EXAMINATION OF THE BACK USING THE BUNNELL SCOLIOMETER IN A BELGIAN SCHOOL POPULATION AROUND PUBERTY

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The present study was designed to determine whether quantified clinical measurement of the back would provide arguments supporting a biomechanical cause of adolescent idiopathic scoliosis (AIS).
Two hundred ninety-two healthy girls (9 to 16 years) and 191 healthy boys (11 to 18 years) were examined clinically with the use of the Bunnell scoliometer. The inter- and intraobserver measurement error was determined.
The accuracy of the Bunnell scoliometer as a biomorphological measurement method is good (variation coefficient ± 10%). The measurement error is not influenced by the site of the rib hump or the type of scoliosis, but by the magnitude of the deformity to be measured.
The present study confirms that the threshold for differentiating a physiological from a pathological gibbosity is 5°, as advanced by Bunnell (1984). The Bunnell measurement shows no statistically significant differences between boys and girls, although the standard deviation of the measurement in the declive segment is larger in girls. In all spinal segments measured, the scoliometer values show the same evolution in the boys and girls of the various age groups. Although the larger standard deviation in the declive segment in girls favors the existence of a physiological scoliosis, the present study shows no evolution in the various spinal segments for the age groups studied, and therefore does not substantiate the biomechanical etiopathogenic theories for the development of AIS.

Keywords : biomorphology ; scoliosis ; back shape ; Bunnell scoliometer ; gibbosity.
Mots-clés : biomorphologie ; scoliose ; topographie du dos ; scoliomètre de Bunnell ; gibbosité.

INTRODUCTION

Adolescent idiopathic scoliosis (AIS) is a spinal deformity characterized by the presence of a curvature and a hump, which is accentuated by having the patient bend forward (Adam's test) (1). In the literature gibbosity measurement has generally been accepted as an objective criterion for AIS screening.

Vercauteren *et al.* (14) studied the back shape of Belgian school children by means of a quantified gibbosity measurement and concluded that trunk asymmetry was a common finding. They were the first to define the limits of physiological scoliosis. Quantitative gibbosity measurement would be the only clinical measurement method directly correlated with the severity of a scoliotic curvature.

The Bunnell scoliometer (3) is a simple and accurate device for gibbosity measurement with a high reproducibility. However, little is known about the possible influence of curve type on the accuracy of the measurement.

According to some biomechanical etiopathogenic theories (3, 13), AIS would develop or progress as a result of a deficient potential to

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control spinal rotation in the thoracolumbar region which gives rise to a gibbosity. Gibbosity measurement should thus be used to study this decompensation (9) in a quantified manner.

Knowledge of the normal scoliometer values in the spinal segments measured (proximal proclive-PPS, distal-DS, and distal proclive segment-DPS (fig. 1)) and their evolution over the various peripubertal age groups might provide arguments in favor of a biomechanical factor in the etiopathogenesis of AIS (3, 13).

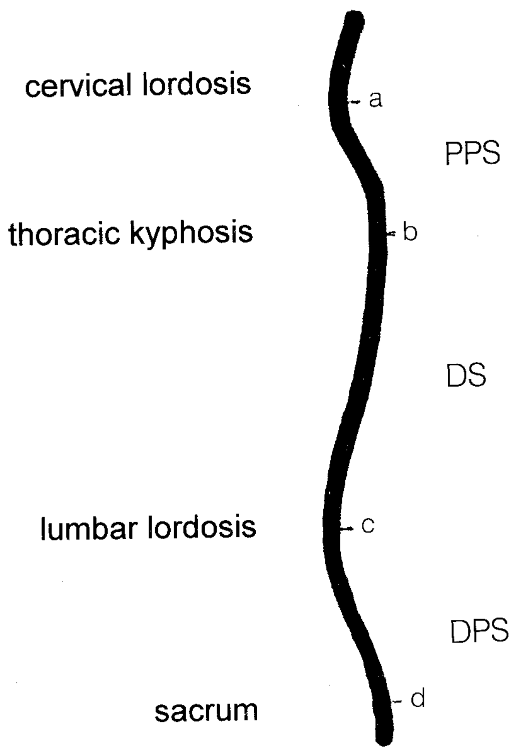

Fig. 1. — Sagittal profile of the spine : proximal proclive (PPS), declive (DS) and distal proclive segment (DPS) of the spine. Sagittal profile of the spine :
— Proximal proclive segment : ab
— Declive segment : bc
— Distal proclive segment : cd

MATERIAL AND METHODS

Our study population included 292 healthy girls and 191 healthy boys from two large schools in the Ghent district. They all had a negative history and a normal school health examination, and were of peripubertal age. Skeletal maturity was assessed using the Tanner and Whitehouse grading system (12). The age distribution is given in table I for the boys and girls of each group examined.

Table I. — Age distribution for the boys and girls of each group examined

Age	Girls	Age	Boys
9 years	24	11 years	22
10 years	49	12 years	25
11 years	41	13 years	24
12 years	49	14 years	26
13 years	36	15 years	24
14 years	41	16 years	26
15 years	36	17 years	22
$\geq$ 16 years	16	18 years	22

Clinical measurement of the gibbosity was performed using the Bunnell scoliometer in the forward-bent test position as described by Adams (1).

For each subject the gibbosity was measured in the 3 spinal segments (PPS, DS, DPS) ; the maximal asymmetry of the two body halves and the left or right orientation were recorded.

The accuracy of the Bunnell measurement was checked as follows : a nonscoliotic child, a patient with moderate scoliosis, one with a severe lumbar curvature and one with severe thoracolumbar scoliosis, all of peripubertal age, were measured several times in the forward bending position with the use of the Bunnell scoliometer. These clinical measurements were performed on the same day by 10 (3 experienced and 7 inexperienced) examiners. For each measurement the patients were repositioned. The declive and distal proclive spinal segment were measured, and the left or right orientation of the deformity was recorded.

To assess the evolution of the Bunnell measurements over the various age groups, linear regression analysis was used (7).

The results of this study indeed represent relative values and are thus independent of the absolute height of the subject examined. A horizontal line indicates no evolution over the various age groups. If the line was not horizontal, it was determined which age groups were situated outside the 95% confidence interval, and the same linear regression analysis was applied to the groups preceding or following these specific age groups. In this way it could be determined if and when stabilization of the parameter occurred.

RESULTS

a. Accuracy of the measurement method

The interobserver error was smaller with experienced observers and was influenced mainly by the magnitude of the deformity to be measured rather than by the site or type of curve (tables II and III).

The same applied to the intraobserver error. A marked improvement was obtained if the first measurement of the inexperienced observers was not considered in the final result (tables IV and V).

Overall, the variation coefficient was about 10%.

b. Results of the Bunnell measurements

In the boys and girls there were only a few age groups that behaved parametrically (fig. 2 and 3). For all spinal segments (PPS, DS, DPS) the evolution over the various peripubertal age groups was the same (the linear regression lines were not significantly different from the horizontal), and there was no statistically significant difference between the boys and girls. However, the standard deviation in the thoracic region (right-sided gibbosity) was larger in girls than in boys. This tendency was not observed in the high-thoracic or lumbar spine (fig. 4).

In girls and boys the two body halves were symmetrical (Bunnell = 0°) in the declive segment

Table II. — Interobserver error with experienced observers (3 observers — mean of 3 measurements in 1 patient)

Bunnell DS	X	SD	CV'
nonscoliotic curve	4.3°	0.4°	11.0%
moderate scoliotic curve (King II)	16.5°	0.4°	2.9%
severe scoliotic curve (King III)	7.7°	0.6°	2.7%
severe scoliotic curve (King IV)	9.4°	0.6°	7.7%
Bunnell DPS	**X**	**SD**	**CV'**
nonscoliotic curve	3.8°	0.4°	9.0%
moderate scoliotic curve (King II)	4.9°	0.5°	11.3%
severe scoliotic curve (King III)	7.3°	0.6°	11.7%
severe scoliotic curve (King IV)	35.7°	2.7°	7.94%

X : mean ; SD : standard deviation ; CV' : corrected variation coefficient for small series = SD × 100/X × (1 + 1/4n).

Table III. — Interobserver error with inexperienced observers (7 observers — mean of 3 measurements in 1 patient)

Bunnell DS	X	SD	CV'
nonscoliotic curve	3.9°	1.47°	37.5%
moderate scoliotic curve (King II)	15.4°	1.52°	9.9%
severe scoliotic curve (King III)	8.2°	1.04°	12.7%
severe scoliotic curve (King IV)	8.9°	1.35°	15.2%
Bunnell DPS	**X**	**SD**	**CV'**
nonscoliotic curve	3.5°	1.94°	56.5%
moderate scoliotic curve (King II)	4.8°	4.99°	10.5%
severe scoliotic curve (King III)	8.0°	1.62°	20.4%
severe scoliotic curve (King IV)	8.0°	0.68°	8.5%

X : mean ; SD : standard deviation ; CV' : corrected variation coefficient for small series = SD × 100/X × (1 + 1/4n).

Table IV. — Intraobserver error with experienced observers (same patient — mean of 3 observers — 5 measurements)

Bunnell DS	X	SD	CV'
nonscoliotic curve	4.3°	0.56°	13.65%
moderate scoliotic curve (King I)	16.5°	0.62°	3.98%
severe scoliotic curve (King III)	20.6°	0.56°	2.87%
severe scoliotic curve(King IV)	11.1°	1.20°	11.41%
Bunnell DPS	**X**	**SD**	**CV'**
nonscoliotic curve	3.7°	0.46°	12.95%
moderate scoliotic curve (King I)	4.8°	0.48°	10.44%
severe scoliotic curve (King III)	9.9°	0.40°	4.26%
severe scoliotic curve (King IV)	9.9°	1.10°	11.83%

X : mean ; SD : standard deviation ; CV' : corrected variation coefficient for small series = SD × 100/X × (1 + 1/4n).

Table V. — Intraobserver error with inexperienced observers (same patient — mean of 7 observers — 3 measurements). The first measurement was not taken into account (trial)

Bunnell DS	X	SD	CV'
nonscoliotic curve	3.7°	1.55°	42.2%
moderate scoliotic curve (King II)	14.9°	1.33°	8.9%
severe scoliotic curve (King III)	18.6°	0.66°	7.8%
severe scoliotic curve (King IV)	8.6°	1.09°	12.8%
Bunnell DPS	**X**	**SD**	**CV'**
nonscoliotic curve	1.5°	1.5°	48.1%
moderate scoliotic curve (King II)	3.4°	3.4°	39%
severe scoliotic curve (King III)	8.3°	1.0°	12.6%
severe scoliotic curve (King I)	7.9°	0.7°	9.6%

X : mean ; SD : standard deviation ; CV' : corrected variation coefficient for small series = SD × 100/X × (1 + 1/4n).

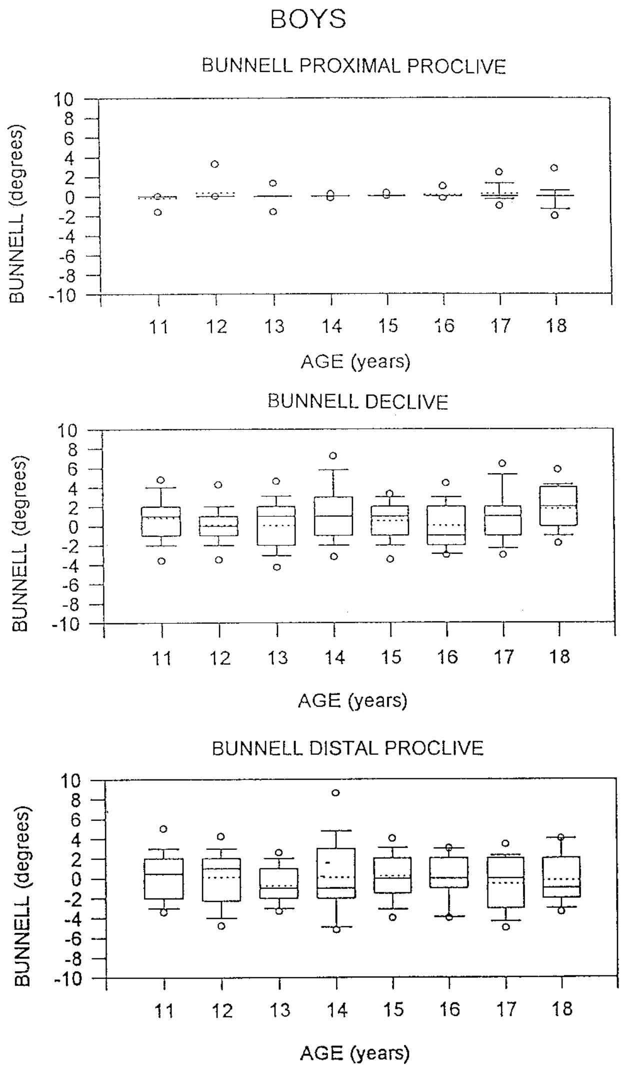

Fig. 2. — Bunnell descriptive statistics — boys
PPS - DS - DPS

- ○ 5th or 95th percentile
- – 10th or 90th percentile
- □ 25th or 75th percentile
- — mean
- ..... median

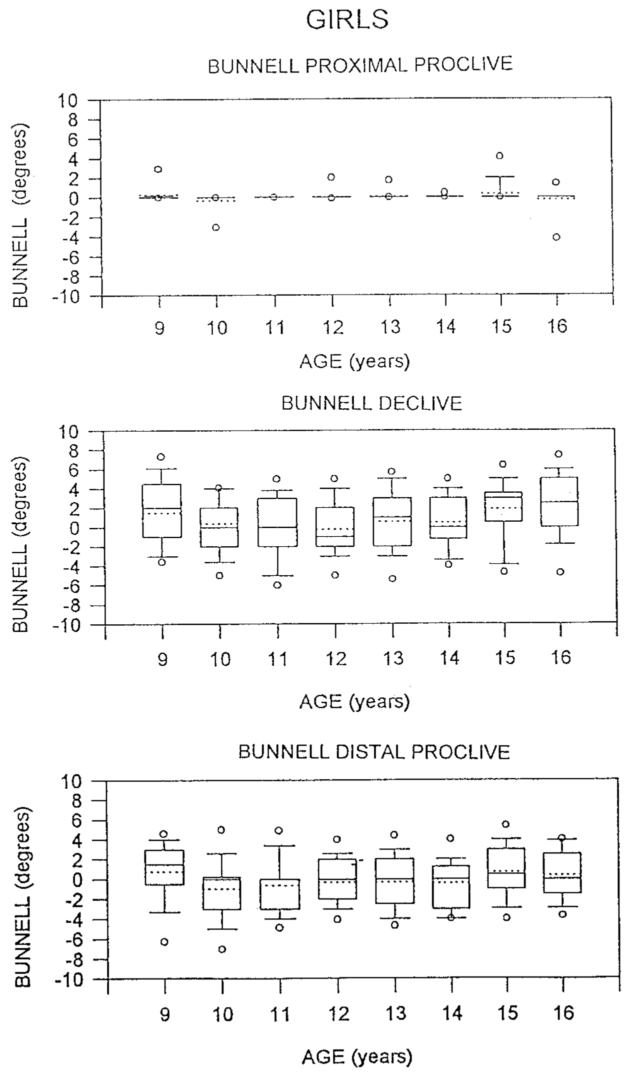

Fig. 3. — Bunnell descriptive statistics — girls
PPS - DS - DPS

- ○ 5th or 95th percentile
- – 10th or 90th percentile
- □ 25th or 75th percentile
- — mean
- ..... median

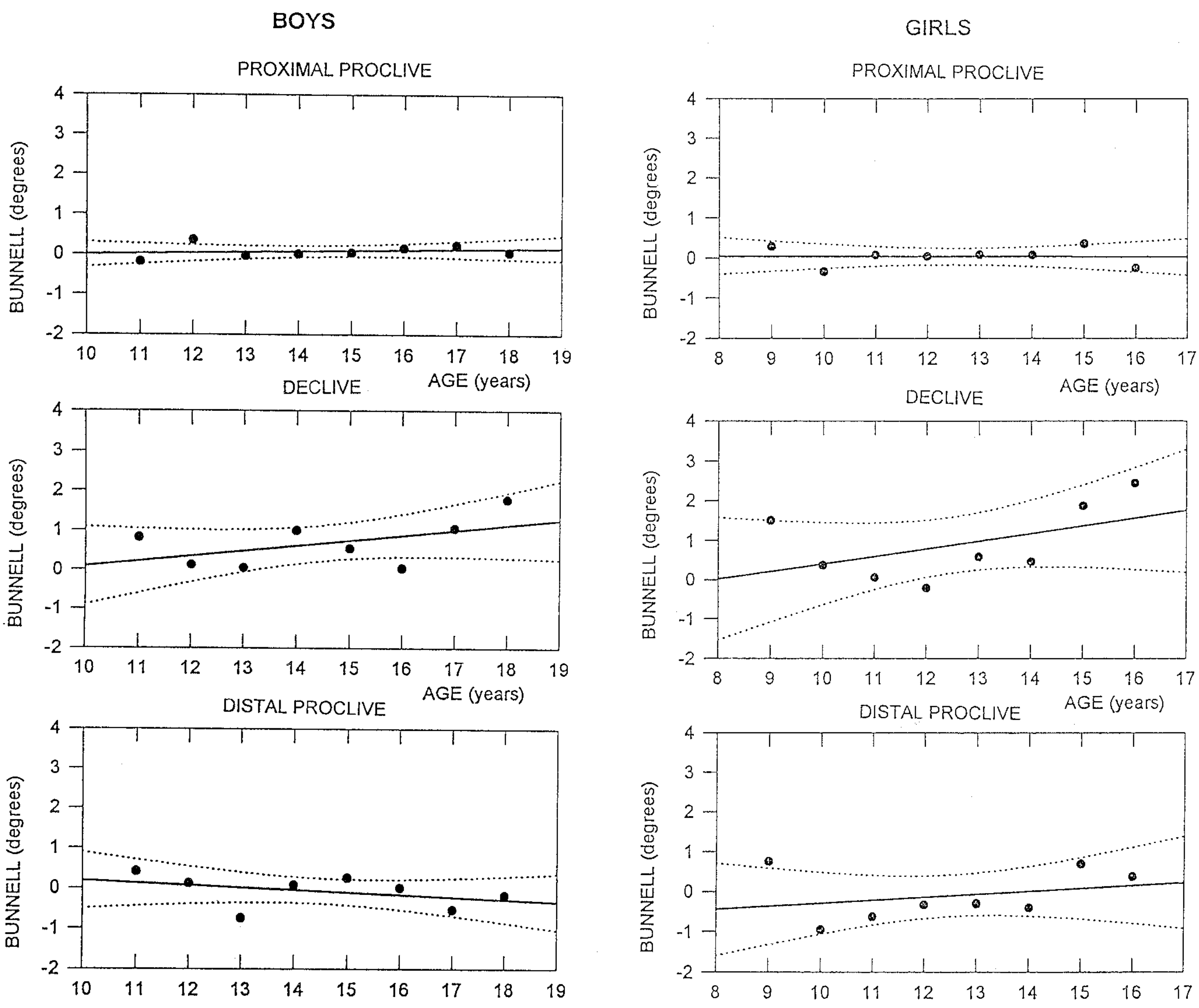

Fig. 4. — Bunnell simple linear regression analysis — boys and girls. PPS - DS - DPS

in 16% and 6%, and in the distal proclive segment in 21% and 10%, respectively.

DISCUSSION

This study was designed to determine whether quantified clinical measurement of the back shape would provide arguments in favor of a biomechanical cause of AIS.

Since AIS becomes manifest mainly in the peripubertal period and is 8 times more prevalent in girls than in boys, healthy adolescents of both sexes were examined around puberty.

From the study of Vercauteren *et al.* (14) it appeared that quantitative measurement of the gibbosity in the forward bending position is the only relevant clinical measurement that can be correlated with the severity of the scoliotic curvature.

According to some biomechanical etiopathogenic theories of AIS (3, 13) the gibbosity would result from and/or aggravate the decompensation of the mechanism controlling spinal rotation. Gibbosity measurement could thus be used to quantify this decompensation (9).

Since the Bunnell scoliometer measures the gibbosity independent of the subject's height (relative value-degrees), a longitudinal study of the various peripubertal age groups can be conducted to identify any differences between the sexes.

a. Accuracy of the Bunnell measurement

AIS measurement with the Bunnell scoliometer is as accurate as the radiographic and Moire measurements (5, 6, 8, 13). The standard deviation is comparable to the values reported in a similar study conducted by Pruijs *et al.* ($<$ and/or $=$ 1.2°-2°) (11). The accuracy diminishes with smaller curvatures, but is not affected by the site of the gibbosity (PPS, DS, DPS) or the type of scoliotic curve. The measurement is preferably performed by an experienced examiner or repeated several times, after which the mean is calculated without considering the first measurement.

The Bunnell measurement perfectly meets the requirements for this longitudinal biomorphological study : it is highly reproducible, both with experienced and inexperienced examiners, completely harmless, and quick and easy to perform.

b. Population study

Whereas the Bunnell measurement shows almost no asymmetry in the high-thoracic region in boys and girls, minor asymmetry between the two body halves (mainly at thoracic but also at lumbar level) appears to be a common finding in both sexes. This is consistent with the findings of Nissinen *et al.* (10), Avikainen and Vaherto (2), and Vercauteren *et al.* (14) (DS : girls 16%, boys 6% - DPS : girls 21%, boys 10%). In all spinal segments the measured values show the same evolution in the boys and girls of the various age groups.

In agreement with the relevant literature (4), it can be stated that a minimum angle of trunk rotation of 5° or more in the declive and/or distal proclive segment in the left or right body half, is a good criterion for identifying pathological curves that require medical referral.

In table VI the pathological Bunnell values for the 3 spinal segments in boys and girls (mean $\pm$ 2 $\times$ SD) and the physiological limits of the Bunnell values, obtained in the 3 spinal segments after

Table VI. — Statistical comparison between boys and girls on the basis of the Bunnell measurements

Segment	Sex	Bunnell value (- = L/+ = R)	Standard deviation	y
PPS	boys	0.0785°	0.911°	accepted
	girls	0.0342°	1.121°	accepted
DS	boys	0.6492°	2.591°	accepted
	girls	0.6541°	3.197°	accepted
DPS	boys	- 0.0733°	2.846°	accepted
	girls	- 0.2329°	2.886°	accepted

The Rank Sum Test was used because of nonparametric distribution. PPS p = 0.802 ; DS p = 0.807 ; DPS p = 0.87.

Table VII. — Pathological Bunnell values for the 3 spinal segments in boys and girls

	boys	girls
PPS	- 1.7° to + 1.9°	- 2.2° to + 2.3°
DS	- 4.5° to + 5.8°	- 5.7° to + 7°
DPS	- 5.8° to + 5.6°	- 6° to + 5.5°

statistical analysis of the results, are given. In the declive segment the standard deviation is larger in girls than in boys. This finding is the only argument found in this study to support a possible biomechanical cause of AIS.

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SAMENVATTING

L. DE WILDE, F. PLASSCHAERT, H. CATTOIR, D. UYTTENDAELE. Het Rugonderzoek met de Bunnellscoliometer van een Belgische Schoolpopulatie rondom de Puberteit.

Deze studie werd opgezet om na te gaan of aan de hand van een gekwantifieerde klinische meting argumenten konden gevonden worden voor een biomechanische oorzaak van idiopathische scoliose adolescentium (AIS).
Er werd een klinisch onderzoek uitgevoerd bij 292 gezonde meisjes en 191 gezonde jongens, in de peripubertaire leeftijd (meisjes : 9-16 jaar ; jongens : 11-18 jaar), met de Bunnellscoliometer. De inter- en intraobservermeetfout van deze methode werd bepaald.
De Bunnellmeting wordt voldoende nauwkeurig bevonden als biomorphologische meting (variatiecoëfficient van $\pm$ 10%). Deze fout wordt niet beïnvloed door de situering van de gibbus, noch door het type scoliose, doch wel door de grootte van de te meten afwijking afwijking. Deze studie bevestigt de door Bunnell (1984) vooropgestelde grens van 5° ter differentiatie van een fysiologische met een pathologische gibbus. Er worden geen statisch significante verschillen weerhouden tussen de sexes onderling aan de hand van de Bunnell meting. Desalniettemin is er bij de meisjes een grotere standaarddeviatie op de meting in het declieve segment dan bij de jongens. Er wordt geen verschillende evolutie genoteerd van de gemeten waarden over de verschillende leeftijdsgroepen, noch bij meisjes of jongens, noch voor de verschillende wervelkolomsegmenten.
Daar waar de grotere standaarddeviatie in het declieve segment bij meisjes een argument is voor het bestaan van de fysiologische scoliose, toont deze studie van de meting van de rug met de Bunnellscoliometer geen evolutie aan in de verschillende wervelkolomsegmenten over de bestudeerde leeftijdsgroepen bij de beide sexen, zodat hieruit geen argumenten worden gevonden ter staving van een biomechanische ethiopathogenese van idiopathische scoliosis adolescentium.

RÉSUMÉ

L. DE WILDE, F. PLASSCHAERT, H. CATTOIR, D. UYTTENDAELE. Examen du dos d'une population d'étudiants en âge pubertaire au moyen du scoliomètre de Bunnell.

Les auteurs ont cherché a déterminer si l'évaluation clinique quantifiée du dos pourrait fournir des arguments à l'appui d'une étiologie biomécanique de la scoliose idiopathique de l'adolescent.
Deux cent quatre-vingt douze jeunes filles (9-16 ans) et 191 garçons (11-18 ans) en bonne santé, ont subi un examen clinique au moyen du scoliomètre de Bunnell. L'erreur de mesure inter- et intra-observateur a été déterminée.
La précision du scoliomètre de Bunnell dans l'évaluation biomorphologique est bien connue ; elle est satisfaisante (coéffficient de variation $\pm$ 10%). L'erreur de mesure n'est pas influencée par la localisation de la gibbosité costale ni par le type de scoliose, mais bien par l'importance de la déformation.
Cette étude confirme que le seuil qui permet de distinguer la gibbosité pathologique de celle qui reste physiologique, est de 5°, comme décrit par Bunnell. Les mesures selon Bunnell ne montrent pas de différence significative entre garçons et filles, quoique la déviation standard de la mesure dans le segment déclive soit plus importante chez les filles.
Dans tous les segments rachidiens etudiés, les valeurs scoliométriques des garçons et des filles sont comparables si l'ont tient compte de l'âge.
Bien que la déviation standard plus importante au niveau des segments déclives chez les filles suggère l'existence d'une scoliose physiologique, cette étude ne démontre aucune tendance évolutive au niveau des différents segments rachidiens, parmi les groupes d'âges étudiées.
Ainsi donc l'examen clinique au moyen du scoliomètre de Bunnell ne fournit pas d'arguments à l'appui d'une étiopathogénie biomécanique de la scoliose idiopathique de l'adolescent.