Nancy Miller 2006

Genetic

Girls, families….

Nancy Miller, M.D.,
John Hopkins Hospital, (Baltimore, Maryland, USA)

1.The aim of this study was :
- identification of gene(s) responsible of idiopathic scoliosis,
- identification of mutations,
- study of correlation between genotype and phenotype

2.Analysis of the genetic aspects in families with idiopathic scoliosis

Alden K, Marosy B, Nzegwu N, Justice C, Wilson A, Miller N. Idiopathic Scoliosis: Identification of Candidate Regions on Chromosome 19p13. Spine 2006; 31: 1815-1819.

Genetic

Nancy Miller 2006

Methods. Model-independent linkage analysis of qualitative and quantitative traits related to scoliosis was used to screen genotyping data from 391 markers in 202 families (1198 individuals).

Table 1. Number of Families and Individuals Within Each Sample Population

Subgroups	No. Families	No. Individuals	No. Affected (males/females)
Genomic screen all families	202	1198	703 (150/553)
Families with Probands ≥30°	141	945	541 (120/421)
Families with probands ≥30°; autosomal dominant mode of inheritance	72	473	286 (85/201)

Subsets of families with probands having a curve >=30° were dichotomized based on the most likely mode of inheritance for each family (autosomal dominant or X-linked dominant). Fine mapping was performed to show linkage to candidate regions on chromosome 19.

Results. When the threshold of disease was set at a curvature of >=30°, qualitative linkage analysis revealed significant results at 2 successive markers on chromosome 19.

Conclusion. The data confirm a previously reported genetic locus on chromosome 19 as potentially significant in the etiology of idiopathic scoliosis.

Alden K, Marosy B, Nzegwu N, Justice C, Wilson A, Miller N. Idiopathic Scoliosis: Identification of Candidate Regions on Chromosome 19p13. Spine 2006; 31: 1815-1819.

Genetic

Carol Wise 2000

Dr Carol Wise, Texas Scottish Rite Hospital for Children, Dallas, Etas-Unis

•How to locate and identify the genes which are in relation with the discovery of an idiopathic scoliosis ?

Linkage between scoliosis and chromosome 4q, 6p, distal 10q, and 18q within one large extended family

Wise CA,Barnes R,Gillum G and al. Localization of susceptibility to families idiopathic scoliosis. Spine 2000; 25; 2372 - 80

Genetic

Goldberg 1997

Dermatoglyphics were compared in 114 female control individuals and 164 female patients with AIS (minimum Cobb angle = 10°)

Significant asymmetry suggesting both;

- Developmental instability
- Directional asymmetry

Goldberg C, Fogarty E, Moore D, Dowling F. Scoliosis and developmental theory: adolescent idiopathic scoliosis. Spine 1997; 22: 2228 – 37.

Genetic

Jen 2004

Growing corticospinal and somatosensory axons cross the midline in the medulla to reach their targets and thus form the basis of controlateral motor control and sensory input.

The motor and sensory projections appeared uncrossed in patients affected with HGPPS, we identified mutations in the ROBO 3 gene, which shares homology with roundabout genes important in axon guidance in developing Drosophila, Zebrafish, and mouse.

Jen J, Chan W, Bosley T and Al. Mutation in a human ROBO gene disrupt hindbrain axon pathway crossing and morphogenesis. Science 2004. 304: 1509 – 13.

Genetic

Ogilvie 2006

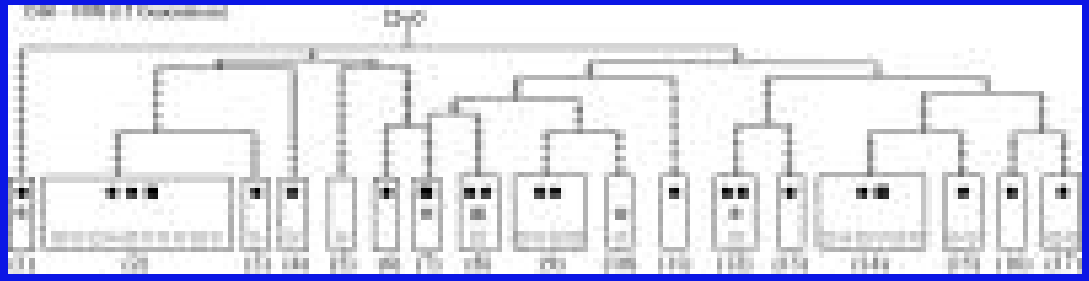
Salt Lake City

145 AIS → 100 from families known to have members affected with AIS

45 → 14 not found in the genealogic database

31 → 27 connected to at least one of the scoliotic family

127 / 131



Ogilvie J, Braun J, Argyle V and Al. The search for idiopathic scoliosis Spine 2006; 31: 679 – 81.

Melatonin

Thillard 1959
Dubousset 1983

Thillard MJ. Déformations de la colonne vertébrale consécutives à l'epiphysectomie chez le poussin.
Extrait des comptes rendus de l'association des anatomistes 1959; 751-8

Dubousset J, Queneau P, Thillard MJ. Experimental Scoliosis Induced by pineal and diencephalic lesions in young chickens; its relation with clinical findings. Orthop Trans 1983; 7:7.

Melatonin

Machida

Professor Masafumi Machida
Nihon University School of Medicine
Tokyo, Japon

Study the role of melatonin in the origin and progression of the scoliosis

Machida M, Dubousset J, Imamura Y and al. An experimental study in chickens for the pathogenesis of idiopathic scoliosis *Spine 1993; 18: 1609-15.*

Machida M,Dubousset J, Imamura Y and al. Role of melatonin deficiency in the development of scoliosis in pinealectomized chickens. *J Bone Joint Surg (Br) 1994; 77: 134-8.*

Machida M, Dubousset J, Imamura Y and al. Pathogenesis of idiopathic scoliosis; SEPs in chicken with experimentaly induced scoliosis and in patients with idiopathic scoliosis.
J Pediatr Orthop 1994; 14: 329-35.

Melatonin

Machida

The prime function of the pineal gland in chicken is the production of melatonin.

The effect of pinealectomy in causing scoliosis in chickens has therefore been attributed to melatonin deficiency.

Machida M,Dubousset J, Imamura Y and al. Melotonin:A possible role in pathogenesis of adolescent idiopathic scoliosis. Spine 1996; 21: 1147-52.

Machida M, Miyashita Y, Murai I and al. Role of serotonin for scoliotic deformity in pinealectomized chicken. Spine 1997; 22: 1297-301.

Melatonin

Thillard MJ. Déformations de la colonne vertébrale consécutives à l'epiphysectomie chez le poussin. Extrait des comptes rendus de l'association des anatomistes 1959; 751-8

Coillard C, Badeaux J,Rivard C. Vertebral deformation and scoliosis. Proceedings of the Québec Scoliosis Society, 1994; 24

Kanemura T, Kawakami N, Deguchi M and al. Natural course of experimental scoliosis in pinealectomised chickens. Spine 1997; 22: 1563 – 7

Wang X, Jiang H,Raso VJ and al. Characterisation of the scoliosis that develops after pinealectomy in the chicken and comparison with the scoliosis seen in adolescent idiopathic scoliosis seen in humans. Spine 1997; 22: 2626 – 35

Wang X, Moreau M, Raso VJ and al. Changes in serum melatonin levels in response to pinealectomy in the chicken: its relation to the development of scoliosis Spine 1998; 23: 2377 – 81

O'Kelly, Wang X, Raso J and al. The production of scoliosis after pinealectomy in young chickens, rats and hamsters. Spine 1999; 24: 35 – 43

Bagnall K, Beuerlein M, Johnson P and al. Pineal transplantation after pinealectomy in young chickens has no effect on the development of scoliosis. Spine 2001; 26: 1022 - 27

Melatonin

Author	Year of publication	%Scoliosis produced	Nber of Scoliosis/ Nber of chickens
Thillard	1959	66%	33/50
Mashida	1993	100%	30/30
Coillard	1994	80%	20/25
Kanemura	1997	68%	17/25
Wang	1997	60%	18/30
Wang	1998	52%	17/33
O'Kelly	1999	48%	10/21
Bagnall	2001	55%	54/98

Melatonin

Beuerlein 2001

109 Chickens		% SCOLIOSIS
Group 1 (9) :	Control group. No surgery.	0%
Group 2 (20) :	Only the skull + 3 sinuses cut	
Group 3 (20) :	Sham procedure, touched but not removed	
Group 4 (25) :	Just cut the pineal stalk	68%
Group 5 (35) :	Complete pinealectomy	60%

Beuerlein M, Wilson J, Moreau M and al. The critical stage of pinealectomy surgery after which scoliosis is produced in young chickens. Spine 2001; 26: 237 240.

Melatonin

Beuerlein 2001

% SCOLIOSIS

Group 4 (25) : Just cut the pineal stalk **68%**

Group 5 (35) : Complete pinealectomy **60%**

Same amount of decrease in serum melatonin level

Beuerlein M, Wilson J, Moreau M and al. The critical stage of pinealectomy surgery after which scoliosis is produced in young chickens. Spine 2001; 26: 237 240.

Melatonin

Cheung 2003

35 Chickens ⟶ Control group with no surgery 10

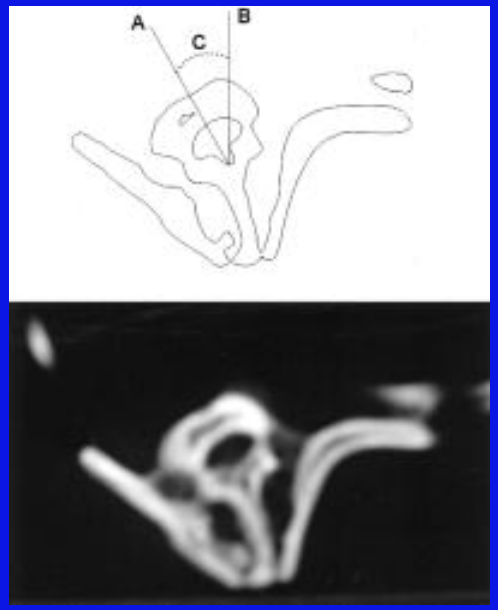
25 had a pinealectomy

13 (52%) had a scoliosis

All scoliosis were thoraco-lumbar with lordosis, rotation and wedging

The thoracic curve above has the appearance of a compensatory curve

Severity of pelvic wing deformity correlated to the Cobb angle



Cheung K, Wang T, Leong J. Primary thoracolumbar scoliosis in pinealectomized chickens. Spine 2003; 28; 2499 - 504.

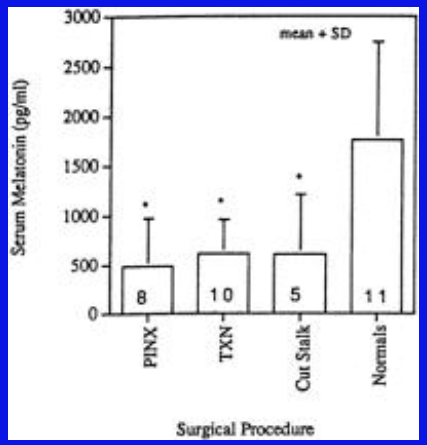
Melatonin

Machida

Mashida showed that intra peritoneal injection of melatonin prevents the development of scoliosis in pinealectomized chickens that otherwise would have developed scoliosis.

After pinealectomy Mashida autografted the removed pineal gland into the thoracic musculature of the chickens.

	%Scoliosis produced	Nber of Scoliosis/ Nber of chickens
Pinealectomy	100%	30/30
Pinealectomy + autografting	10%	3/30



Melatonin

Bagnall 2001

	Number of chickens	Killed at 1 week	5 weeks F.U.	% scoliosis
Pinealectomy	43	8	35	58%
Cut stalk	43	5	38	44%
Pinealectomy + transplantation	35	10	25	64%
Control	25	11	14	0%

?

Bagnall K, Beuerlein M, Johnson P and al. Pineal transplantation after pinealectomy in young chickens has no effect on the development of scoliosis. Spine 2001; 26: 1022 - 27

Melatonin

Bagnall 2001

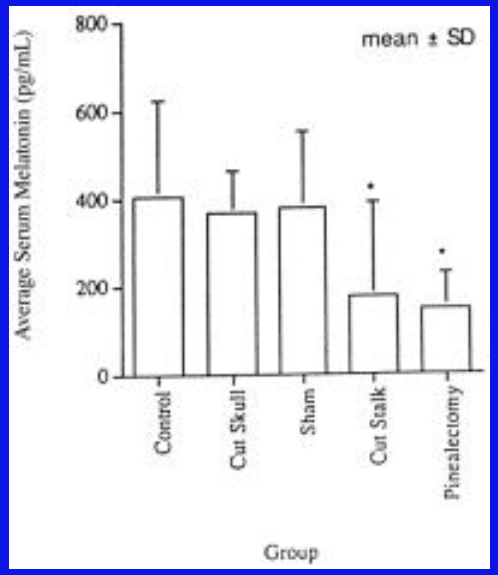
	Number of chickens	Killed at 1 week
Pinealectomy	43	**8**
Cut stalk	43	**5**
Pinealectomy + transplantation	35	10
Control	25	**11**

Average peak melatonin level ↘ Significantly

Melatonin

Bagnall 2001

	Number of chickens	Killed at 1 week
Pinealectomy	43	**8**
Cut stalk	43	**5**
Pinealectomy + transplantation	35	**10**
Control	25	**11**



Average peak melatonin level did not increase

Melatonin

Wu 1993

In mammals transplantation to the anterior chamber of the eye is the only effective means to restablish pineal function.

Similar results might be expected in avian species

Most scoliosis develops in pinealectomized chickens within the first 2 weeks after surgery.

Wu W, Scott D, Reiter R. Transplantation of the mammalian pineal gland: Studies of survival, revascularisation, reinnervation, and recovery of function. Exp Neurol 1993; 122: 88 -99

Melatonin

Machida

Mashida could not produce the same result with rats and concluded that the bipodal condition may play an important role in the development of scoliosis

Pinealectomy in rats maintened in a bipodal condition produces a scoliosis

Melatonin

Machida 1999

Pinealectomy in

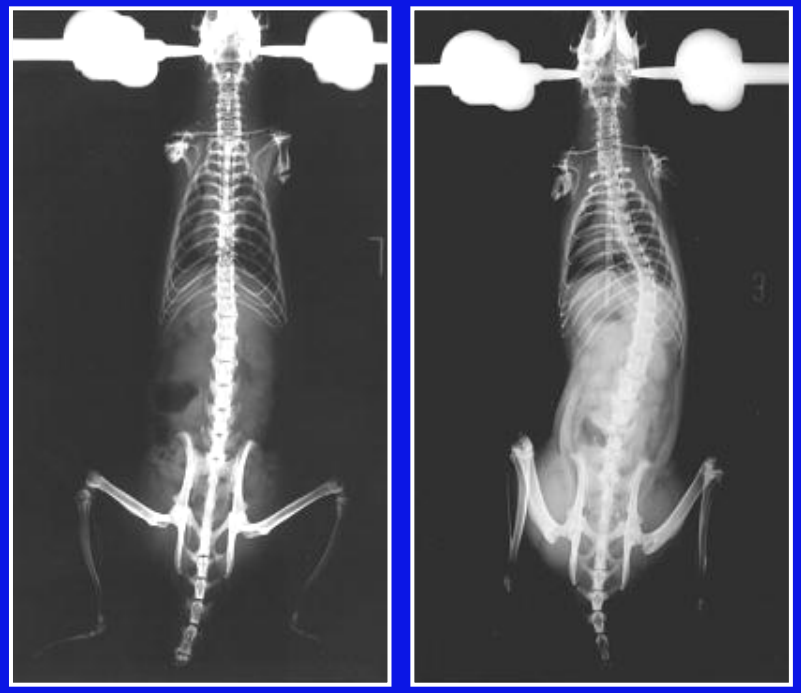
4 sham operation → No scoliosis

10 quadrupedal rats → No scoliosis

20 bipedal rats → 100% scoliosis

10 bipedal + melatonin pellets
100 mg per 90 days release

→ 10% scoliosis



Machida M, Ichiro M, Miyashita Y, Dubousset J, Yamada T, Kimura J. Pathogenesis of idiopathic scoliosis: experimental study in rats. Spine 1999; 24: 1985 – 1995.

Melatonin

Hilibrand AS, Blackmore LC, Loder RT, and al. The role of melatonin in the pathogenesis of adolescent idiopathic scoliosis.
Spine 1996; 21: 1140-6.

Bagnal KM, Raso VJ, Hill DL and al. Melatonin levels in idiopathic scoliosis: Diurnal and nocturnal serum melatonin levels in girls with adolescent idiopathic scoliosis *Spine 1996; 21: 1974-8.*

Fagan AB, Kennaway DJ, Sutherland AD. Total 24-hour melatonin secretion in adolescent idiopathic scoliosis. *Spine 1998; 23: 41-6.*

Kennaway D. Cause of idiopathic scoliosis (letter to the editor).
Spine 2000; 25; 2552-3.

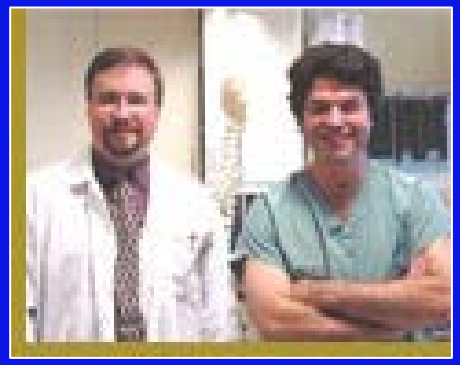
Melatonin

Moreau

Docteurs Alain Moreau and Hubert Labelle

Hôpital Sainte Justine Montréal, Québec, Canada

Analysis of molecular expression and neurological systematisation of melatonin



Melatonin

Moreau 2004

The idea was that a defect of melatonin signaling activity could generate effects similar to a melatonine deficiency.

Cellular model = Osteoblastes
- Bone is a tissue responding to melatonin
- Persistent osteopenia often reported in AIS

AIS = 41, Non Idiopathic Scoliosis = 15, Control Group = 2

Moreau A, Wang D, Forget S and al. Melatonin signaling dysfunction in adolescent idiopathic scoliosis. Spine 2004; 29: 1772 – 81.

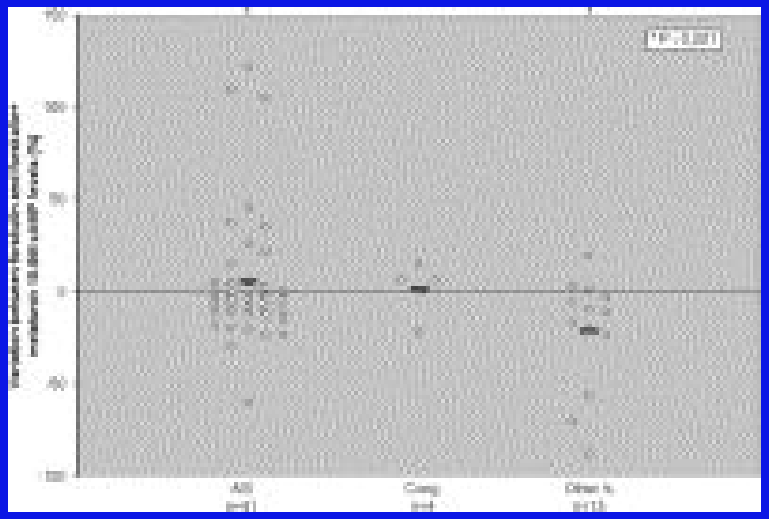
Melatonin

Moreau 2004

Osteoblasts from patients with AIS showed hardly any capability to inhibit forskolin – stimulated adenyl – cyclase activity in response to melatonin, clearly indicating an impairement of melatonin signaling in AIS.

Melatonin signaling is clearly impaired in ostéoblasts of all patients with adolescent idiopathic scoliosis tested.

Classification of patients with adolescent idiopathic scoliosis in three groups based on functional *in vitro* assays suggests the presence of distinct mutations.



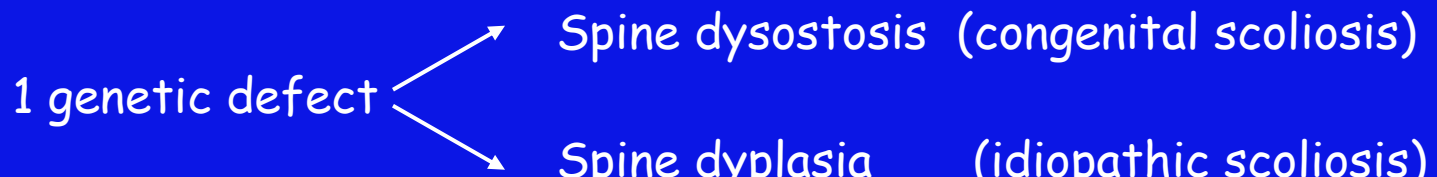
Moreau A, Wang D, Forget S and al. Melatonin signaling dysfunction in adolescent idiopathic scoliosis. Spine 2004; 29: 1772 – 81.

Melatonin

Purkiss 2002

Comparison between AIS and congenital scoliosis groups showed no significant variation in those assays, suggesting a possible link between AIS and some type of congenital scoliosis

Purkiss reported a high rate of AIS (17.3%)in families affected by congenital scoliosis



Purkiss SB, Driscoll B, Cole WG and al. Idiopathic scoliosis in families of children with congenital scoliosis. Clin Orthop 2002; 27 - 31

Genetic and melatonin

Morcuende 2003

Linkage between scoliosis and chromosome 4q, 6p, distal 10q, and 18q within one large extended family

Wise CA,Barnes R,Gillum G and al. Localization of susceptibility to families idiopathic scoliosis. Spine 2000; 25; 2372 - 80

In mammals two subtypes of melatonin receptors have been isolated: melatonin 1A and 1B

The gene for melatonin 1A is located on chromosome 4q

Morcuende J, Minhas R, Dolan L and al. Allelic variants of human melatonin 1A receptor in patients with familial adolescent idiopathic scoliosis. Spine 2003; 28: 2025 – 28.

Genetic and melatonin

Morcuende 2003

113 AIS and 64 non affected patients

No evidence of linkage to chromosome 4q and no mutation in the coding region of the gene for human melatonin receptor

Table 2. Chromosome 4 Marker Location (cM) and Scores

Marker	cM	LOD Score (alpha, HLOD)	NPL Score	*P* Value
GATA28F03	75.52	−0.226181 (0.0244, −0.0043)	−0.10764	0.18
GATA24H01	78.43	−0.056807 (0.4963, −0.0167)	−0.23682	0.2
GATA10G07	83.00	−0.009259 (0.4994, −0.0024)	−0.05804	0.2
GATA2A03	93.48	0.168095 (0.9663, 0.1630)	0.15879	0.14
GATA2F11	104.94	0.115270 (0.9204, 0.1074)	0.10158	0.26
GATA62A12	114.04	0.193347 (0.9737, 0.1889)	0.16212	0.24
ATA26B08	126.00	0.260977 (0.9856, 0.2577)	0.19484	0.24
GATA11E09	143.31	0.088356 (0.8901, 0.0777)	0.11754	0.16
GATA107	145.98	−0.238942 (0.0303, −0.0047)	0.20149	0.21
GATA8A05	157.99	−0.240786 (0.0175, −0.0036)	−0.18986	0.24
GATA27G03	167.55	−0.078469 (0.1572, −0.0116)	−0.17862	0.16
GGAA19H07	176.19	0.196658 (0.9867, 0.1917)	0.23256	0.25
GATA42H02	181.93	0.125540 (0.9263, 0.1180)	0.15691	0.12
AFM165xc11	195.06	0.255775 (0.9841, 0.2524)	0.24918	0.15
AFM238VE	206.98	0.134231 (0.9498, 0.1280)	0.13594	0.14
GATA5B02	208.07	0.197257 (0.9799, 0.1934)	0.15040	0.24
GATA22F02	208.07	0.181932 (0.9764, 0.1777)	0.18596	0.20
AFMA224XH1	208.07	0.163455 (0.9671, 0.1585)	0.18712	0.22
UT7694	208.07	0.196238 (0.9762, 0.1940)	0.21511	0.27
AFM224xh1	208.07	0.227884 (0.9809, 0.2241)	0.21699	0.22

Morcuende J, Minhas R, Dolan L and al. Allelic variants of human melatonin 1A receptor in patients with familial adolescent idiopathic scoliosis. *Spine 2003; 28: 2025 – 28.*

Disco-ligamentous concept

Fairbank 2005

Jeremy Fairbanks, M.D. and Jill Urban, M.D. Oxford, UK

•Role of the « soft tissue » : fibroblasts and elastic fibers abnormalities ?

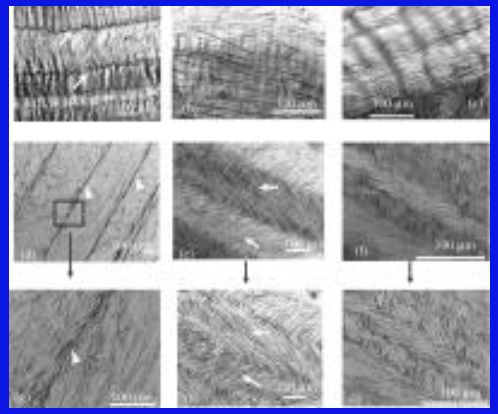
Yu J, Fairbank J, Roberts S and al. The elastic fiber network of the anulus fibrosus of the normal and scoliotic human intervertebral disc. Spine 2005; 30: 1815 – 20.

Disco-ligamentous concept

Fairbank 2005

Control discs : 2 patients (1 tumor, 1 trauma)

Scoliotic discs : 6 patients (3 AIS, 3 neuromuscular scoliosis)



Abundant and organized network of elastic fibers in control group

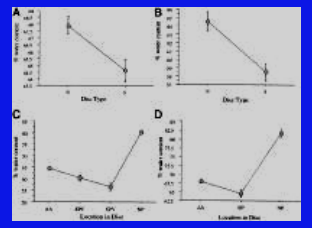
Sparse and disrupted network in Scoliotic group

Could be involved in the progression of the spinal deformity

Yu J, Fairbank J, Roberts S and al. The elastic fiber network of the anulus fibrosus of the normal and scoliotic human intervertebral disc. Spine 2005; 30: 1815 – 20.

Inter vertebral disc IVD

Antoniau 2001



15 IVD in AIS were obtained intraoperatively

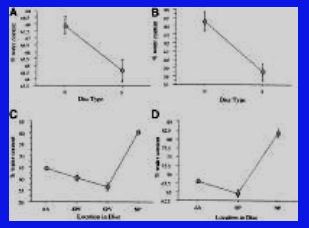
17 IVD from normal spines obtained post - mortem

	Anulus	Nucleus	End plates
Total collagen content	S ↘		S ↘
Glycosaminoglycan		S ↘	S ↘
Total protein content		↗	S ↗
Water content	S ↘		S ↘

Antoniou J, Arlet V, Goswani T and Al. Elevated synthetic activity in the convex side of scoliotic intervertebral discs and endplates compared with normal tissues. Spine 2001; 26: 2 198 – E 206.

Inter vertebral disc IVD

Antoniau 2001



15 IVD in AIS were obtained intraoperatively

17 IVD from normal spines obtained post - mortem

No differences Concave / Convexe

The higher collagen Type II synthetic levels and increased total protein content with no matrix turnover suggest that scoliotic changes are due to an altered and ineffective response to a pathologic mechanical environment

Antoniou J, Arlet V, Goswani T and Al. Elevated synthetic activity in the convex side of scoliotic intervertebral discs and endplates compared with normal tissues. Spine 2001; 26: 2 198 – E 206.

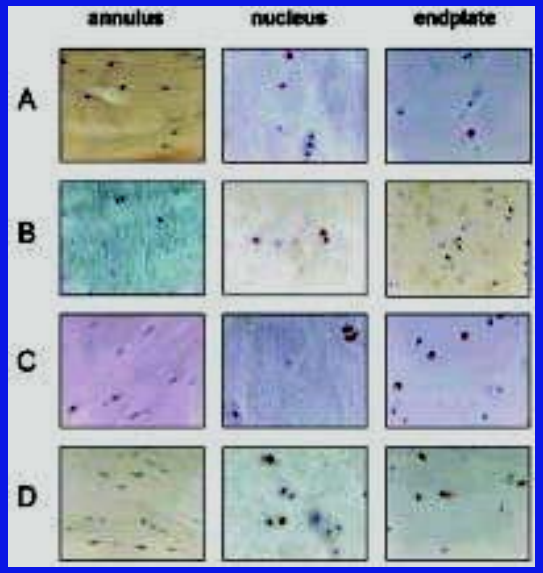
Inter vertebral disc IVD

Chen 2005

APOPTOSE

70 Discs from 16 Scoliotic patients (8 M – 8 F) 9 AIS, 7 Neuro Musc.

Mean age : 20.6 Y (10 – 48 Y)



Increased number of apoptotic cells in the nucleus of scoliotic discs and the apex disc suppose a pivotal role of programmed cell death for the progression of this common disorder.

The simultaneous increase of Fas and Fas – ligand expression in areas with increased cell death point to an activation of the apoptotic process via the Fas/Fas-L system.

Chen B, Fellenberg J, Wang H and Al. Occurrence and regional distribution of apoptosisin scoliotic discs. Spine 2005; 30: 519 – 24..

Inter vertebral disc IVD

Heidari 2004

A mathematical model was used to determine the contribution of collagen fibre orientation and directional imbalance within the annulus fibrosus to vertebral rotation and overall deformity of thoracic spine.

Imbalance in the ratio of clockwise and anti – clockwise collagen fibres within the annulus fibrosus has been demonstrated to have the potential to contribute to the progression of scoliosis.

Heidari B, Fitzpatrick D, Synnott K, McCormack D. Modelling of annulus fibrosus imbalance as an aetiological factor in adolescent idiopathic scoliosis. Clinical Biomechanics 2004; 19: 217 – 24.

Morphology

Professor Alain Berthoz, Collège de France

•Observation of cranio-facial asymetry : CT of the skull

Professor Robert Pashman, Cedar Sinaï Institute for spinal disorder, Los Angeles, USA

•Circulation of the cerebro-spinal fluid : convexe side compare to concave, apex of the scoliosis

Morphology

Height and AIS

Taller mean standing height in girls with scoliosis compared to healthy control

Girls with AIS have an earlier growth spurt and earlier attainment of adult height

Length measurements of the sitting height

- Without correction for the error due to scoliosis itself
- Corrected using the method described by Bjure and Al.

No difference in growth pattern or height between AIS and control group

Paravertebral Musculature

Muscle's abnormalities

Muscle spindle

Individual muscle fiber morphology

Histochemistry

Electromyography

Sarcolemma abnormalities at the muscle – tendon junction

Calcium, copper and zinc concentrations

Muscle imbalance

Calmodulin

Platelet = « mini » skeletal muscle

. Protein contractile system: Actin and Myosin

. No axial attachments

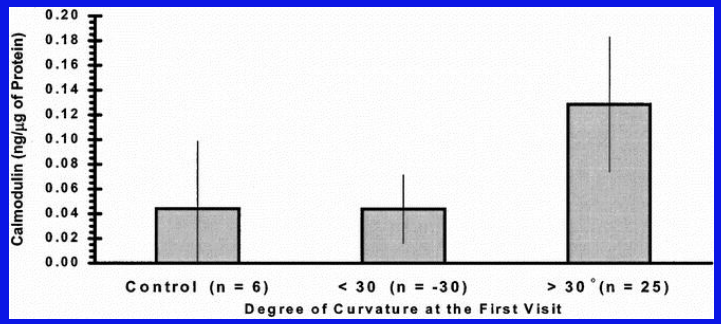
. Calmodulin regulates the contractile properties trough its interaction with actin and myosin

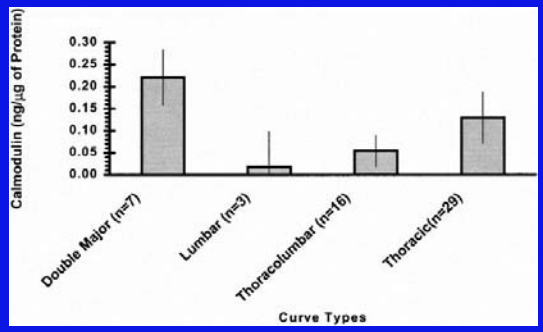
Secretion in correlation with melatonin

Dr Jocelyne Enouf,Hôpital Lariboisière, Paris.

Calmodulin

Lowe 2002





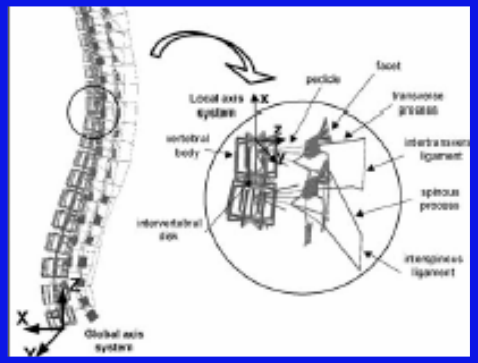
Results. Calmodulin levels increased in all the patients with progressive curves (13/13), remained stable in 73% of the patients with nonprogressive curves (11/15), and were higher generally in curves greater than 30° and double structural curves. Calmodulin levels usually decreased in patients undergoing brace treatment (14/17) or spine fusion (9/10).

Correlation with nonprogressive curves was not as consistent, with 27% non correlation.

Lowe T, Lawellin D, Smith D, Price C and Al. Platelet Calmodulin Levels in Adolescent IdiopathicScoliosis: Do the Levels Correlate With Curve Progression and Severity? Spine 2002; 27: 768-775

Mechanical; frontal plane

Villemure 2004



Biomechanical spine finite element model

Five pathogenesis hypotheses of AIS from an initial geometrical eccentricity;

Line imbalance of 3mm or 2° rotation leads to right thoracic scoliosis up to 39° with an apical vertebral rotation up to 7° while the apical wedging increase to 8.5°

A sole eccentricity in the sagittal plane generated a non significant frontal plane deformity

Villemure I, Aubin C, Dansereau J, Labelle H. Biomechanical simulations of the spine deformation process in adolescent idiopathic scoliosis from different pathogenesis hypotheses. Eur Spine J 2004; 13: 83 - 90

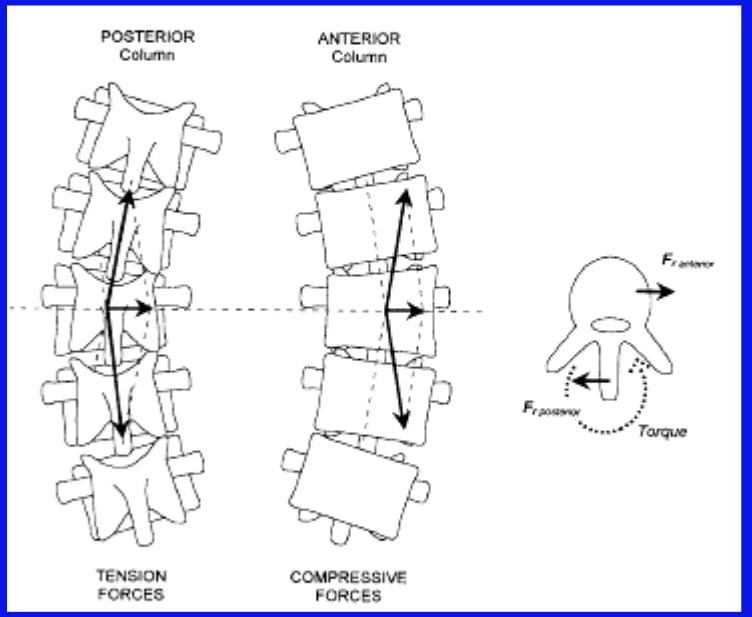
Mechanical; sagittal plane

Vedhuizen 2000

Euler Theory

Deacon, Dickson and co-workers reported that the height of the anterior vertebral body of the apical vertebra was significantly greater than the posterior vertebral body height

Thoracic lordosis which is cause by an overgrowth of the anterior part of the vertebral body, triggers the initiation of scoliosis by buckling

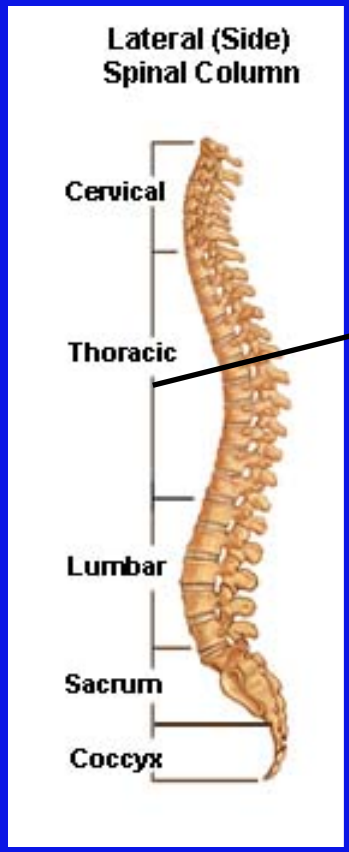


Vedhuizen A, Wever D, Webb P. The aetiology of idiopathic scoliosis: biomechanical and neuromuscular factors. Eur Spine J 2000; 9: 178 – 184.

Mechanical; sagittal plane

Castelein 2005

Backward inclination



Frontward inclination

Backward inclination of the thoracic vertebrae rather than lordotic condition could play a role in the mechanism of rotation and thus the onset and progression of AIS

Facet orientation, predominant posterior location and longitudinal alignment of major muscles and ligament are not well suited to counteract dorsal shear forces

Castelein R, Van Dieên J, Smit T. The role of dorsal shear forces in the pathogenesis of adolescent idiopathic scoliosis. A hypothesis. Medical Hypotheses 2005; 65: 501 - 508.

The Thoracospinal Theory

Sevastik 1998

Rib osteotomy/shortening in growing rabbits induces scoliosis

In 5 of 6 deceased women with right convex thoracic IS, the left ribs were somewhat longer than the right ones

The left breast in scoliotic, but not in normal, girls was significantly more vascularized than that of the right one

In growing rabbits resection of 4 intercostal nerves, including the sympathetic fibres, leads to increased vascularity of the denervated hemithorax, increased osteogenetic activity at the costochondral junction, increased longitudinal rib growth and progressive scoliosis concave to the side of denervation, with decreased kyphosis and vertebral rotation to the convexity.

Sevastik, J. A. The role of the ribs in the pathogenesis of idiopathic scoliosis J Bone Joint Surg 1998 80 B (3S) Supplement III, November 1998, p 223

The Thoracospinal Theory

Sevastik 1998

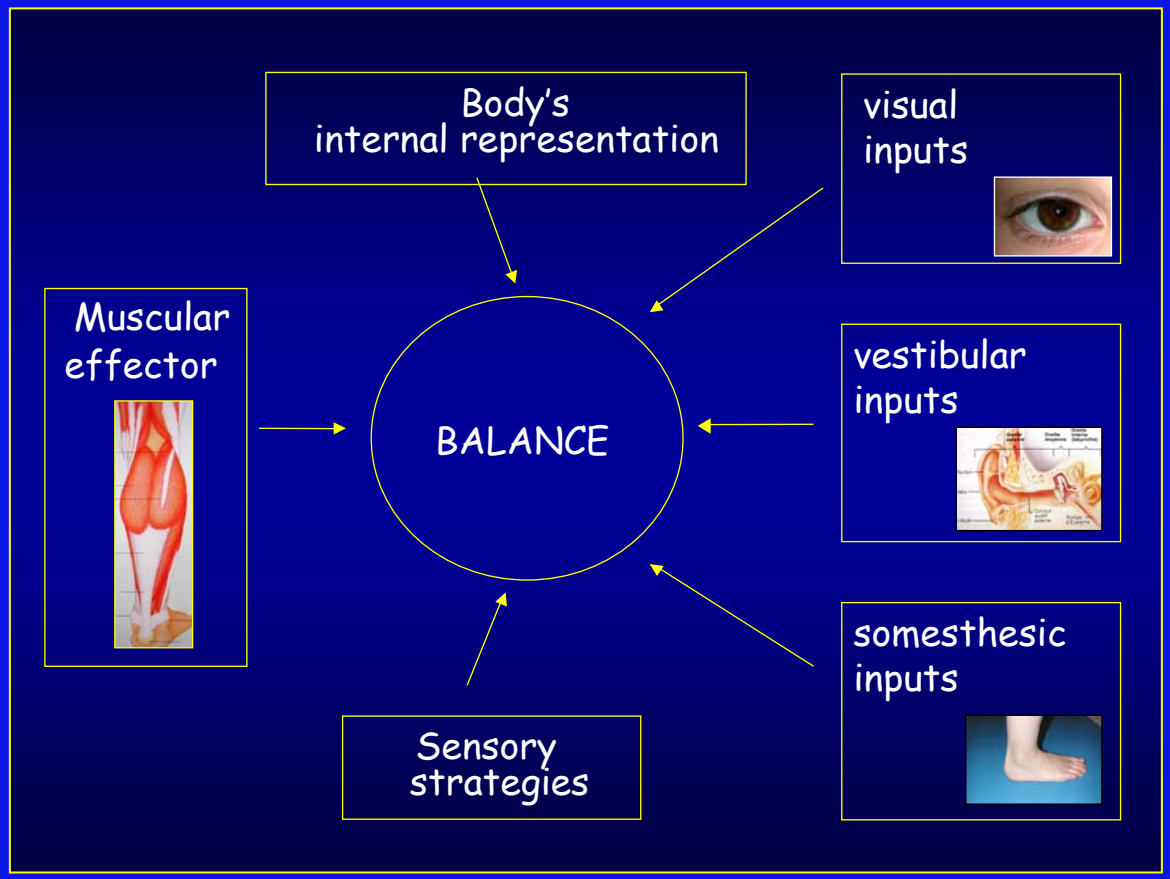
Forced mechanical lengthening of one rib in rabbits produces scoliosis

The thoracospinal theory of the pathogenesis of IS according to which overgrowth of the left ribs, due to hypervascularity of the ipsilateral anterior hemithorax, alters the equilibrium of forces controlling the alignment of the normal spine, as it is predisposed to rotate to the right, and triggers the thoracospinal deformity in IS.

The theory better than any other hypothesis explains the mode of origin of at least the most common form of IS, with location on the thoracic spine, concavity to the left, apex at the T7-T9 level, vertebral rotation to the right, decreasedkyphosis and almost exclusive affection of adolescent girls.

Sevastik, J. A. The role of the ribs in the pathogenesis of idiopathic scoliosis J Bone Joint Surg 1998 80 B (3S) Supplement III, November 1998, p 223

Postural Control



Equilibrium and posture

Docteur Sylvette Wiener-Vacher, Paris

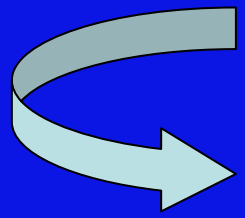
•Predictive and prognosis of vestibular and otolithic tests

Professor Jack Chun Yiu Cheng,
Chinese University of Hong Kong

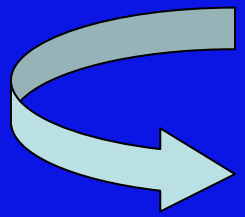
•Relationship between postural equilibrium, evoked somato-sensitive potential and progression of the curve

Equilibrium and posture

Defect in the Vestibular System



Semicircular canal examination



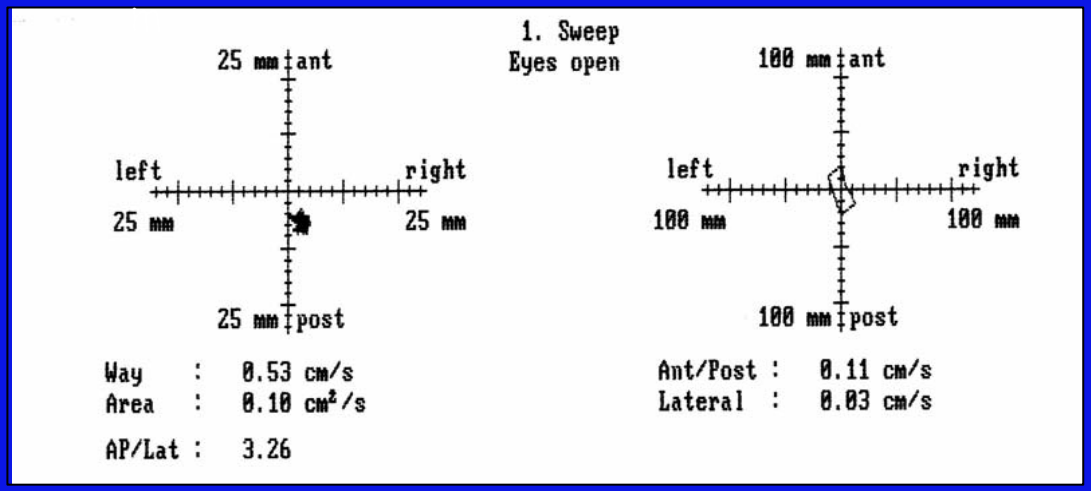
Asymmetric sensitivity

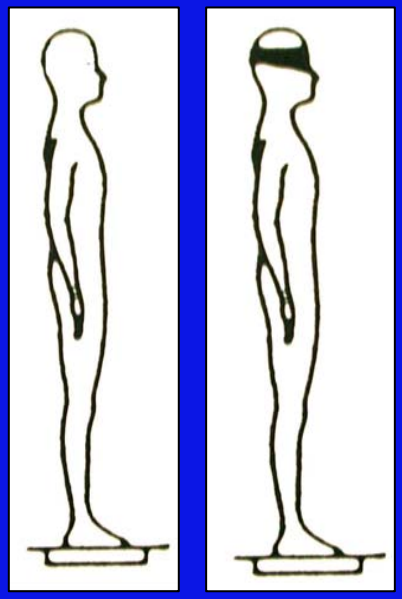
Sahlstrand T, Petruson B, Ortengren R. Vestibular reflex activity in patients with adolescent idiopathic scoliosis: Postural effects during caloric labyrinthine stimulation recorded by stabilometry. Acta Orthop Scand 1979; 50: 275 – 81.

Yamamoto H, Tani T, MacEwan G and Al. An evaluation of brainstem function as a prognostication of early idiopathic scoliosis. J Paediatr Orthop 1982; 2: 521 – 7.

Postural Control

statokinesiogra





Eyes opened

Eyes closed

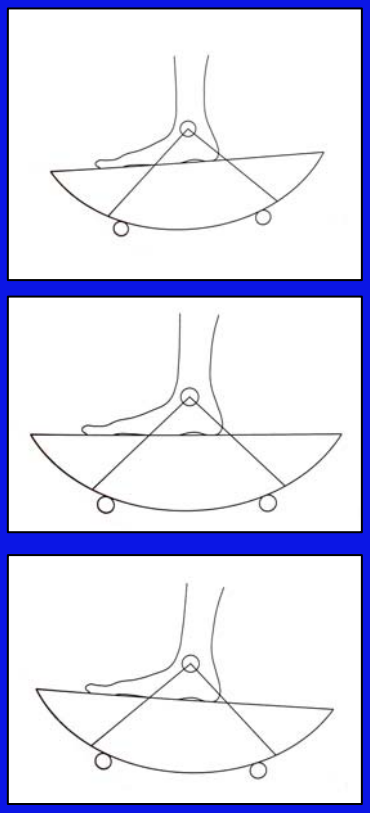
length

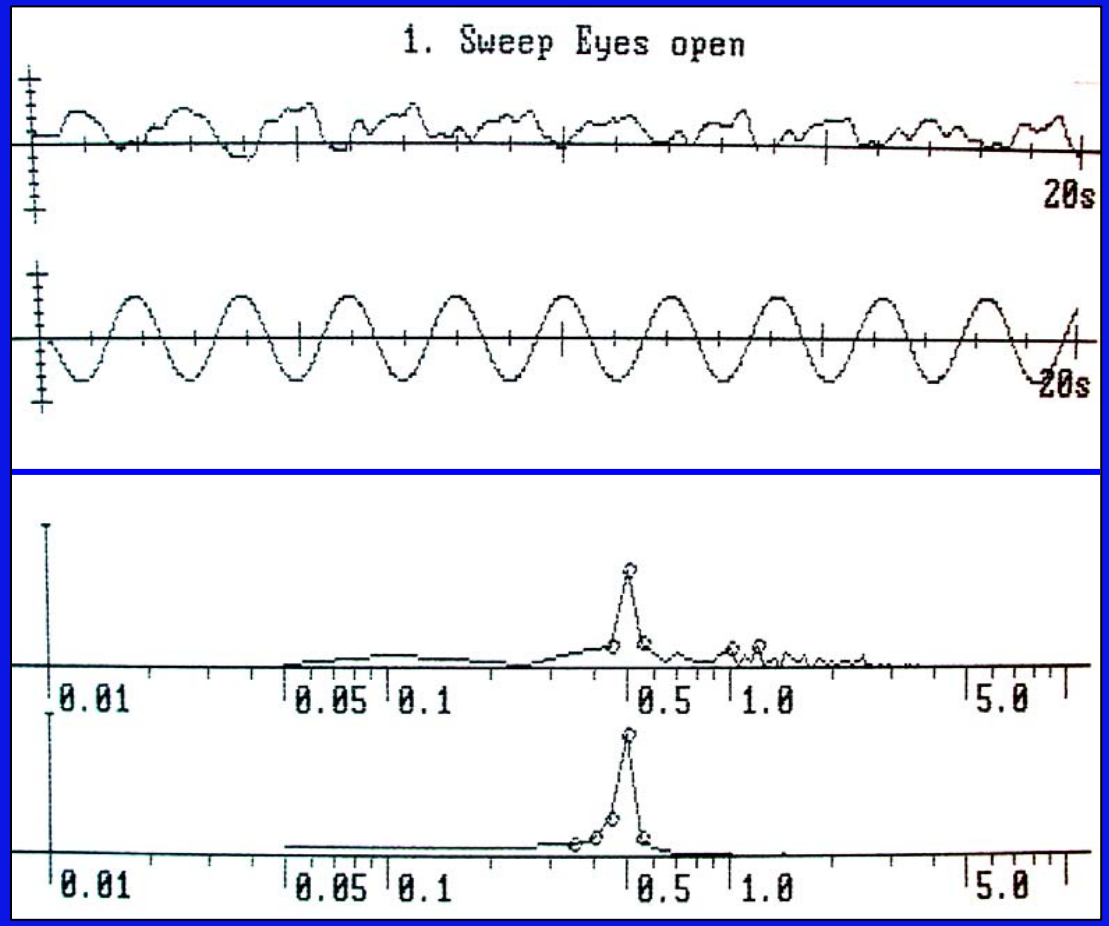
surface

Toennies® GmbH, Freiburg, Allemagne

Gauchard G., Lascombes P., Khunast M, Perrin P. Influence of Different Types of Progressive. Idiopathic Scoliosis on Static and Dynamic Postural Control. Spine 2001; 26: 1052-58

Postural Control



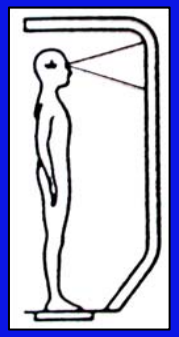
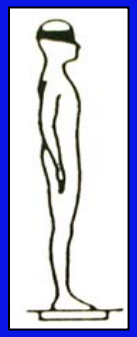
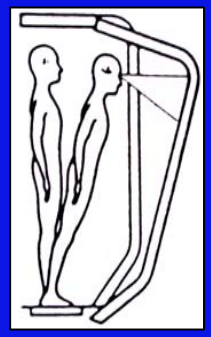
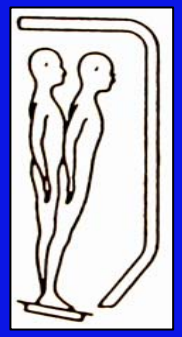
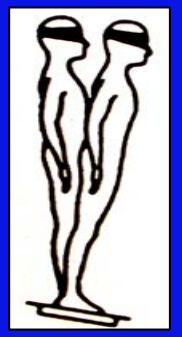
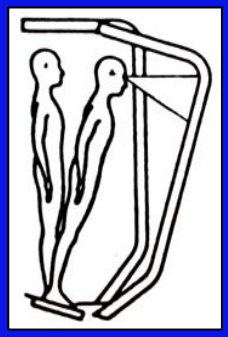


Oscillation amplitude 4°
frequency 0.5 Hz

TYPE 1
slow dynamic test

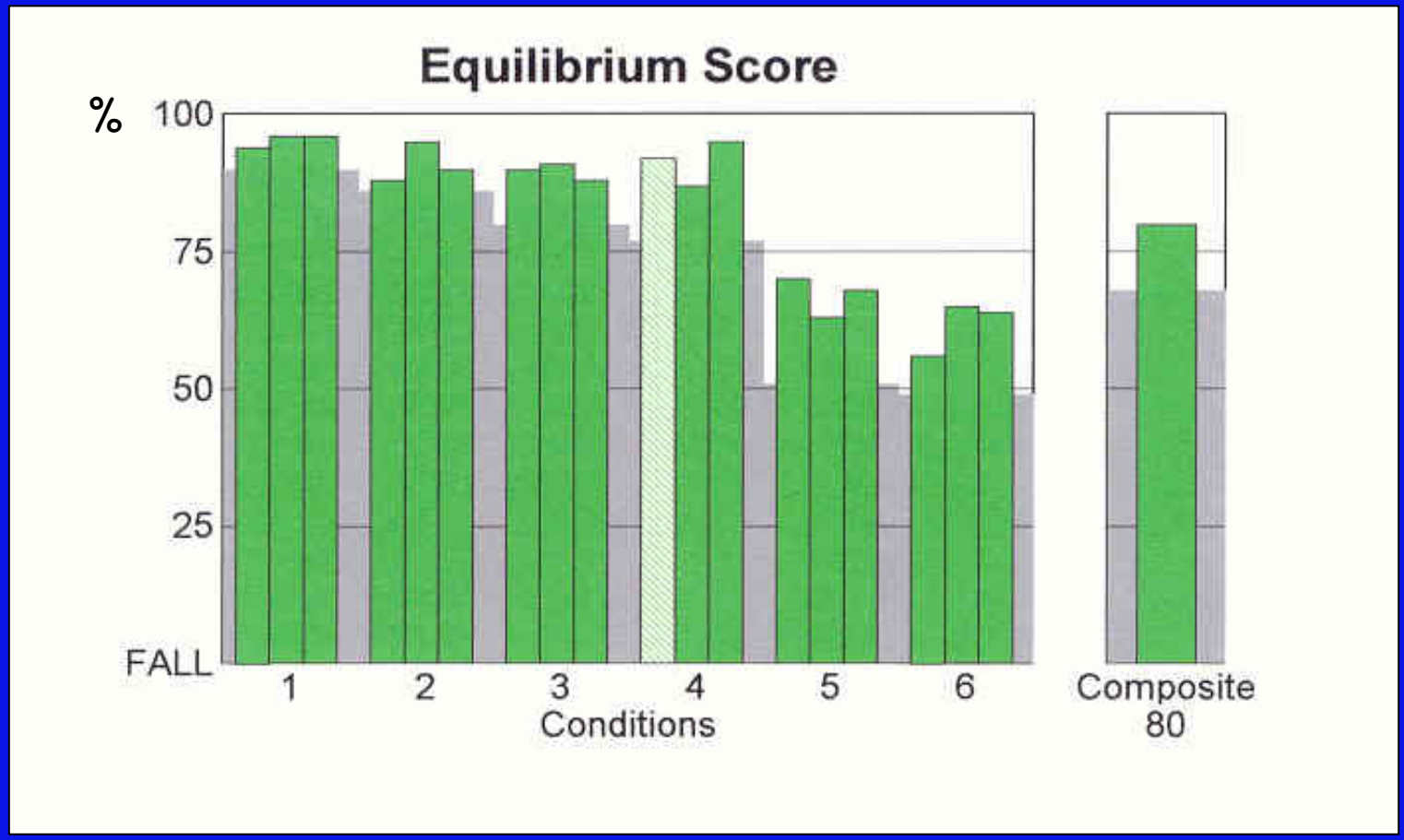
Postural Control

Posturography

Conditions	1	2	3	4	5	6
Vision	+	-	Faussée	+	-	Faussée
Somesthésie	+	+	+	Faussée	Faussée	Faussée
vestibule	+	+	+	+	+	+

Postural Control



Postural Control

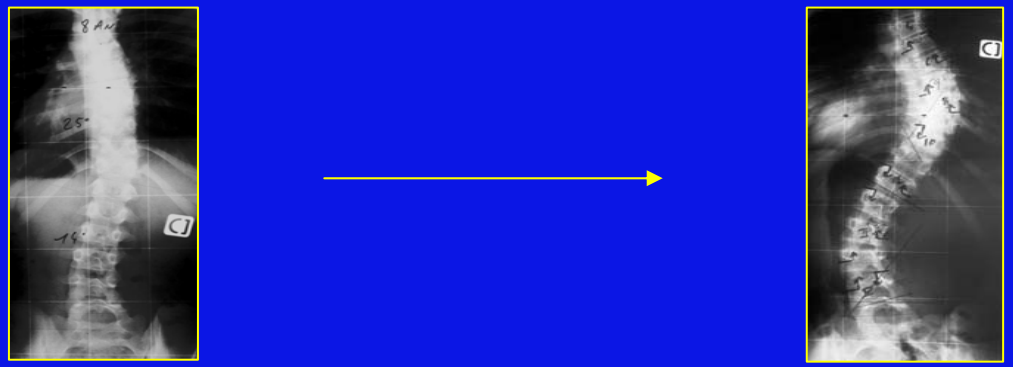
Slow sinusoidal dynamic tests

In group IS >13° (Cobb angle):

- Greater preference in visual inputs
- Greater instability and postural adjustment = lower integration of informations
- Relationship between the importance of spine deformation and the importance of postural control disorders for IS not very severe *at the beginning of their evolution.*

Postural Control

•These sensitive and powerful tools allow the search for a predictive index of the progression of a scoliosis.



The posturography would represent a non invasive examination of choice to pose the indication of an orthopaedic, surgical treatment even medicinal in the future.

Equilibrium and posture

Disorders in smooth visual pursuit in AIS

Disorders in vestibular – induced nystagmus in AIS

Jensen G, Wilson K. Horizontal postrotatory nystagmus response in female subjects with adolescent idiopathic scoliosis. Phys Ther 1979; 59: 1226 – 33.

Yamamoto H, Tani T, MacEwan G and Al. An evaluation of brainstem function as a prognostication of early idiopathic scoliosis. J Paediatr Orthop 1982; 2: 521 – 7.

Proprioceptive disorders in AIS

Barraack R, Whitecloud T, Burke S. Proprioception in idiopathic scoliosis. Spine 1984; 9: 681 – 5.

Keessen W, Crowe A, Hearn M. Proprioceptive accuracy in idiopathic scoliosis. Spine 1992; 17: 149 – 55.

Yekutiel M, Robin G, Yarom R. Proprioceptive function in children with adolescent idiopathic scoliosis. Spine 1981; 6: 560 – 6.

Byl N, Holland S, Jurek A and Al. Postural imbalance and vibratory sensitivity in patients with idiopathic scoliosis: implication for treatment. J Orthop Sports Phys Ther 1997; 26: 60 – 8.

Equilibrium and posture

Disturbed vestibulo – ocular reflex in AIS

Herman R, MacEwan G. Idiopathic Scoliosis: A visuovestibular disorder of the central nervous system. In Zorab P, Siegler D Edits. Scoliosis, 1979. New York: Academic Press, 1979: 61 – 9.

Spontaneous occurrence of nystagmus in AIS

Sahlstrand T, Petruson B. A study of labyrinthine function in patient with adolescent idiopathic scoliosis: 1. An electronystagmographic study. Acta Orthop Scand 1979; 50: 759 – 69.

Gravity – sensitive otolith examination discloses a correlation between idiopathic scoliosis and vestibular asymmetry.

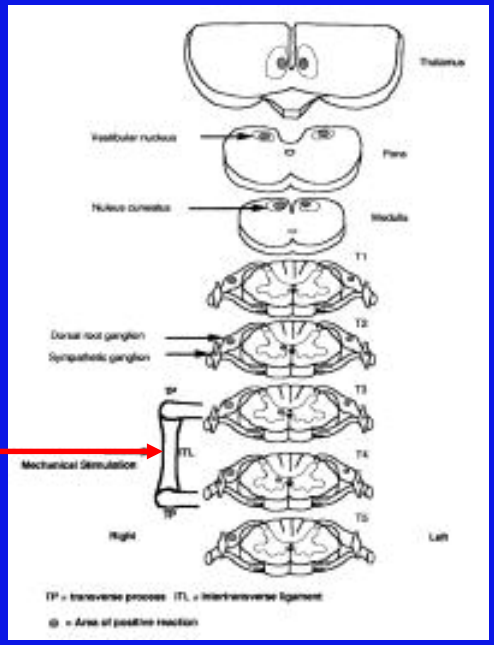
Wiener-Vacher SR, Mazda K. Asymetric otolith vestibulo – ocular responses in children with idiopathic scoliosis. J Paediatr 1998; 132: 1028 – 32.

Postural Control

Sensory feedback from several spinal cord levels on both sides of the spinal cord. This sensory information also is transferred to higher levels in the brain, including the nucleus gracilis and cuneatus, the vestibular nuclei, and the thalamus.

The presence of Fos indicates neurons that had been stimulated

Mechanical stretch on the intertransverse ligament on the right side at T3 – T4 in 4 week-old-chickens.



Jiang H, Moreau M, Raso J, Russell G, Bagnall K. Identification of the location, extent, and pathway of sensory neurologic feedback after mechanical stimulation of a lateral spinal ligament in chickens. Spine 1997; 22: 17 – 25.

Postural Control ; Vision

Catanzariti 2001

75 Children visually handicapped (mean age : 11 Y 7 m) 47 M 28 F

728 Healthy control participants (mean age : 10 Y 2 m) 464 M 264 F

		Clinical exam. Rib hump > 5mm	Moire At least 1 fringe	RX Rot > 5° Cobb > 10°
75	Visually handicapped	26 (34.7%)		18
728	control	42 (5.7%)		

1/3 Cervico – thoracic curves 3/26 evolving conditions

Catanzariti J, Salomez E, Bruandet J, Thevenon A. Visual deficiency and scoliosis Spine 2001; 26: 48 – 52.

Melatonin and vision

Turhan 2006

60 Chickens divided in three groups:

	Scoliosis	Right	Left
Group 1 (20) = Pinealectomy	65%	12	1
Group 2 (20) = Pinealectomy + left side blinded	55%	7	4
Group 3 (20) = Pinealectomy + Right side blinded	60%	7	6

Visually impaired chickens have a significantly higher likehood of left thoracic curves regardless of the side of the blindness

Turhan E, Acaroglu E, Bozkurt G, Alanay A, Yazici M, Surat A. Unilateral enucleation affects the laterality but not the incidence of scoliosis in pinealectomized chicken. Spine 2006; 31: 133 – 8.