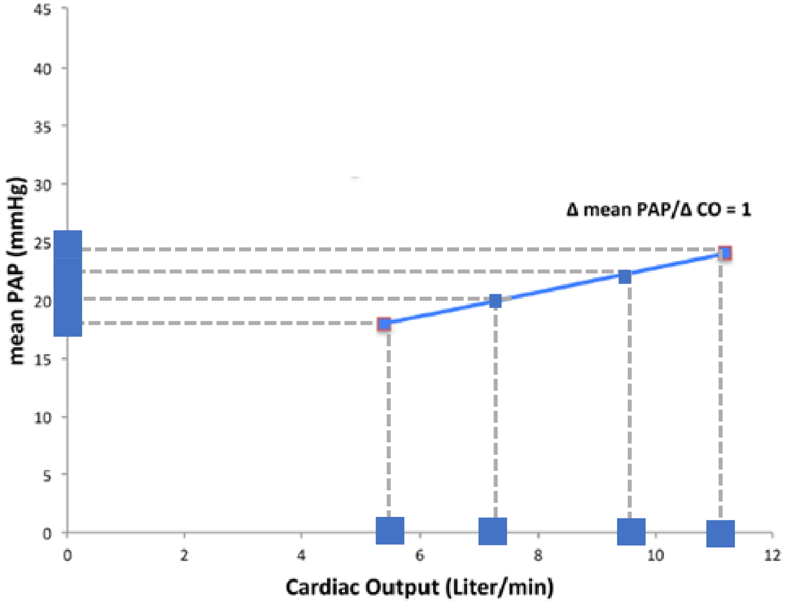
PULMONARY VASCULAR RESISTANCE

- **At exercise, pulmonary vascular resistance (PVR) ↘**
  (Kovacs, Eur Respir J, 2012 ; Naeije, Am J Respir Crit Care Med,2013)

- PVR can be measured by echocardiography with greater precision by multiple measurements during stress echocardiography

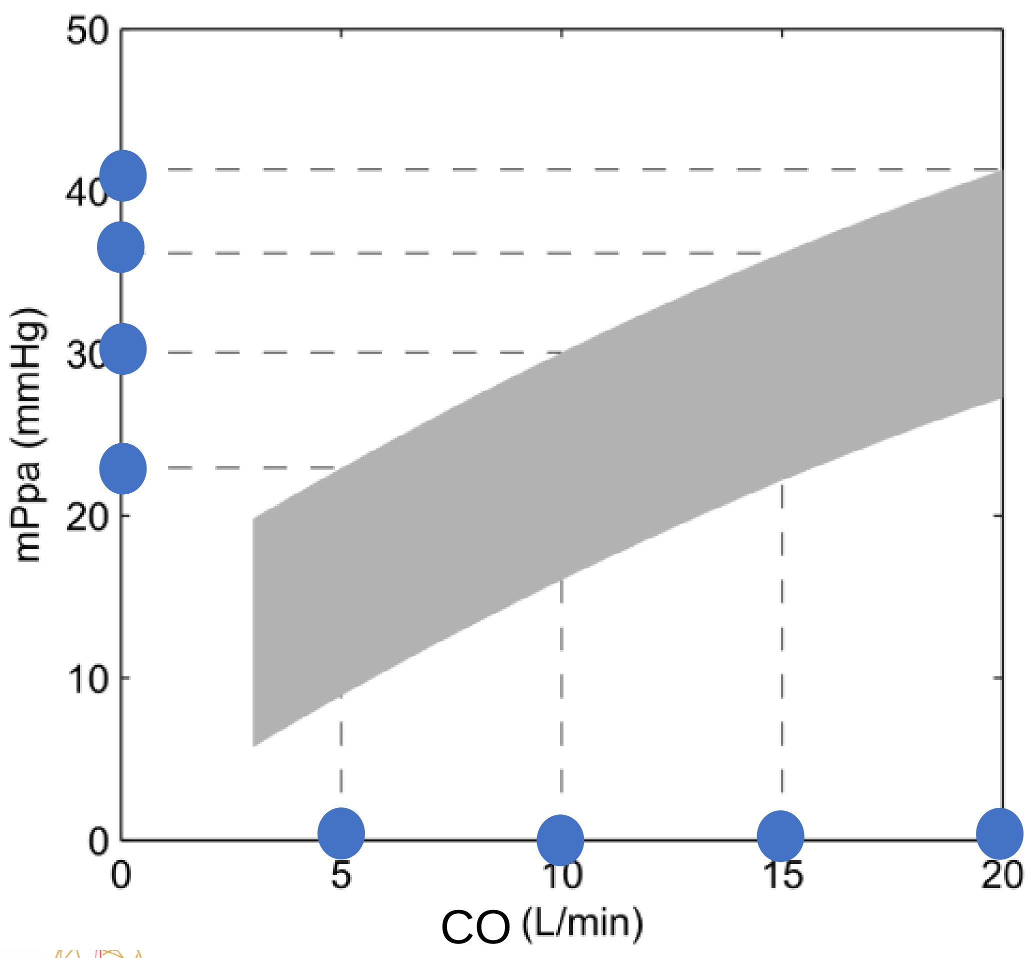
$$PVR = \frac{meanPAP - LAP}{CO}$$





Ferrara F et al. Int J Circ I 2021

PULMONARY VESSELS DISTENSIBILITY



- **Distensibility** of pulmonary vasculature
  - mPAP-CO not strictly linear
  - **CURVILINEAR MODEL** : distensibility of pulmonary resistive vessels *(Linehan, J Appl Physiol, 1992)*

Distensibility coeficient α

$$PVR = [(1 + \alpha PAP)^5 - (1 + \alpha LAP)^5] / 5\ \alpha . CO$$

α : Percentage of diameter change in resistive pulmonary vessel per mmHg increase in transmural pressure during exercise (%/mmHg).

- 1~2 %/mmHg *(Naeije, Am J Respir Crit Care Med,2013 ; Reeves, Am J Physiol Lung Cell Mol Physiol, 2005)*

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AIM

?

It remains uncertain how much training affects the vascular **distensibility (α)** of the pulmonary circulation. A more distensible circulation would smoothen the RV afterload. This is of particular interest as **the right ventricle (RV)** function is under heavy stress during exercise at high CO *(La Gerche, J Appl Physiol, 2010)* .

Because right and left ventricles are working together, the aim of this study is to assess **systemic vascular compliance** ; the less efficient factor would indeed limit the CO.

Highly trained athletes should present vascular pulmonary and systemic adaptations compared to sedentary controls.

We therefore compared the RV and pulmonary circulation response at exercise among athletes and sedentary subjects, with the exercise systemic vascular response.

METHODOLOGY

STUDY DESIGN

STUDY DESIGN

PRE-EFFORT

Clinical Exam

Weight
Height
HR
SaO_2
…

Questionnaires

GPAQ

Resting Measures

Lung diffusion
Capacity test

Echo-
cardiography

Beat by beat
finapress
BP

EFFORT

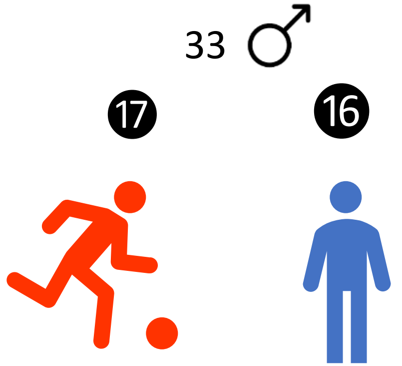
CPET
Stress echocardiography
Continuous BP

POST-EFFORT

Lung diffusion
Capacity test
<30s

POPULATION

POPULATION

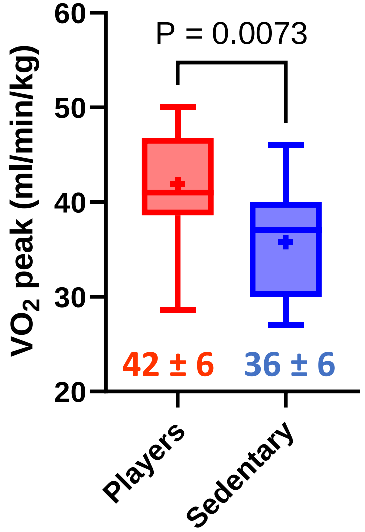


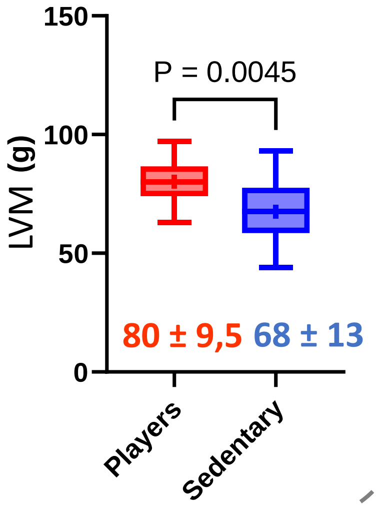
Professional Football Players

Sedentary controls

	PLAYERS	SEDENTARY
Height (cm)	181,5 ± 6,8	179,5 ± 7,4
Weight (kg)	77,2 ± 5,5	75,1 ± 9,7
Age (years)	24 ± 3	24 ± 3
BMI (kg/m²)	23 ± 1	23 ± 3
BSA (m²)	1,98 ± 0,1	1,93 ± 0,15

■ Sedentary
● Players





LVM = Left Mass Ventricle (echocardiography)

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EXPERIMENTS

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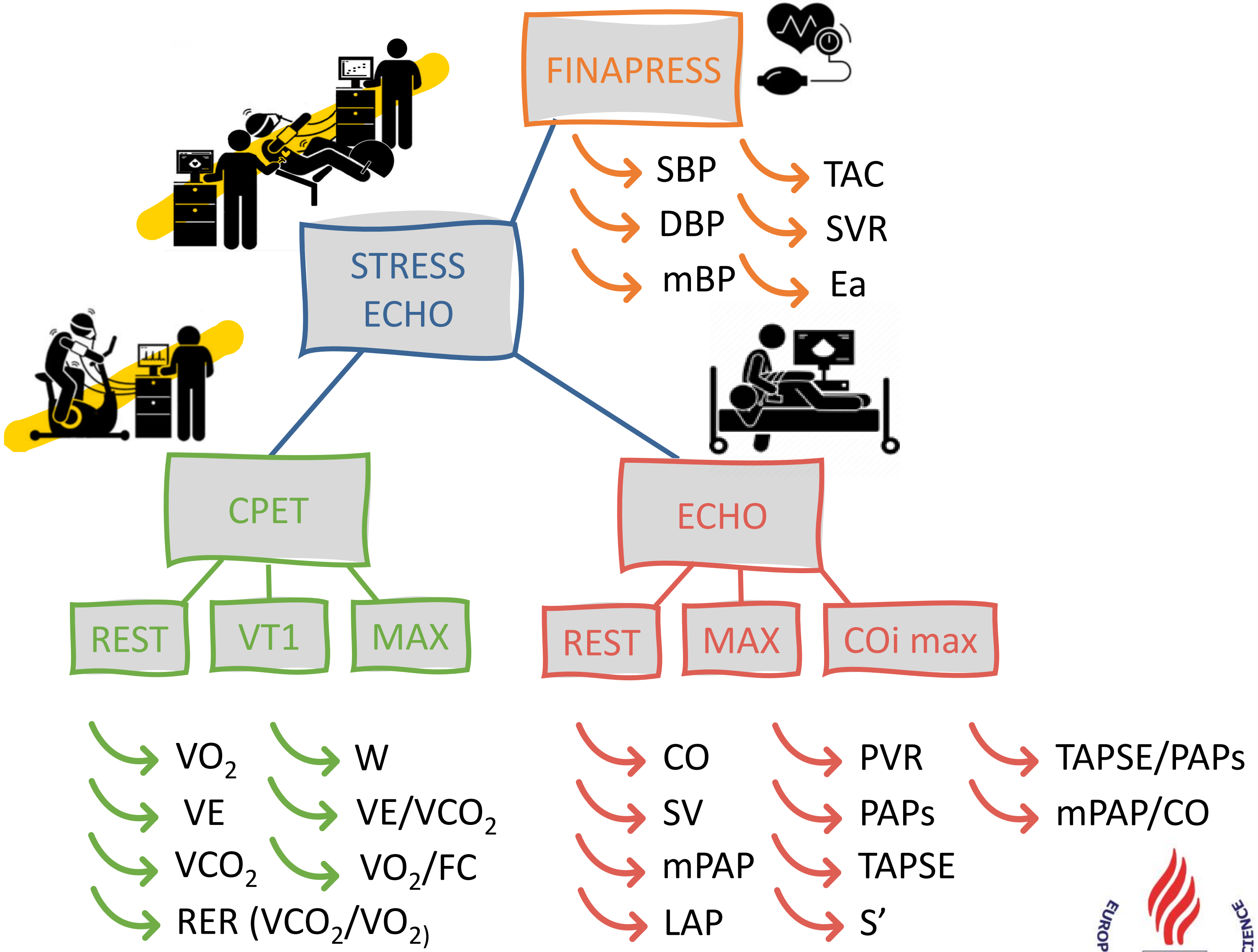

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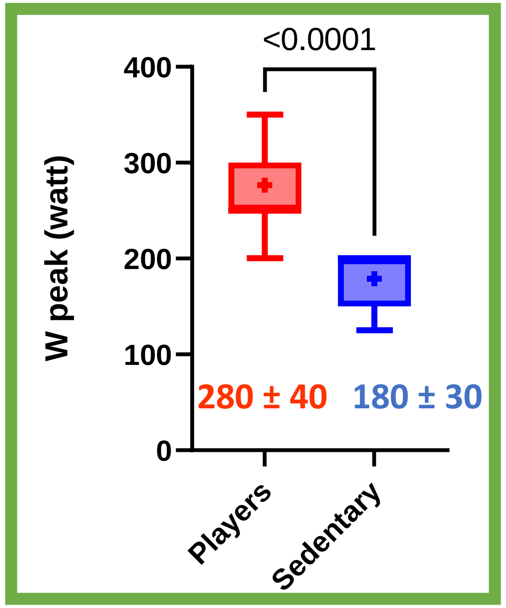
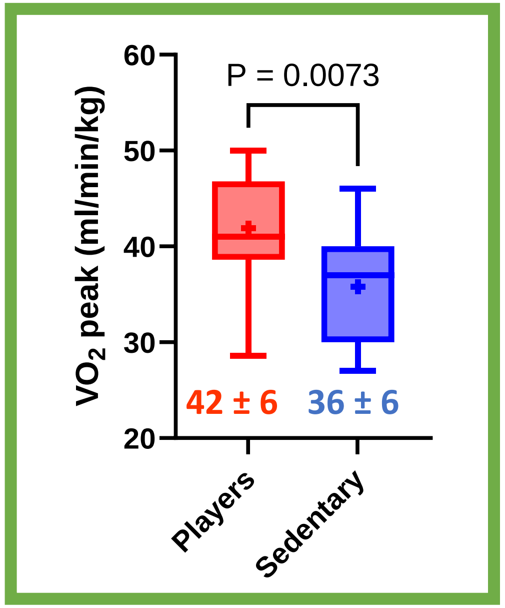
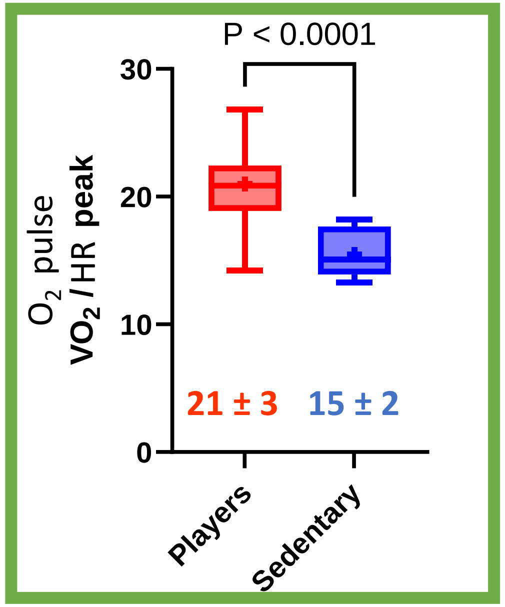
RESULTS AND DISCUSSION

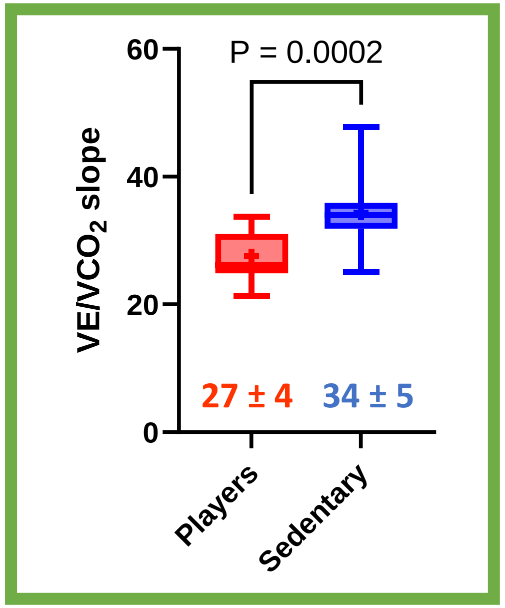
CARDIOPULMONARY EXERCISE TESTING (CPET)

HR peak (bpm)	VO_2 VT1 (ml/min/kg)	VE peak (L/min)	RER peak
155 ± 15 ***	32,69 ±4,77 ****	100± 22	1,07 ± 0,07 ****
173 ± 16	21,15 ± 5,93	114 ± 17	1,24 ± 0,07









As expected, athletes displayed smoothened chronotropic and enhanced inotropic response to exercise as compared to sedentary subjects.

Despite lower relative exercise intensity among athletes (RER peak), they reached higher VO_2 max.

SYSTEMIC CIRCULATION

Systemic Vascular Resistance

$$SVR = \frac{SBP + 2DBP}{3} * \frac{1}{COtot}$$

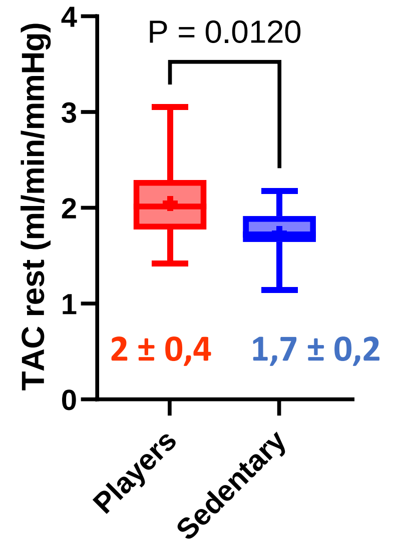
Total Arterial Compliance

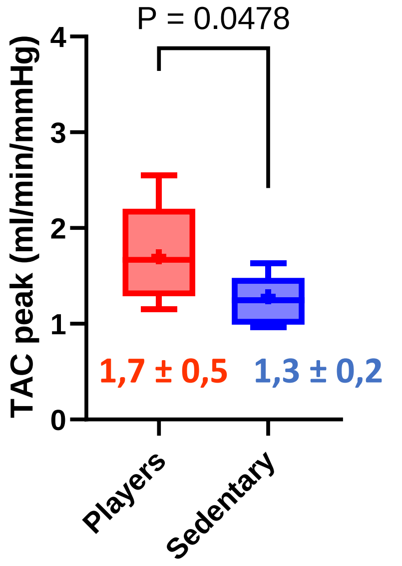
$$TAC = \frac{SV}{SBP - DBP}$$

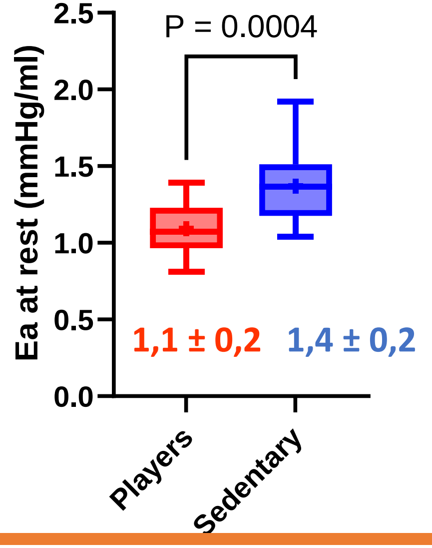
Arterial Elastance

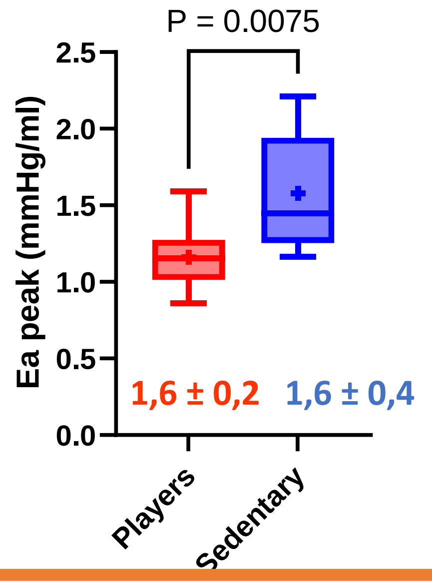
$$Ea = 0,9 * \frac{SBP}{SV}$$

MBP rest (mmHg)	MBP peak (mmHg)	SVR rest (mmHg/L/min)	SVR peak (mmHg/L/min)
83 ± 6 ****	111 ± 15 ***	14,67± 3,68	5,86 ± 1,63
95 ± 8	139 ± 10	14,7 ± 3,3	7,27 ± 2,52





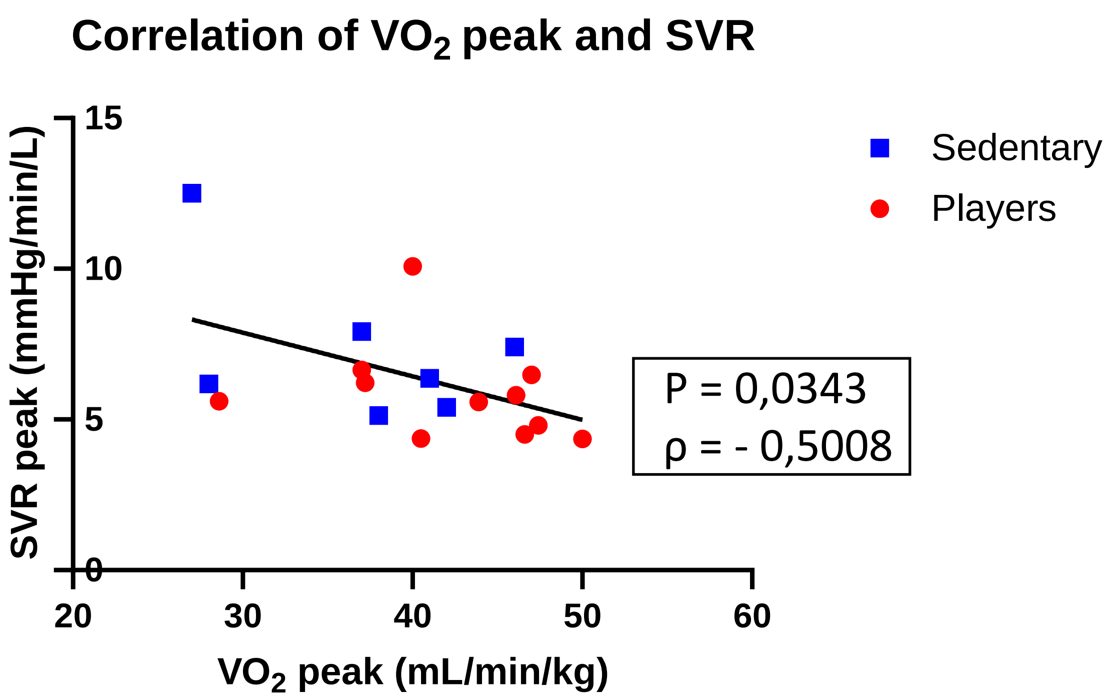


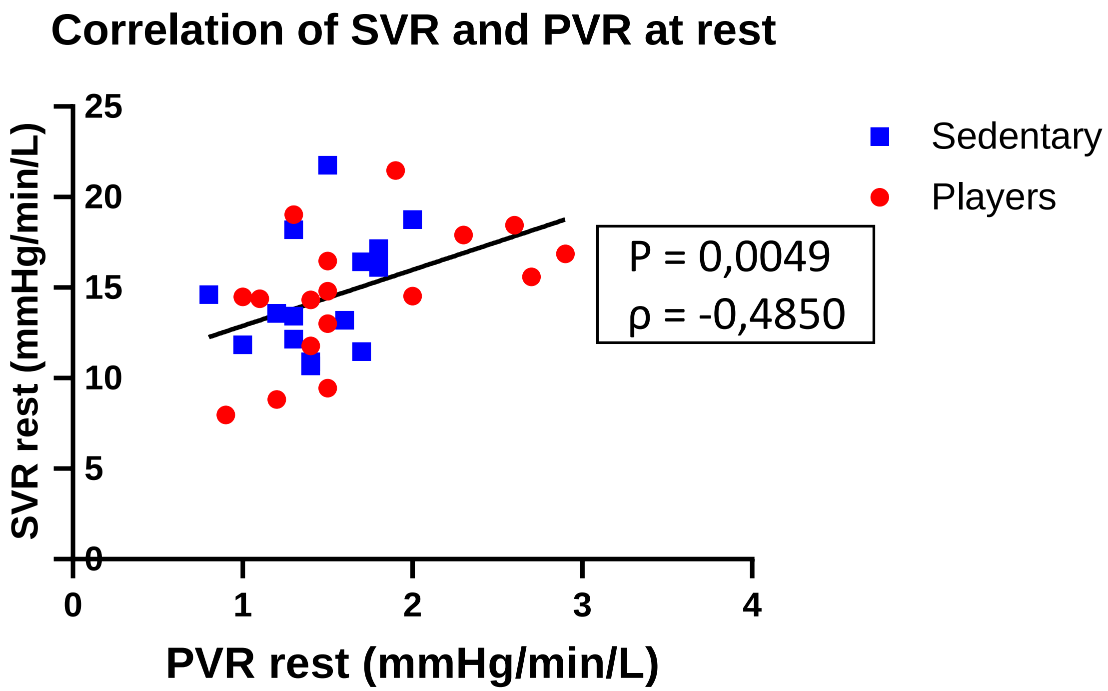


TAC during exercise are greater in compliant arteries than stiff arteries : compliant arteries being more sensitive to blood pressure changes than stiff arteries *(Kingwell, Am J Physiol Heart Circ Physiol 1995).*
With training, TAC tends to increase and Ea to decrease *(Otsuki, Am J of Physiol-Reg, Int and Comparative Physiology 2008).*

Systemic circulation seems to be more adapted among athletes than sedentary controls (Ea).

SYSTEMIC AND PULMONARY CIRCULATIONS



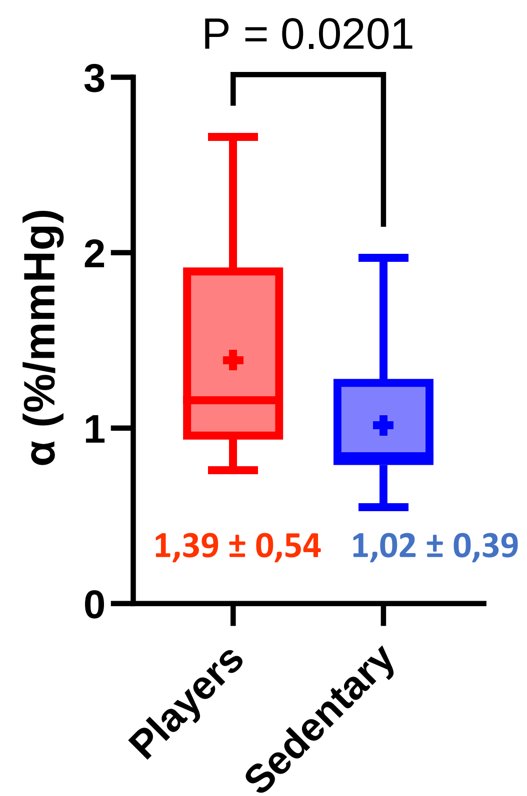


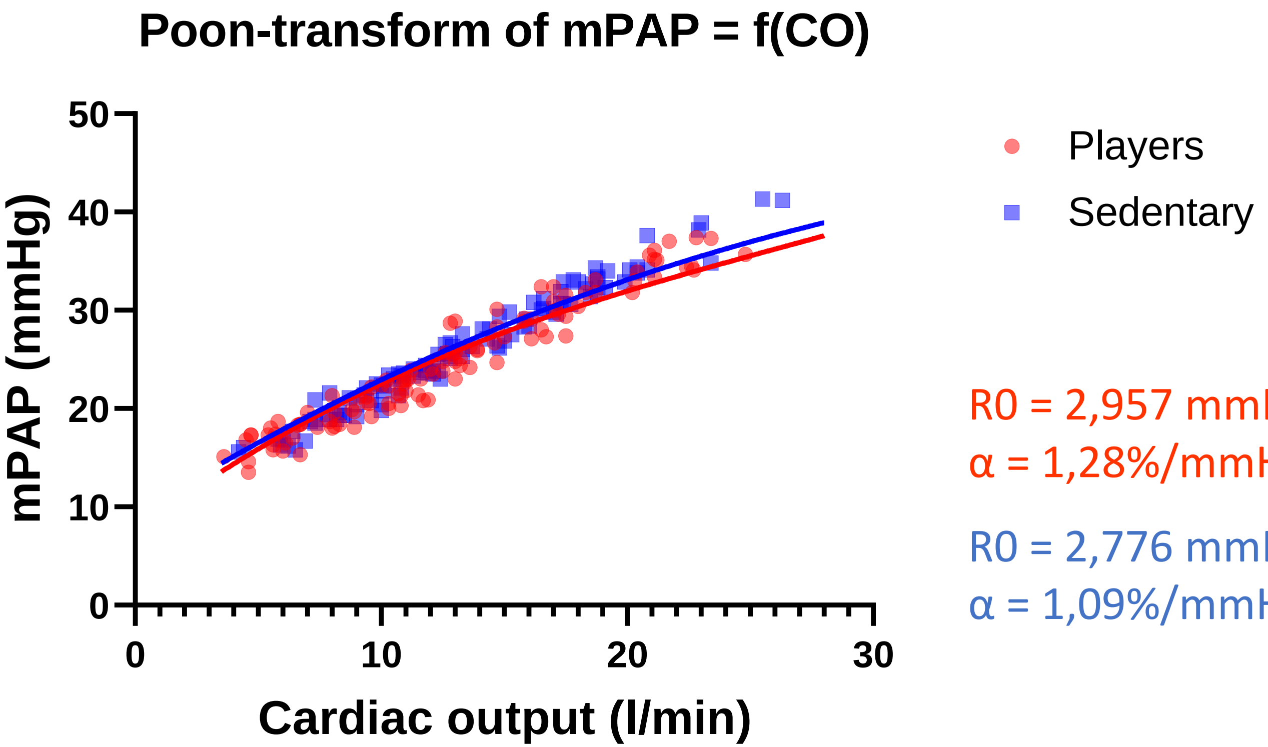
The higher the VO_2, the lower the SVR.

Athletes are chronicaly exposed to high CO states, and that seems to lower the vascular resistance. This could be an advantage for both ventricles whose function is determined by the ventricular afterload.

Pulmonary or systemic vascular resistive vessel stiffening could eventually limit maximum cardiac output and thus also aerobic exercise capacity.

PULMONARY VASCULAR DISTENSIBILITY α



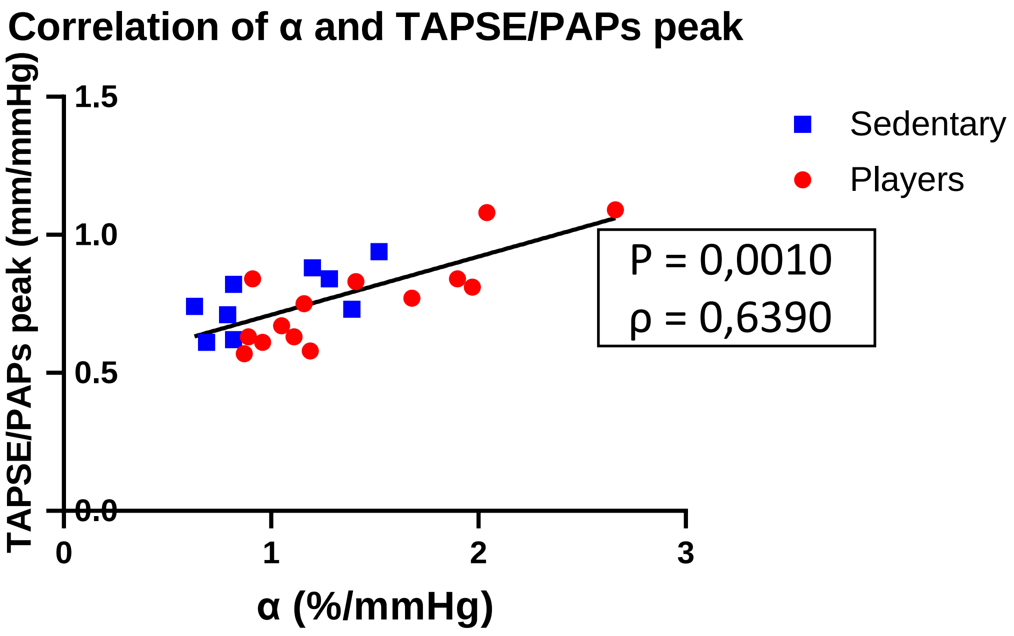


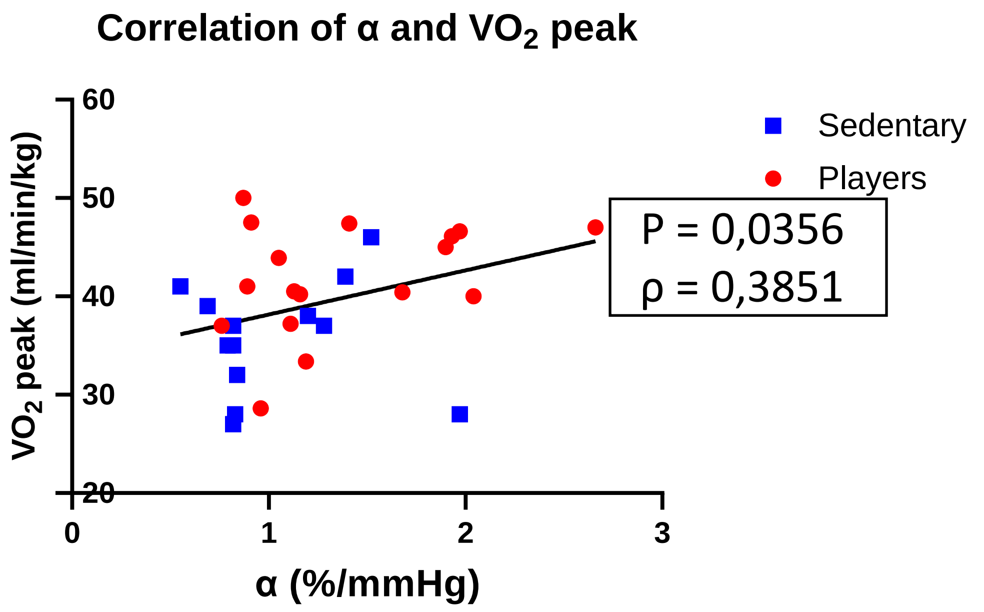
R0 = 2,957 mmHg/min/L
α = 1,28%/mmHg

R0 = 2,776 mmHg/min/L
α = 1,09%/mmHg

Vessel distensibility in the pulmonary vasculature may be an adaptation for preserving the optimal distribution of pulmonary blood flow in the face of large variations in cardiac output *(Krenz, American Journal of Physiology-Heart and Circulatory Physiology 2003).*

PULMONARY VASCULAR DISTENSIBILITY α





α_{pulm} is correlated with TAPSE/PAPs ratio among football players and sedentary subjects, suggesting that a better α_{pulm} allows a better RV-arterial coupling, an ideal advantage for aerobic capacity.

In healthy individuals, VO_{2max} is linked with a more distensible pulmonary circulation, which is in keeping with the notion that a greater pulmonary vascular reserve allows for a higher aerobic exercise capacity *(Lalande, The Journal of Physiology, 2012).*

CONCLUSION

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CONCLUSION

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AEROBIC PERFORMANCE

Greater pulmonary vascular distensibility seems beneficial to reach greater $VO_{2\ max}$

SYSTEMIC CIRCULATION

Athletes show better systemic adaptations with a higher TAC compared with sedentary controls

PULMONARY and SYSTEMIC CIRCULATIONS

Athletes seem to present adaptations in both circulations. Subjects with the greatest systemic adaptations also present greatest pulmonary adaptations

PULMONARY CIRCULATION

Athletes show better pulmonary adaptations with a higher pulmonary vessel distensibility compared with sedentary controls

It remains to be determined whether this is a training-related pulmonary vascular physiological effect and whether it constitutes an advantage for aerobic performance, given that better pulmonary vascular distensibility was associated with better function right ventricular during exercise.

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- Friend : Joseba McIntyre Bengotxea and family : Claudia Costacurta

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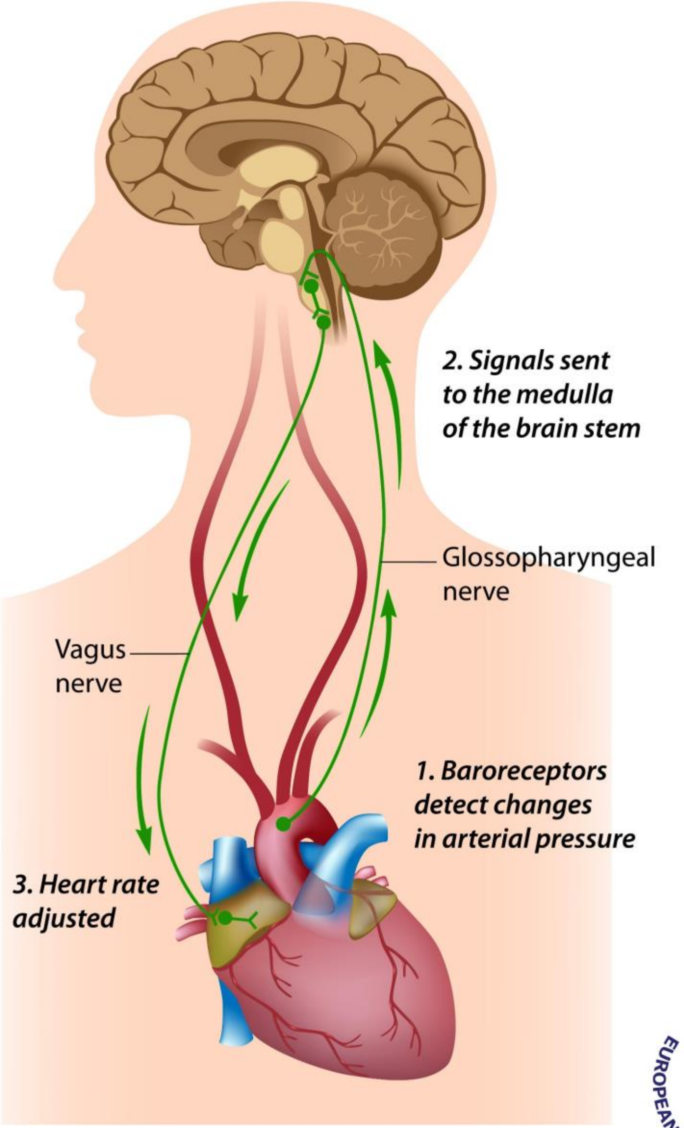
SYSTEMIC CIRCULATION : BAROREFLEX

- MAP ↑ → **BARORECEPTORS**
  - Attenuation of the sympathetic outflow to the peripheral vessels and the heart
  - **MAP normalized**

- MAP ↓ → **BARORECEPTORS**
  - Increase sympathetic outflow : vasoconstriction + ↓ CO
  - **MAP normalized** *(Trasher, Am J Physiol Regul Integr Comp Physiol, 2012)*



ECHOCARDIOGRAPHY

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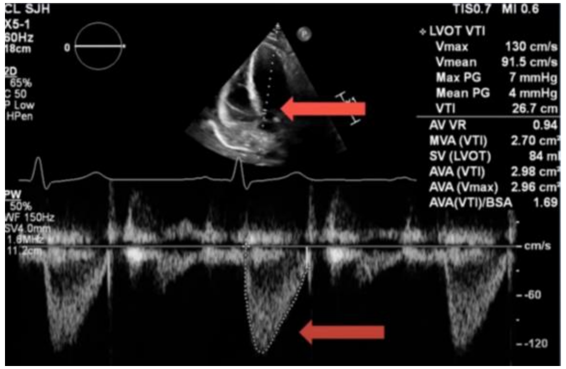
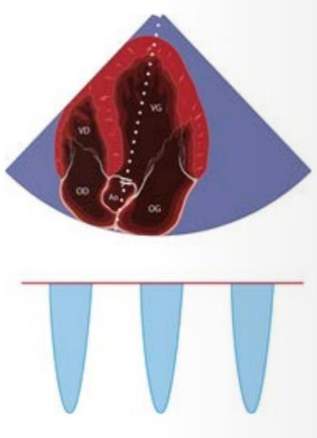
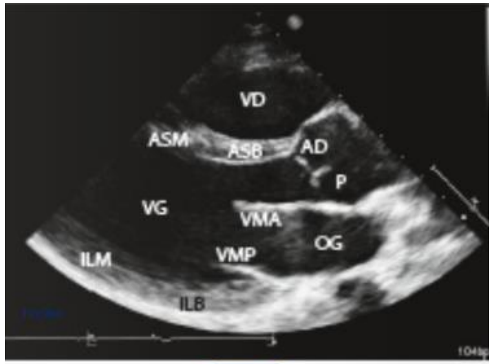
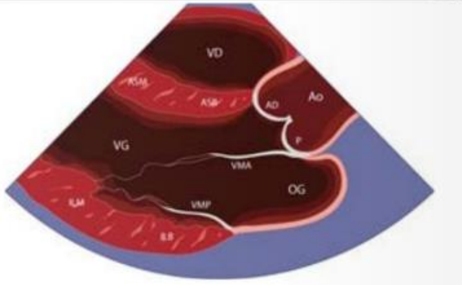
CARDIAC OUTPUT





$$CO = SV * HR$$
$$= LVOT\ VTI * \varnothing\ LVOT * HR$$





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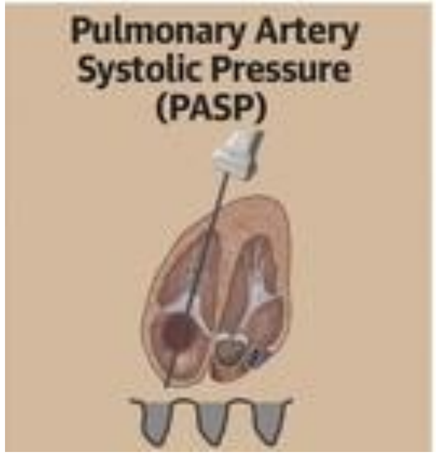
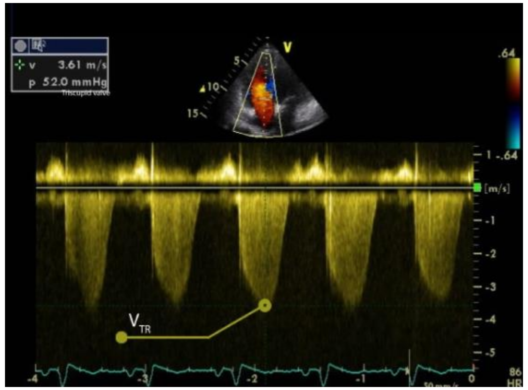
ECHOCARDIOGRAPHY

RIGHT VENTRICULO-ARTERIAL COUPLING



$PAPs = 4 * (V_{TR})^2 + RAP$

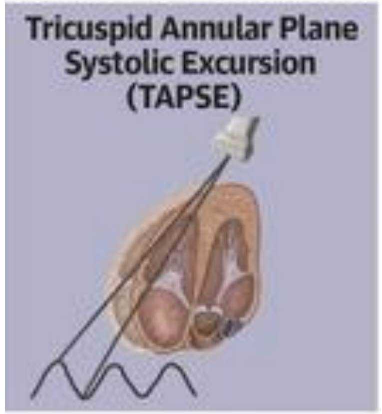


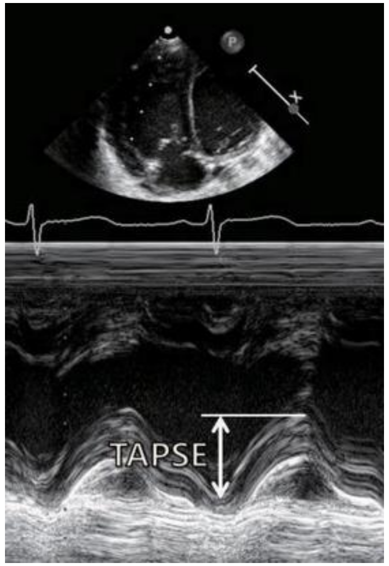
TAPSE/PAPs

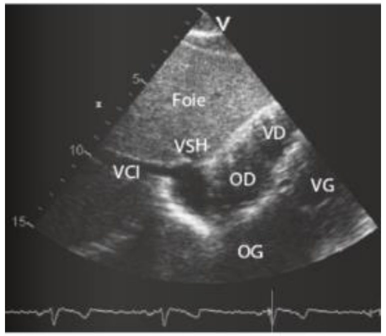
Inferior vena cava diameter (cm)	Respiratory collapse (%)	RAP (mmHg)
<2.1	≥50%	3 (0-5)
>2.1	<50%	15
>2.1	≥50%	8 (5-10)
<2.1	<50%	8 (5-10)

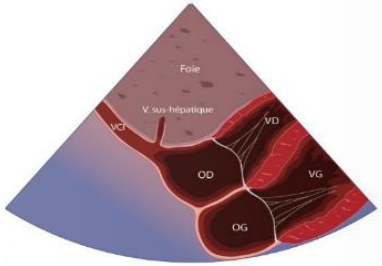
RAP = Right atrium pressure

mPAP = 0,61 * PAPS + 2 mmHg









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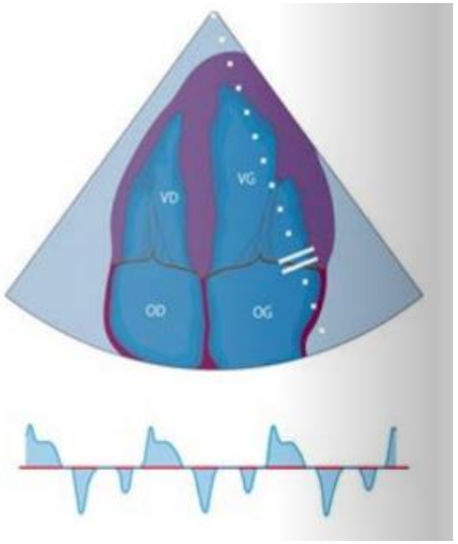
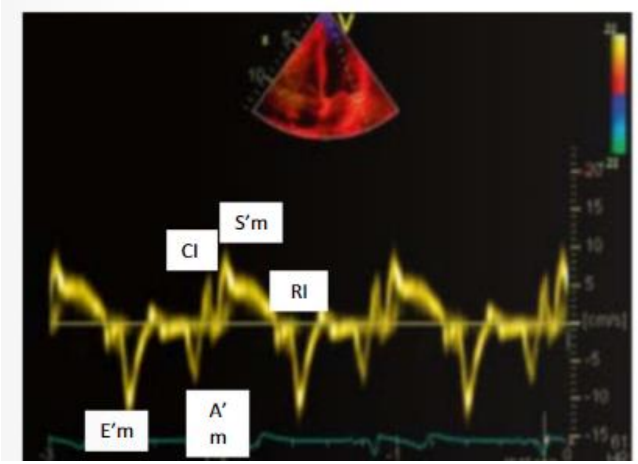
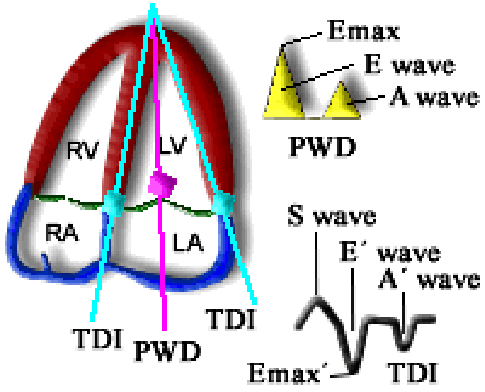
RIGHT VENTRICULO-ARTERIAL COUPLING



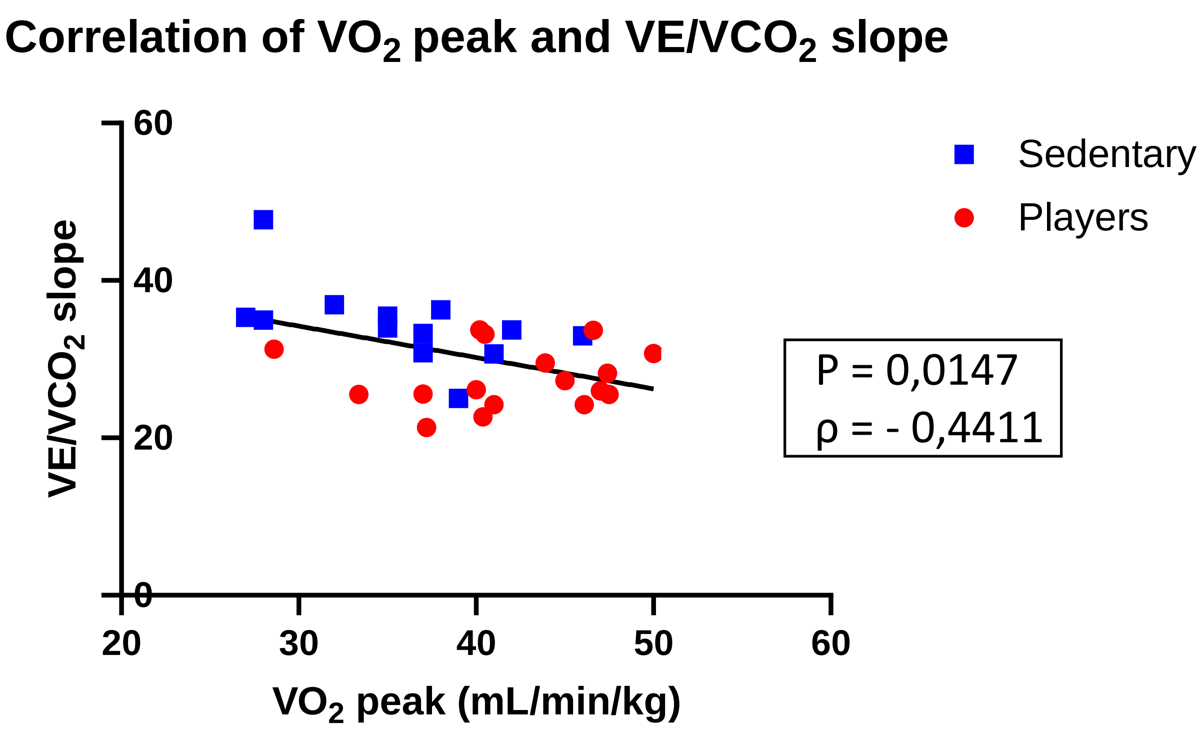


$LAP = 1{,}55 + 1{,}47 * (E/e'_{sep\ \&\ lat})$

TDI Scan of the MV Annulus

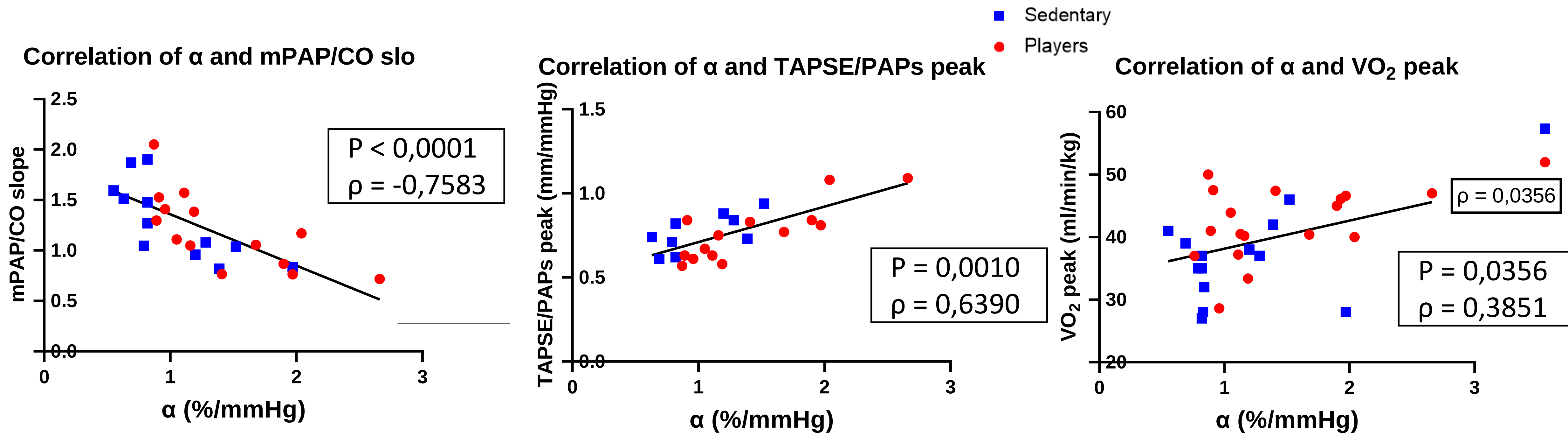


CPET



VE/VCO2 slope witness of the respiratory efficiency during the effort : the higher the VO_2 peak, the better respiratory efficiency.

PULMONARY VASCULAR DISTENSIBILITY α



The more distensible the pulmonary vessels are, the lower the PVR.

α_{pulm} is correlated with TAPSE/PAPs ratio among football players and sedentary subjects, suggesting that a better α_{pulm} could allow to have a better RV-arterial coupling, an ideal advantage for aerobic capacity.

In healthy individuals, VO_{2max} seems to be linked with a more distensible pulmonary circulation, which is in keeping with the notion that a greater pulmonary vascular reserve allows for a higher aerobic exercise capacity *(Lalande, The Journal of Physiology, 2012).*