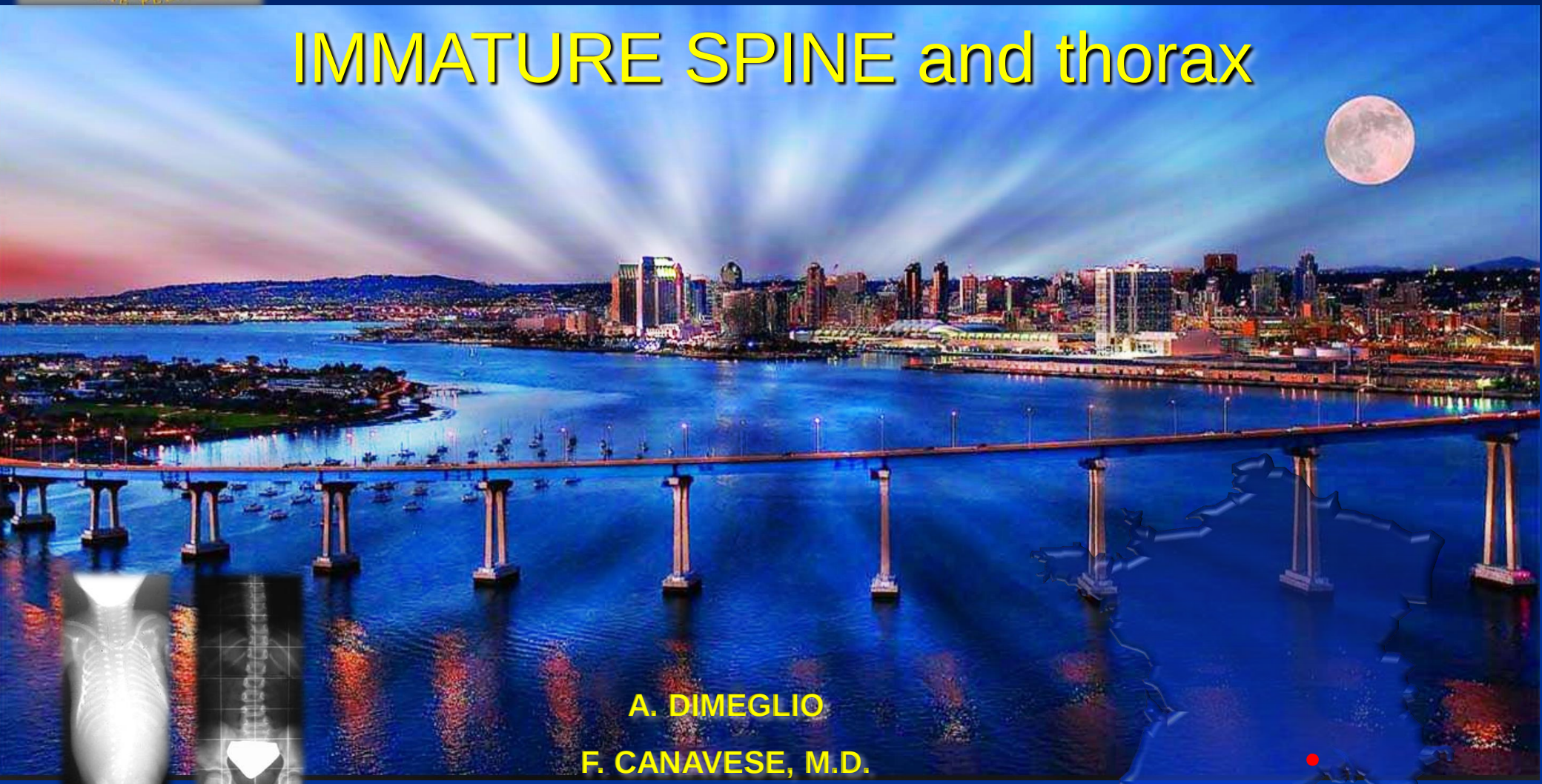
SAN DIEGO 2 0 1 7

IMMATURE SPINE and thorax



A. DIMEGLIO

F. CANAVESE, M.D.

Montpellier

The growing spine : What we have learned?

- The thorax is the heart of the problem in severe scoliosis
- Growth of the spine, thorax, lung are intricated
- The spine and ribs dictate lung function
- The cranckshaft phenomenon is an uncontrollable factor

The growing spine : What we have learned ?

Mosaic of growth plates
Changes in rhythm
All parameters do not progress at the same speed
The thorax is the fourth dimension

Challenging the growing spine: to maintain
spinal growth, thoracic growth, lung growth
and keep the spine supple

ONE DEFICIT LEADS TO AN OTHER DEFICIT

- Consider the complete life span
- What is the functional benefit ?
- What is the morbidity risk ?
- What quality of Life ?

Domino effect

The goal is to break up the vicious circle.

The growing spine now

- Still high morbidity
- The first priority is the pulmonary growth
- Differents etiologies, different strategies
- Keep the spine supple
- Avoid thorax retraction
- Have a pediatric approach

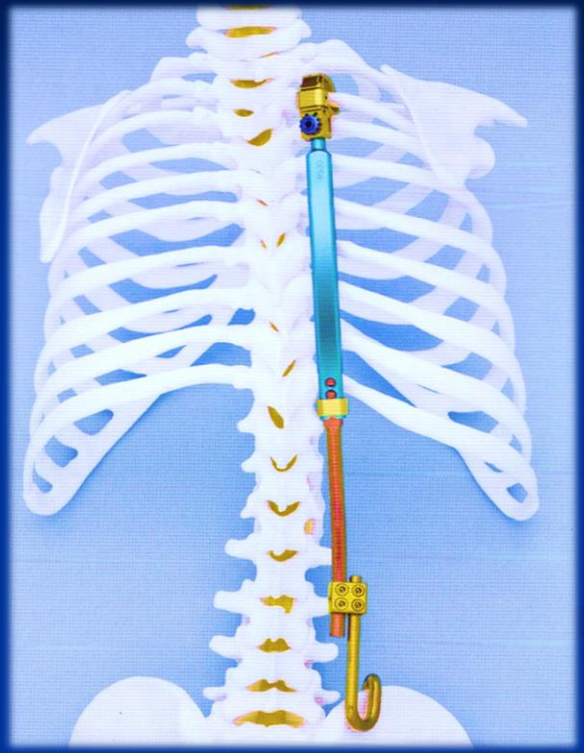
The final dream?

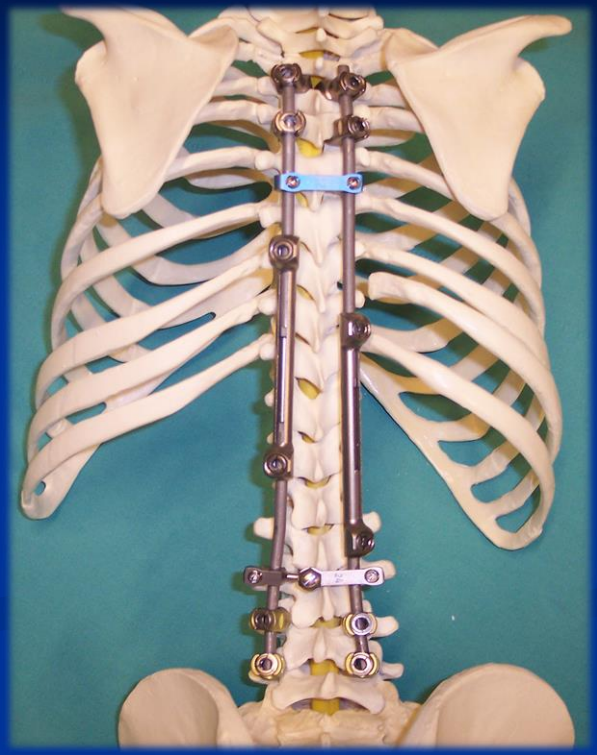
- Avoid arthrodesis

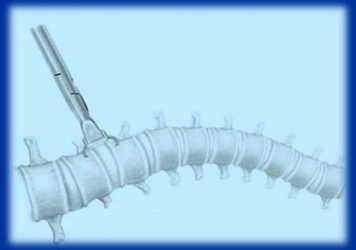
The final goal

- Weight : 40 Kg
- T1 – T12: 22 cm
- T1 – S1 : 30 cm
- VC : 50 %

No ideal device !







Shilla…Phenix…Ellipse…Staples…Vertebral body tethering

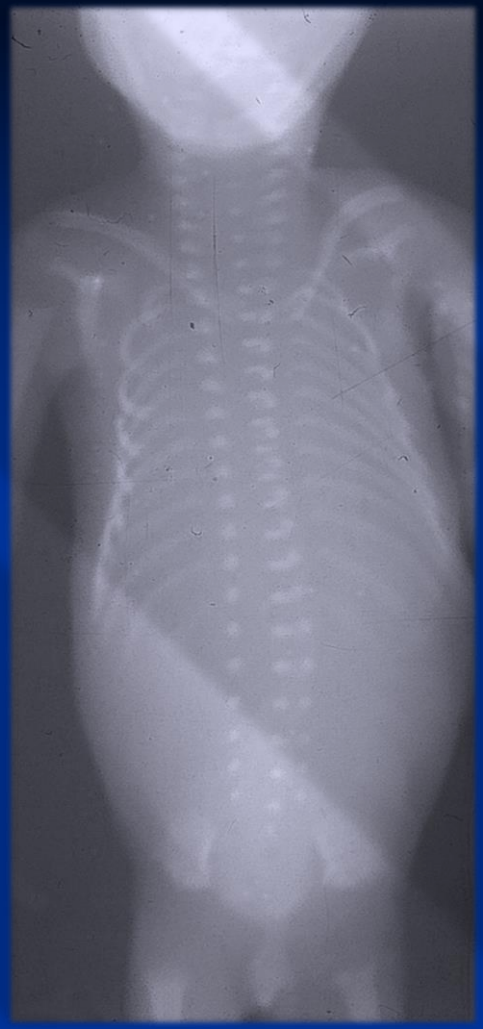
The growing spine

130 growth plates working in a perfect synchronisation

EOS breaks

Harmony Hierarchy Synergy

With the growing spine EOS becomes a growth plate disorder

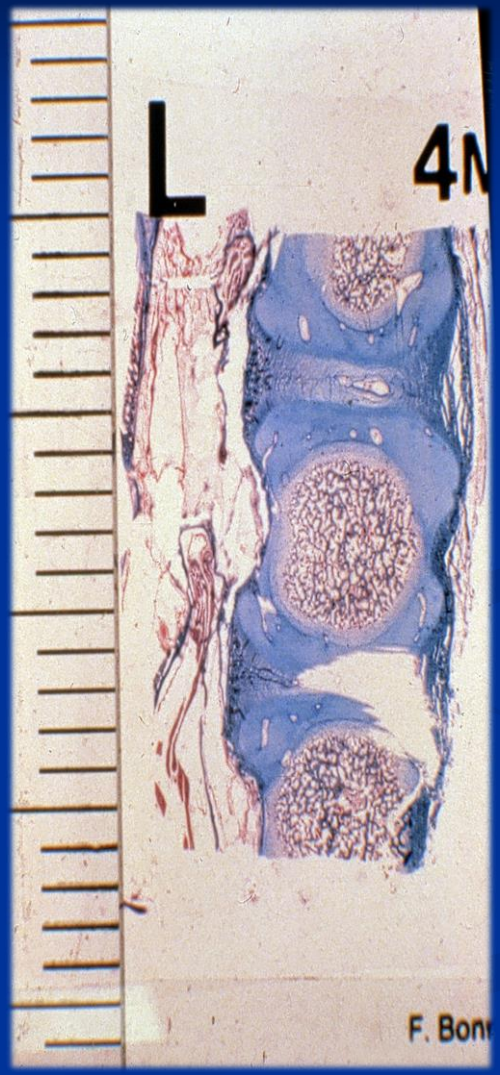


Ossification starts at the third month of intra-uterine life

3 months
intra-uterine life

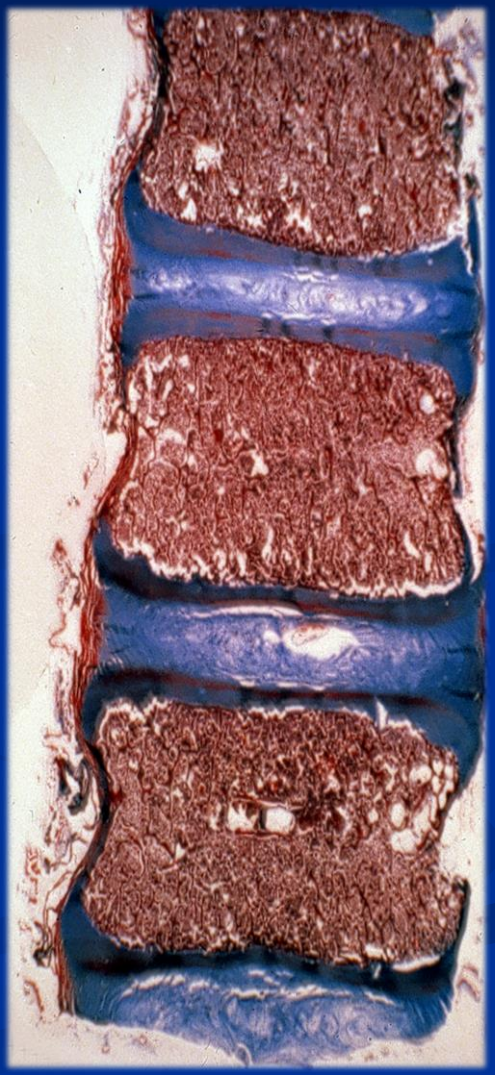
Lentil

4 months
intra-uterine life

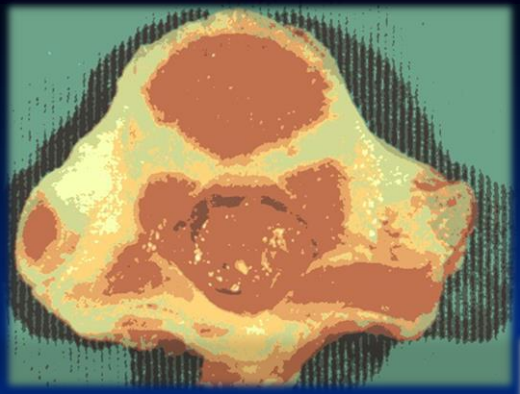


Ovoid

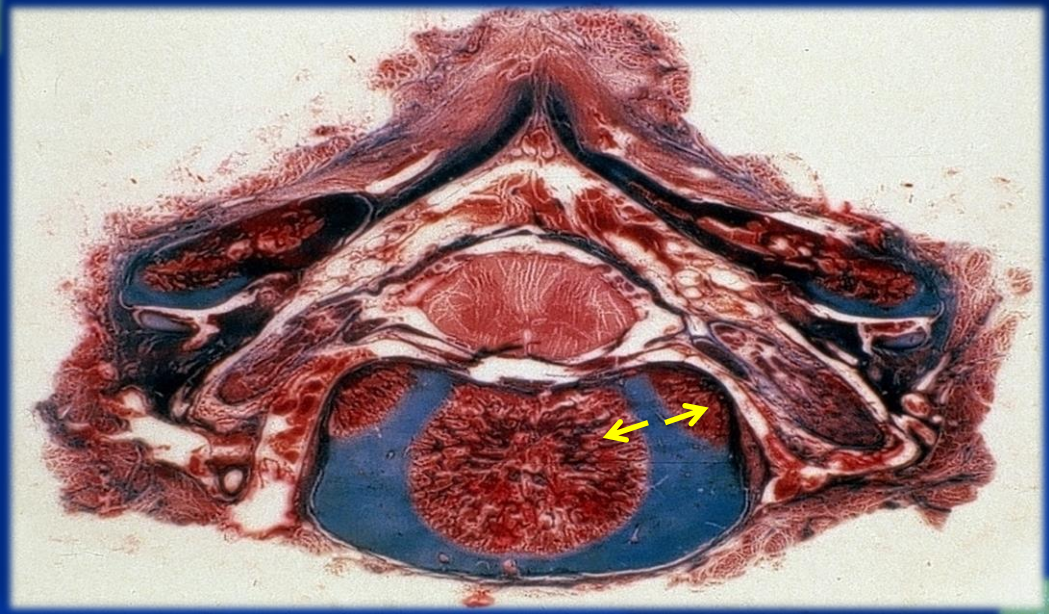
8 years

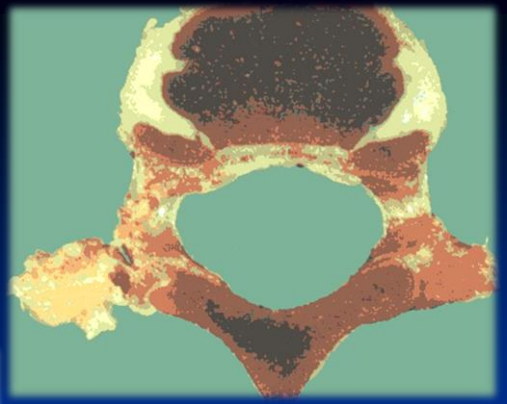


Rectangular

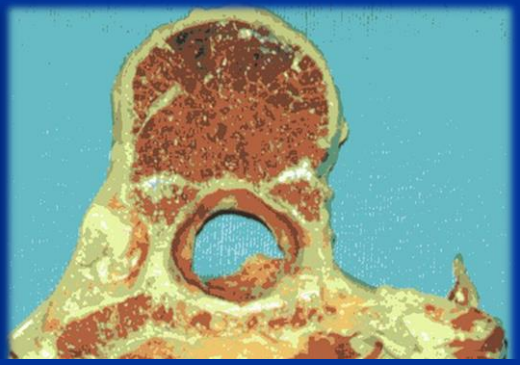


3 Months





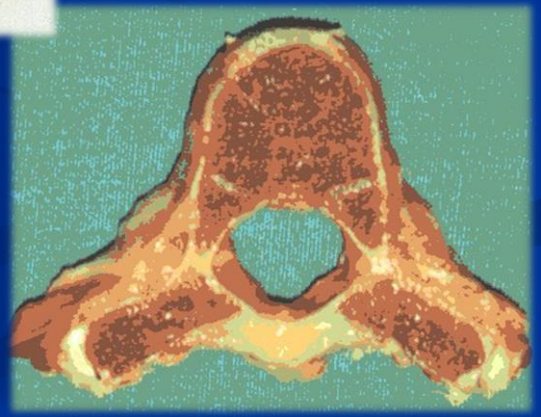
2 Years



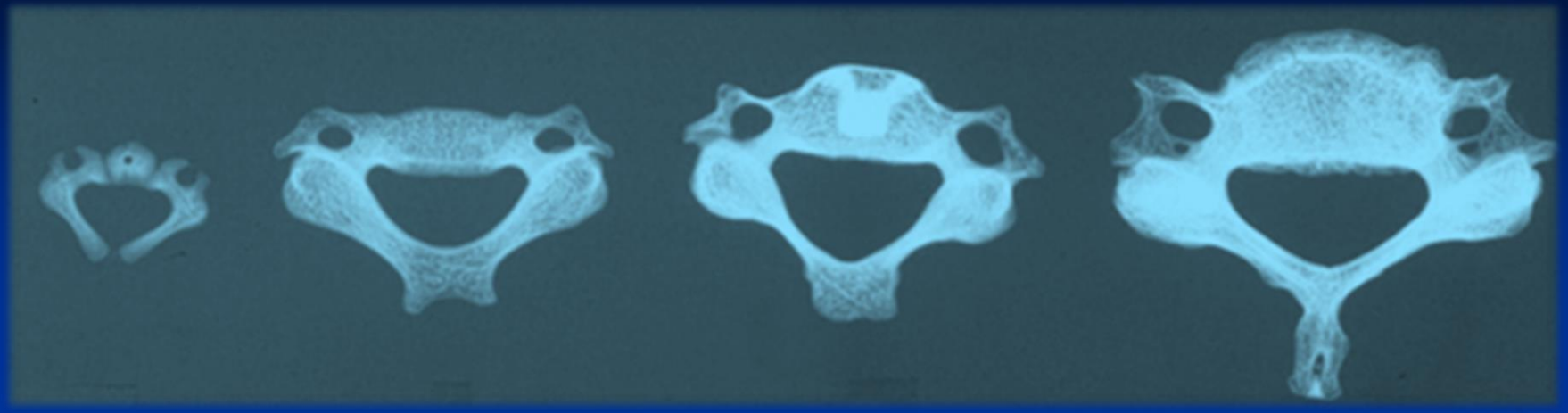
9 Years

Closure at eleven years

Zang Sucato 2008



11 Years

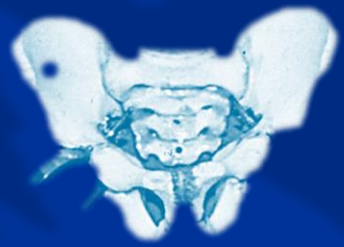


New Born 5 10 15 years

At age 5 years, the spinal canal has grown to 95% of its definitive size.

The growing spine before age five . J Pediatric ortho B 1993

GROWTH IS A VOLUMETRIC REVOLUTION

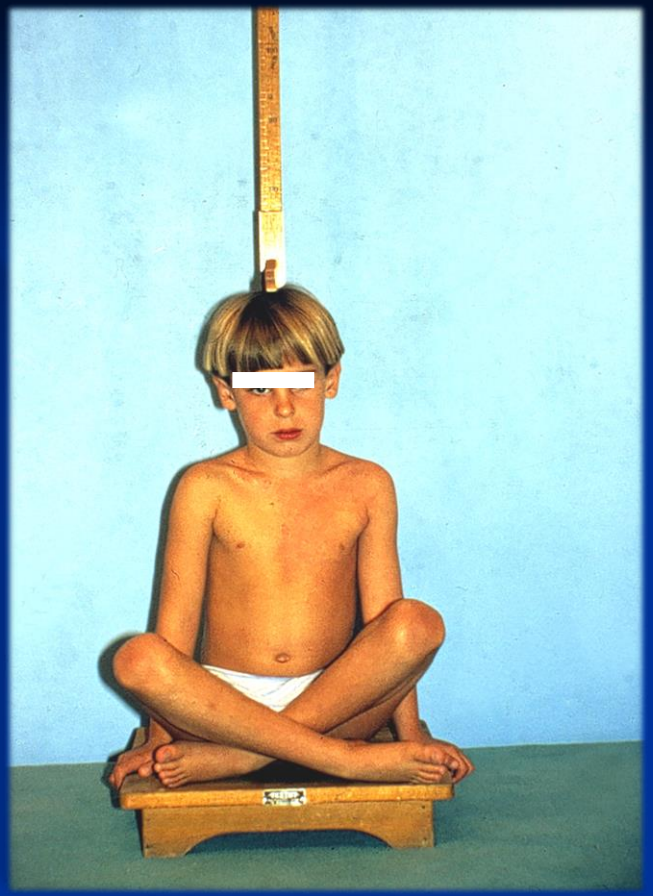


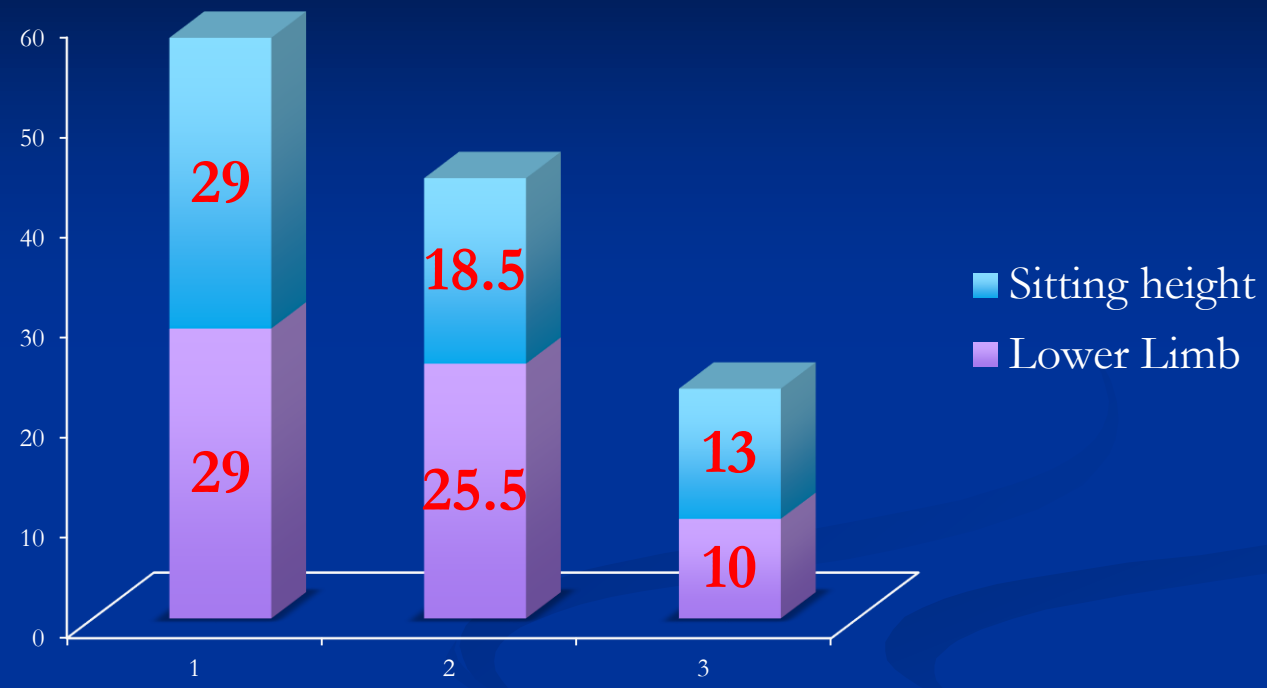
Newborn 5 years Sk. maturity

AT BIRTH 30% OF THE SPINE IS OSSIFIED

Repeat the measurements

…To understand the dynamic of growth and to anticipate





SITTING HEIGHT INCREASES
BY 29 CM IN BOYS AND 28 CM IN GIRLS
FROM BIRTH TO AGE OF 5 YEARS

The growing spine Springer 2009

ANNUAL GROWTH VELOCITY

SITTING HEIGHT BOYS

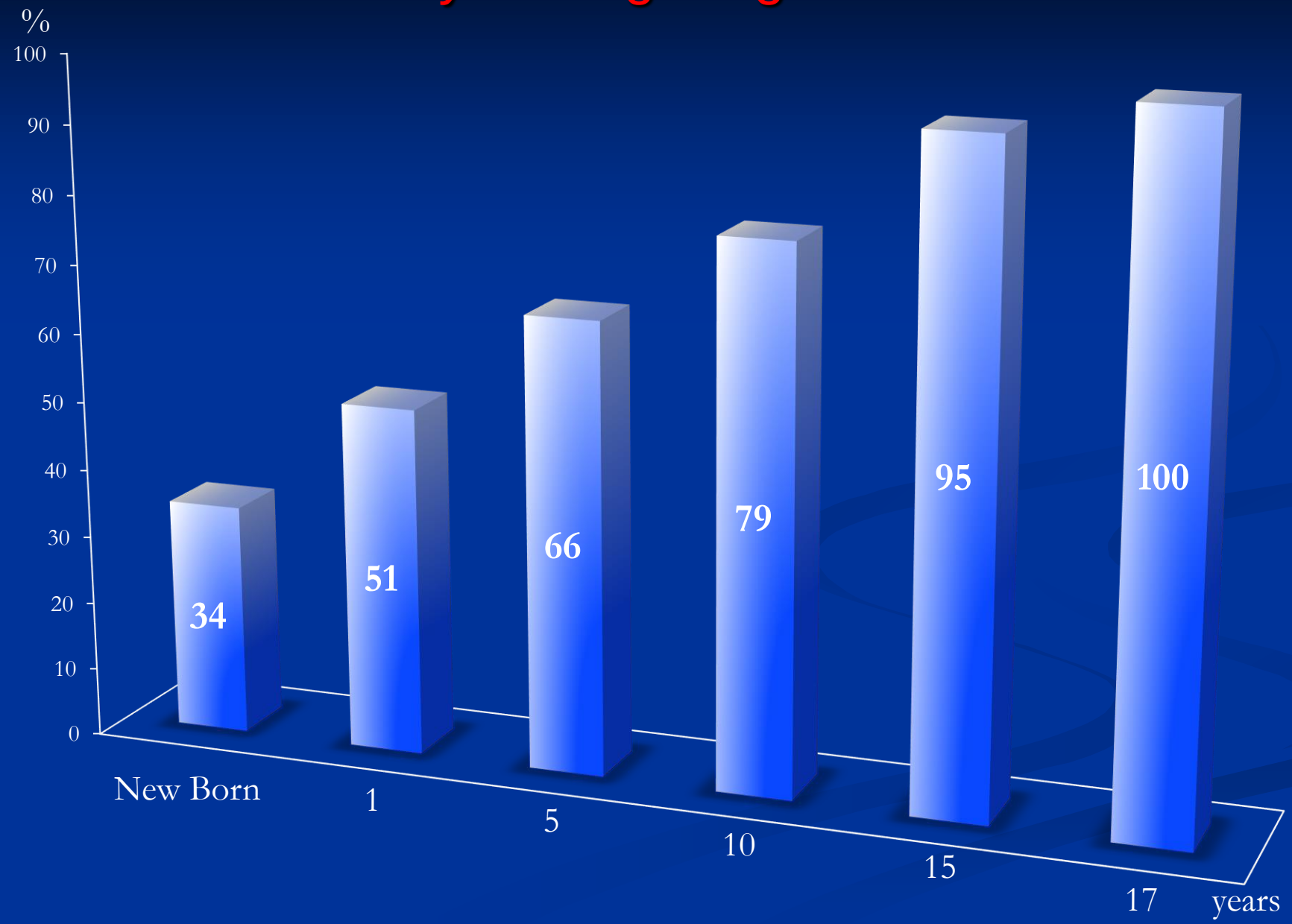
27 cm

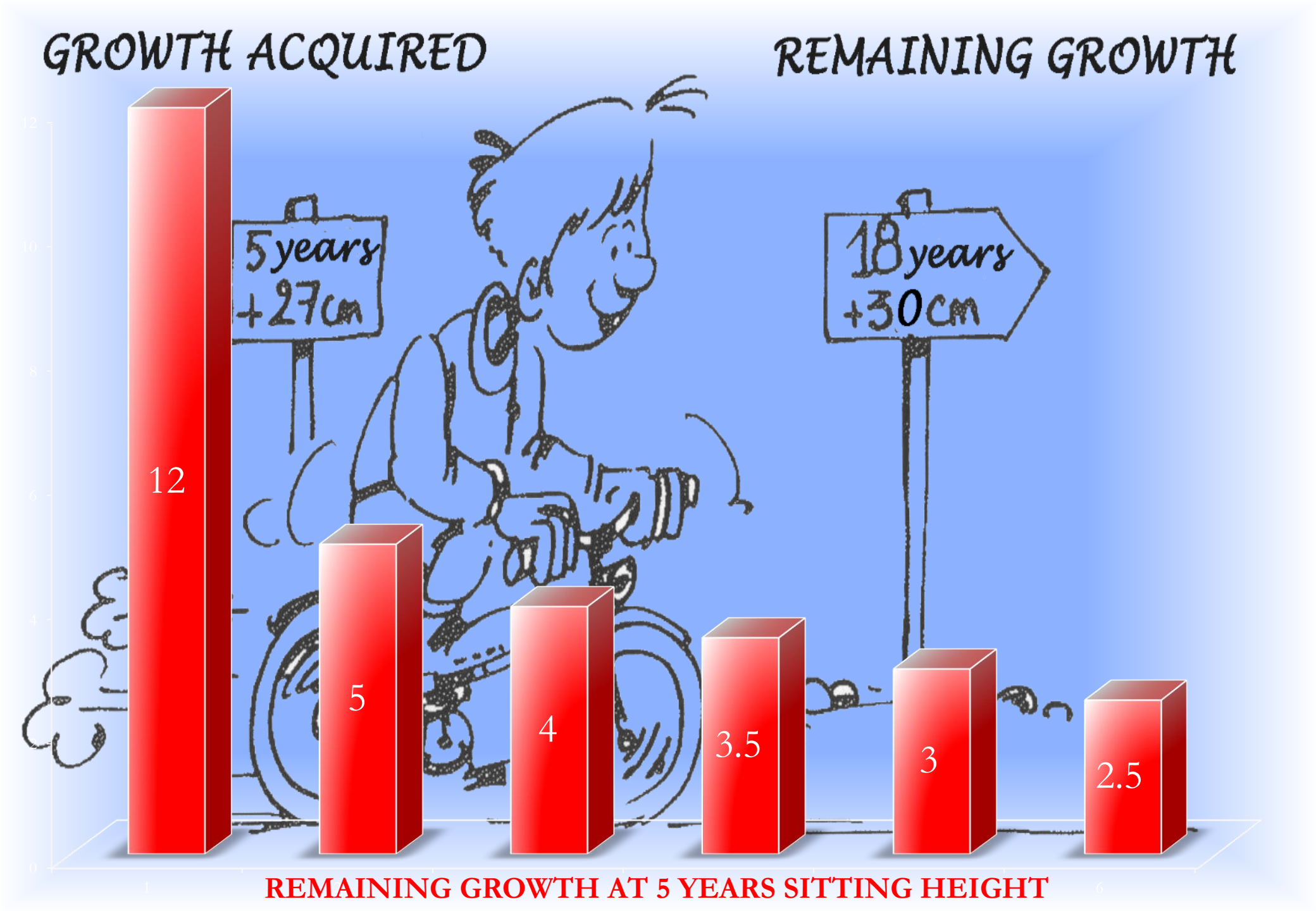
18,5 cm

13 cm

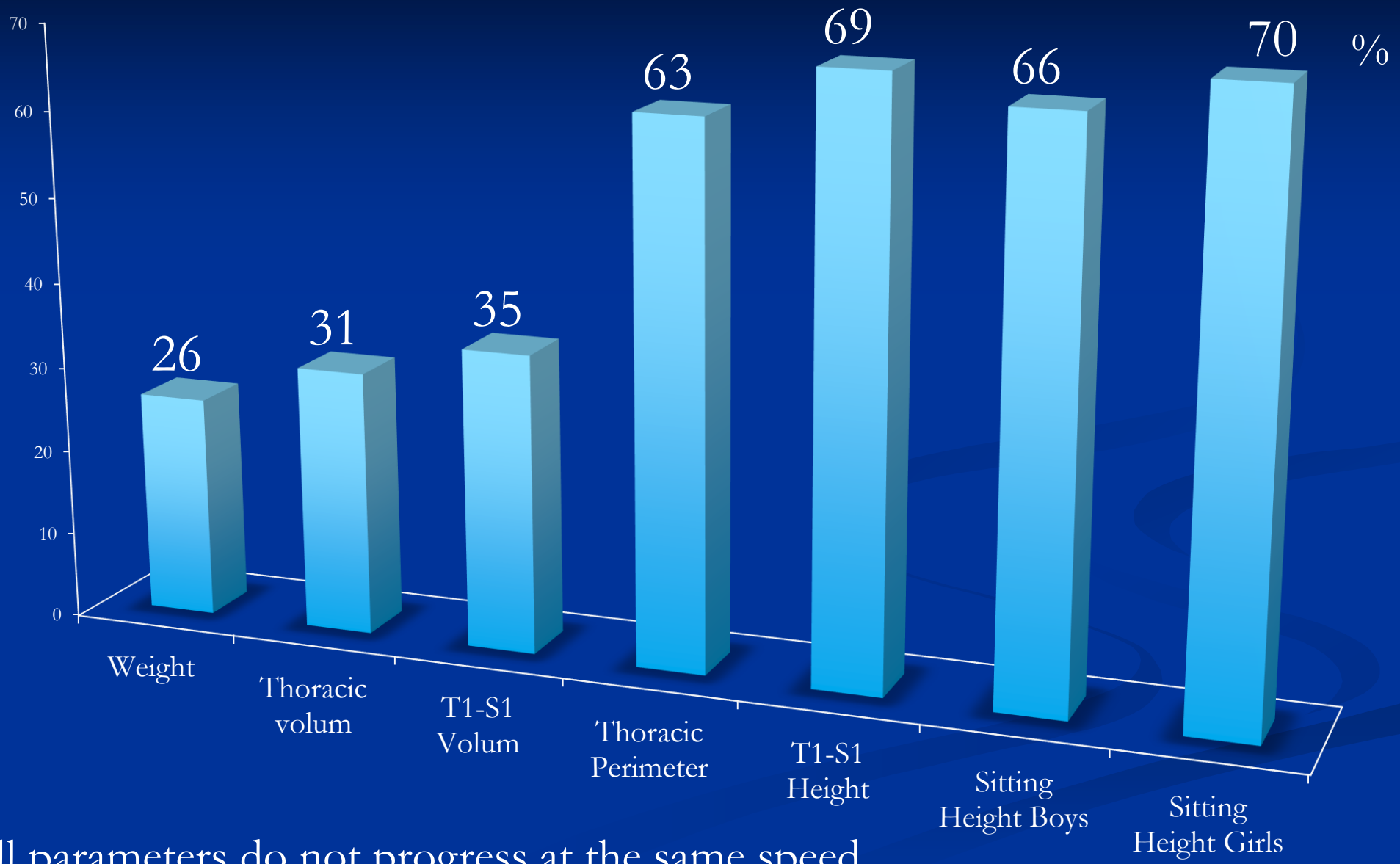
Girls sitting Height

Boys sitting Height




GROWTH ACQUIRED
REMAINING GROWTH
5 years
+27cm
18 years
+30cm
12
5
4
3.5
3
2.5
REMAINING GROWTH AT 5 YEARS SITTING HEIGHT

5 years



All parameters do not progress at the same speed

WEIGHT : an excellent parameter

Many chidren are hypotrophics !

Birth: 3.5 Kg

5 years: 20 Kg

10 years: 30 Kg

After 1 year, the annual gain is 2.5 Kg / year…up to puberty

ANNUAL GROWTH VELOCITY WEIGHT

Puberty : weight > 40 Kg

Thorax is the heart of the problem

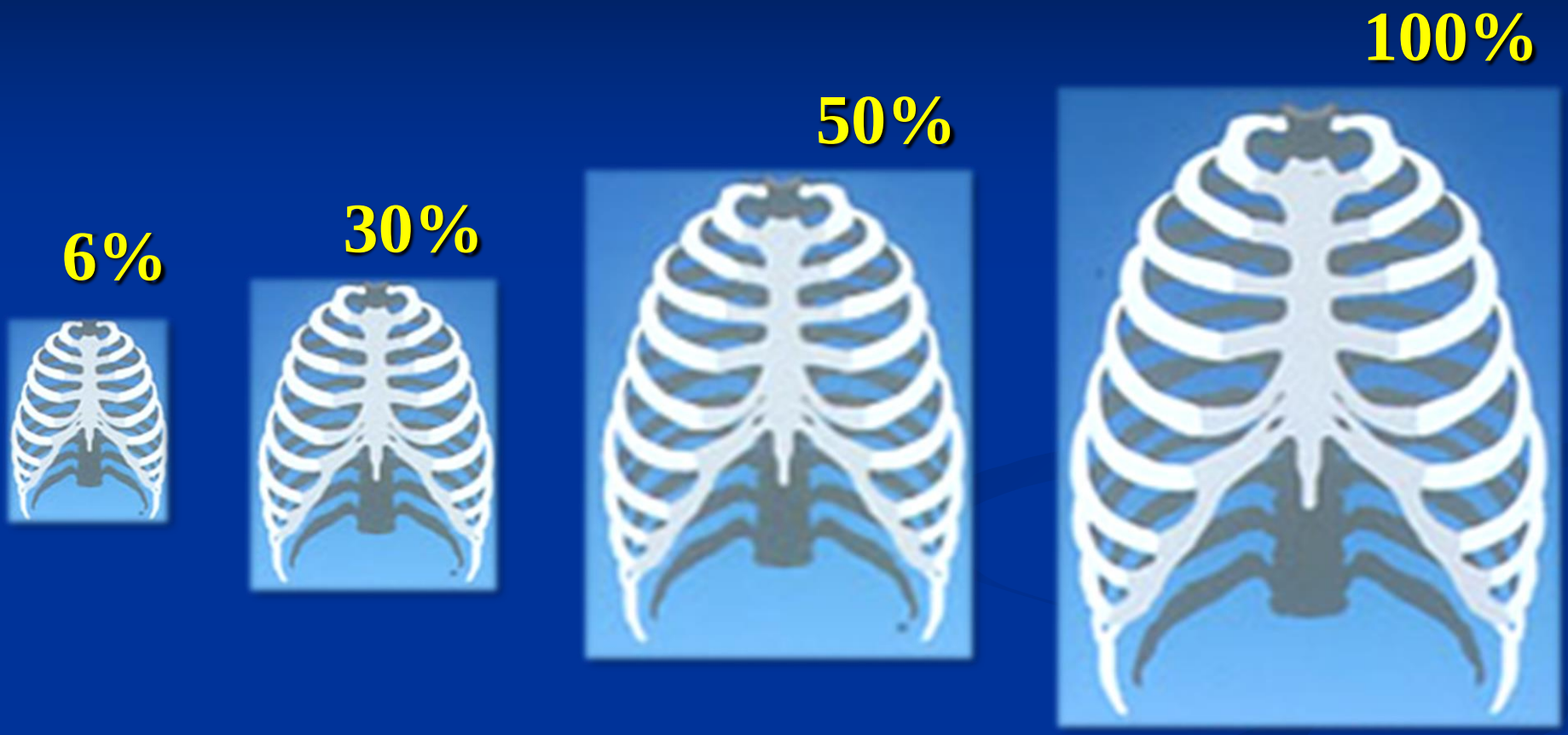
Deformities change the shape of the thorax and reduce its normal mobility.

The rib-vertebral-lung complex should be considered as a whole,
it is an elastic structural model,

scoliosis it becomes rigid preventing from normal development lungs.

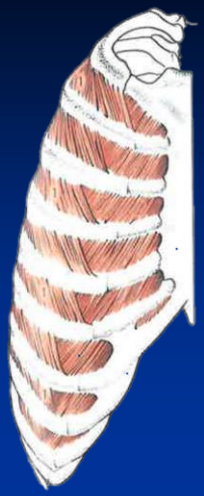
VOLUMETRIC GROWTH

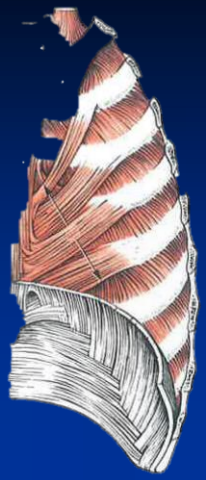
The thorax: the fourth dimension of the spine

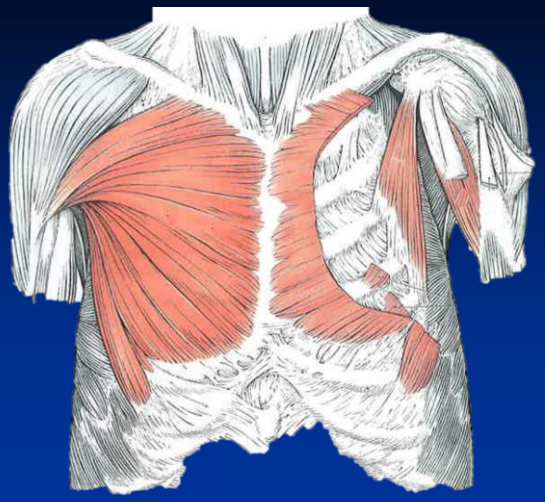


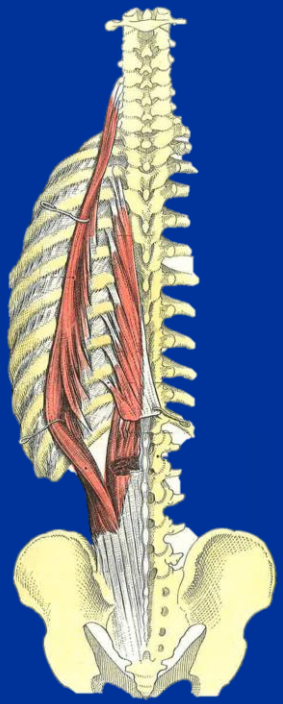
The growing spine, Springer Velarg 1990

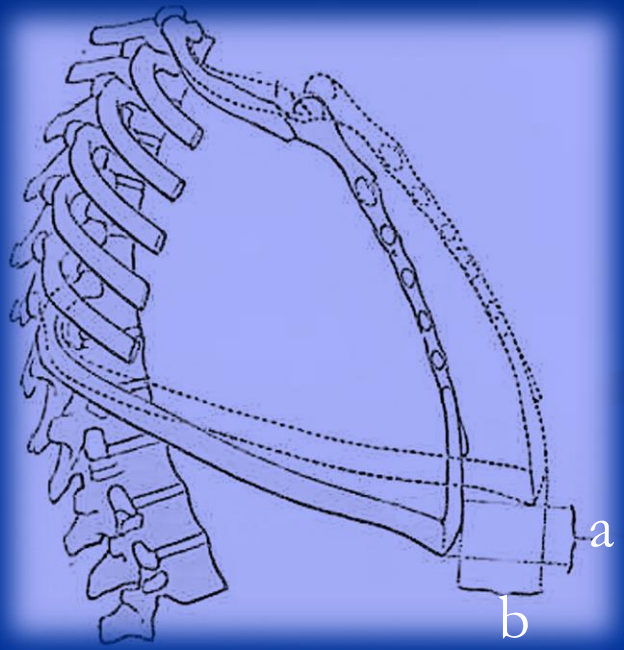
Physiotherapy

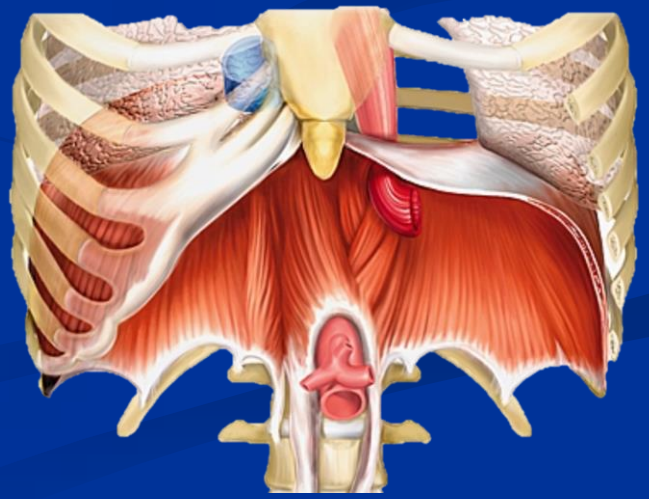








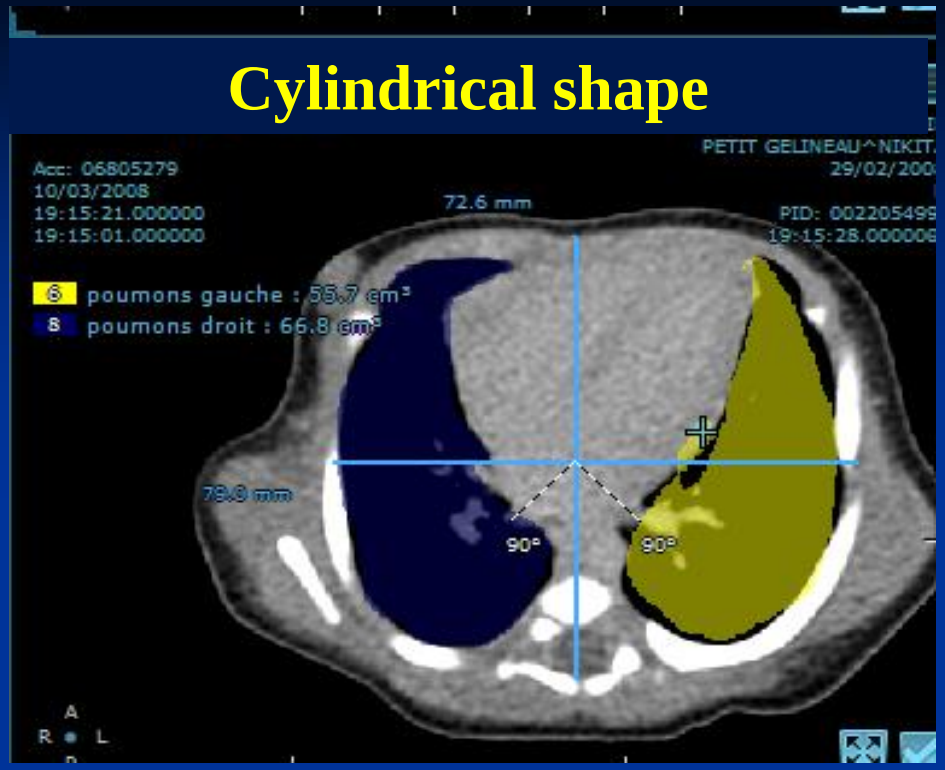




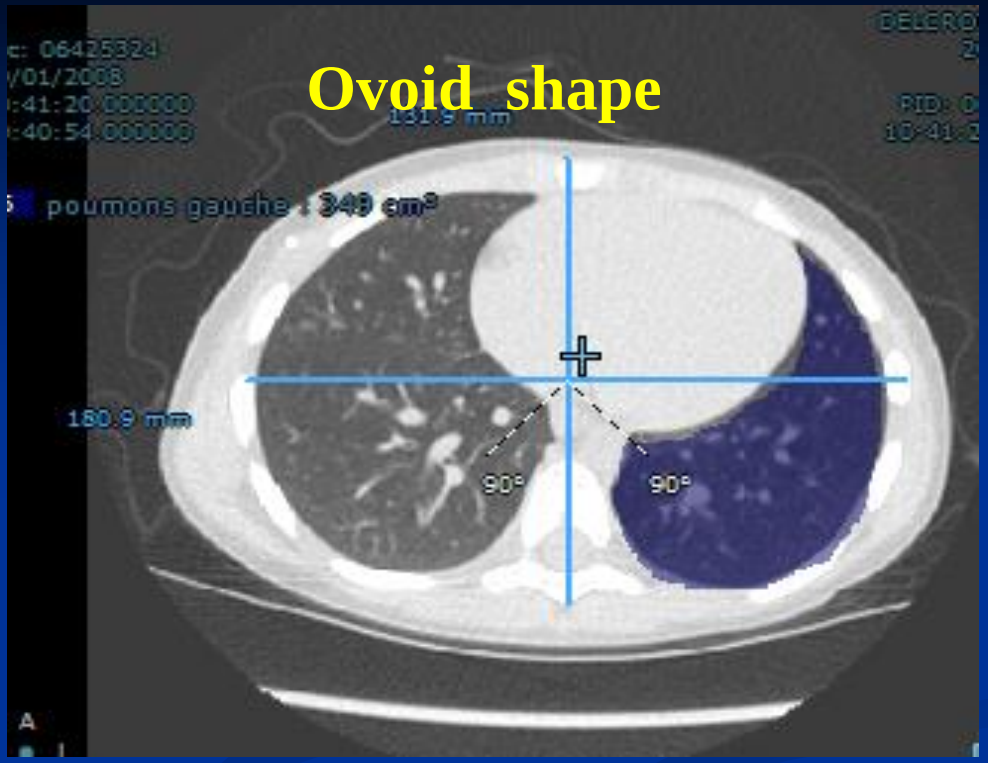
20 muscles

10 insertions by rib

Cylindrical shape



Ovoid shape



Birth

AP : 70 mm
FL : 80 mm
Volume Right 70 cm3
Volume Left 60 cm3

5 years

AP : 130 mm
FL : 180 mm
Volume Right 400 cm3
Volume Left 350 cm3

Frontal diameter grows faster than AP Diameter

Thoracic volume X5

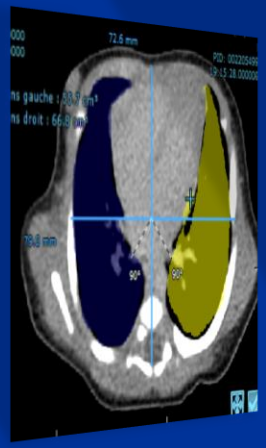
Gollogly spine 2004

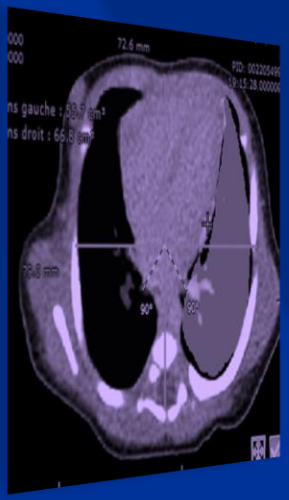
Birth

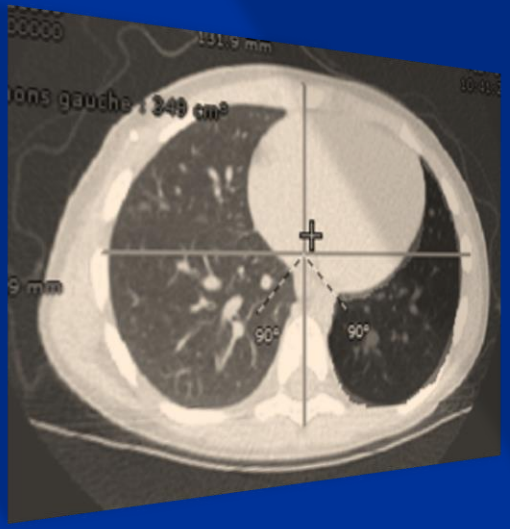
5 years

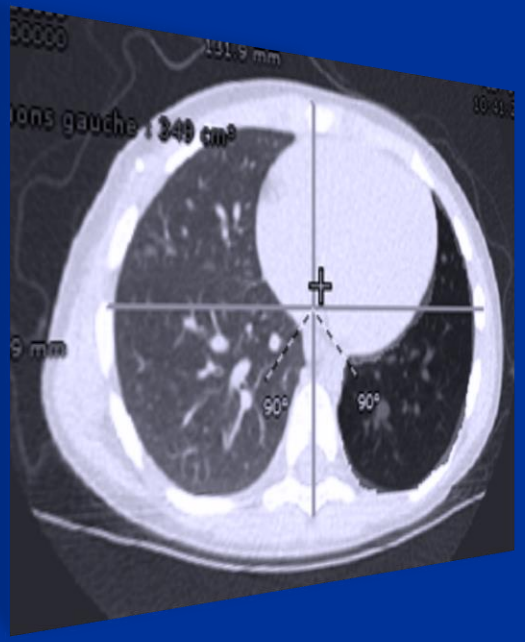
10 years

18 years









80

130

160

210 mm

70

180

220

280

mm

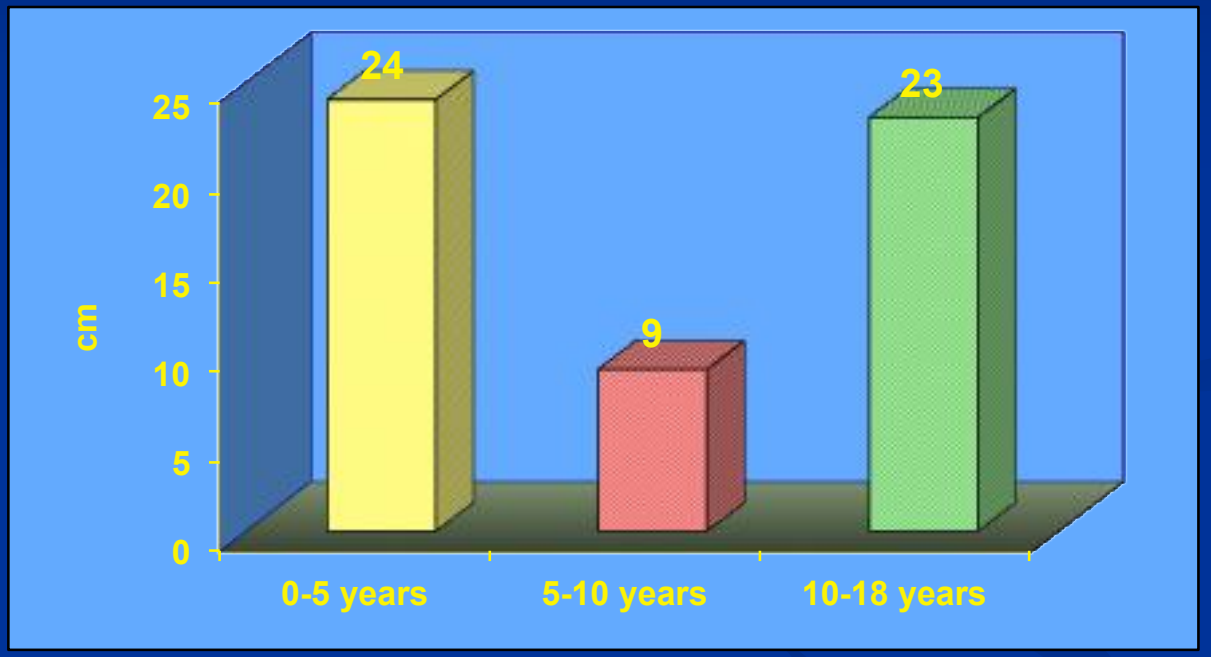
≠10

≠50

≠60

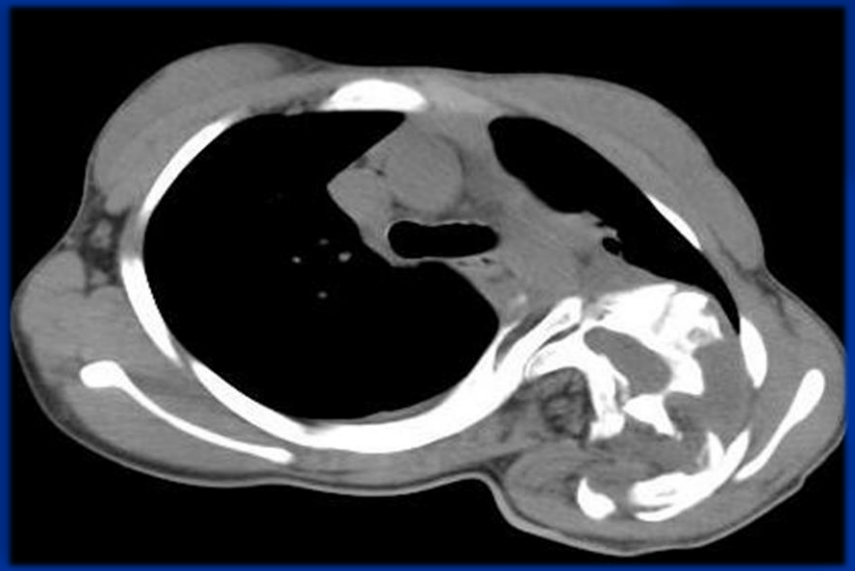
≠70

THORACIC PERIMETER GROWTH



The gain is particularly important the first 5 years (24 cm) with a slow down after 5 years and a new peak at puberty.

Infantile scoliosis, 16 Years
Deficit on the sitting height 25 cm
Weight 22 kg
Normal Length of the lower limbs



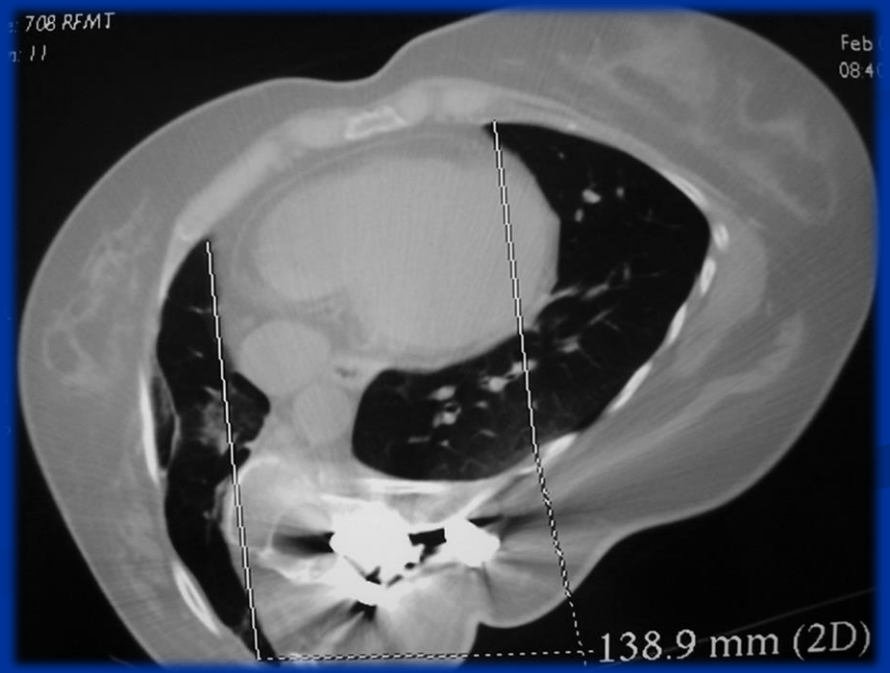

3.5mm/rot

Thoracic deformity in severe scoliosis

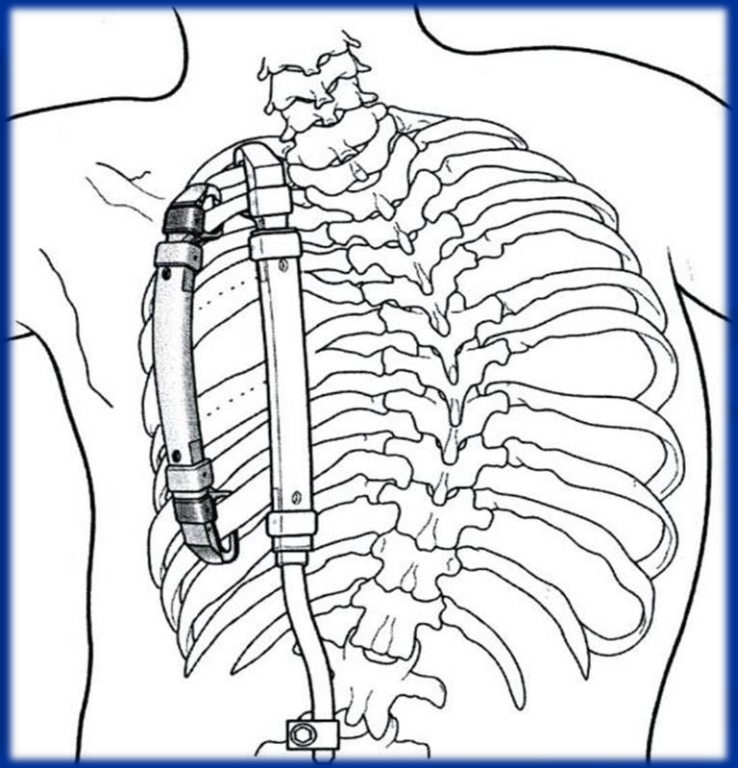
- Thoracic insufficiency Syndrome
- Congenital scoliosis and fused ribs
- Campbell et al. J Bone Joint Surg (Am) 2003
- Spinal penetration index

  Neuromuscular scoliosis Syndromes

  Dubousset et al. J Orthop Sci 2003



Influence of idiopathic scoliosis on volumetric thoracic growth and proportions?



Parasol effect

Campbell et al. J Bone Joint Surg (Am) 2003

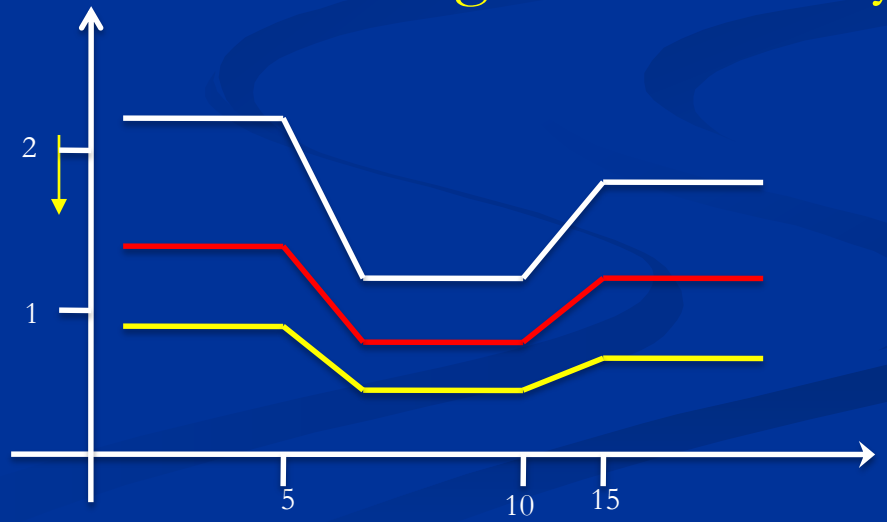
Follow the different stages of growth

- The first five years : crucial period
- After five years : a slowing down
- Puberty : thoracic peak

ANNUAL GROWTH VELOCITY T1 – L5

Birth – 5 yr	2.2 cm
5 yr – 10 yr	1.1 cm
10 yr – Puberty	1.8 cm

Curves of growth velocity



Magnetic device ?

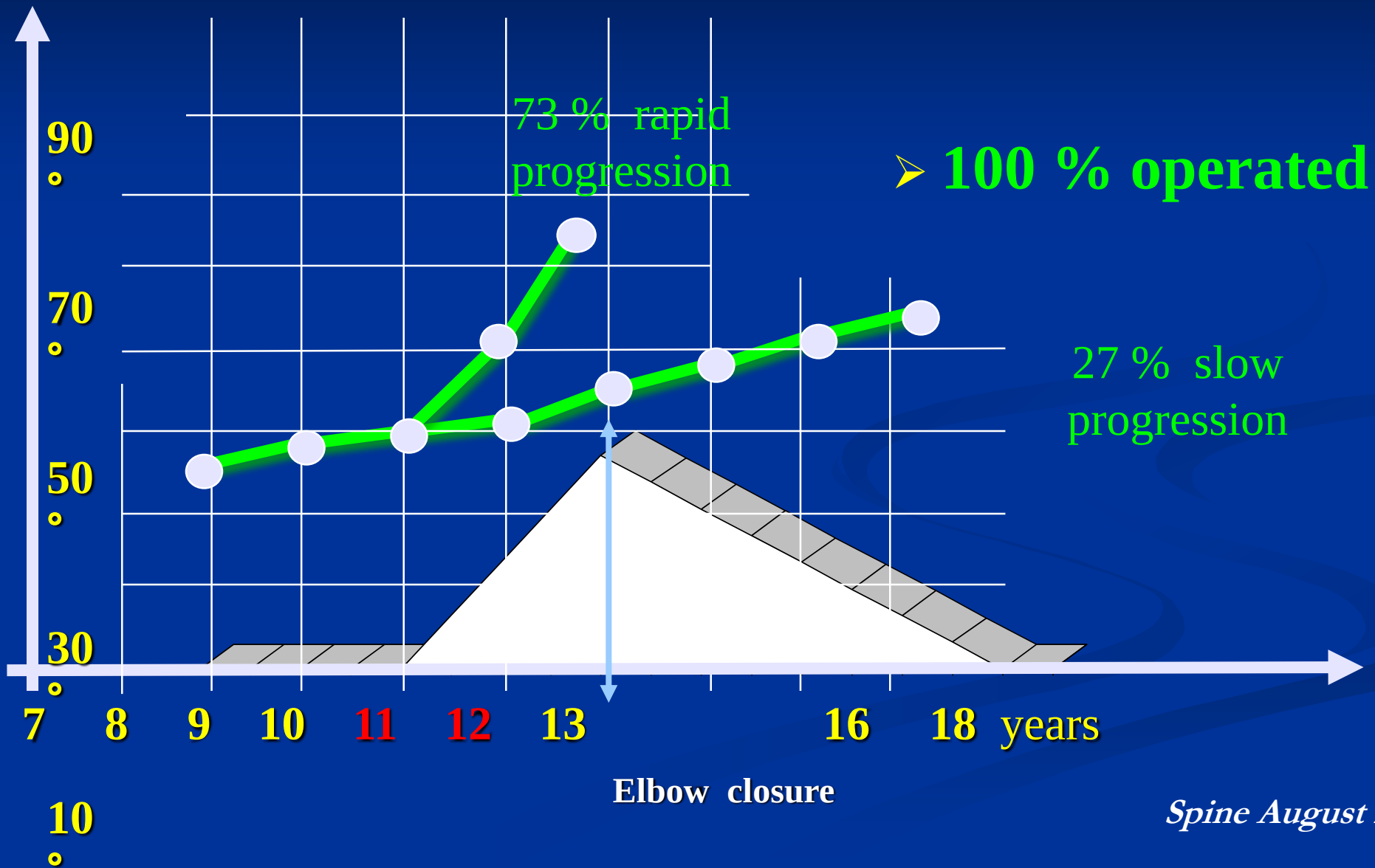
PUBERTY IS A TURNING POINT

Girls: remaining sitting height is 12 cm (14%)

Boys: remaining sitting height is 13 cm (15%)

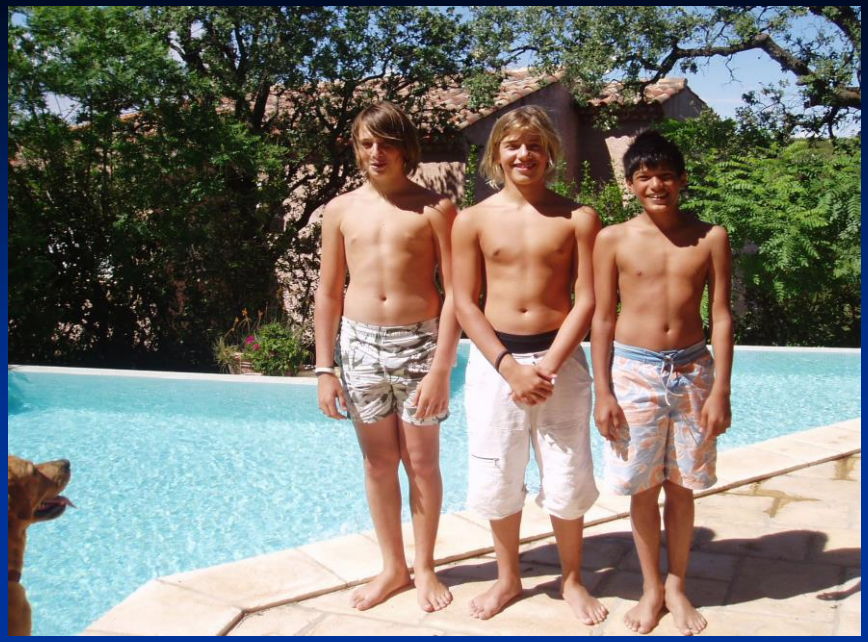
Curves > 30° at onset of puberty

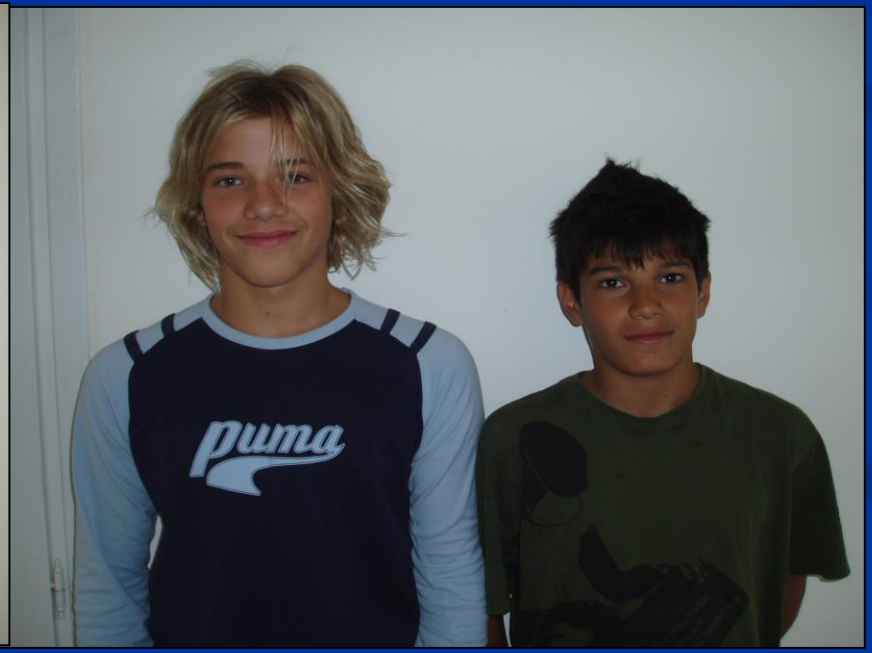
n = 40 / 205

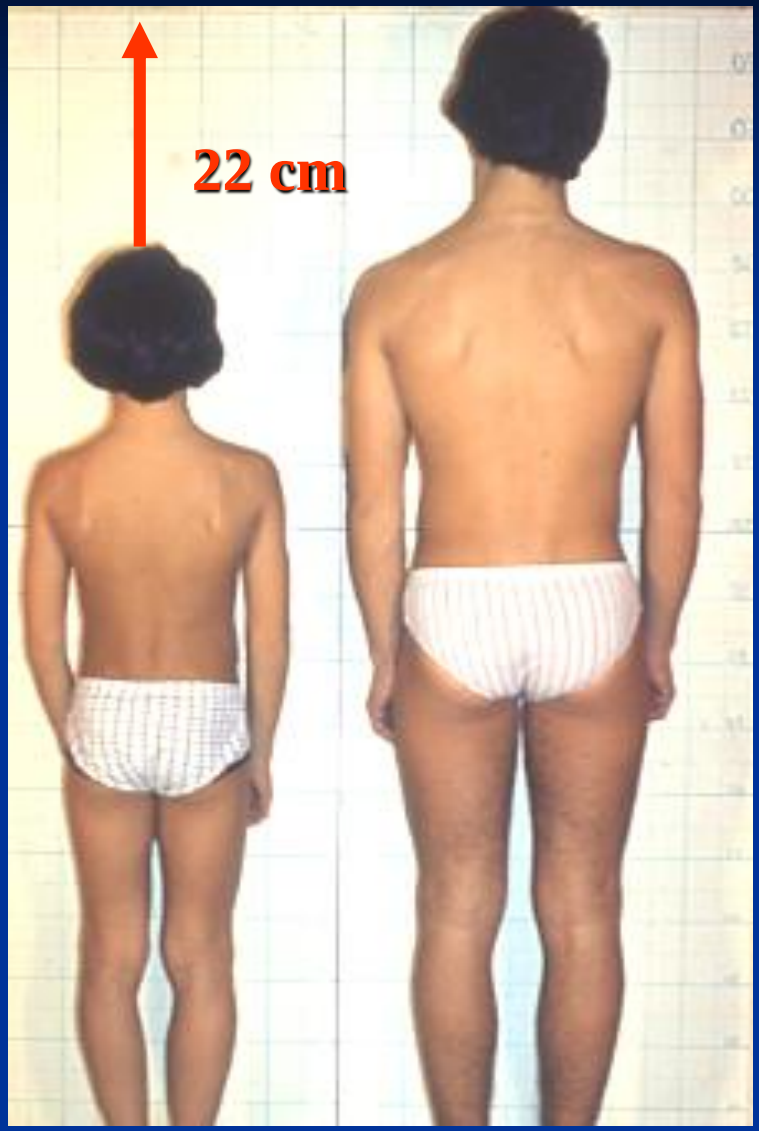


- **100 % operated**

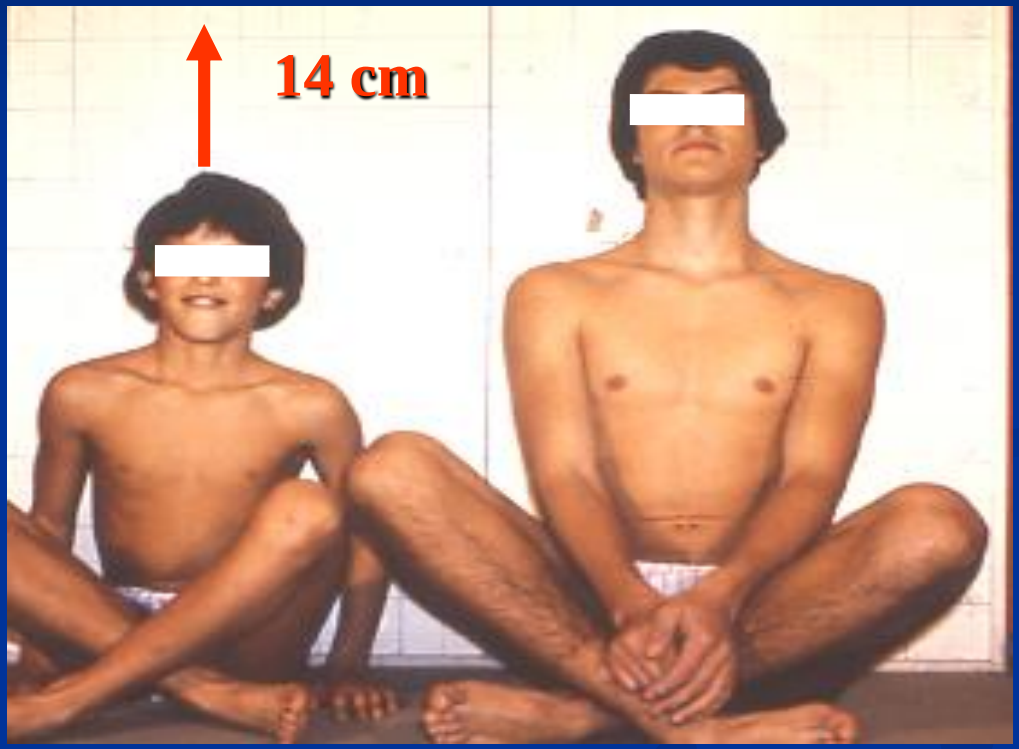
Spine August 2006




puma

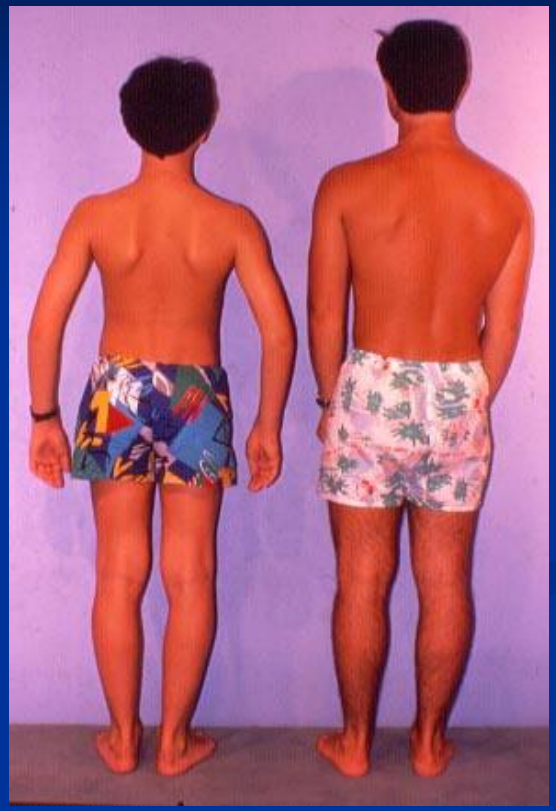


Annual gain : 5 Kg



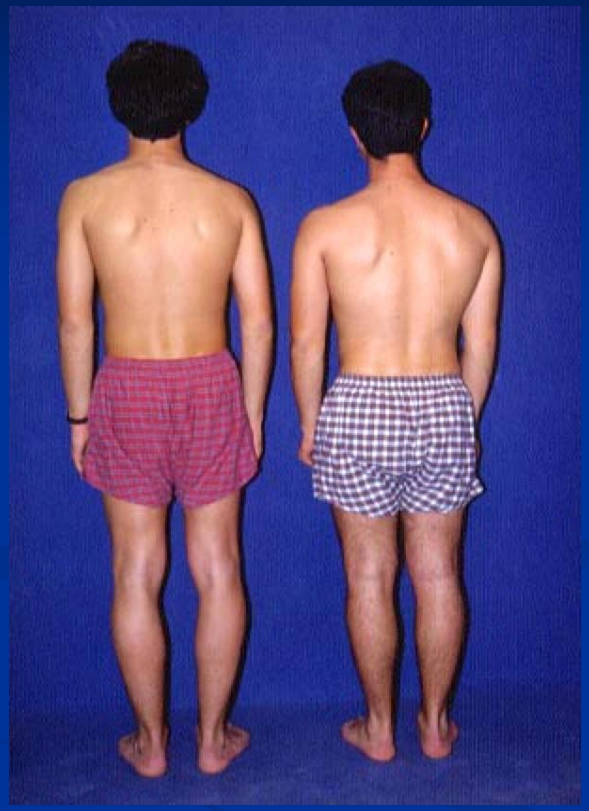
Remaining growth : 13%
Remaining weight : 40%

13 YEARS



15.6 YEARS

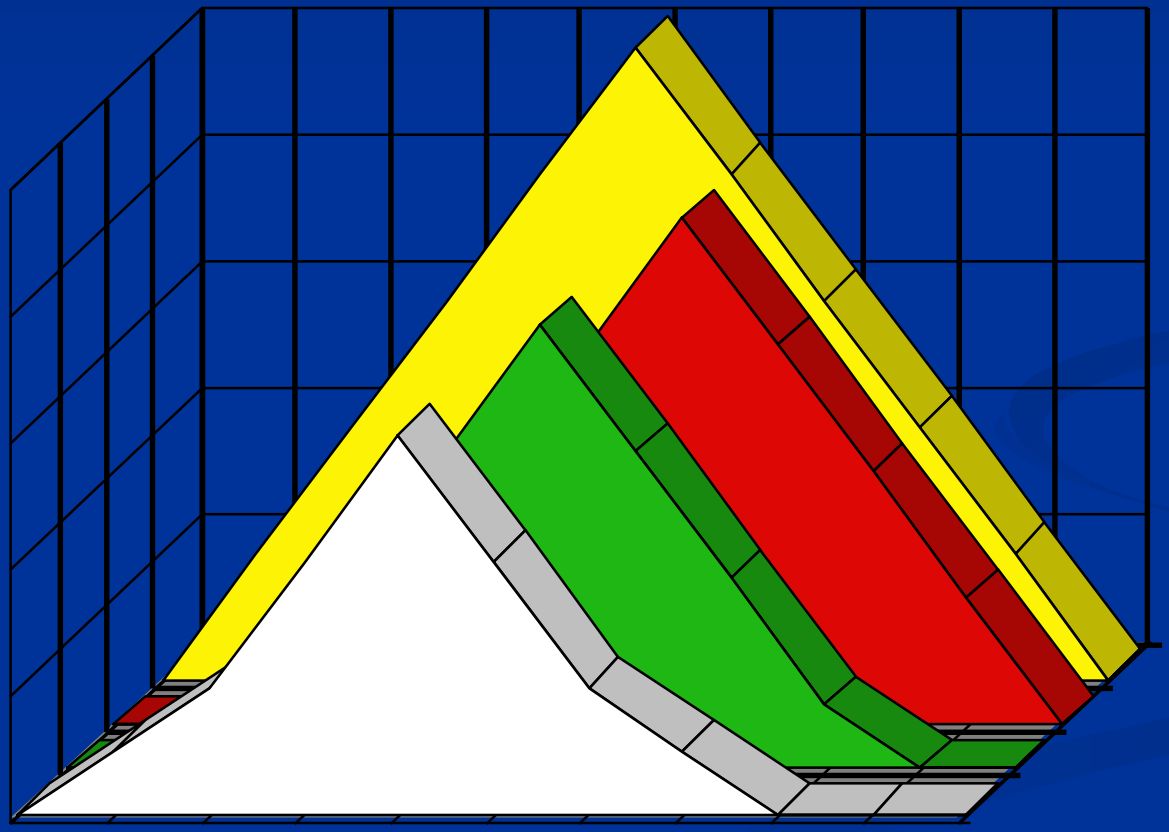
RISSER I



18 YEARS

RISSER V

3 Periods in growth / Standing height

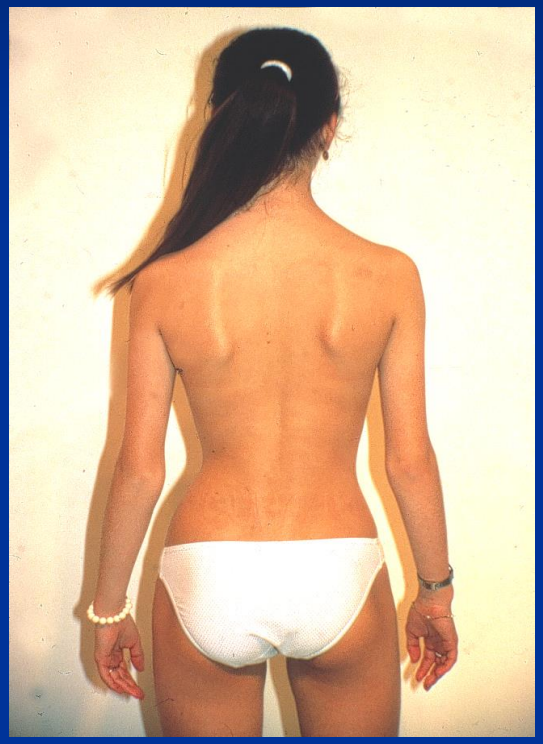


Standing height

Thorax

Sitting height

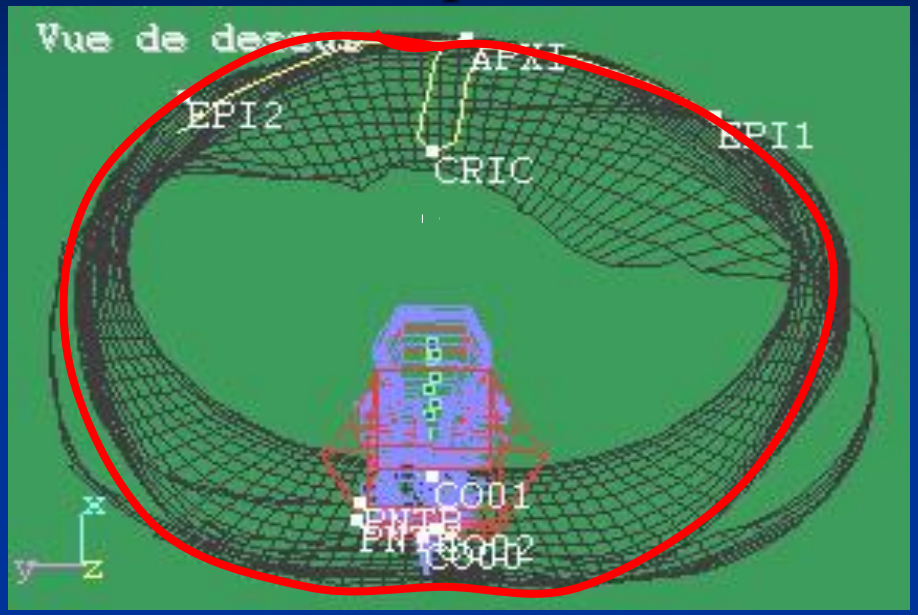
Lower limb



THE THORACIC VOLUME DOUBLES BETWEEN 10Y AND SKELETAL MATURITY

Constant relationships during growth

Thoracic perimeter

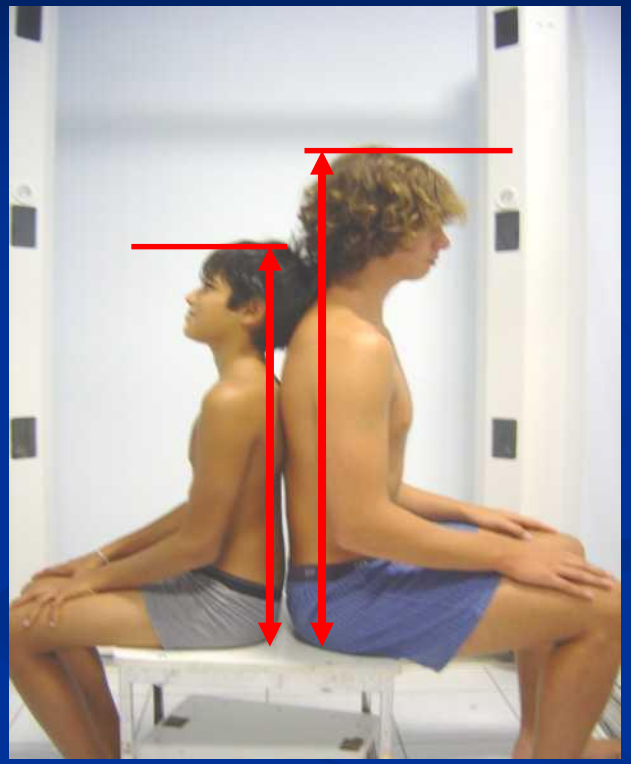


birth = 100%

5y = 90%

15y = 96%

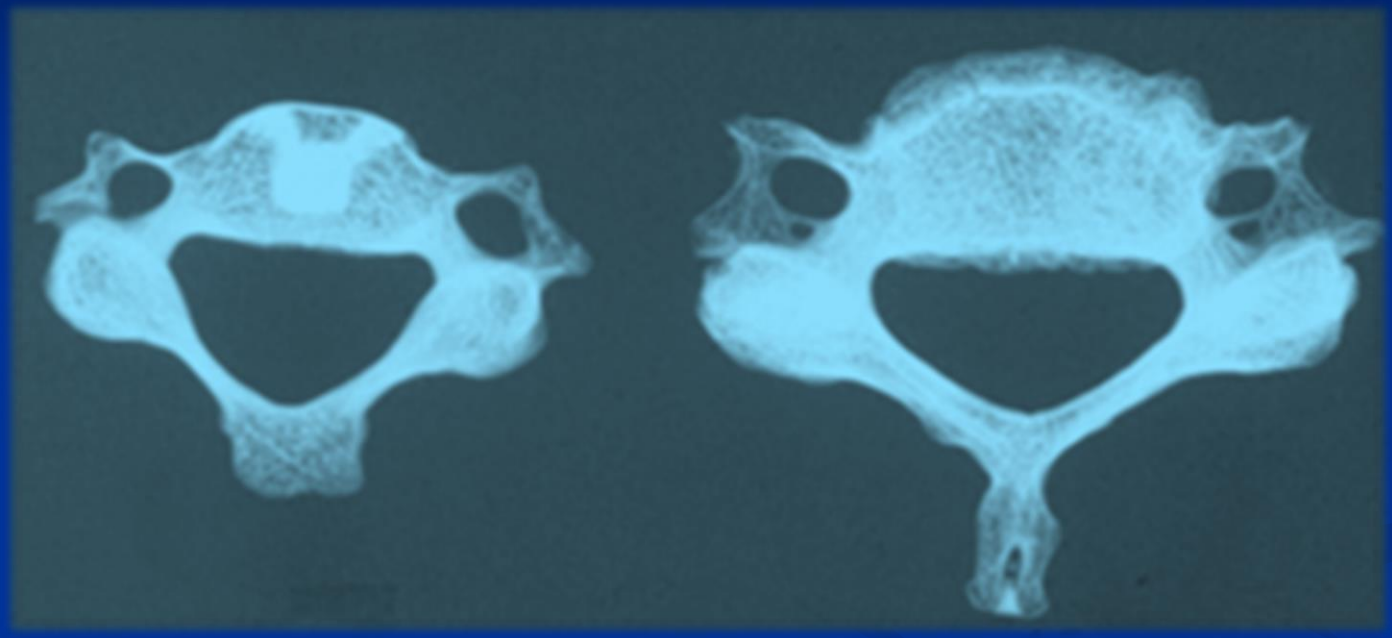
Sitting height



Risser 1

five years : remaining growth of the thorax is 70%

remaining sitting height is 35%



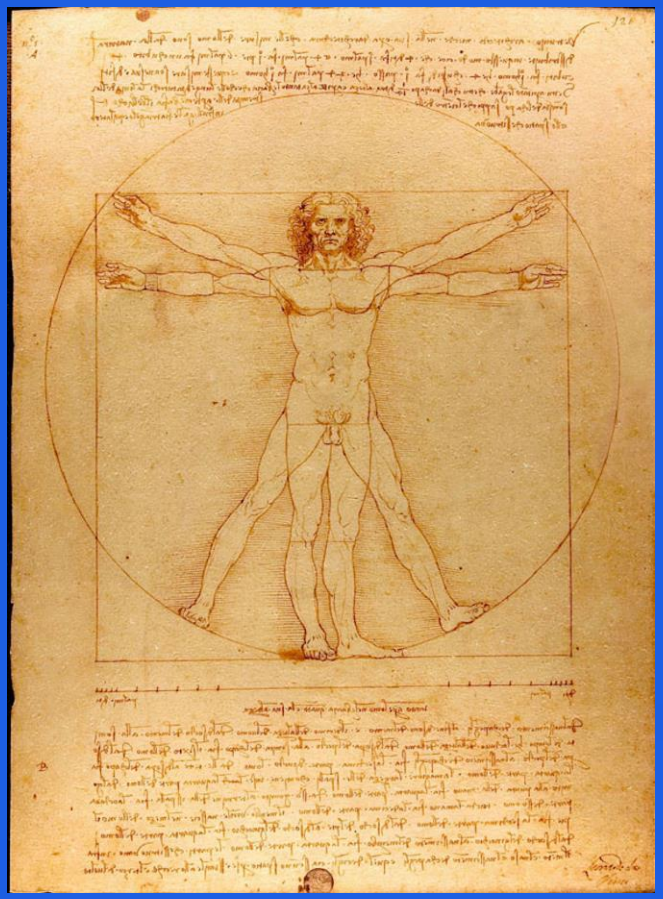
10y

15y

Arm span

Sitting height = 50%

T1- S1 = 25%

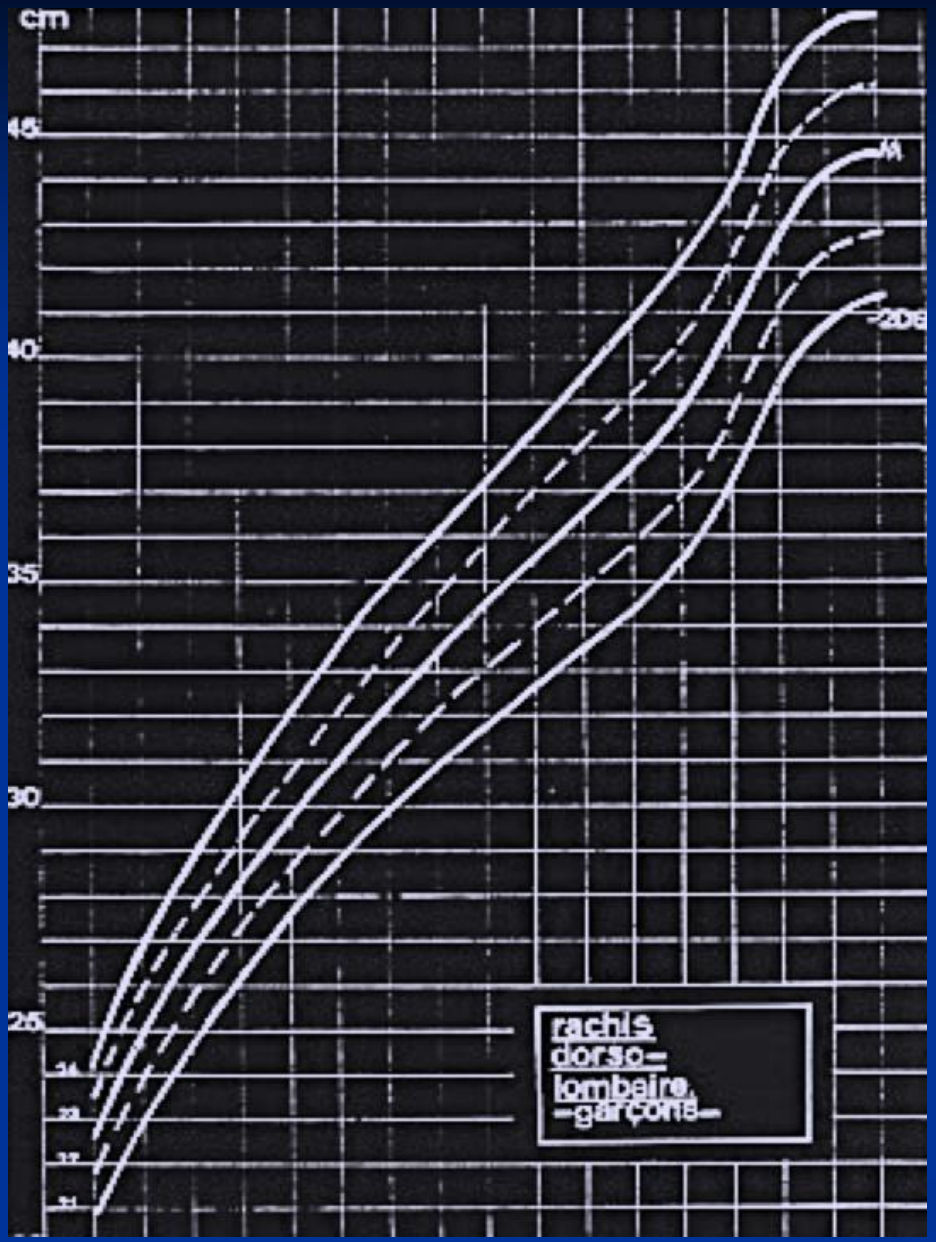


T1 – S1 a strategic segment

T1 – S1 : 50% of the sitting height

T1 – T12 : 32%

L1 – S1 : 18%



GROWTH CURVE T1 – S1

BOYS

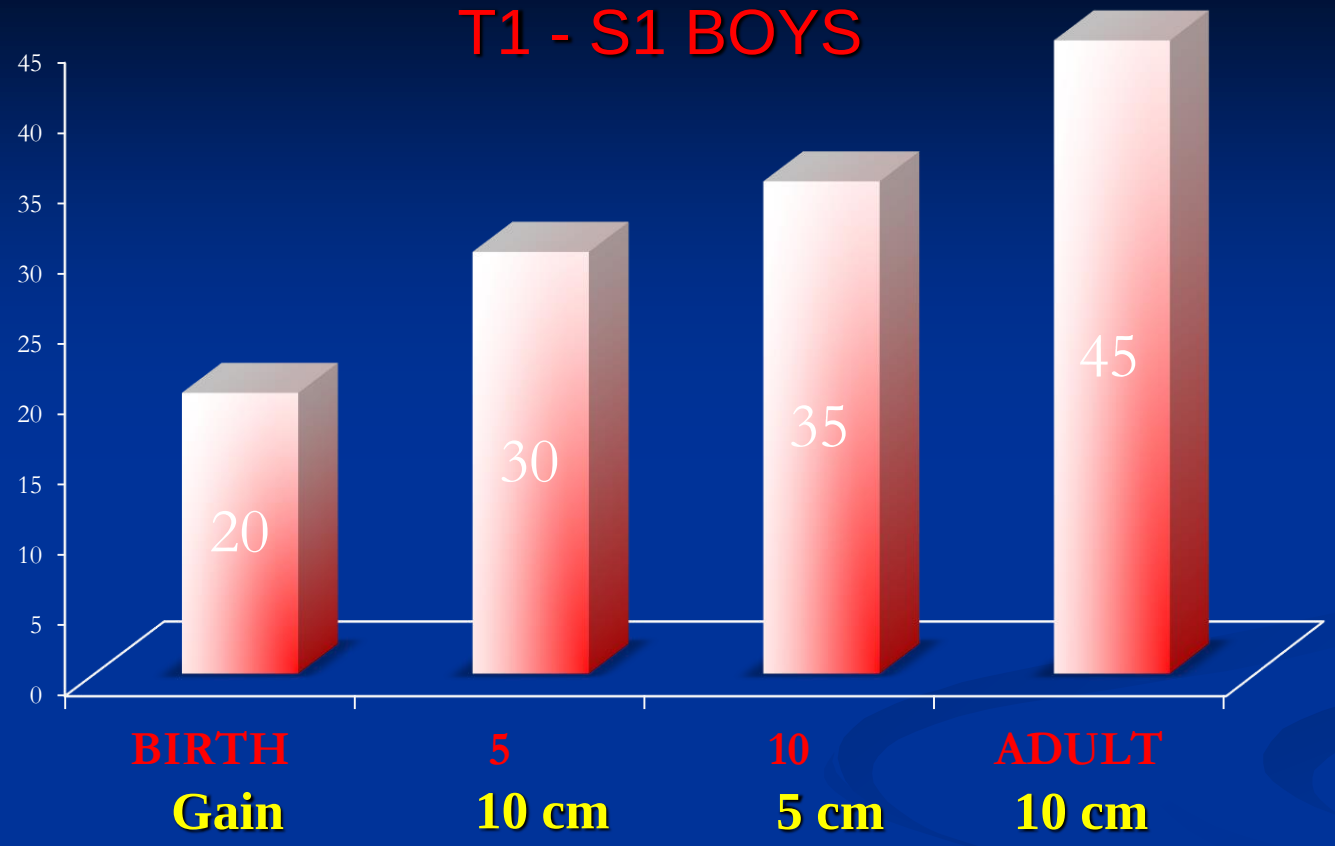
GAIN

T1 – S1 : 25 cm

T1 – T12 : 16 cm

L1 – L5 : 9 cm

From birth to skeletal maturity

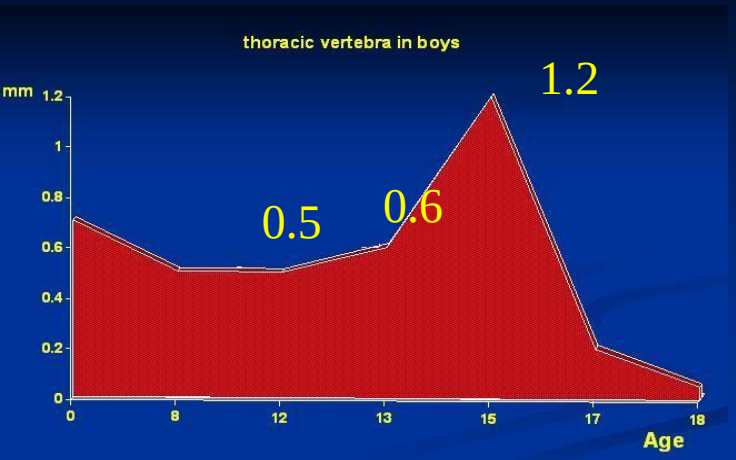


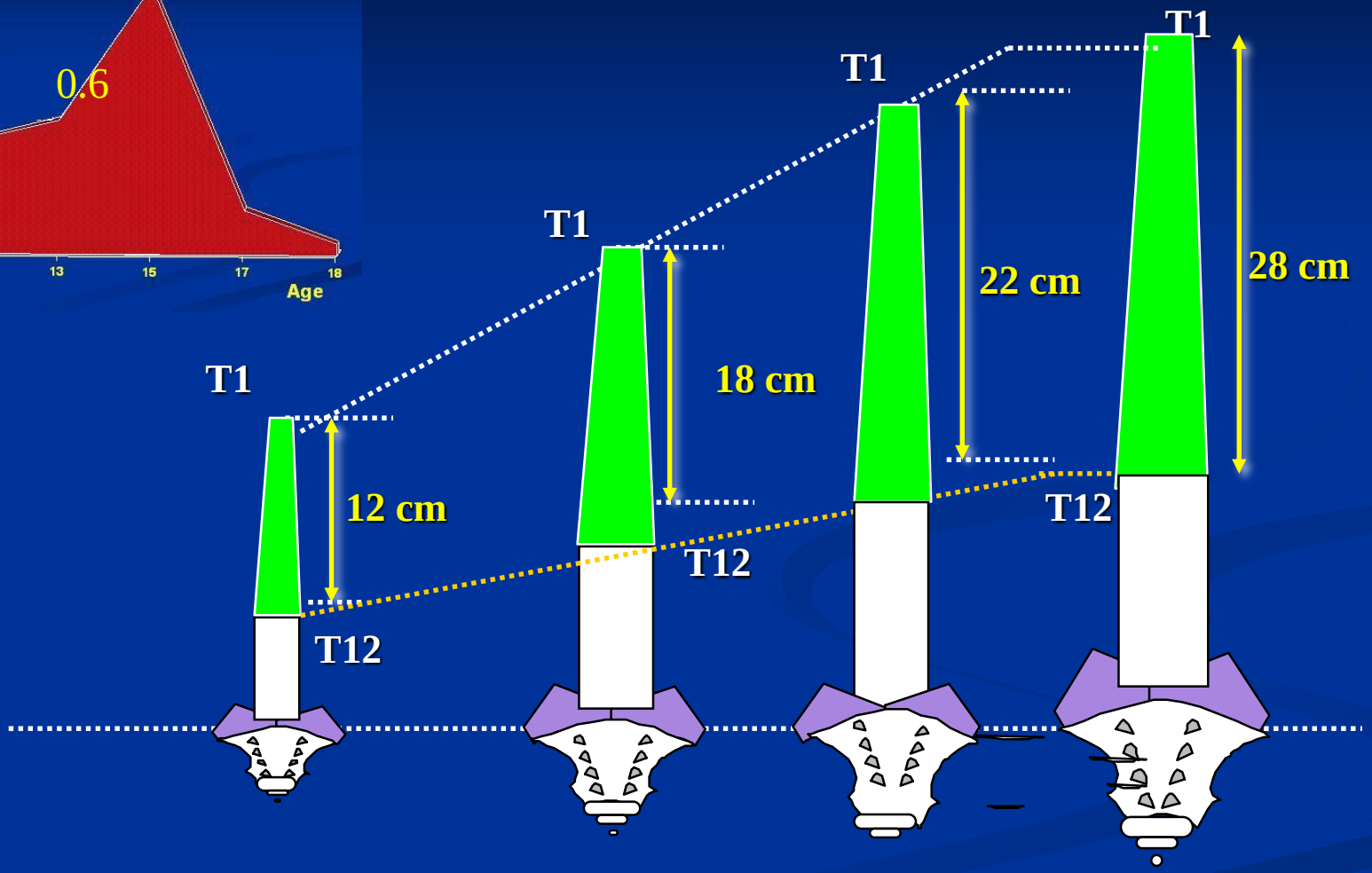
A peri-vertebral arthrodesis in the T1-S1 segment at 5 years causes

a sitting height deficit of 15 cm

T1 – T12 = 10 cm; L1 – L5 = 5 cm

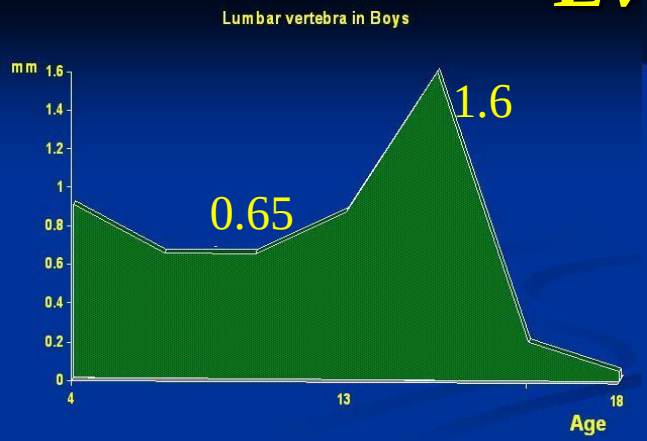
Evolution of T1-T12 Segment





The growing spine, Springer Verlag 2009

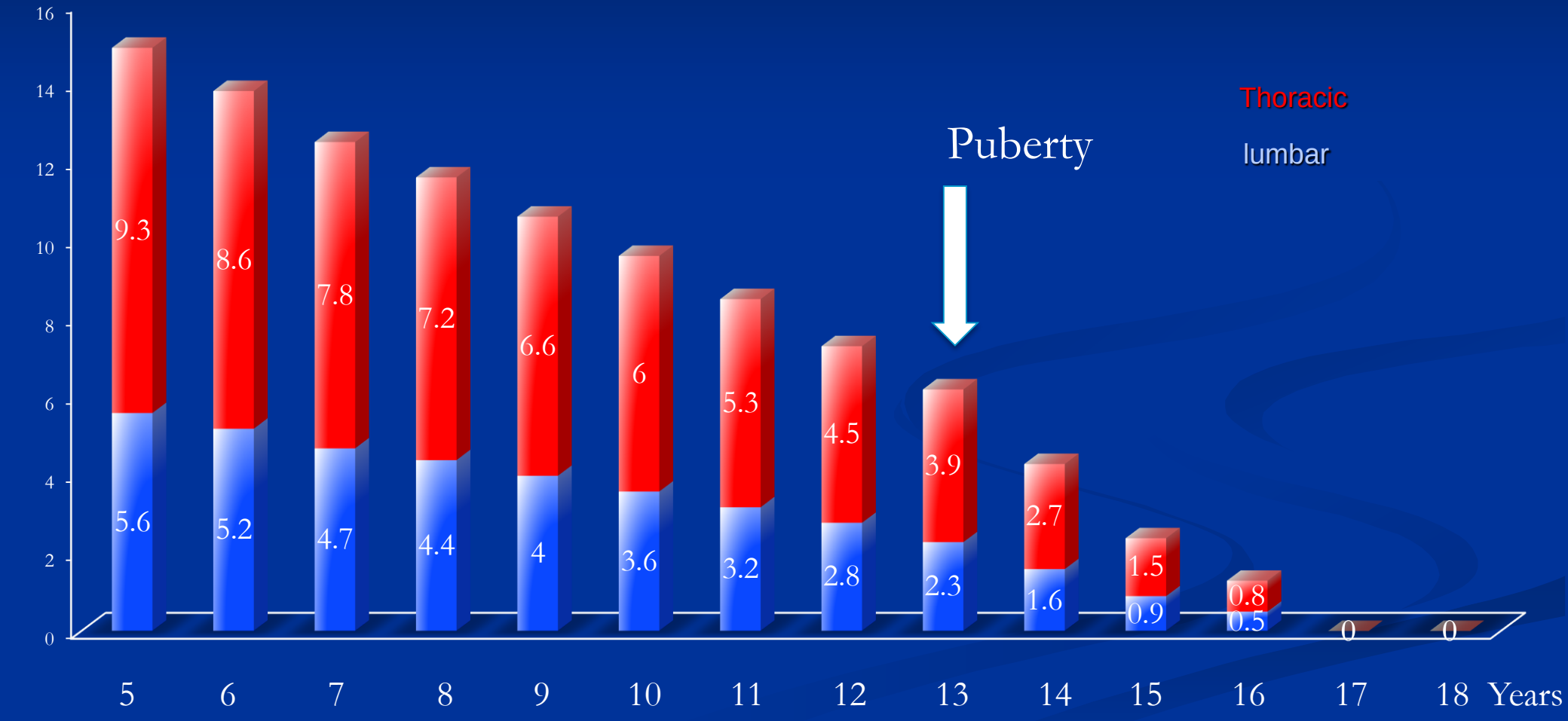
Evolution of L1-L5 Segment



Birth 5 years 10 years Adult

The growing spine, Springer Verlag 2009

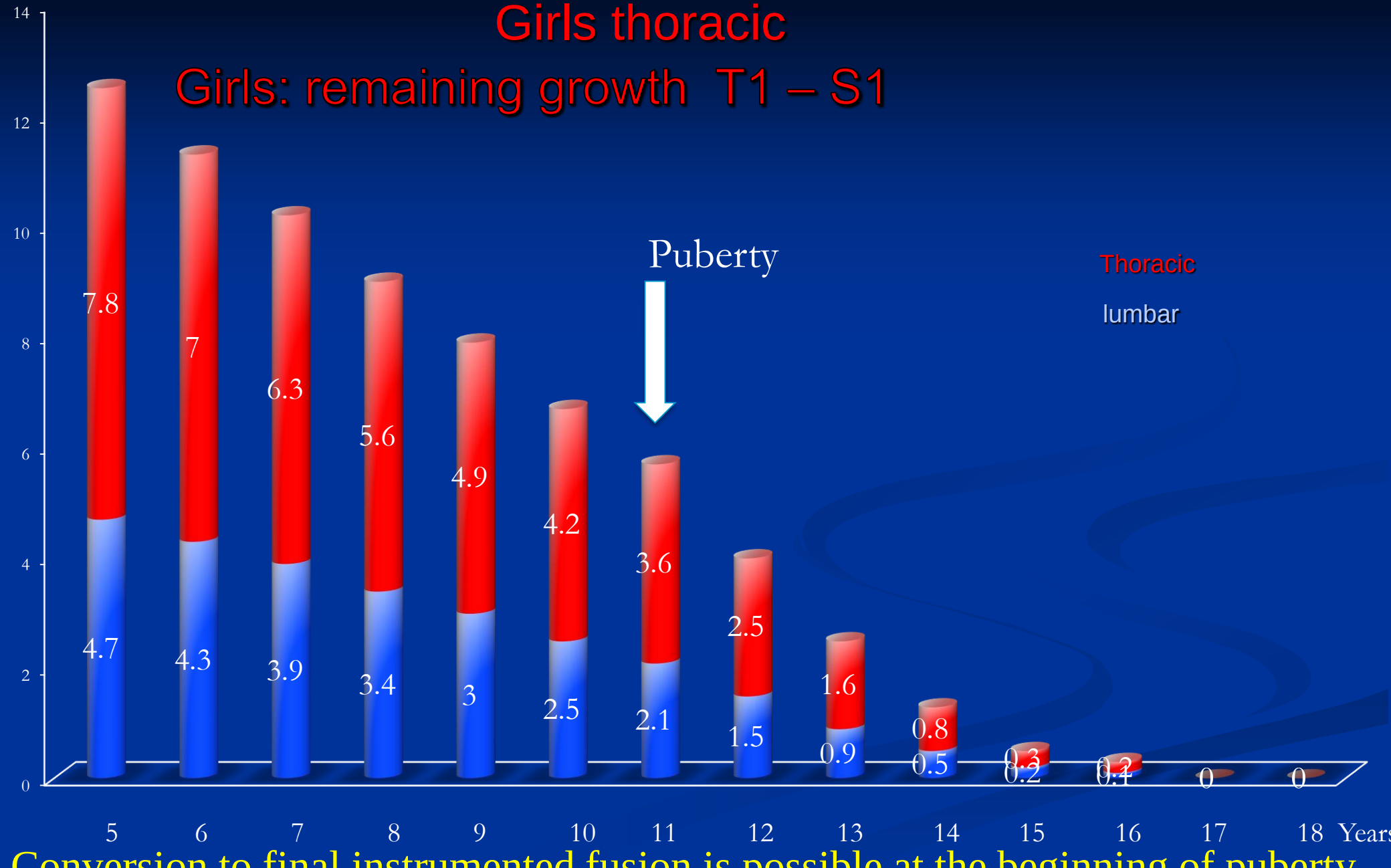
Boys: remaining growth T1 – S1



Conversion to final instrumented fusion is possible at the beginning of puberty

Girls thoracic

Girls: remaining growth T1 – S1

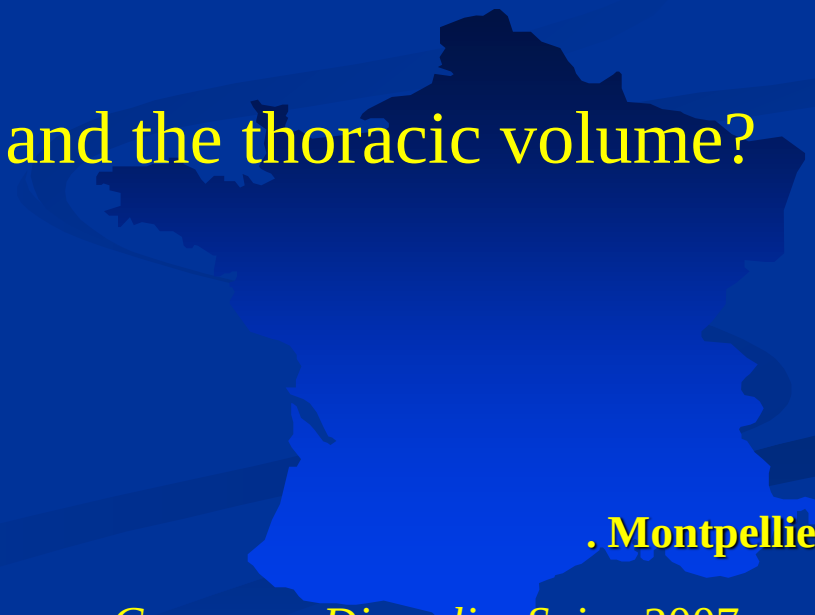


Conversion to final instrumented fusion is possible at the beginning of puberty

Avoid early arthrodesis

POSTERIOR ARTHRODESIS OF THE THORACIC SPINE IN PRE-PUBERTAL RABBITS: EFFECTS ON THORACIC GROWTH

Does a posterior arthrodesis influence the thoracic growth patterns, the length of the sternum and the thoracic volume?



. Montpellier

Canavese, Dimeglio Spine 2007.

MATERIAL AND METHODS

•12 female White New Zeland pre pubertal rabbits 9 weeks old

•Implant of 2 “C” shaped titanium bars placed beside the spinous processes
•of the first 6 thoracic vertebrae

• 3 CT SCAN: day 10 (T1)
day 55 (T2)
day 139 (T3)

• Myran Pro® program : Thoracic Diameters
Lung Volume
Vertebral Body Size

Canavese, Dimeglio Spine 2007.

RESULTS

Vertebral Body Size

- In the complete fusion group:
- decrease in the length of the vertebral body.
- reduction of thoracic kyphosis due to Crankshaft Phenomenon
- Decrease the growth of lungs

Canavese, Dimeglio Spine July 2007.

Metha spine 2006

Growing rabbit model : a unilateral deformity of the spine or the thorax induces both scoliosis and thoracic cage deformity with asymetric lung volumes.

Karol JBJS A. 2008

Early arthrodesis reduces AP diameter, shortens T1-T12 index.

Fusion causes respiratory insufficiency.

Optimum length T1-T12 : 22 cm

Respiratory insufficiency worsens after skeletal maturity

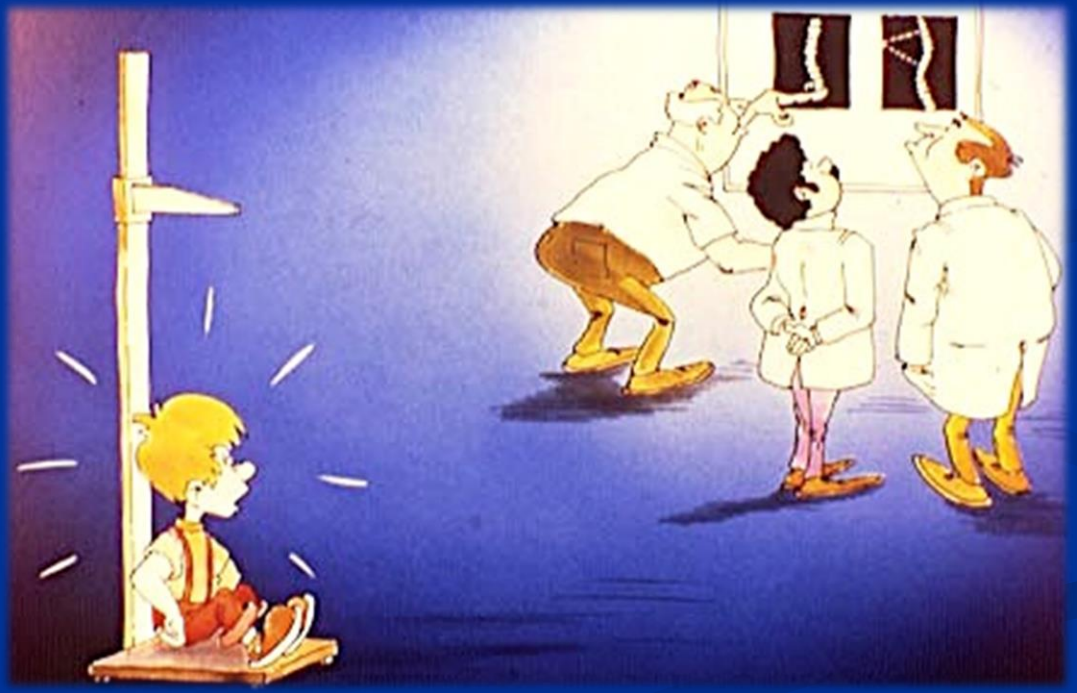
The growing spine tomorow

- We must go to the ideal by taking in consideration the reality
- We have to believe in the magic of the impossible
- Repetitive surgery leads to fibrosis
- Magnetic rod is the future
- The maximum is not the optimum
- The grey matter is more important than the material

E. O. S is not an orthopedic disease. It's a Pediatric disease !

- Annual trunk velocity ?
- Annual weight velocity ?
- Respiratory status ?

Don't stick on X Ray



More attention to vital capacity and spinal penetration index

Distance T1 – T 12

thoracic perimeter

28

22

18

10

15 y

10 y

5 y

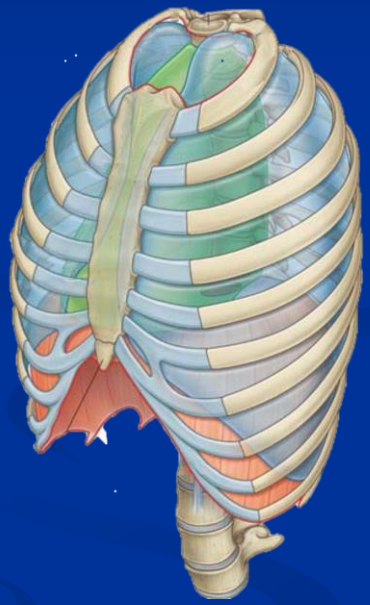
N born

32

56

66

89



height T1 – T 12 = thoracic frontal diameter

Thorax : volumetric expression of the growing spine
More growth on the horizontal plan

We can overcome the issue of EOS by the summation of ours intelligences

alaindimeglio@wanadoo.fr

We can overcome the issue of EOS by the summation of ours intelligenc

alaindimeglio@wanadoo.fr

Influence of idiopathic scoliosis on three-dimensional thoracic growth

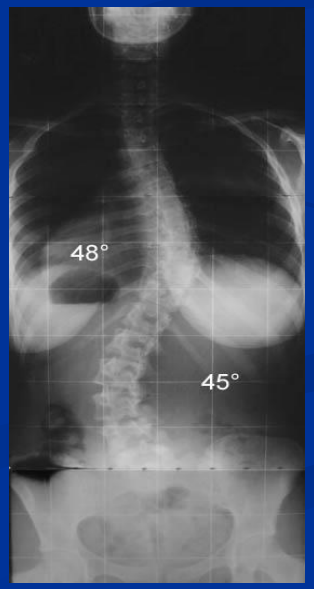
A. Diméglio
Y.P. Charles
M. Marcoul
J.-F. Bourgin
A. Marcoul
M.-C. Bozonnat

Service d' Orthopédie Pédiatrique

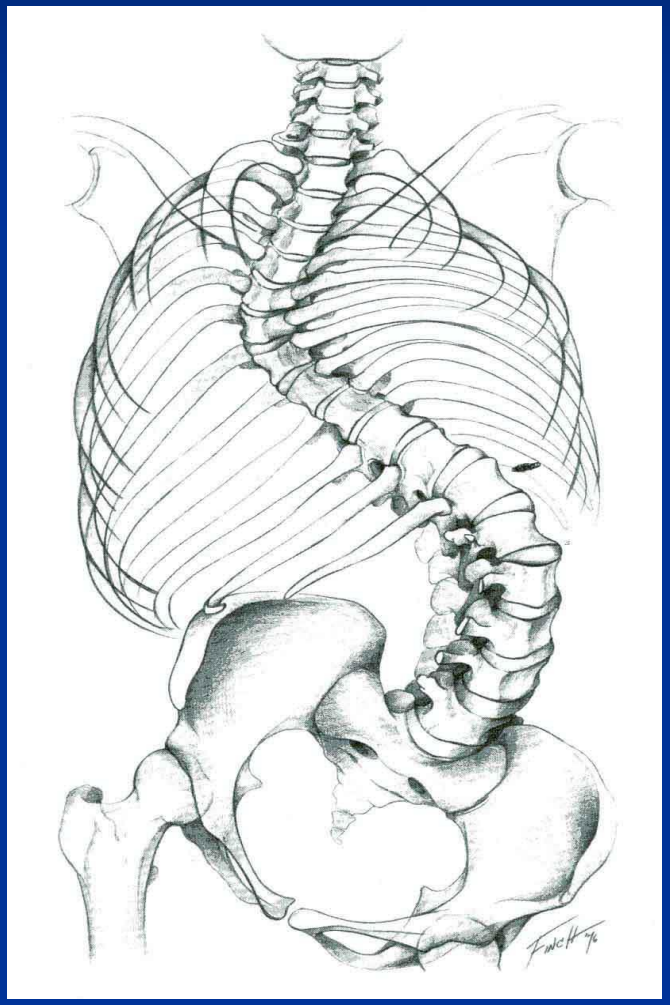
Centre Hospitalier Universitaire Montpellier •

Scoliosis - 3D spinal deformity

- Frontal plane
- Sagittal balance
- Vertebral rotation



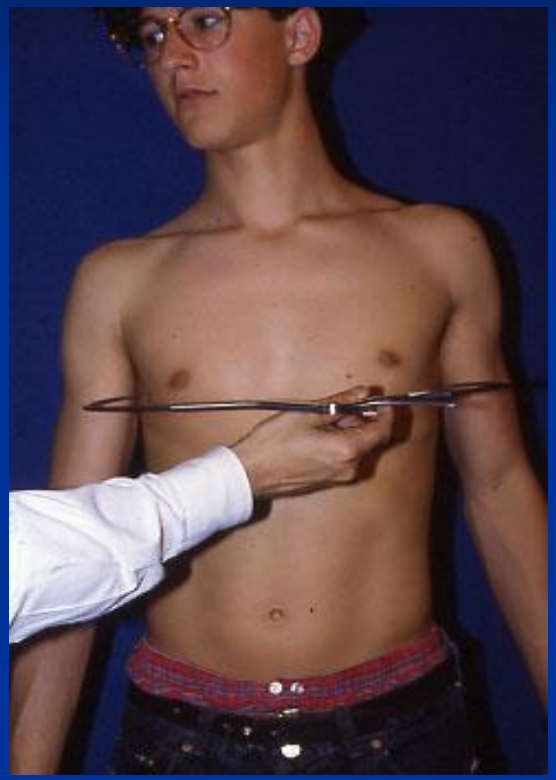
Thorax - fourth dimension of scoliosis



- Brace concepts
- Surgical strategies

Thoracic growth

Assessment of thoracic growth



Transversal diameter

=

30% sitting height

AP diameter

=

21% sitting height

Thoracic perimeter

=

95% sitting height

Thoracic deformity in severe scoliosis

- Thoracic insufficiency Syndrome

  Congenital scoliosis and fused ribs

  Campbell et al.

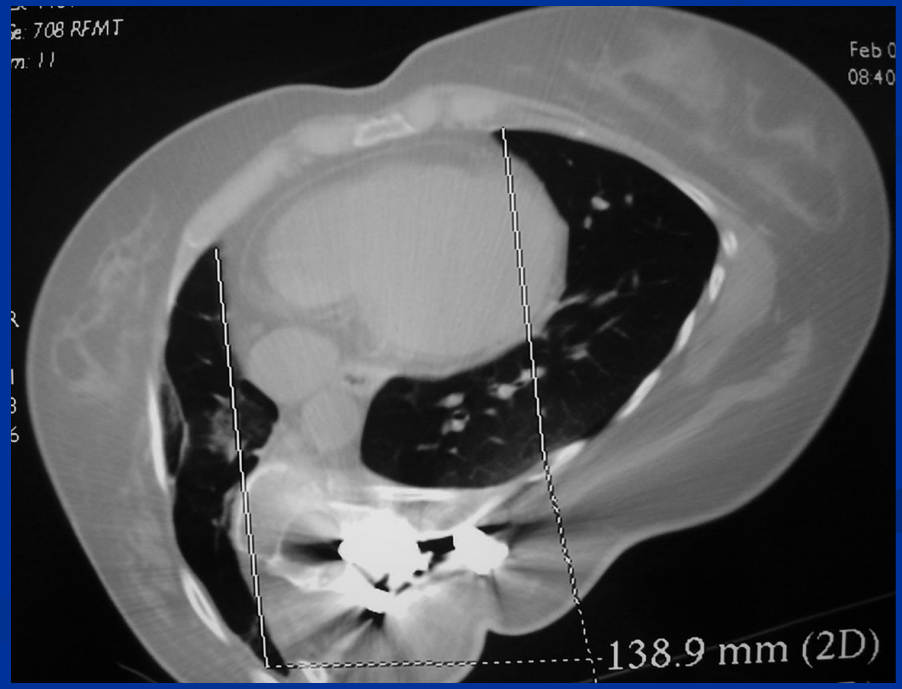
  J Bone Joint Surg (Am) 2003

- Spinal penetration index

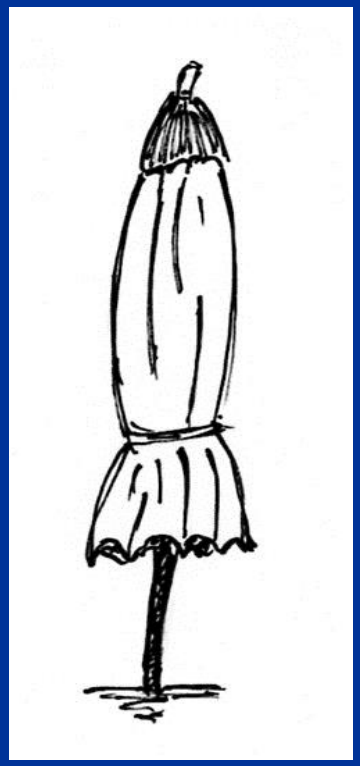
  Neuromuscular scoliosis
  Syndromes

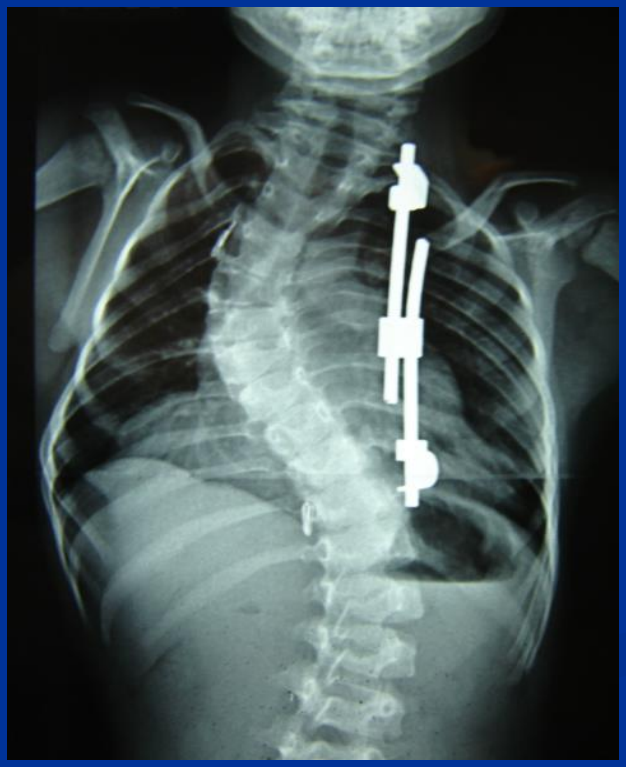
  Dubousset et al.

  J Orthop Sci 2003



Influence of idiopathic scoliosis on volumetric thoracic growth and proportions?



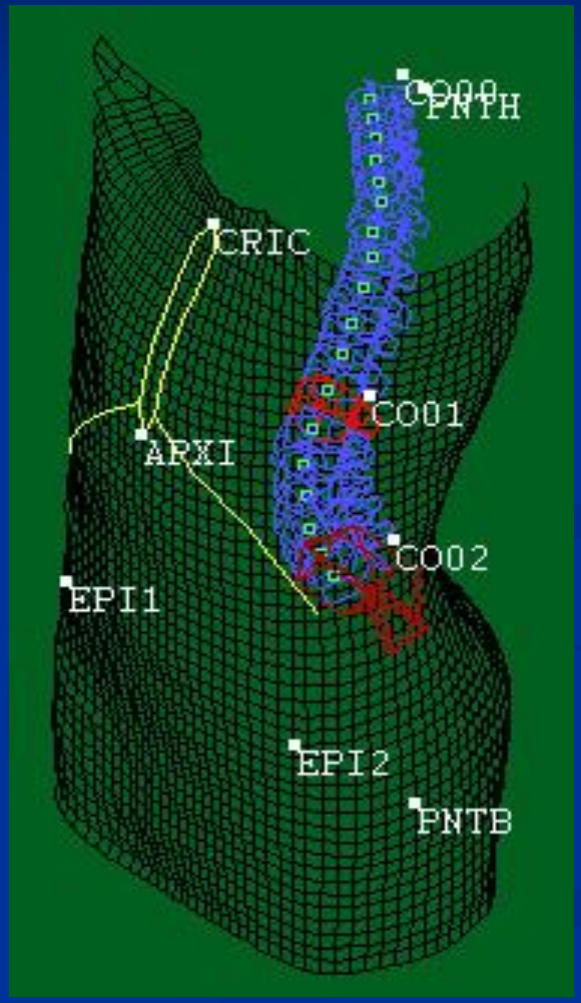


Optical data acquisition

Orten System

Thoracic growth parameters

- AP diameter
- Transversal diameter
- Thoracic perimeter



- Sternal length
- T1-T12 length
- ***Thoracic volume***

Patient groups

- Reference group: n = 126

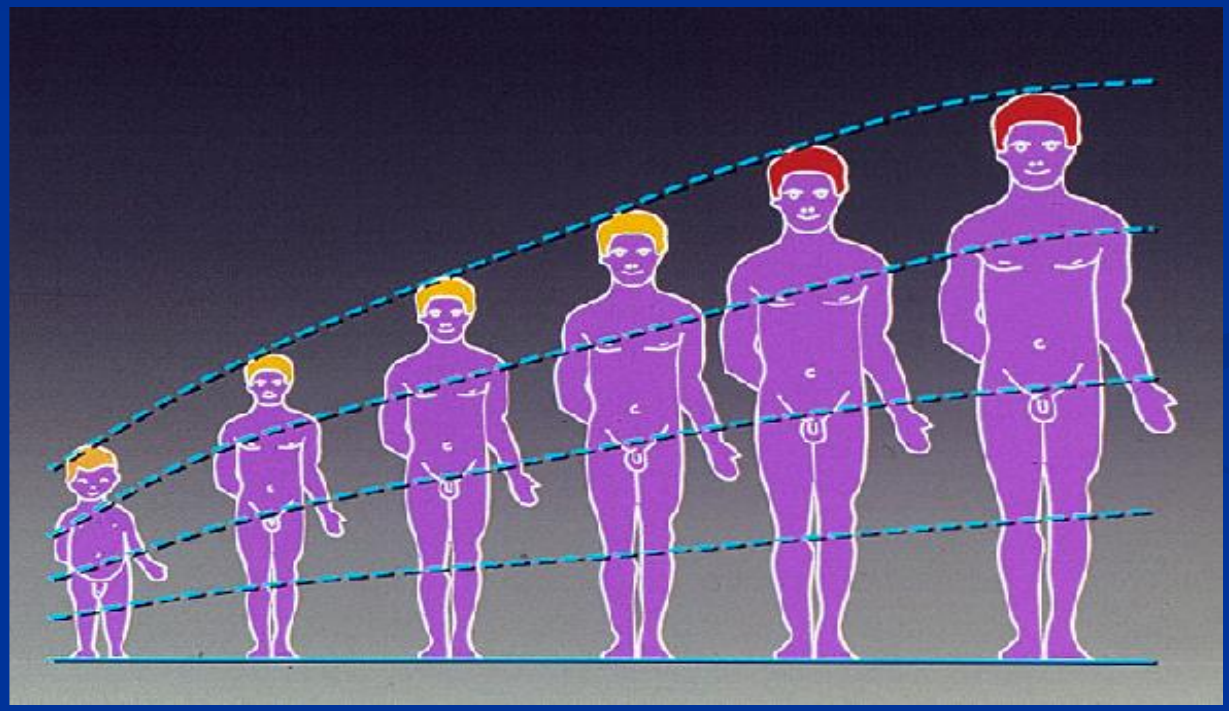
  61 boys / 65 girls

- Scoliosis group: n = 130

  20 boys / 110 girls

- Age range: 4 - 16 years

Clinical growth parameters



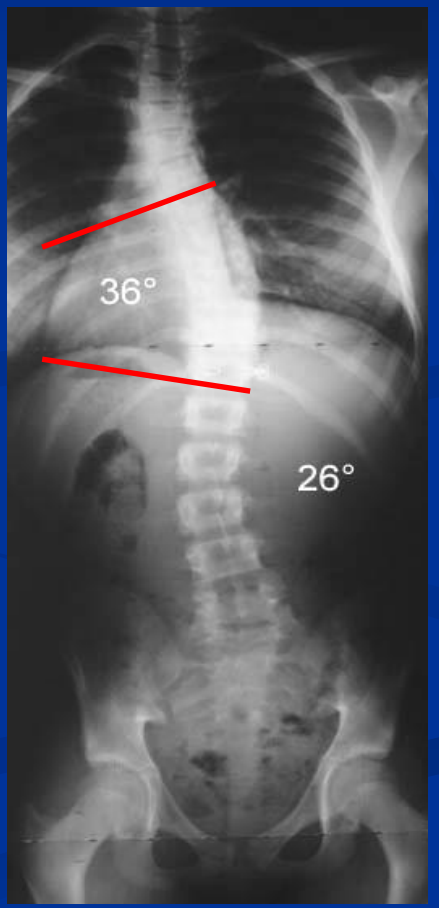
- Standing height
- Sitting height
- Weight

Spinal deformity assessment

- Frontal standing radiographs

  Cobb angle range: 15° - 45°

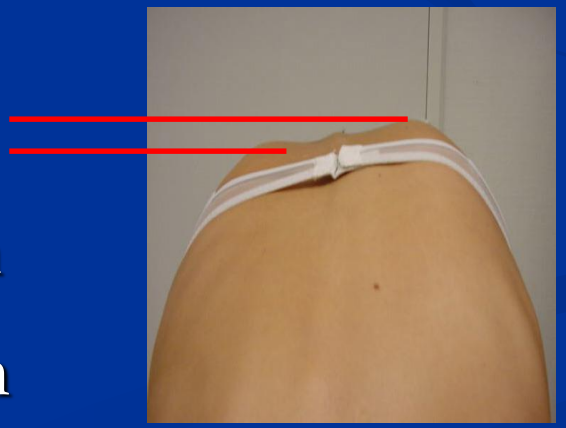
  Average = 24°



- Rib hump

  Range: 5 - 25 mm

  Average = 11 mm



Average thoracic parameters

in reference and scoliosis < 45° groups

	Boys		Girls	
	normal	scoliosis	normal	scoliosis
Volume	8.9 dm^3	7.9 dm^3	7.4 dm^3	8.3 dm^3
Perimeter	68.3 cm	66.5 cm	64.1 cm	66.8 cm
AP diameter	17.0 cm	16.2 cm	15.8 cm	16.0 cm
Transv. diameter	24.5 cm	23.0 cm	22.9 cm	24.1 cm
T1-T12 length	24.6 cm	23.4 cm	23.2 cm	24.4 cm
Sternum	16.0 cm	15.8 cm	15.3 cm	16.4 cm

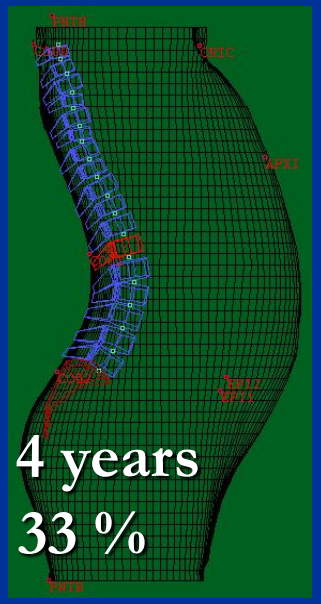
- No significant difference : Wilcoxon test $p > 0.05$

Thoracic growth - Boys

Average volumes

Normal

4.9 dm³



4.7 dm³

Scoliosis

x 1.7

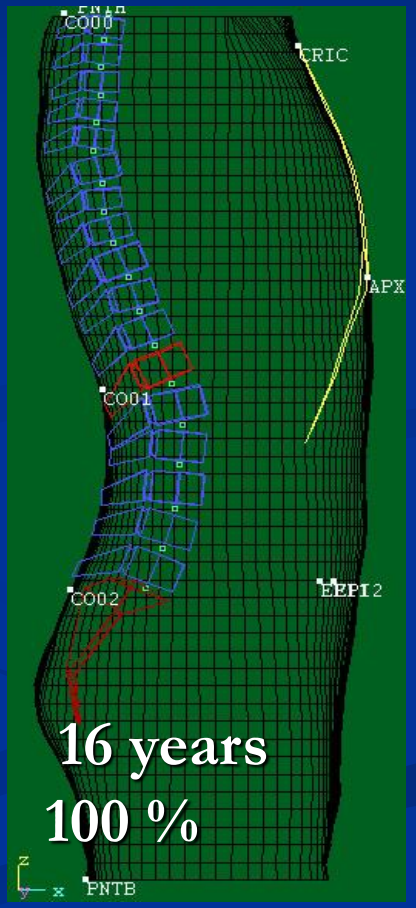
8.0 dm³

8.1 dm³

x 3

x 1.8

14.1 dm³



14.8 dm³

Thoracic growth - Girls

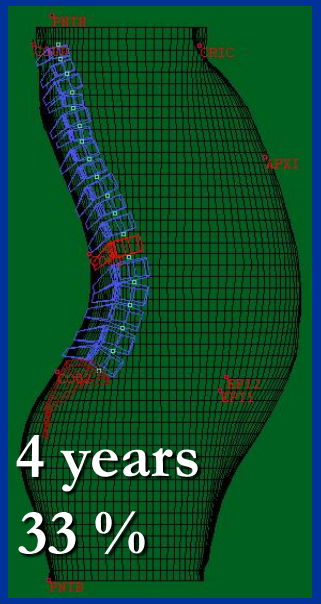
Average volumes

12.2 dm³

Normal

6.8 dm³

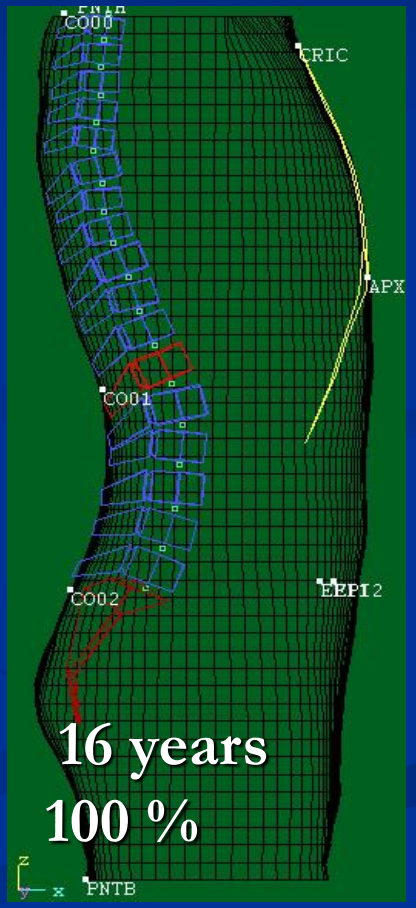
4.0 dm³



x 1.7

x 3

x 1.8



3.8 dm³

6.4 dm³

Scoliosis

11.5 dm³

Regression analysis

Thoracic volume - growth parameters

	Boys		Girls	
	normal	scoliosis	normal	scoliosis
Age	r = 0.73	r = 0.43	r = 0.69	r = 0.58
Standing height	r = 0.84	r = 0.87	r = 0.76	r = 0.69
Sitting height	r = 0.85	r = 0.88	r = 0.70	r = 0.69
Weight	r = 0.92	r = 0.92	r = 0.90	r = 0.87

- Growth parameters better than chronological age

Constant relationships during growth

in reference and scoliosis < 45° groups

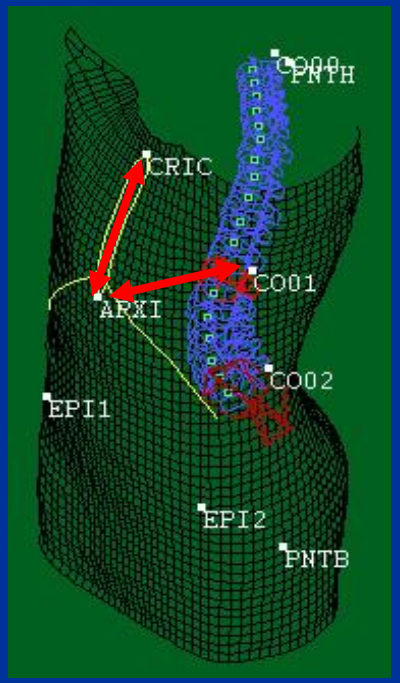
AP diameter

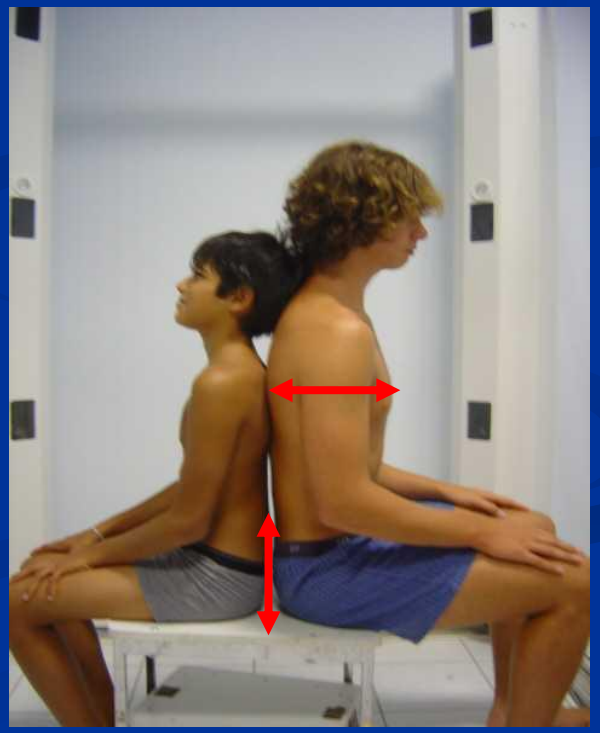
r = 0.78

r = 0.88

20% sitting height

Sternal length





Constant relationships during growth

in reference and scoliosis < 45° groups

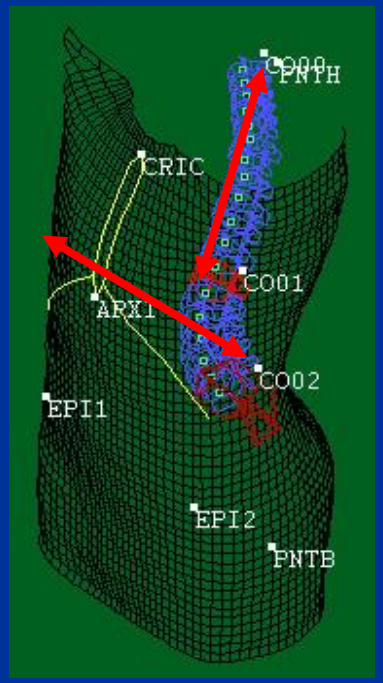
Frontal diameter

r = 0.85

r = 0.89

30% sitting height

T1-T12 length



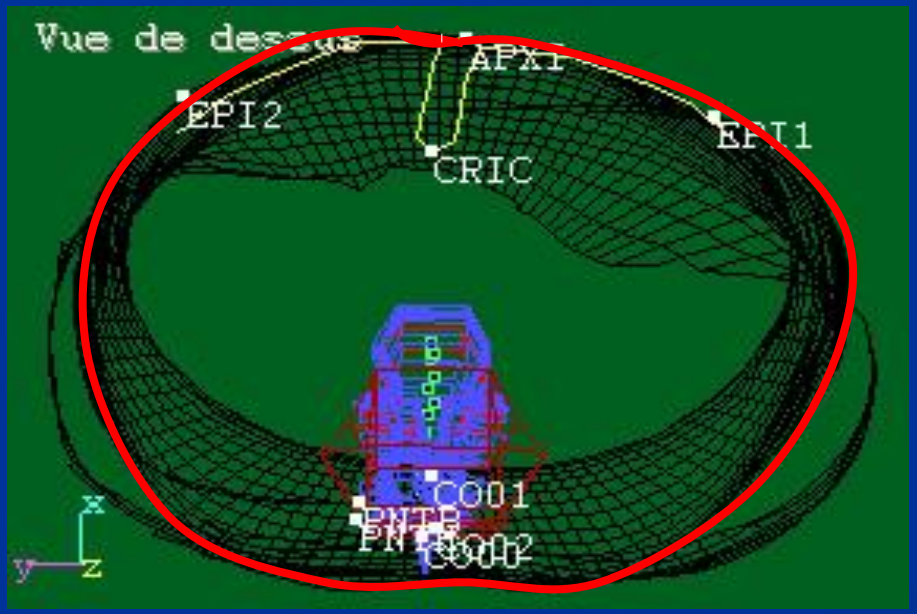
Constant relationships during growth

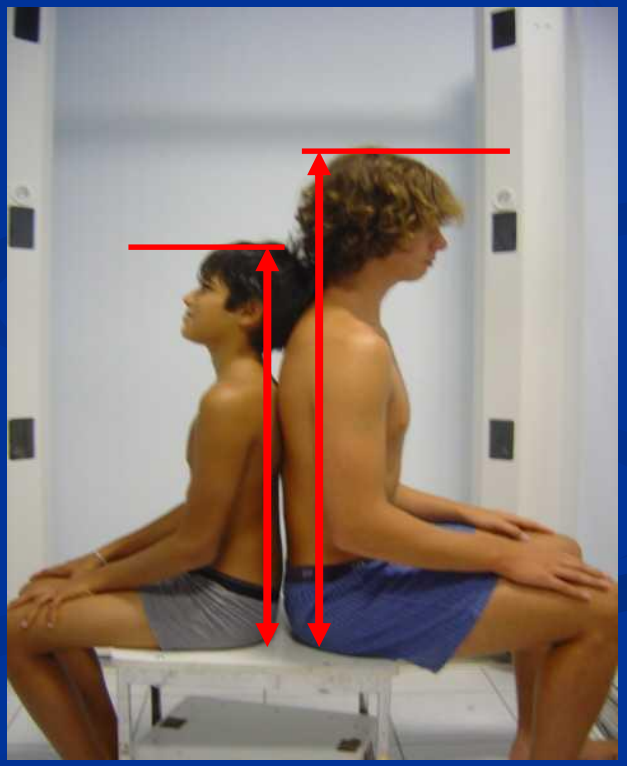
in reference and scoliosis < 45° groups

r = 0.93

Thoracic perimeter

Sitting height



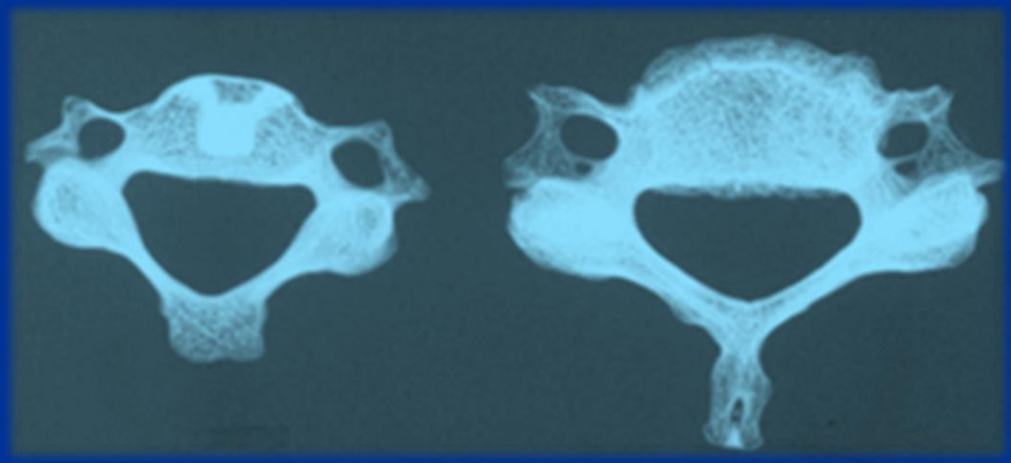


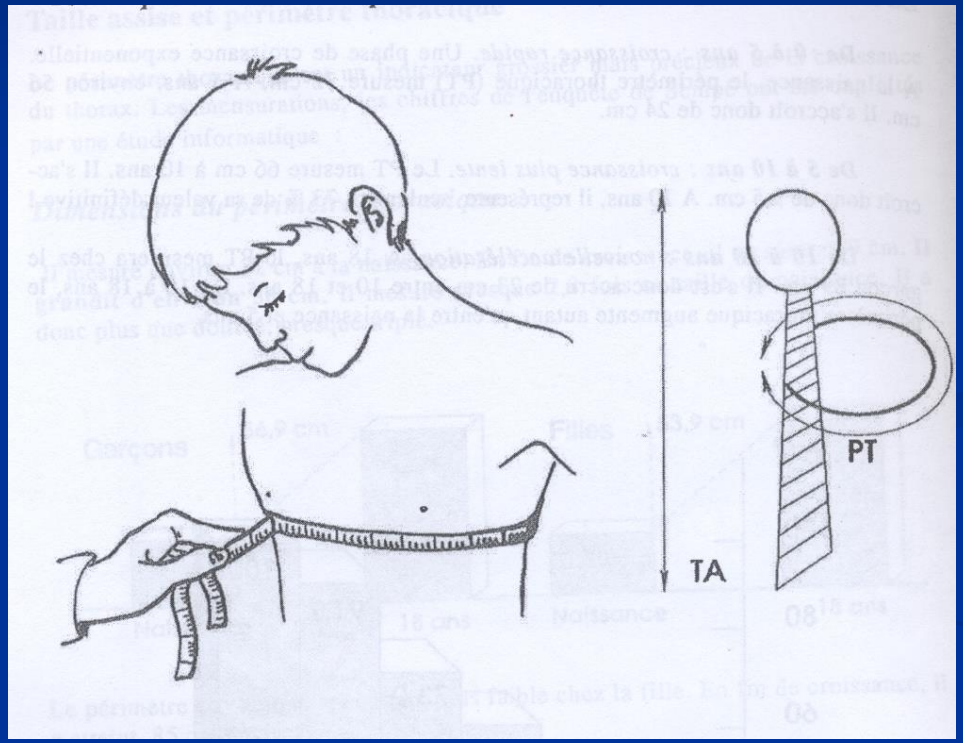
Conclusions

- Thoracic parameters need to be related to sitting height
- Thoracic volume triples from 4 to 16 years and doubles during pubertal growth
- No significant difference of thoracic volume between normal subjects and scoliosis < 45°

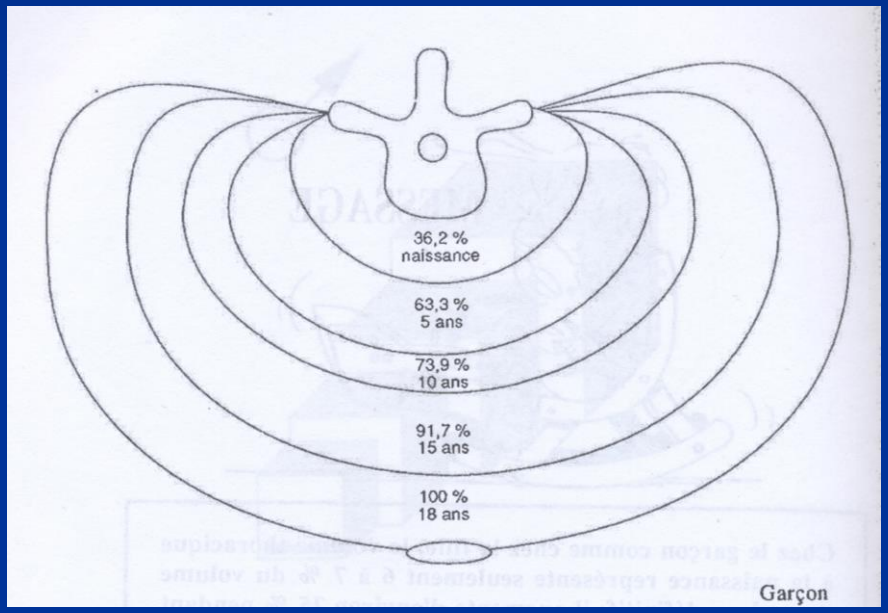
Clinical relevance of three-dimensional thoracic concept

- Conception of optimised braces
- Analysis of surgical strategies
- Further investigation on major scoliosis leading thoracic deformity

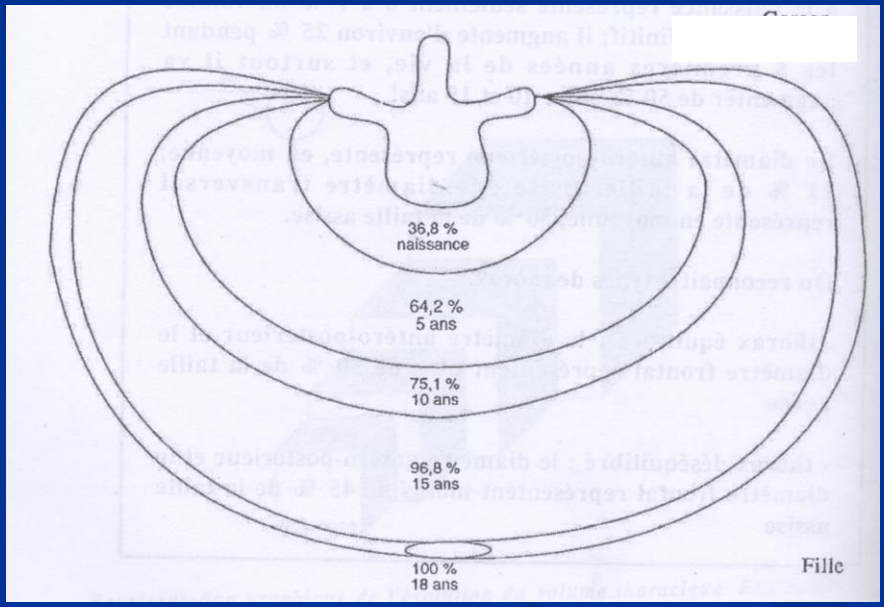



TA
PT

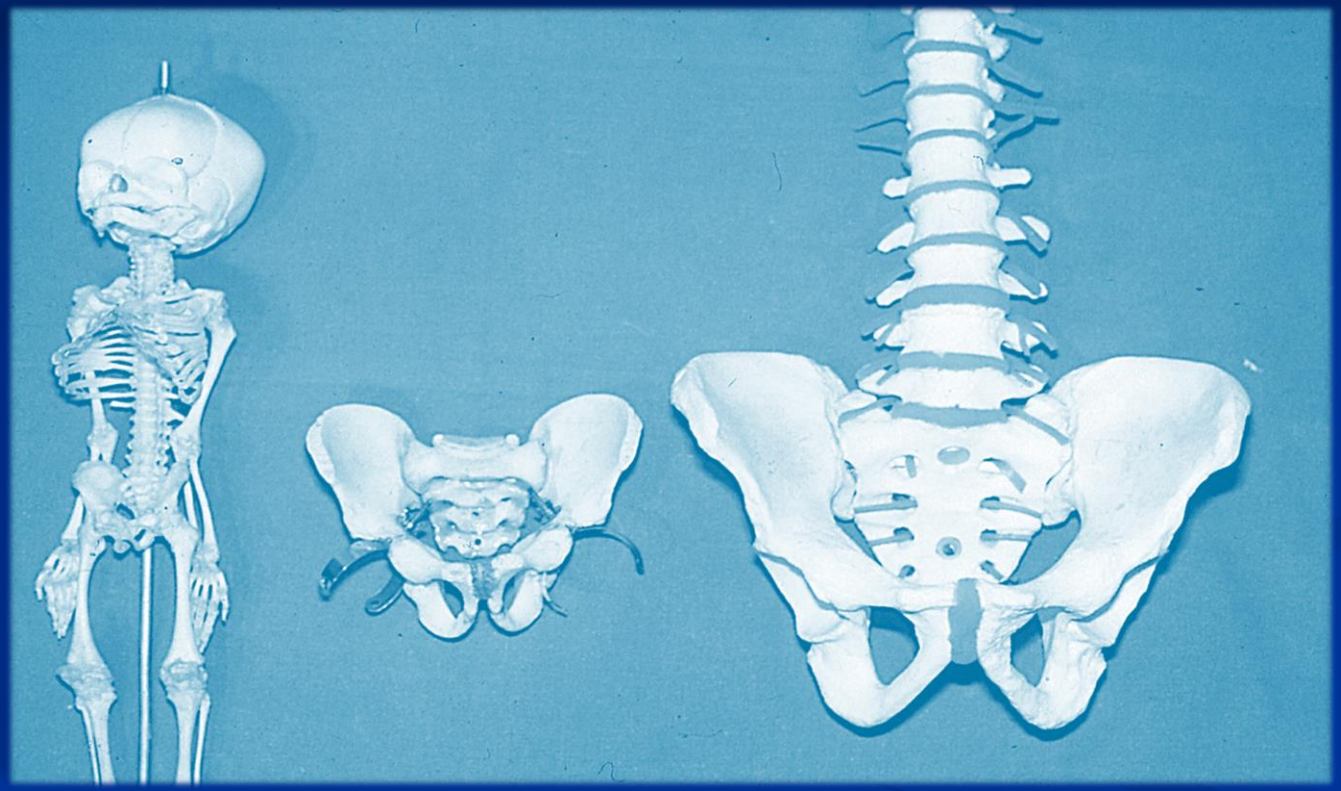
Garçon



Fille



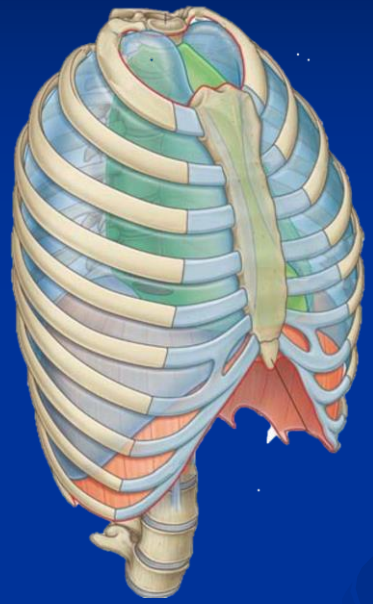
GROWTH IS A VOLUMETRIC REVOLUTION



Newborn 5 years Sk. maturity

AT BIRTH 30% OF THE SPINE IS OSSIFIED

Thorax is the heart of the problem



Deformities change the shape of the thorax and reduce its normal mobility.

The rib-vertebral-lung complex should be considered as a whole,
it is an elastic structural model,

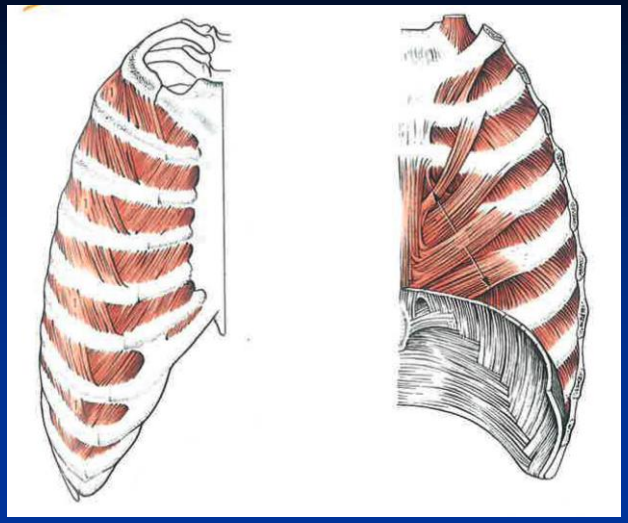
scoliosis it becomes rigid preventing from normal development lungs.

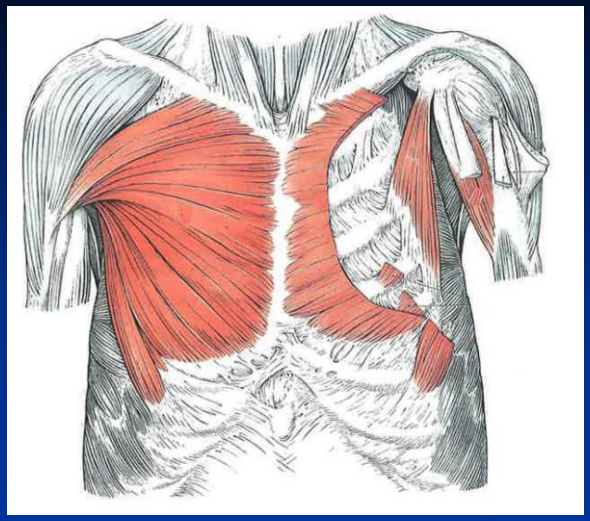
GROWTH IS A VOLUMETRIC REVOLUTION

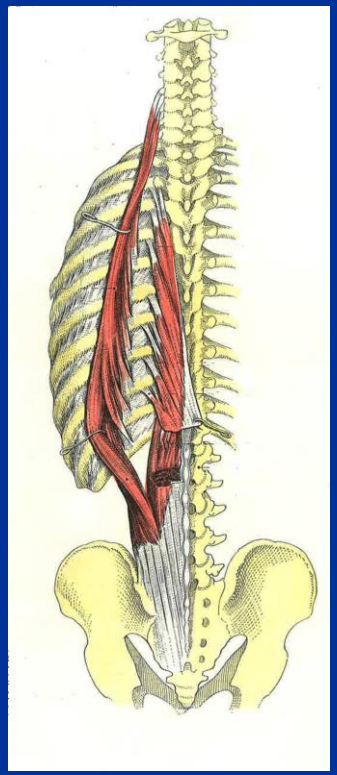
Newborn 5 years Sk. maturity

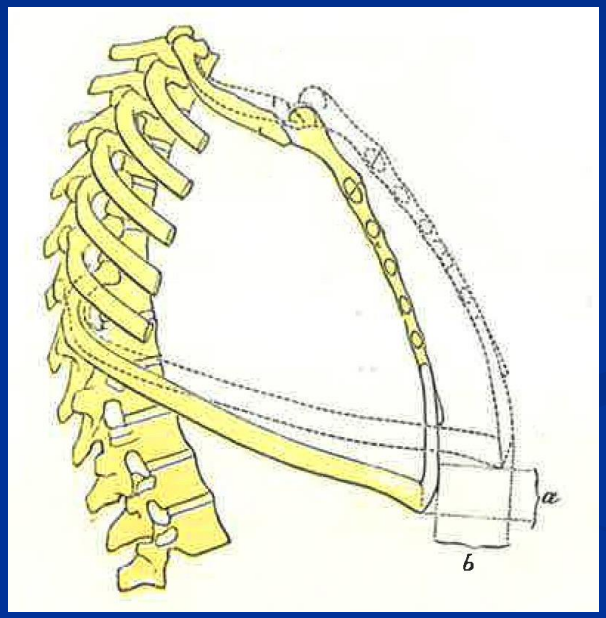
AT BIRTH 30% OF THE SPINE IS OSSIFIED

Physiotherapy

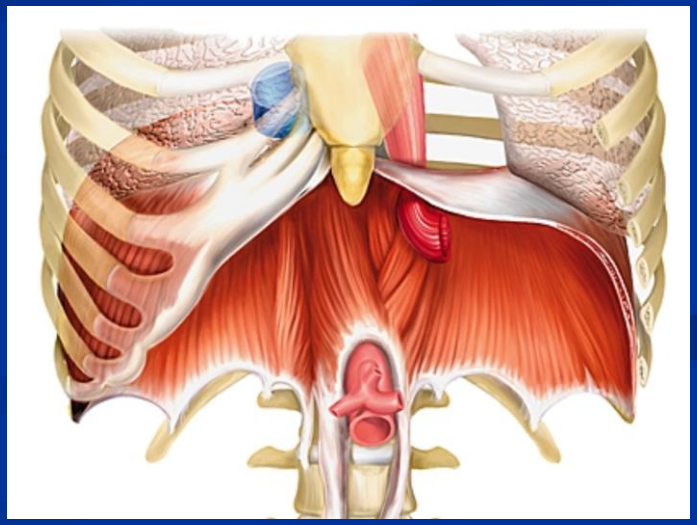






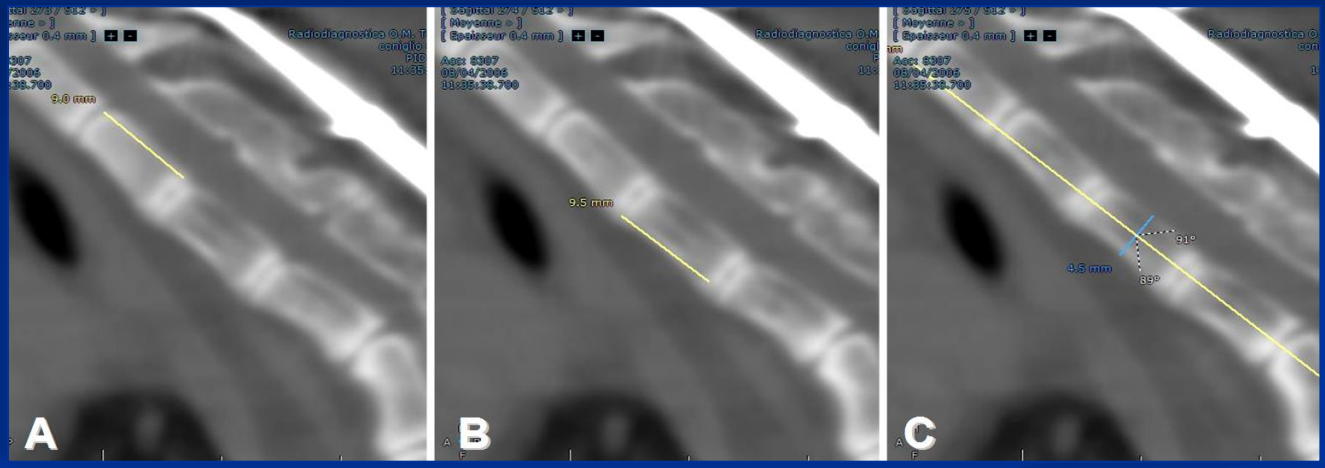


20 muscles
10 insertions by rib



RESULTS

Vertebral Body Size



- In the complete fusion group:
- decrease in the length of the vertebral body.
- reduction of thoracic kyphosis due to Crankshaft Phenomenon
- Decrease the growth of lungs

Canavese, Dimeglio Spine July 2007.

LUMBAR VERTEBRA VOLUME

5 10 15 years

5 10 30 cm^3

The vertebrae volume triple after ten.

Where are we going ?

- 1 There is a normal interaction between the spine, the thoracic cage and the lungs.
- 2 Deformities of the spine adversely affect the development of the thorax by changing its shape and reducing its normal mobility.
- 3 The rib-vertebral-lung complex should be considered as a whole, it is an elastic structural model; in the presence of scoliosis it becomes rigid thus preventing from normal development lungs.