

Séquelles de Dysplasie Bronchopulmonaire

Explorations fonctionnelles Tolérance à l'effort

Dr Bernard Wuyam

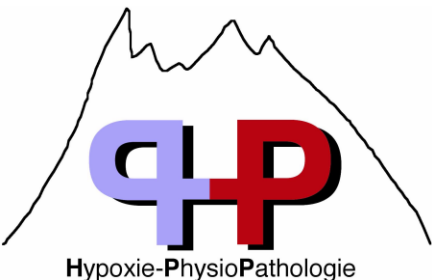
Clinique de **Physiologie Sommeil & Exercice**

UM Sports & Pathologies

CHU de Grenoble

Hôpital SUD

Réseau 'Naitre & Devenir
Grenoble



Atteinte bronchique : un problème de calibre

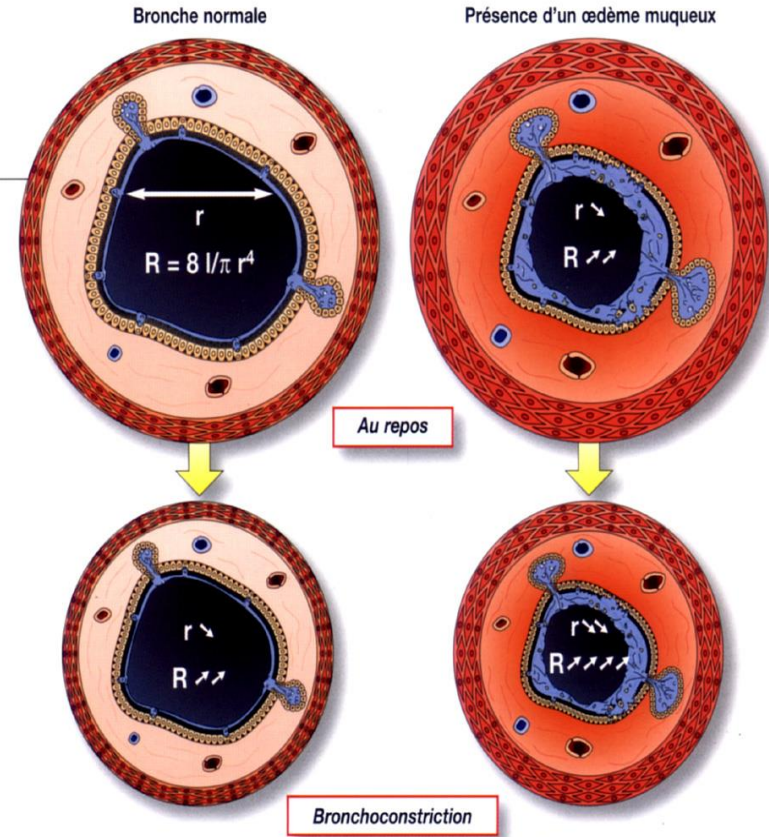
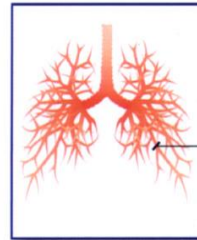
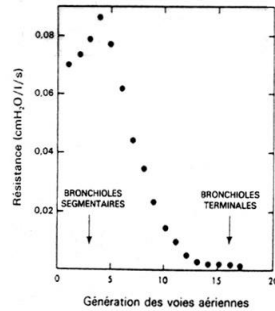
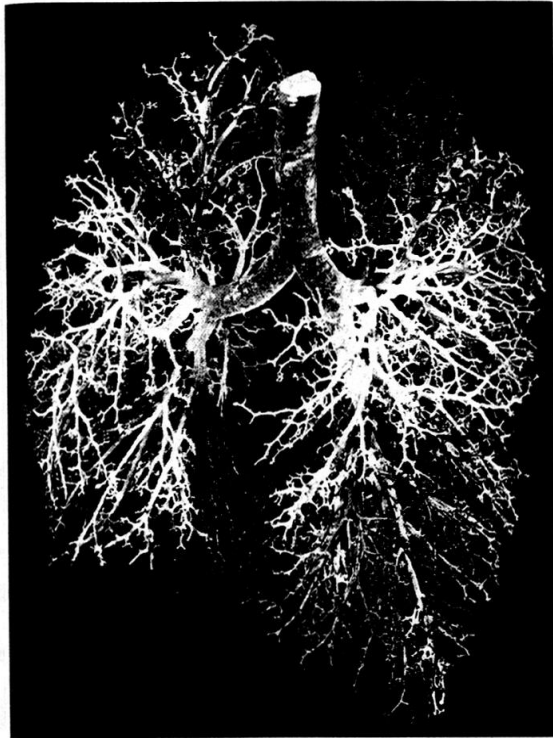


Figure 1.3 Moulage des voies aériennes d'un poumon humain. Les alvéoles ont été enlevés permettant de distinguer les voies aériennes de la trachée jusqu'aux bronchioles terminales.

Explorer le souffle chez l'enfant

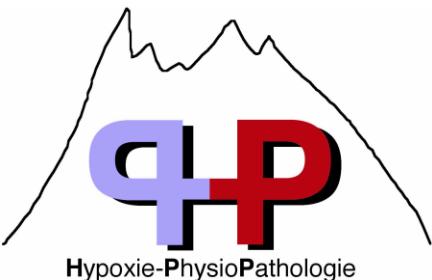
Méthodes sans coopération

Mesure CRF

Spirométrie

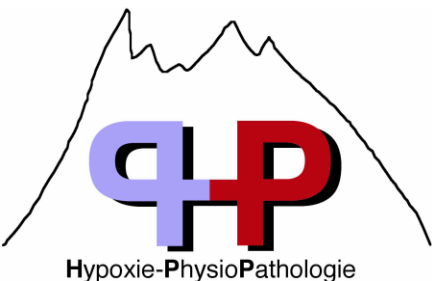
Diffusion

Tests exercice



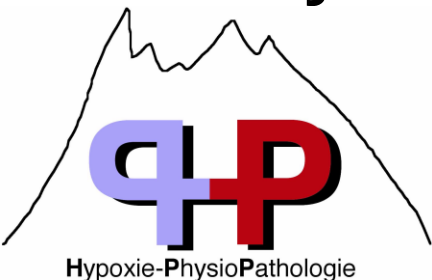
Enfants pré-scolaires (3-6ans)

- Rint (résistances interruption) : +++
- CRF (dilution Hélium) : +/-
- Ocillations forcées : +/-



Rint : 3-6ans

- Ventile (pince-nez, embout/masque).
- Volume courant + occlusion brève du courant aérien + réouverture immédiate.
- Acceptabilité. Coopération.
- Estimation de P_{alv} , rapportée au débit d'air juste avant l'occlusion : **Résistance**



Rint : 3-6ans



Figure 8. Measurement conditions: position of the child and the operator's hands during the test.

Rint : 3-6ans

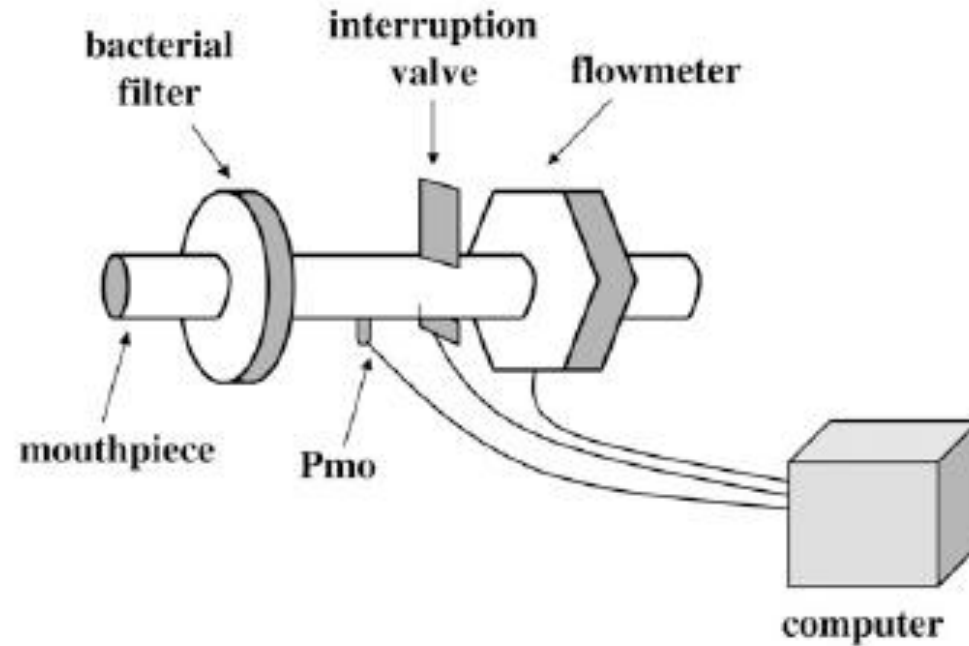


Figure 7. Schematic picture of the equipment used for the interrupter technique. Pmo = mouth pressure.

Rint : 3-6ans

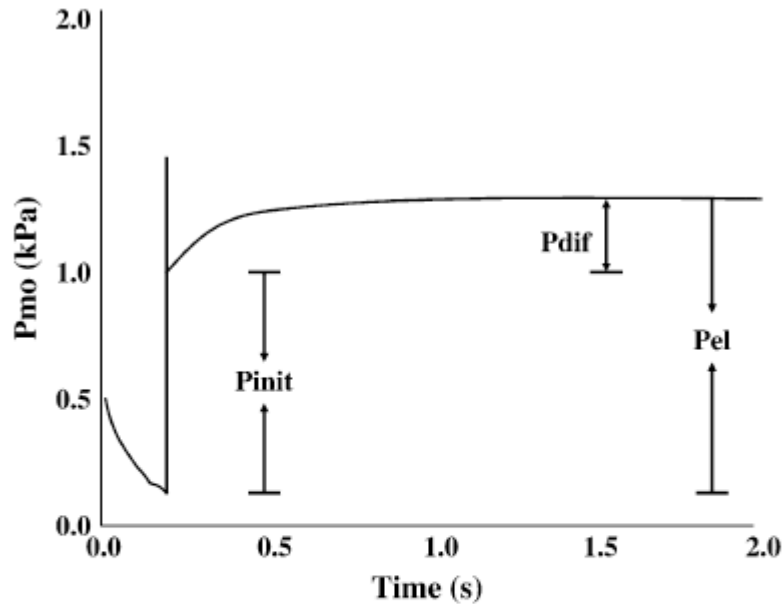
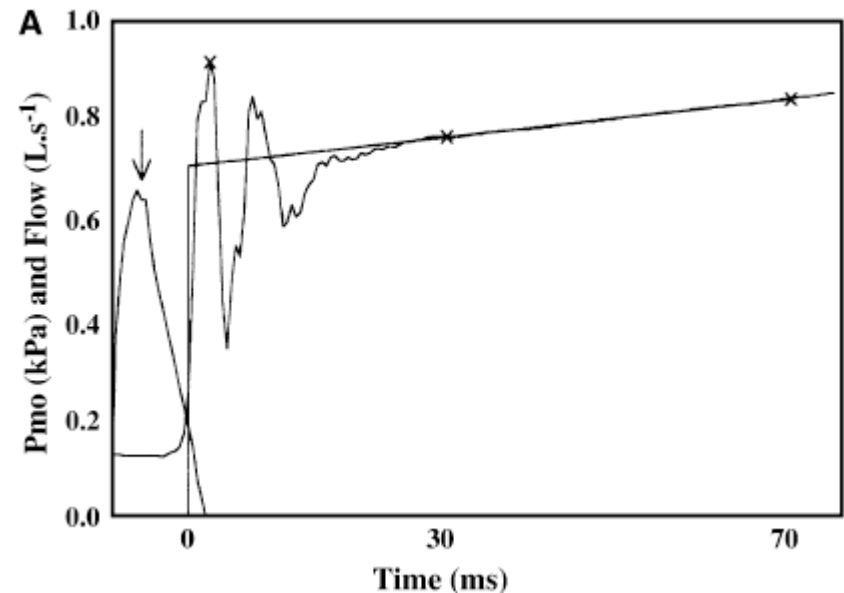


Figure 5. Schematic description of the pressure–time curve showing mouth pressure (P_{mo}) changes after a sudden airflow interruption at midexpiration. P_{dif} = secondary slower change in P_{mo} ; P_{el} = final plateau representing the pressure due to the elastic recoil of the respiratory system; P_{init} = rapid initial change in P_{mo} . Modified by permission from Reference 138.



An Official American Thoracic Society/European Respiratory Society Statement: Pulmonary Function Testing in Preschool Children

Am J Respir Crit Care Med Vol 175. pp 1304–1345, 2007



Rint : 3-6ans

TABLE 6. INTERRUPTER TECHNIQUE: INTRA- AND INTERMEASUREMENT VARIABILITY

Authors	Diagnosis	n	Age Range (yr)	Intrameasurement Variability CV (%)	Time Interval	Intermeasurement Variability CR ($kPa \cdot L^{-1} \cdot s$)
Beydon and colleagues (25)	Healthy	91	2.9–7.9	12.1 (SD, 3.2%)		
Beydon and colleagues (27)	Asthma	74	3.2–7.8	11.7 (SD, 3.9%)		
Beydon and colleagues (26)	Cystic fibrosis	39	3.0–8.2	11.9 (SD, 3.6%)		
Delacourt and colleagues (159)	Stable asthma/cough	118	3–16	11.4 (SD, 6.4%)		
Merkus and colleagues (22)	Healthy, cough/wheeze	139	1–7	11.6 (SD, 5.6%)		
Bridge and colleagues (24)	Healthy, cough/wheeze	22	2–3		30 s	0.21
		40	3–4		30 s	0.17
		58	4–5		30 s	0.15
Beelen and colleagues (158)	Healthy (field conditions)	32	3.7–4.9		20–30 min	0.28
	History of wheeze (field conditions)	25	3.7–4.9		38 d	0.37
	Healthy (standardized conditions)	15	3.2–5.9		11 d	0.28
Chan and colleagues (57)	Healthy, cough, stable wheeze	85	2.0–9.9		15 min	0.17
	Healthy	72	2.2–9.8		3 wk	0.23
	Cough	57	2.0–9.4		3 wk	0.38
	Stable wheeze	95	2.0–9.5		3 wk	0.44
Lombardi and colleagues (21)	Stable wheeze/cough	69	2.6–6.5		1 min	0.24
	Stable wheeze/cough	26	3.1–5.8		2.5 mo	0.21

Definition of abbreviations: CR = coefficient of repeatability (2 SD of the mean difference between two sets of measurements); CV = coefficient of variation (SD/mean × 100).

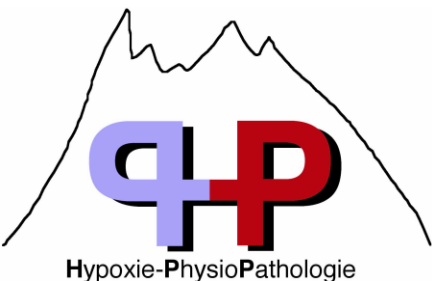
Rint : 3-6ans

Pre/Postbronchodilator Interrupter Resistance Values in Healthy Young Children

Nicole Beydon, Francis Amsallem, Michèle Bellet, Michèle Boule, Michèle Chaussain, André Denjean, Régis Matran, Bernard Wuyam, Corinne Alberti, Claude Gaultier, and the French Pediatric Programme Hospitalier de Recherche Clinique Group

TABLE 3. PRE- AND POSTBRONCHODILATOR INSPIRATORY AND EXPIRATORY INTERRUPTER RESISTANCE VALUES

	$R_{int_{insp}}$ (KPa · L ⁻¹ · second)	CV $R_{int_{insp}}$ (%)	$R_{int_{exp}}$ (KPa · L ⁻¹ · second)	CV $R_{int_{exp}}$ (%)
Prebronchodilator	0.78 ± 0.21	11.1 ± 3.4	0.78 ± 0.20	12.1 ± 3.2*
Postbronchodilator	0.66 ± 0.18 [†]	12 ± 3.8	0.69 ± 0.19 ^{†‡}	13.8 ± 4.8 ^{*§}



-15%

-12%



Rint : previous wheeze

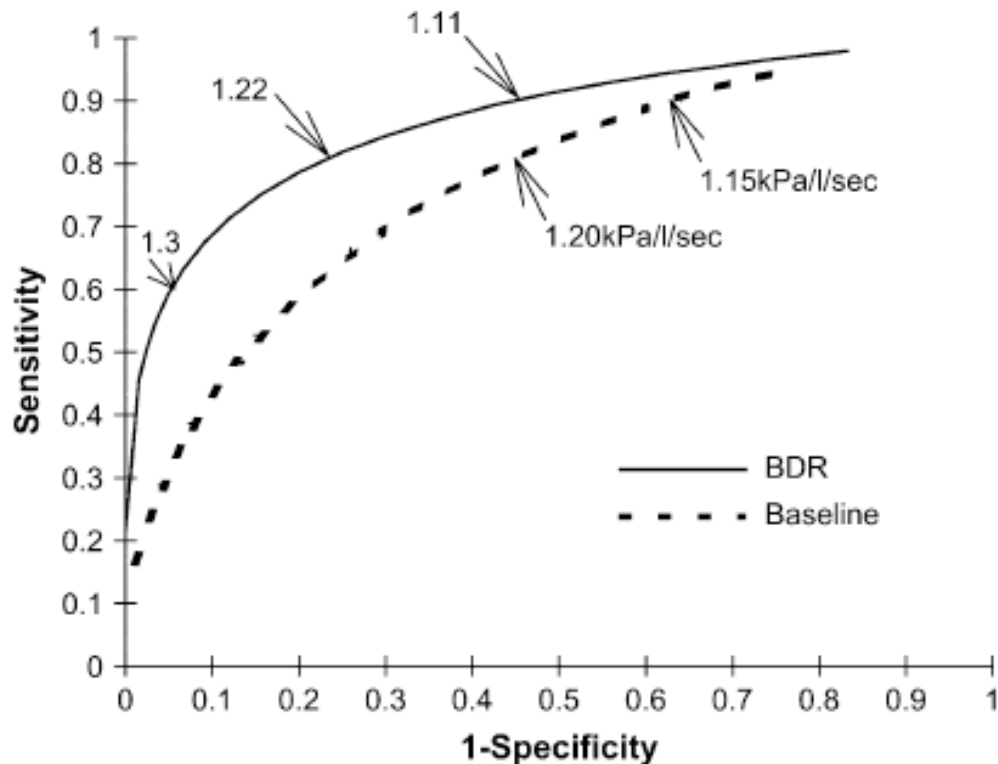


Figure 1. Measurements of baseline interrupter resistance (Rint; $\text{kPa} \cdot \text{L}^{-1} \cdot \text{s}$) and bronchodilator responsiveness (BDR; baseline Rint:post-bronchodilator Rint) plotted as receiver operating curves for previous wheeze.



An Official American Thoracic Society/European Respiratory Society Statement: Pulmonary Function Testing in Preschool Children

Am J Respir Crit Care Med Vol 175. pp 1304–1345, 2007

Rint : mucoviscidose

Pulmonary Function Tests in Preschool Children with Cystic Fibrosis

Nicole Beydon, Francis Amsallem, Mireille Bellet, Michèle Boulé, Michèle Chaussain, André Denjean, Régis Matran, Isabelle Pin, Corinne Alberti, Claude Gaultier, and the French Paediatric PHRC Group

TABLE 3. COMPARISON OF PULMONARY FUNCTION TEST RESULTS AT BASELINE BETWEEN HEALTHY CONTROL CHILDREN AND CHILDREN WITH CYSTIC FIBROSIS

	Healthy (n = 79)	Cystic Fibrosis (n = 39)
FRC (l)	0.84 ± 0.19	0.83 ± 0.25
Z-score FRC	0.00 ± 1.00	0.34 ± 1.27
Rint _{exp} (kPa · L ⁻¹ · s)	0.80 ± 0.20	1.05 ± 0.36*
Z-score Rint _{exp}	0.19 ± 0.97	1.31 ± 1.72*
Gint _{exp} (L · kPa ⁻¹ · s ⁻¹)	1.33 ± 0.34	1.04 ± 0.27*
sGint _{exp} (kPa ⁻¹ · s ⁻¹)	1.63 ± 0.43	1.29 ± 0.34*

CRF hélium

20

STANDARDISATION DES EPREUVES

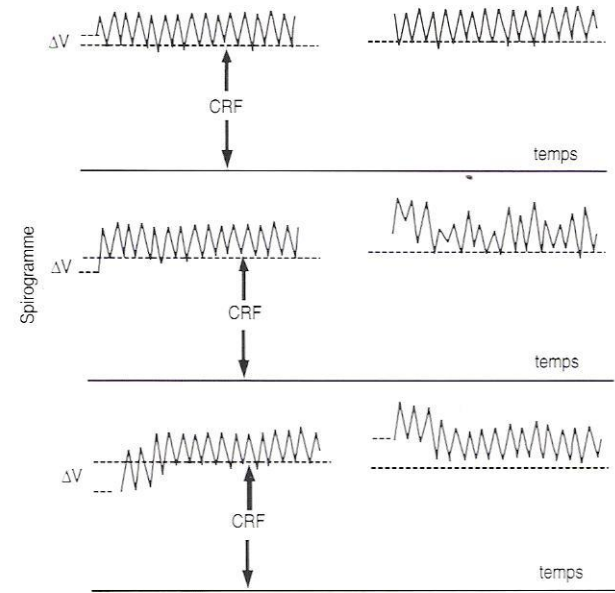
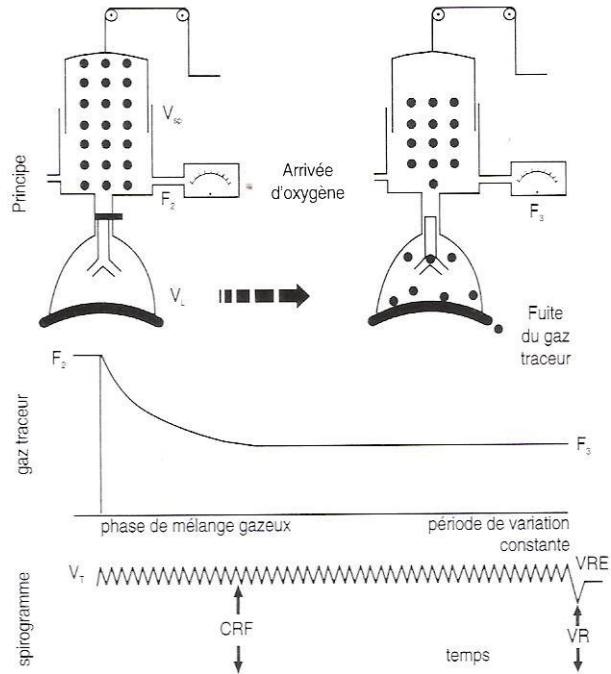


Fig. 7. Le sujet n'a pas été connecté au spiromètre à son véritable volume de fin d'expiration. La CRF est le volume pulmonaire mesuré, auquel il faut ajouter la correction ΔV .

Volume gazeux thoracique (VGT)

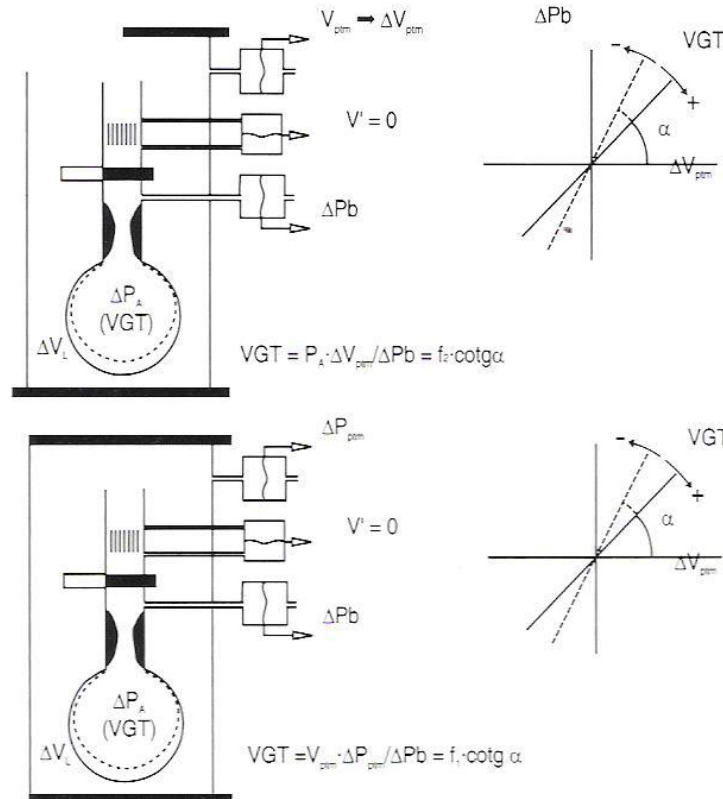


Fig. 8. Schéma de la mesure du volume gazeux thoracique à l'aide d'un pléthysmographe à déplacement de volume (en haut) et à volume constant (en bas). Modifié de (148) avec la permission des auteurs.

Ocillations forcées

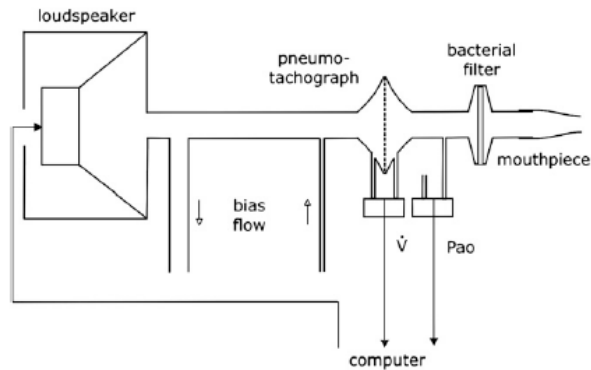


Figure 9. A typical arrangement of the forced oscillatory impedance measurement.

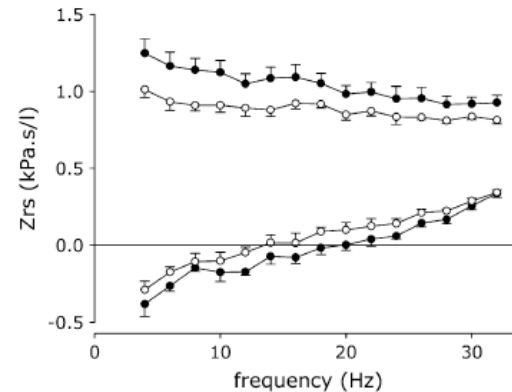
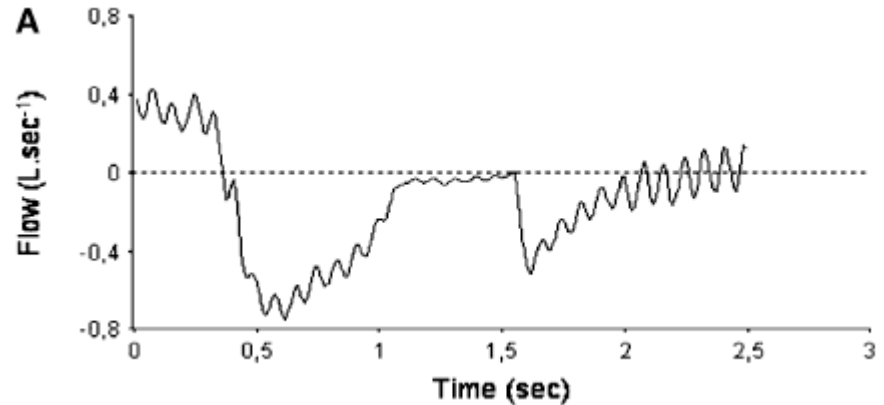
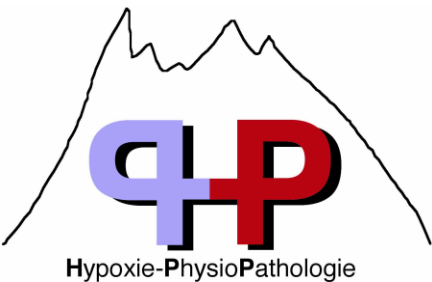


Figure 11. Real part or resistance (top) and imaginary part or reactance (bottom) of the total respiratory impedance (Z_{rs}) as a function of frequency in a 4-year-old healthy child before (closed circles) and after (open circles) bronchodilatation. Mean and SD values (bars) from five successive measurements in each condition, using a conventional input impedance setup, are shown.



Méthodes et normes enfant

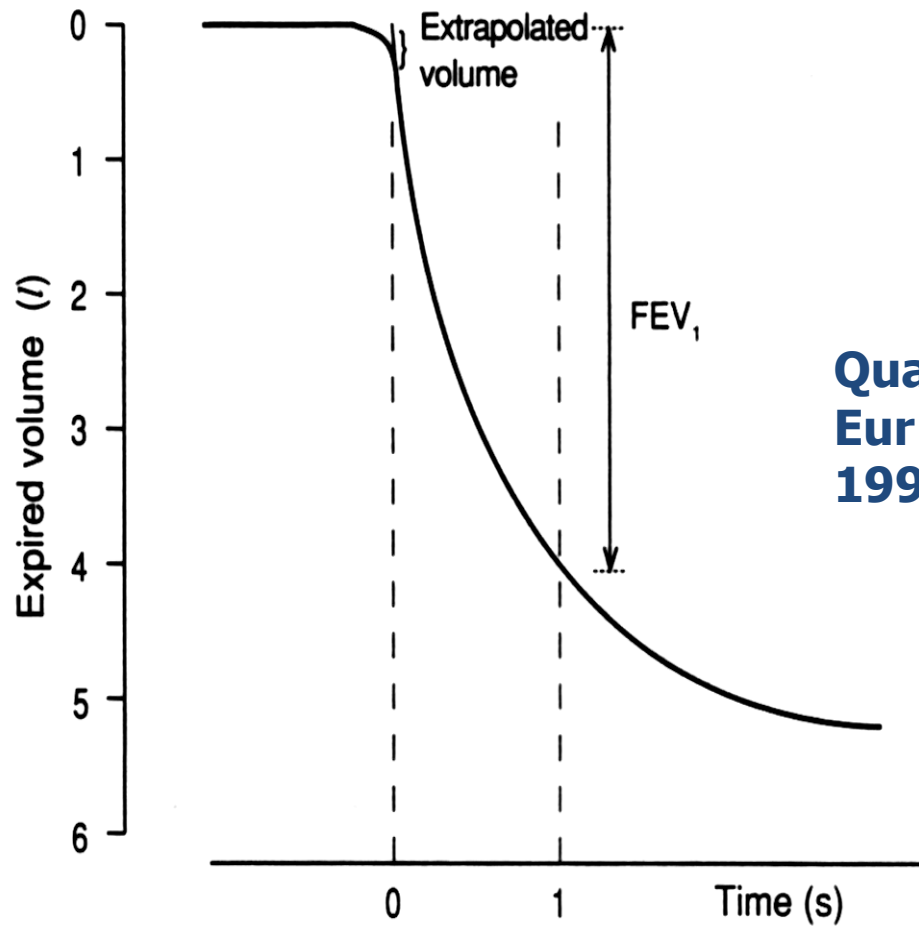
TABLE 1. SUMMARY OF PUBLISHED REFERENCE DATA (50 OR MORE SUBJECTS)

Published Normative Data	No. of Subjects	Age (yr)	Notes
FRC: helium dilution			
Beydon and colleagues, 2002 (26)	79	3-7.9	9 <100 cm*
Spirometric measurements			
Eigen and colleagues, 2001 (5)	214	3-7	25 <100 cm
Nystad and colleagues, 2002 (9)	603	3-6	None <100 cm; 158 aged 3-4 yr
Zapletal and colleagues, 2003 (10)	173	3-6	4 <100 cm; 24 < 5 yr
Interrupter resistance (Rint)			
Merkus and colleagues, 2001 (22)	54	2-7	3 <100 cm
McKenzie and colleagues, 2002 (53)	216	2-10	27 <100 cm
Lombardi and colleagues, 2001 (21)	284	3-6.4	10 <100 cm
Beydon and colleagues, 2002 (25)	79	3-7.9	9 <100 cm
Klug and Bisgaard, 1998 (174)	120	2-7	16 <3 yr
Plethysmography: sRaw			
Klug and Bisgaard, 1998 (174)	119	2-7	28 <3 yr
Lowe and colleagues, 2002 (292)	303	3	
Forced oscillation technique			
Duiverman and colleagues, 1985 (15)	255	2.3-12.5	18 <100 cm
Ducharme and colleagues, 1998 (195)	206	3-17	16 at 100 cm
Mazurek and colleagues, 2000 (16)	61	2.8-7.4	8 <100 cm
Klug and Bisgaard, 1998 (174)	121	2-7	16 <3 yr

The Notes column identifies the number of children in the cohort who are at the short or young end of the height or age range.

* Raw data from authors.

Spirométrie



Quanjer et al.
Eur Respir J.
1993. 6(S16):5-40



spirométrie et CDV

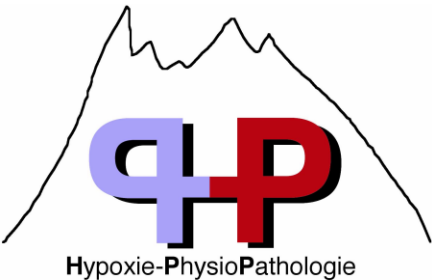
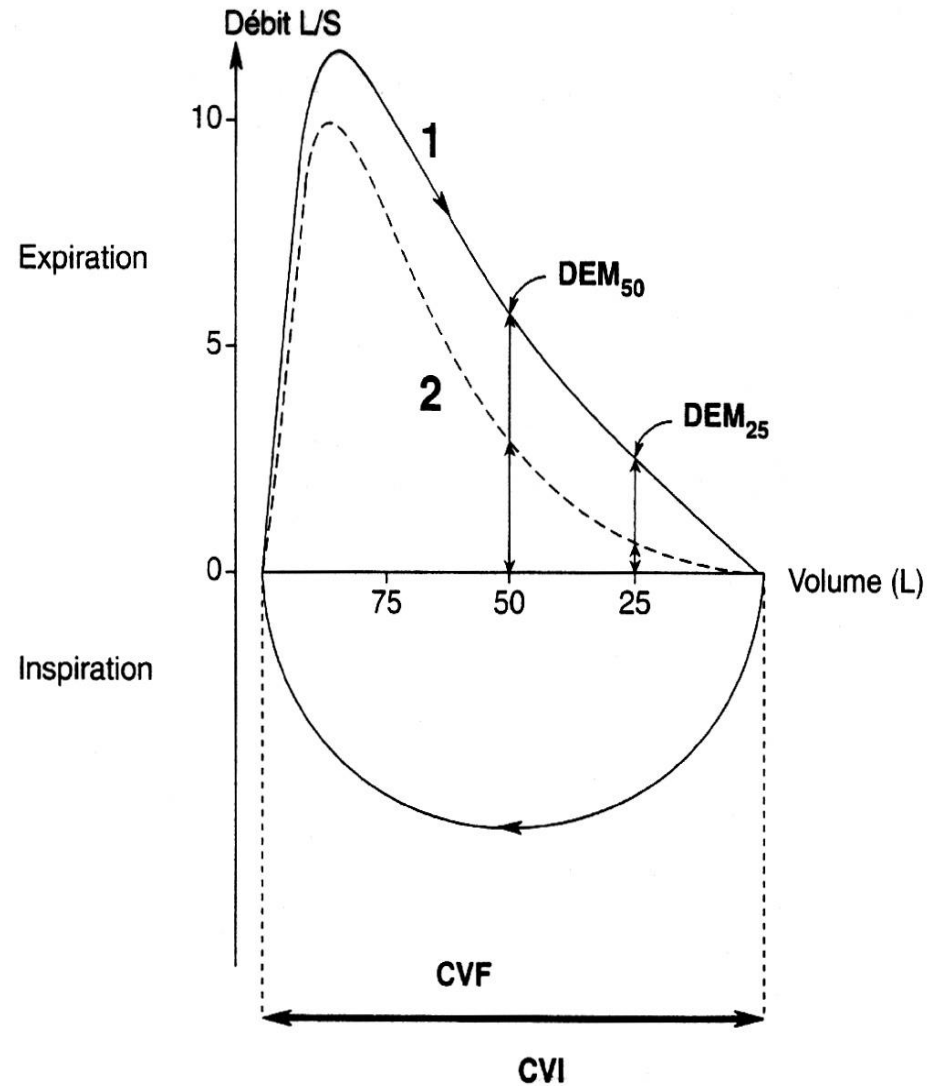
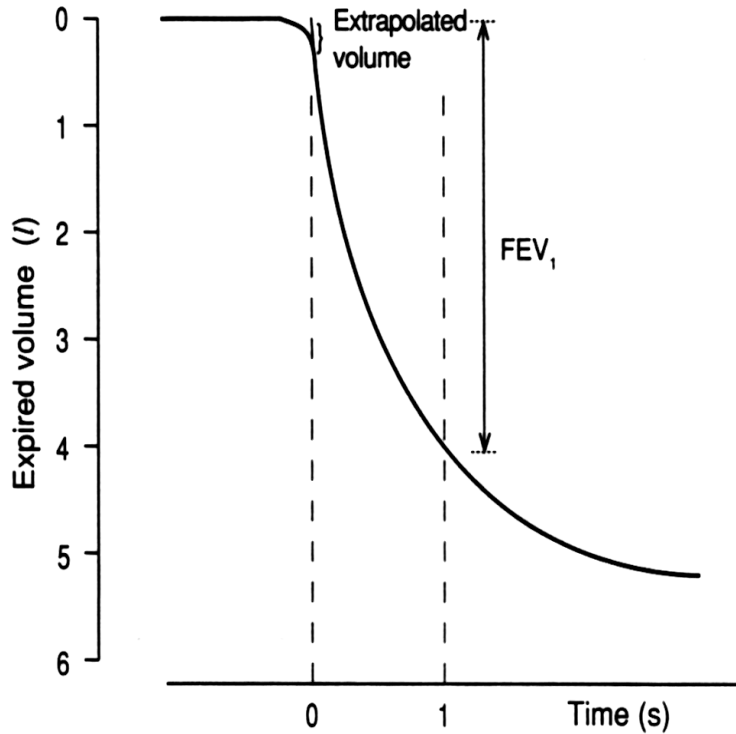
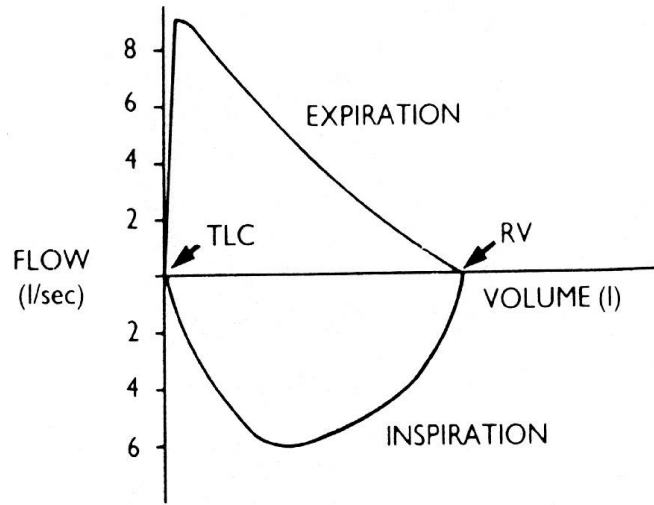
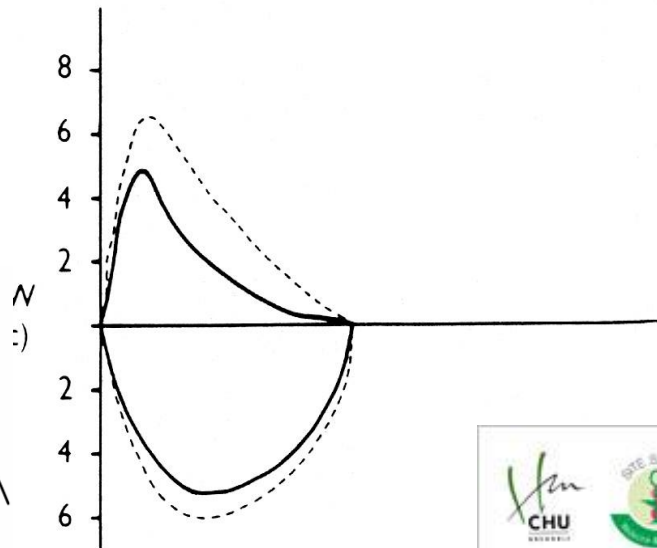


Figure 1.2 – Courbe débit-volume (V/V ou CDV) avec boucle complète inspiratoire et expiratoire.
Courbe 1 = sujet normal. Courbe 2 = sujet obstructif.

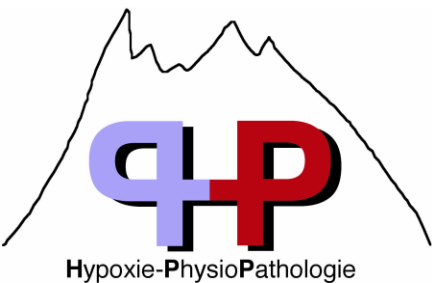
Débit aériens normaux et pathologiques



Normal



Asthme



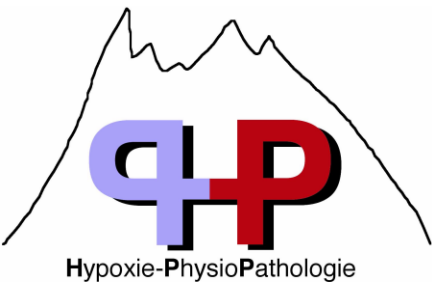
Interprétation

- VEMS/CV : TVO [$VEMS/CV < 70\%$ ou $< 1.96 ETR$]
- Restriction : CPT ($CPT < 80\%$ ou écart CPT CPT théorique $> 1.96 ETR$)
- Hyper-inflation (VGT VR/CPT)
- Critères enfant
 - VEMS, VEM0.5, CVF difficile
 - Time to peak flow

Paramètre	Unité	Equation de régression	ETR	1,64 RSD
Hommes				
CVI	l	6,10H - 0,028A - 4,65	0,56	0,92
CVF	l	5,76H - 0,026A - 4,34	0,61	1,00
CPT	l	7,99H - 7,08	0,70	1,15
VR	l	1,31H + 0,022A - 1,23	0,41	0,67
CRF	l	2,34H + 0,009A - 1,09	0,6	0,99
VR/CPT	%	0,39A + 13,96	5,46	9,0
CRF/CPT	%	0,21A + 43,8	6,74	11,1
VEMS	l.s ⁻¹	4,30H - 0,029A - 2,49	0,51	0,84
VEMS/CV	%	-0,18A + 87,21	7,17	11,8
DEM _{25-75%}	l.s ⁻¹	1,94H - 0,043A + 2,70	1,04	1,71
DEP	l.s ⁻¹	6,14H - 0,043A + 0,15	1,21	1,99
DEM ₇₅	l.s ⁻¹	5,46H - 0,029A - 0,47	1,71	2,81
DEM ₅₀	l.s ⁻¹	3,79H - 0,031A - 0,35	1,32	2,17
DEM ₂₅	l.s ⁻¹	2,61H - 0,026A - 1,34	0,78	1,28
Femmes				
CVI	l	4,66H - 0,026A - 3,28	0,42	0,69
CVF	l	4,43H - 0,026A - 2,89	0,43	0,71
CPT	l	6,60H - 5,79	0,60	0,99
VR	l	1,81H + 0,016A - 2,00	0,35	0,58
CRF	l	2,24H + 0,001A - 1,00	0,50	0,82
VR/CPT	%	0,34A + 18,96	5,83	9,6
CRF/CPT	%	0,16A + 45,1	5,93	9,8
VEMS	l.s ⁻¹	3,95H - 0,025A - 2,60	0,38	0,62
VEMS/CV	%	-0,19A + 89,10	6,51	10,7
DEM _{25-75%}	l.s ⁻¹	1,25H - 0,034A + 2,92	0,85	1,40
DEP	l.s ⁻¹	5,50H - 0,030A + 1,11	0,90	1,48
DEM ₇₅	l.s ⁻¹	3,22H - 0,025A - 1,60	1,35	2,22
DEM ₅₀	l.s ⁻¹	2,45H - 0,025A - 1,16	1,10	1,81
DEM ₂₅	l.s ⁻¹	1,05H - 0,025A - 1,11	0,69	1,13

H : taille (m); A : âge (ans) ; ETR : écart type résiduel.

Entre 18 et 25 ans, prendre l'âge égal à 25 ans dans les équations. Résultats obtenus à la fois avec un débitmètre de pointe (mini)Wright et un pneumotachographe : d'autres travaux sont nécessaires.



Critères de qualité des spirométries (pré-scolaire)

- $V_{be} \leq 75$ ml and $\leq 10\%$ of FVC,
- time-to-PEF < 120 msec, and
- repeatability:
 - ΔFEV_1 and $\Delta FEV_{0.5} \leq 110$ ml and $\leq 10\%$ of best effort,
 - $\Delta FVC \leq 100$ ml and $\leq 12.5\%$.
- These were obtained in 85%, 93%, 94%, 90%, and 89% of children, respectively.

Critères de qualité des spirométries (pré-scolaire)

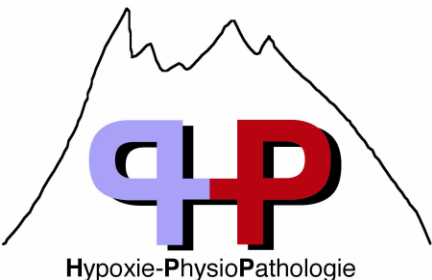
Pour des raisons pratiques, il est suggéré de choisir le même seuil pour tous les critères de répétabilité, à savoir,

ΔFVC , ΔFEV_1 , and $\Delta FEV_{0.5}$

≤ 110 ml and $\leq 10\%$ de la meilleur valeur .

Dysplasie bronchopulmonaire & exercice

- L'exercice est un aspect important de la santé et du développement de l'enfant
- Réponse intégrative
 - Locomotion
 - Ventilation
 - Coordination corticale

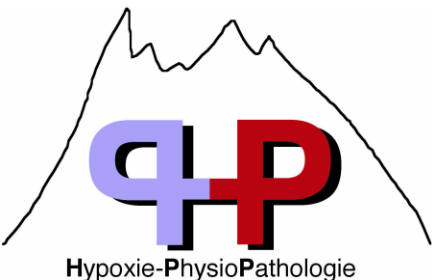


[Pediatrics](#). 2008 Aug;122(2):e287-93.

Reduced exercise capacity in children born very preterm.

[Smith LJ](#), [van Asperen PP](#), [McKay KO](#), [Selvadurai H](#), [Fitzgerald DA](#).

- In the largest (n=123, 27 semaines) cohort of school-aged children (born very preterm in the 1990s) to undergo extensive lung function and fitness assessments, we demonstrated **significant impairment in exercise capacity despite evidence of only mild small-airway obstruction** and gas trapping.
- Additional studies are required to evaluate the cause of this exercise limitation and whether it can be improved with a training program.



Exercice

The EPICure study: maximal exercise and physical activity in school children born extremely preterm.

[Thorax](#). 2010 Feb;65(2):165-72. Epub 2009 Dec 8.

- **38** enfants de 11 ans nés <25 semaines gestationnelles vs. full-term controls.
- Z-scores plus bas (mean (95% CI) of difference) pour
 - VEMS : -1.74 (-2.25 to -1.23) and gas transfer (-0.73 (-1.31 to -0.17)),
- Z-scores plus hauts (mean (95% CI) of difference):
 - (RV; 0.58 (0.10 to 1.10)) and
 - RV/total lung capacity (TLC; 0.74 (0.29 to 1.19)).



significant reduction in peak oxygen consumption



Epicure-exercice

- Significant reduction in peak oxygen consumption ($\dot{V}O_2$)
- EP children employed greater breathing frequencies and lower tidal volumes during peak exercise.
- No differences were observed in physical activity between groups.
- The reduction in peak oxygen consumption in children born EP, and alterations in ventilatory adaptations during peak exercise were not explained by differences in physical activity



Pediatrics. 2008 Aug;122(2):e287-93.

Reduced exercise capacity in children born very preterm.

Smith LJ et al. , AUSTRALIE

- 126 enfants (10 ans) < 27 semaines
- TM6 & incremental shuttle test
- Spirométrie & mesure CPT
 - Obstruction légère
 - Pas de restriction
 - TM6 identique
 - Shuttle test : moindre capacité à l'exercice maximal

Exercice (n<25)

Kaiantie E et al. *Pediatrics*, 2010 Oct;157(4):610-6, 616.e1. Epub 2010 May 20.

C Karila et coll. Rev Mal Respir. 2008 Mar;25(3):303-12.

Pianosi PT, *Pediatr Res. 2000 May;47(5):653-8.*

- Mitchell SH, *Am J Respir Crit Care Med. 1998 May;157(5 Pt 1):1406-12.*

Baisse de VO₂ max

Réponse ventilatoire variable

Désaturation inconstante

Corrélation avec AP non constante

Corrélation avec masse maigre

Altération de la diffusion

- [Lovering AT](#), et al. [High Alt Med Biol.](#) 2007 8(1):62-7.

Excessive gas exchange impairment during exercise in a subject with a history of bronchopulmonary dysplasia and high altitude pulmonary edema.

27 ans

OPHA à basse altitude 2500m

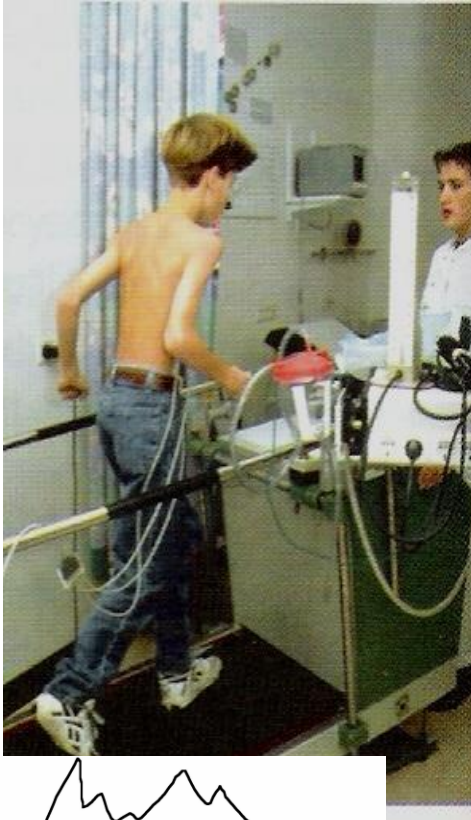
VO₂ max et EFR normale

Désaturation en altitude

pas d'hyposensibilité à O₂ (HVR)



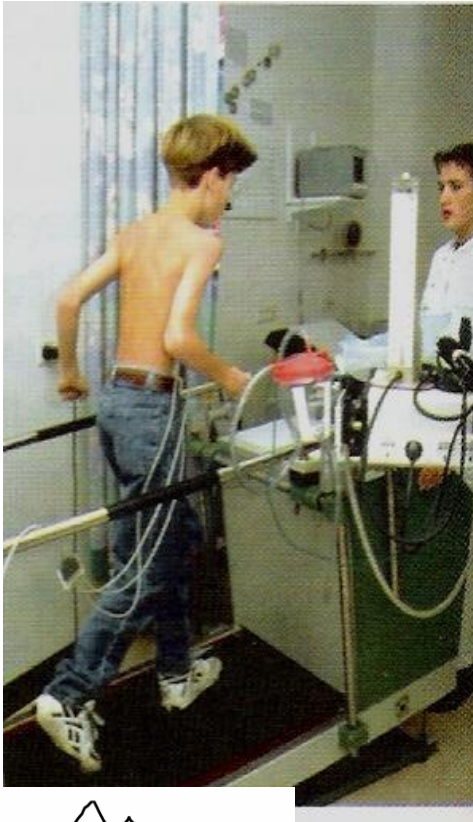
Tests d'effort



- **Jeunes enfants : simplifiés**
 - tapis
 - Vitesse marche 4 km/h
 - Sécurité
 - Pente augmente de 2% par minute
 - fc (ECG), SpO2, examen clinique



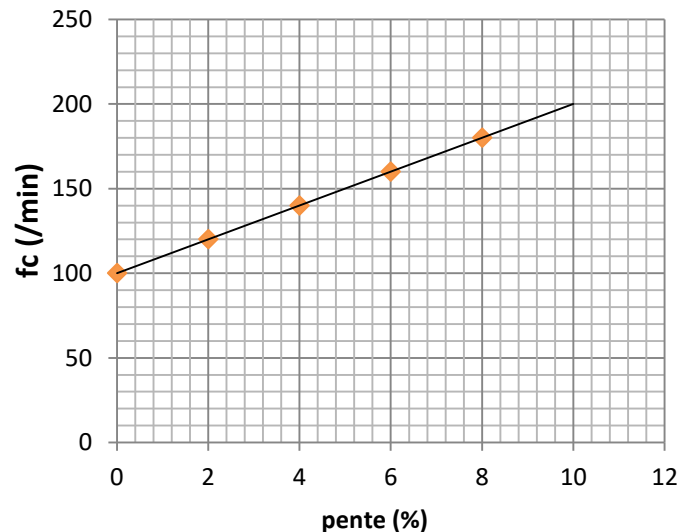
Tests d'effort jeunes enfants



- **Tests effort : même jeunes enfants**
 - sous maximaux (fcmax 170/min)
 - Relation fc/W ascensionnel
 - SpO₂
 - Auscultation + Rint avant/après : diagnostic de l'asthme de l'enfant

Tests d'effort jeunes enfants

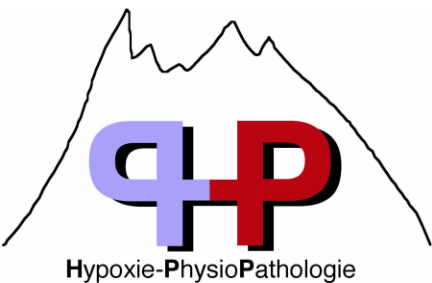
NOM	PRENOM	date de naissance
Poids (kg) 20		Vitesse (km/h) 4
pente	fc	travail
0	100	
2	120	
4	140	
6	160	
8	180	
10		



$\Delta fc / kg / \%pente$

◆ fc
— Linéaire (fc)

- Allure générale de l'enfant
- Vitesse maximale (performance / poids)
- Cardio-accélération (éjection systolique / extraction périphérique)
- Désaturation
- *Argument pour HRB*



En conclusion

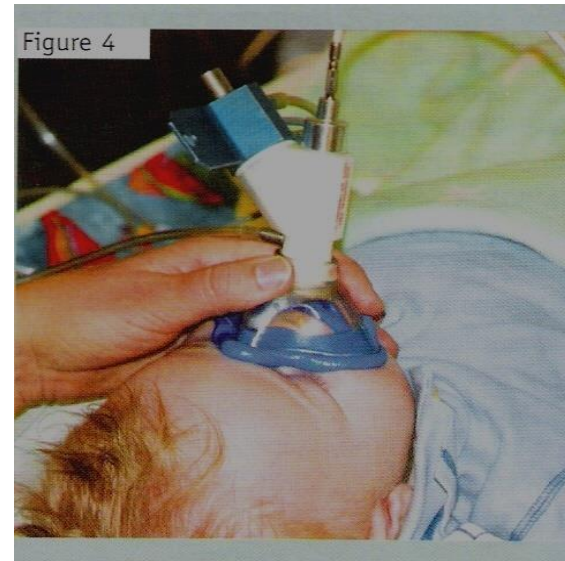
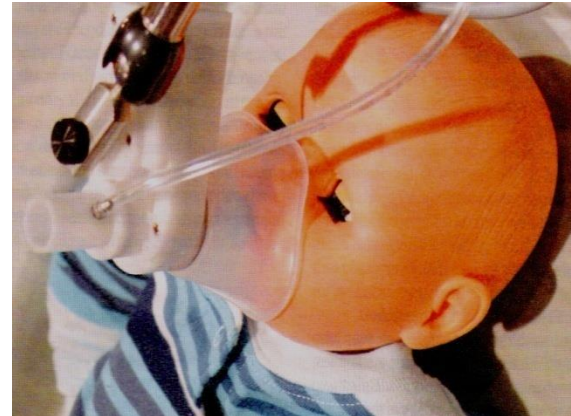
- Séquelles obstructives (et/ou restrictives) en général faciles à reconnaître
- Enfant pré-scolaire : Rint, CRF
- Comportement à l'effort intéressant :
 - dé-saturation,
 - sensibilisation de la famille pour AP
 - Manque de normes et de 'validité' : résultats 5 ans vs. résultats VO2 ultérieurs ?



**Additional
sides**

Nourrissons

- Au cours du sommeil:
 - Spontané +++
 - Chloral (50-90 mg/kg, si autorisé)
- Masque & PNT pour mesure du débit
- Information parentale



Nourissons (2)

- Respiration calme :
 - Volume jusqu'au débit maximal expiratoire
 - Débit de pointe expiratoire
 - Débit de pointe inspiratoire
 - VT; fR

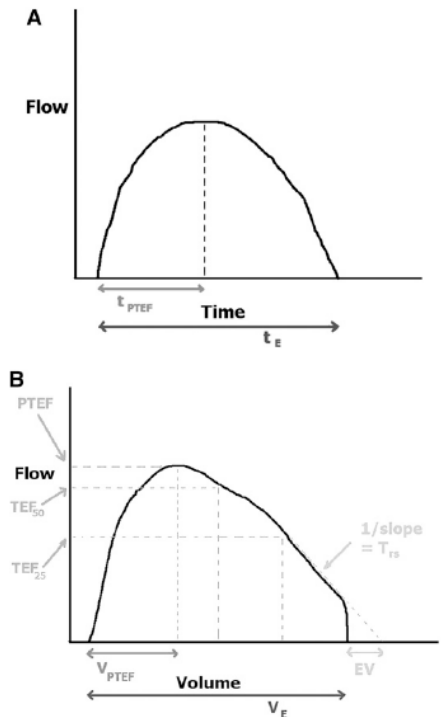
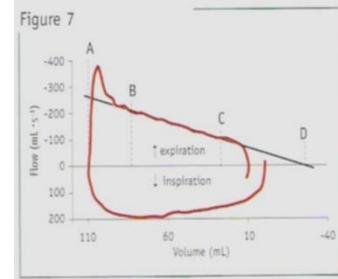
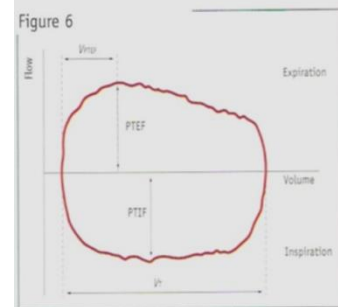
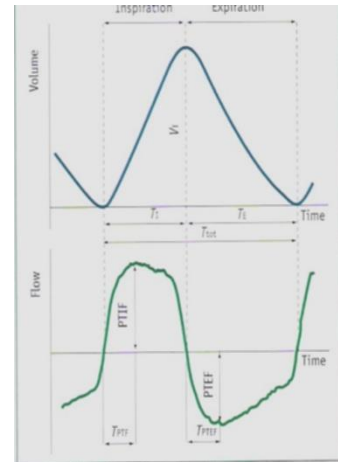
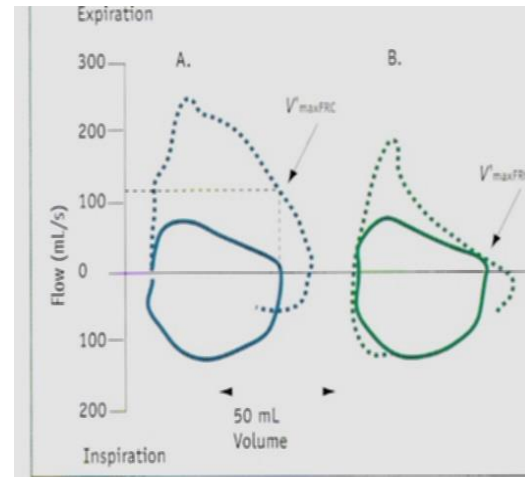
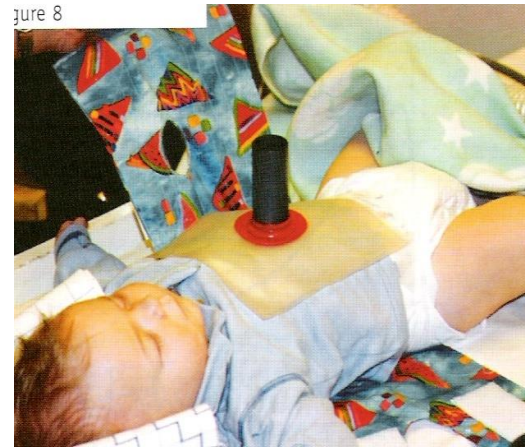


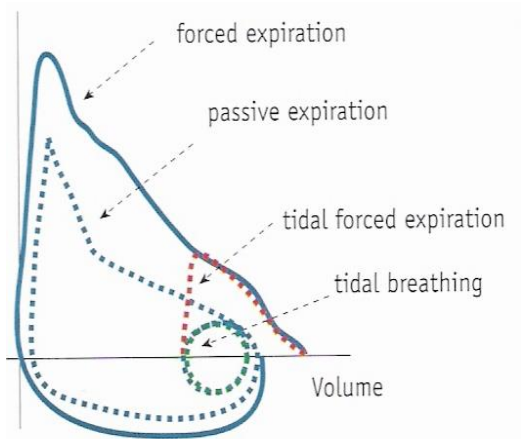
Figure 2. Tidal expiratory flow indices. (A) Flow–time plot illustrating measurement of time to peak tidal expiratory flow (t_{PTEF}) and total expiratory time (t_E); (B) flow–volume plot illustrating measurement of volume at peak tidal expiratory flow (V_{PTEF}), expired tidal volume (V_E), tidal time constant of the respiratory system (T_{rs}), extrapolated volume (EV), PTEF, flow at 50% of tidal volume (TE_{50}), and TE_{25} .

Nourissons (2)

- Expiration forcée :
 - Compression abdominale,
 - 20-30 cm H₂O,
 - V_{max}CRF, allure de la courbe expi forcé
 - Normes



Nourrissons (3)



- Pression positive à l'ouverture des VA (20-30 cm H₂O),
- Puis déflation par la jaquette
- Etend la gamme des volumes explorés (quasi CDV grands enfants)

