

Physiopathologie de l'intolérance à l'altitude

Aspects cardiovasculaires Protocole ALT

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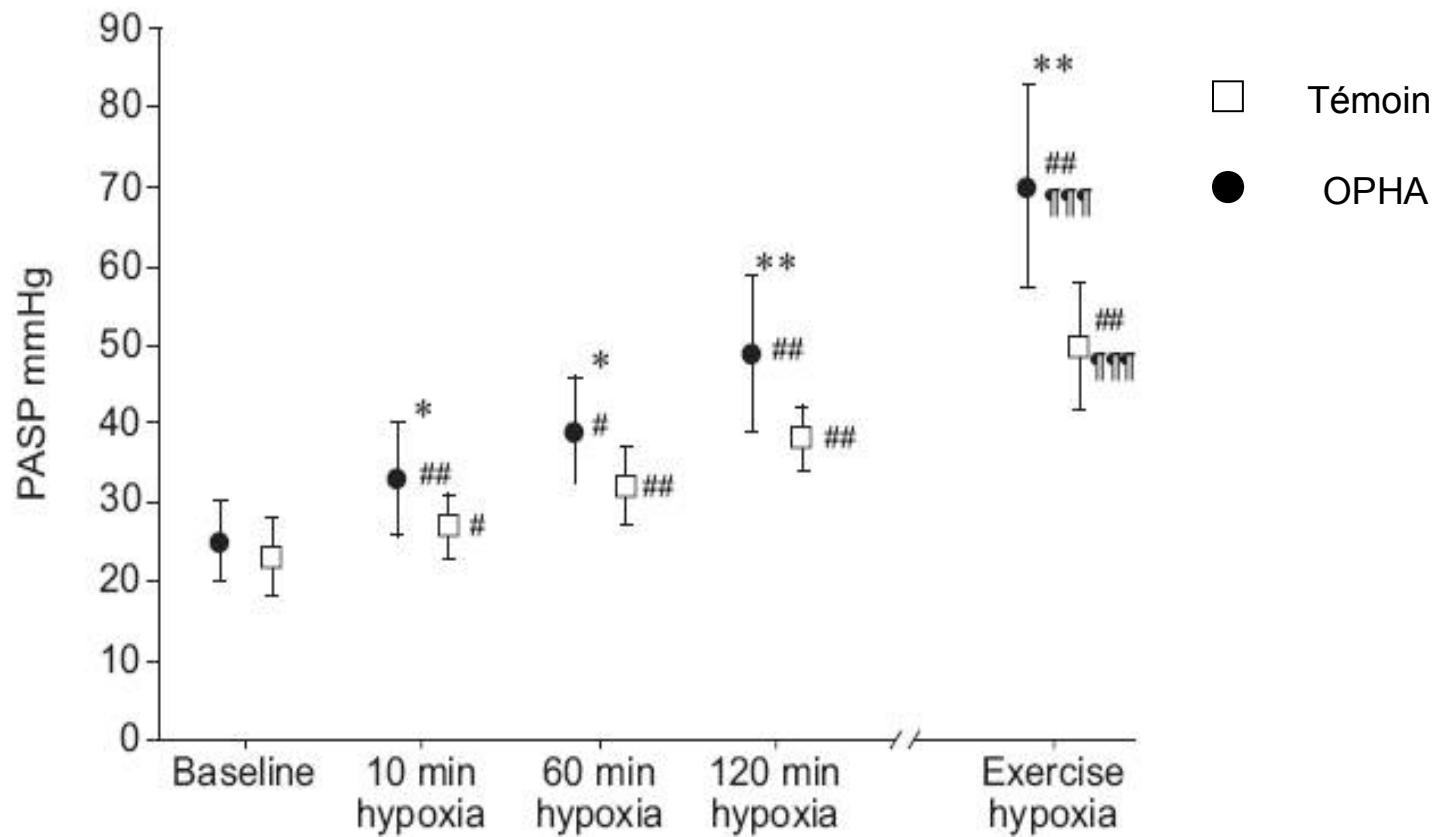
Intolérance à l'altitude

- MAM
 - Score de Lake Louise/score de Hackett
 - Symptômes apparaissant en hypoxie
 - Mécanisme?
- OPHA
 - Clinique
 - Élévation des pressions artérielles pulmonaires
- OCHA

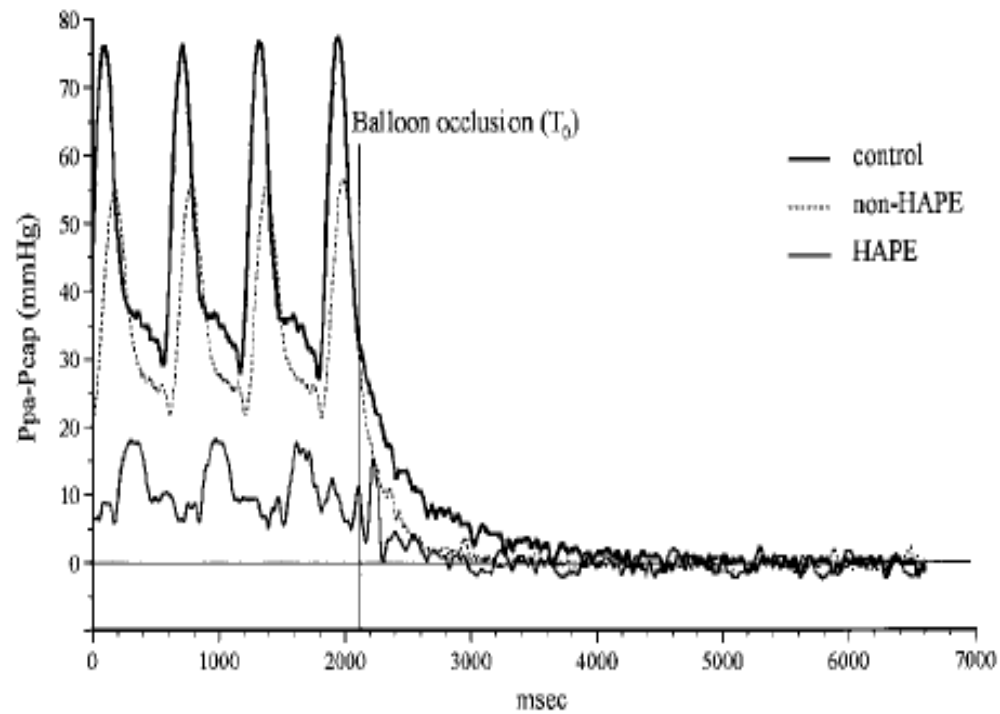
OPHA



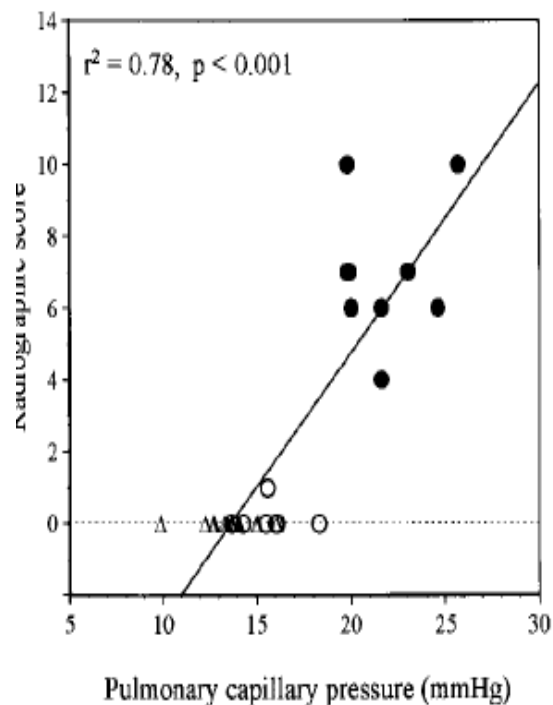
PAPs en hypoxie



Pression capillaire



Pressions dans la circulation pulmonaire

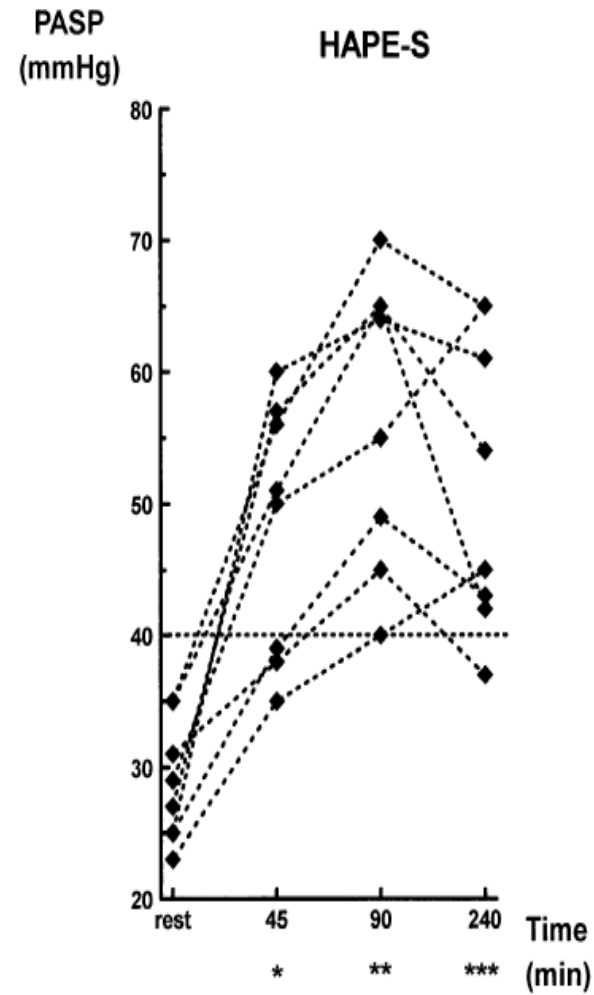
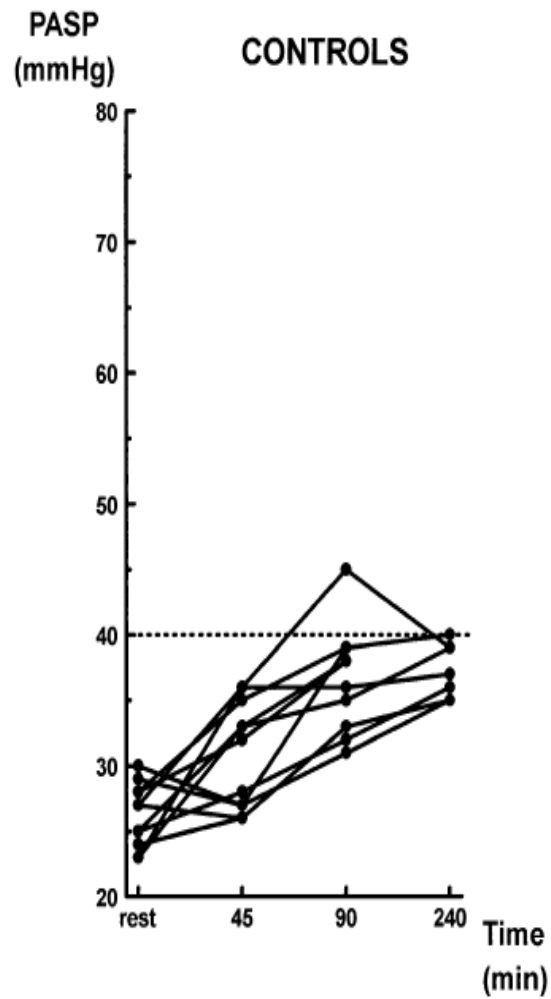


	Low Altitude (490 m)		High Altitude (4559 m)	
	Baseline	Hypoxia	Baseline	Hyperoxia
No. of subjects				
Control	14	14	14	14
HAPE-susceptible	15	15	16	16
Pao ₂ , mm Hg				
Control	92±2	38±1†	45±1†‡	90±2‡§
HAPE-susceptible	92±4	39±2†	40±1†	76±3*†‡§
Paco ₂ , mm Hg				
Control	34±1	32±1†	27±1†‡	31±1†§
HAPE-susceptible	37±1	33±1†	27±1†‡	30±1†‡§
Q̇, L · min ⁻¹ · m ⁻²				
Control	3.3±0.1	4.5±0.2†	3.7±0.2‡	3.2±0.1‡
HAPE-susceptible	3.1±0.2	3.8±0.3*†	3.7±0.1†	3.2±0.2‡§
Ppa, mm Hg				
Control	14±1	22±1†	26±1†‡	22±1†§
HAPE-susceptible	16±1	27±2*†	38±2*†‡	31±2*†‡§
Pc, mm Hg				
Control	10±1	12±1†	13±1†	12±1†
HAPE-susceptible	9±1	13±1†	19±1*†‡	16±1*†‡§
Ppao, mm Hg				
Control	8±1	9±1	10±1	9±1
HAPE-susceptible	7±1	8±1	10±1†	9±1
Pulmonary leak index, 10 ⁻³ /min				
Control	10.0±0.5		9.3±0.8	
HAPE-susceptible	8.4±0.5		11.8±0.9†	

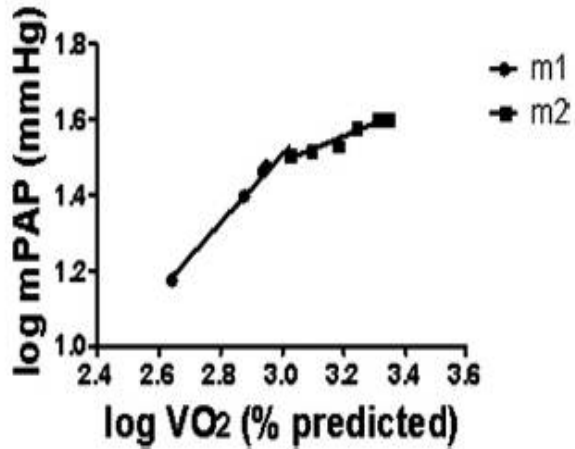
Mean values are given as mean±SEM.

P≤0.05 *vs control, †vs low-altitude baseline, ‡vs low-altitude hypoxia, §vs high-altitude baseline.

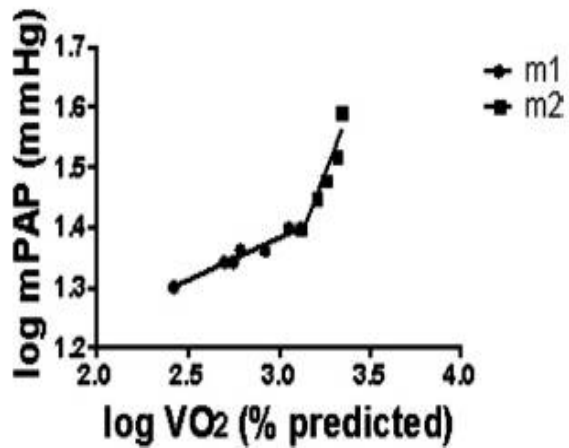
PAPs l'effort



HTAP d'effort

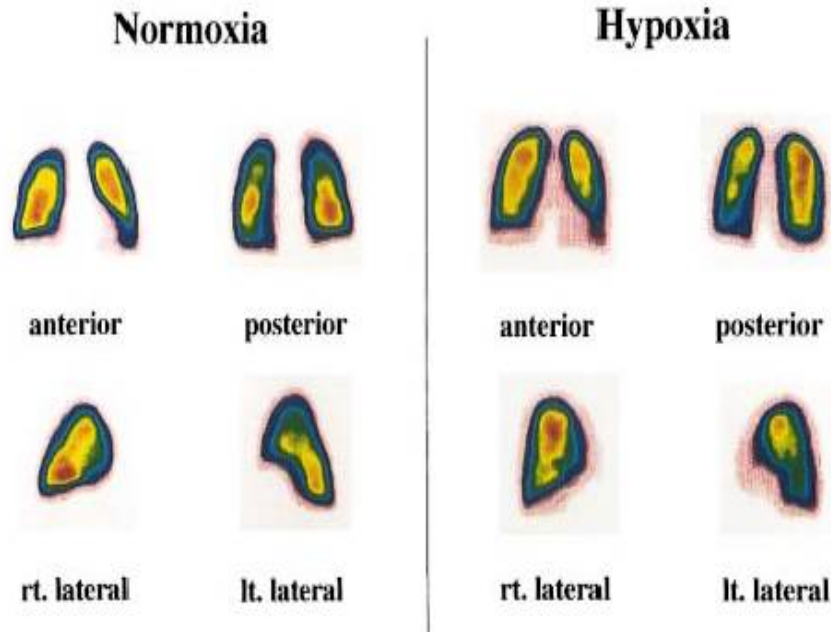


Patient ayant une HTAP de repos



Patient sans HTAP

Perfusion pulmonaire



-Perfusion hétérogène

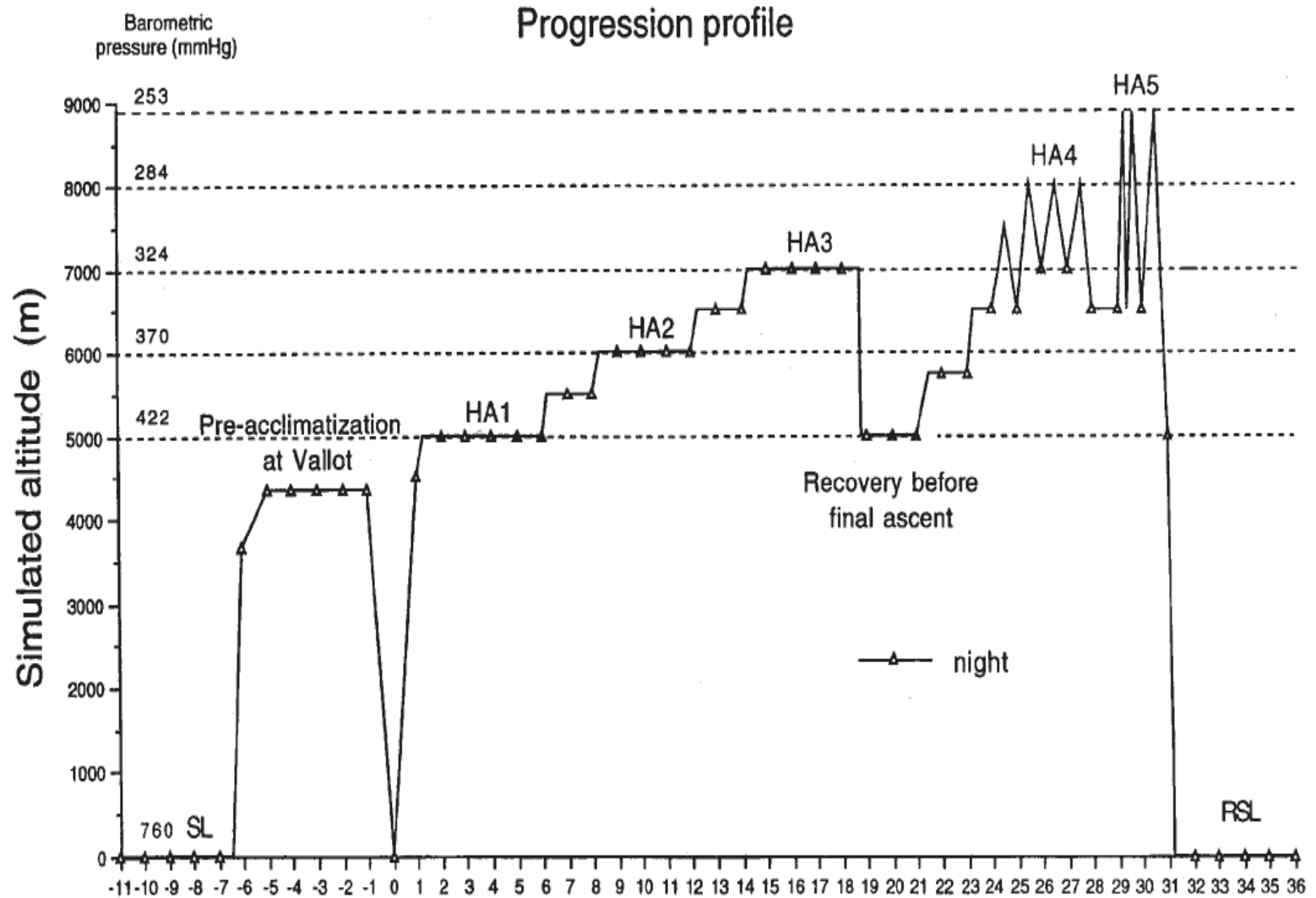
-Hyper-perfusés

-Lésions capillaires

-Œdème alvéolaire mécanique

=> Rôle du NO?

Fonction myocardique



Fonction myocardique

HR, Pa AND Q*

	HR (beats/min)	Systolic Pa (mm Hg)	Diastolic Pa (mm Hg)	Ao VTI	Q (L/min)
SL	62.8 ± 7.7	122.2 ± 10.5	71.6 ± 10.3	23.3 ± 3.8	5.7 ± 1.4
5,000 m	79.1 ± 11.0 ^{††}	132.9 ± 13.3	79.7 ± 6.8	17.2 ± 2.1 ^{††}	5.3 ± 0.8
7,000 m	90.4 ± 13.7 ^{††}	122.1 ± 16.0	72.9 ± 9.3	18.0 ± 2.4 ^{††}	6.4 ± 1.3
8,000 m	89.0 ± 11.3 ^{††}	118.4 ± 9.1	63.9 ± 4.1	17.5 ± 2.9 ^{††}	6.1 ± 1.2
RSL	63.5 ± 10.0	115.7 ± 10.7	69.9 ± 6.4	21.1 ± 2.7	5.3 ± 1.3

* Data are expressed as mean ± SEM.

[†] p < 0.05 versus SL.

[‡] p < 0.05 versus RSL.

LV SYSTOLIC FUNCTION*

	FE (%)	%SF (%)
SL	67.7 ± 5.1	31.6 ± 3.5
5,000 m	74.9 ± 4.1	36.9 ± 3.4
7,000 m	72.6 ± 6.3	35.4 ± 5.0
8,000 m	70.1 ± 3.2	33.3 ± 2.4
RSL	72.5 ± 3.4	35.2 ± 2.8

* Data are mean ± SEM.

Fonction myocardique

TRANSMITRAL FLOW*

	E max Velocity	A max Velocity	E/A	IVRT
SL	91.1 ± 14.7	43.6 ± 10.1	2.16 ± 0.42	75.0 ± 11.9
5,000 m	68.7 ± 10.4 ^{††}	55.4 ± 11.9	1.31 ± 0.43 ^{††}	87.5 ± 12.8
7,000 m	75.25 ± 14.0	62.4 ± 14.3 [†]	1.24 ± 0.32 ^{††}	80.0 ± 13.1
8,000 m	62.9 ± 17.3 ^{††}	55.7 ± 11.0	1.13 ± 0.20 ^{††}	80.0 ± 10.7
RSL	94.9 ± 9.7	46.2 ± 5.4	2.07 ± 0.30	81.2 ± 8.3

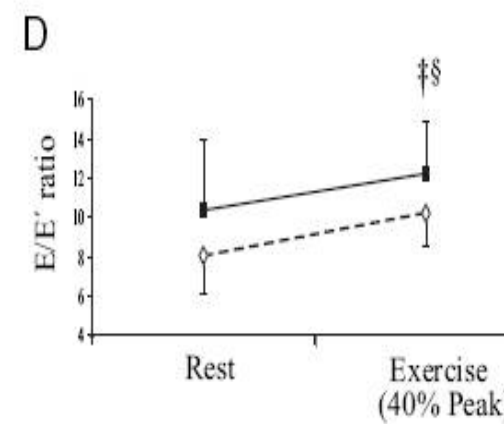
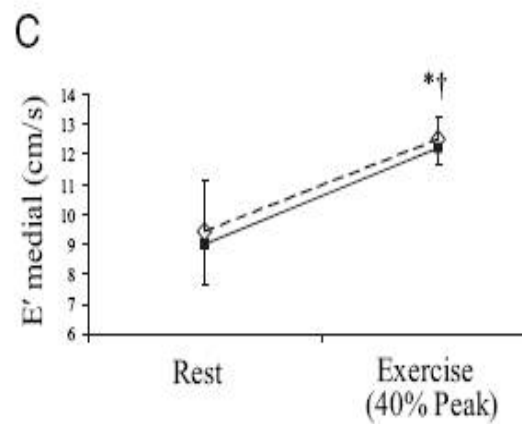
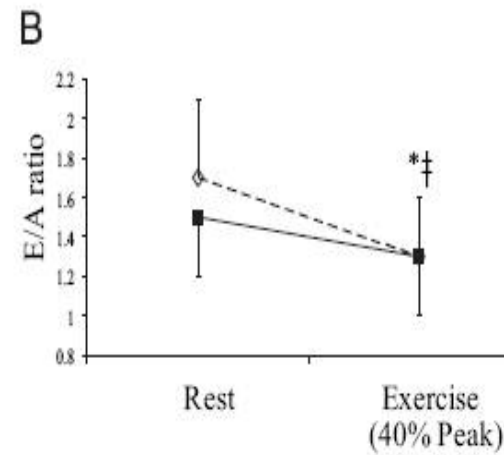
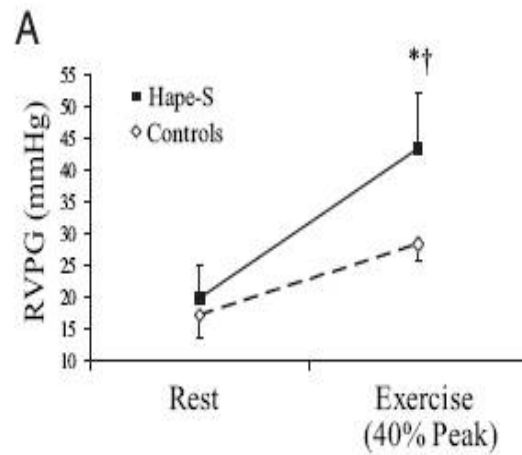
PULMONARY VENOUS FLOW*

	D max Velocity	S max Velocity	D/S
SL	64.9 ± 9.7	52.5 ± 12.2	1.29 ± 0.32
5,000 m	47.5 ± 9.6 [†]	63.4 ± 11.0	0.76 ± 0.17
7,000 m	56.5 ± 9.5	45.9 ± 7.3 [†]	1.23 ± 0.07
8,000 m	49.7 ± 8.7 [†]	55.2 ± 12.9	0.93 ± 0.21
RSL	59.1 ± 4.8	52.2 ± 6.6	1.14 ± 0.13

RV AND LV PRESSURES INDICES*

	RA/RVg	A Mitral Duration	A Pulmonary Reversal Flow Duration	A Mitral/A Pulmonary Duration Ratio
SL	19.0 ± 2.4	115.7 ± 8.3	102.5 ± 15.8	1.12 ± 0.20
5,000 m	22.8 ± 1.9	116.2 ± 22.0	90.0 ± 13.1	1.31 ± 0.27
7,000 m	35.5 ± 5.4 ^{††}	101.2 ± 21.7	91.2 ± 20.3	1.13 ± 0.24
8,000 m	40.1 ± 3.3 ^{††}	113.7 ± 10.6	87.5 ± 11.6	1.32 ± 0.21
RSL	30.3 ± 3.4	112.5 ± 4.6	90.0 ± 7.6	1.26 ± 0.11

Fonction myocardique

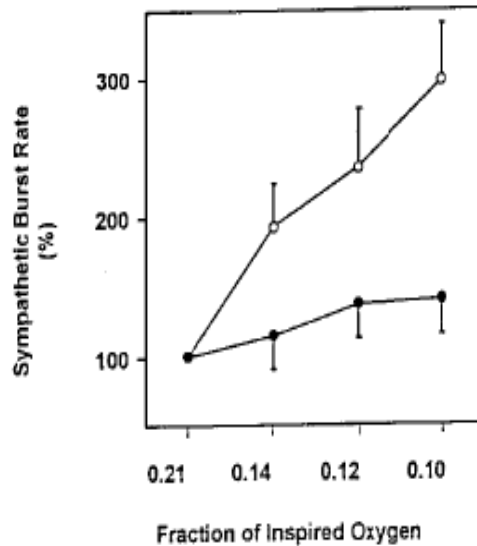


Fonction VD

	0 m	4300 m	
RV Tei index †	0.21 ± 0.12	0.52 ± 0.12	<0.001

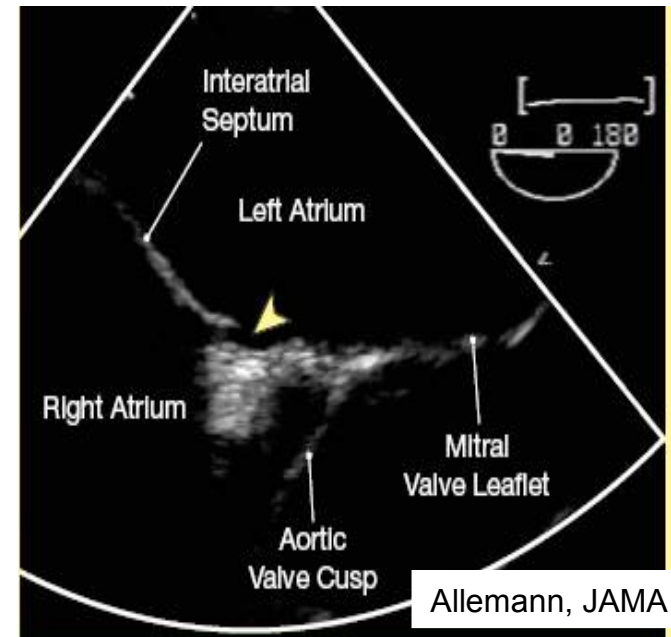
Maignan, Chest 2007

Système sympathique



Duplain, Circ 1999

FOP



Allemann, JAMA 2006

Protocole ALT

- Objectif : comprendre les mécanismes physiopathologiques de l'intolérance à l'altitude
- Matériel et méthodes
 - 13 Sujets ayant une intolérance à l'altitude
 - 13 Sujets sains
 - Explorations du sommeil, de la réponse ventilatoire en hypoxie, à l'exercice...
 - Explorations cardiovasculaires
 - Autres

Exploration cardiovasculaire

- Critère principal de jugement : Etablir le lien entre la PAPs à l'effort et le débit cardiaque au-delà du seuil anaérobie
- Critères secondaires :
 - Fonction VD
 - Fonction VG
 - Prévalence du FOP en normoxie et hypoxie

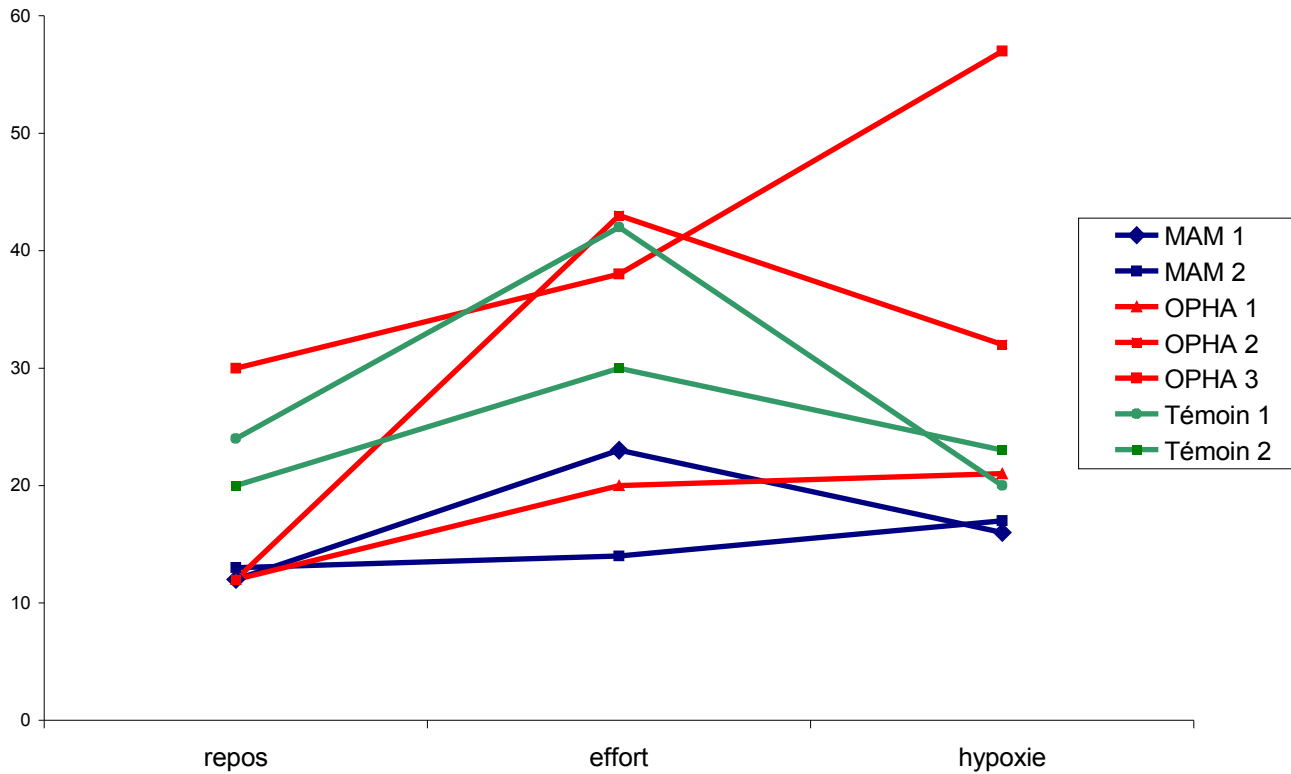
	Base	hypoxie
CC Ao		
SIVs		
PPVGs		
DTDVG		
DTSVG		
TAC		
VTI Pulm		
E		
A		
durée A mitrale		
TRIVG		
Ea		
durée Ap		
VTI sous-aortique		

Résultats

	témoins	MAM	OPHA
nombre	2	2	3
Age (ans)	38,5	38,0	39,3
Repos			
FC (bpm)	62	70	65
PAS (mmHg)	100	113	116
PAD (mmHg)	70,0	79,5	73
SpO2 (%)	98	98	97
FEVG (%)	66	53	65
DC (L/mn)	4,5	3,9	4,6
Grad OD-VD (mmHg)	22	12	21
FOP	0/2	0/2	0/2
Effort maximal			
Puissance (w)	300	263	250
intensité/FMT (%)	87,5	92,5	89,0
FC (bpm)	156	173	165
PAS (mmHg)	225	223	190
PAD (mmHg)	135	97	83
SaO2 (%)	97	92	93
Grad OD-VD (mmHg)	36	23	33
Hypoxie			

Résultats

PAPs (mmHg)



Conclusion

- Etude en cours...
- Intolérance à l'altitude multi-factorielle
- Rôle du système cardiovasculaire :
 - Circulation pulmonaire pathologique?
 - Trouble de la relaxation du VG?
- Lien entre le MAM et l'OPHA?