Statistical investigation about spinal clinical asymmetry in a school population

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ARTICLE INFO

Keywords:

Scoliosis

Spine

Physical examination

ABSTRACT

Background: Spinal disorders and obesity are increasing and are an important cause for concern among health-care and educational bodies. There is a wide variability in the literature of clinical positivity for scoliosis in the examination of the spine.

Aim: Our study aims to investigate a relationship between scoliosis hump in schoolchildren and obesity, evaluating different kind of variables.

Methods: The sample was comprised by 478 schoolchildren from Italy, with a mean age of 12.6 years (SD: 1.861). They were classified by using ATR test, body mass index (BMI), the Edinburgh Inventory, the deep flexion test.

Results: Results of ATR test evidence 26 subjects (5,4%) positive for $ATR \geq 7$; 102 subjects (21,3%) positive for $ATR \geq 6$; and finally 191 subjects (40,0%) positive for $ATR \geq 5$. There were 191 (40%) subjects with scoliosis; obesity was present in 62 (13%) cases and, after the regression, associations were found between scoliotic posture and gender, presence of obesity, and flexibility.

Conclusions: Our study confirms a relationship between obesity and scoliosis, which increases with the age. Female subjects have higher risks to develop humps and spinal disorders. It is advisable to use a combination of several parameters to achieve a more sensitive evaluation.

1. Introduction

Idiopathic scoliosis is a three-dimensional deformity of spine and trunk causing asymmetric disposition of the torso, it occurs and progresses more frequently during puberty growth, between 11 and 15 years, and is more prevalent in females.^{1–3} As reflected by numerous studies the prevention at early ages is a crucial aspect to avoid pathologic complications. Spinal alterations, and specifically scoliosis, are deformities that alter the spinal column three-dimensionally (the hump consists of a vertebral rotation), see Fig. 1. These alterations can occur at any stage of life, from the neonatal period, as in congenital scoliosis, to adulthood. Most cases occur during childhood and adolescence, and

usually they evolve asymptotically.^{4,5} The optimal age to perform scoliosis-screening studies is currently a subject of debate in numerous forums.^{6,7} Although many studies acknowledge the limitations of population-based scoliosis screening, they emphasize on the benefits of receiving an early diagnosis and treatment of spinal deformities, thus avoiding future surgical interventions.⁸ Clinical evaluations of the spine asymmetries are based on the following main parameters: plumb line, symmetry of the waist shape, measurement of the hump by gibbometer and scoliometer of Bunnell®. Studies performed on the relationship between obesity and scoliosis are limited, but in the past few decades, attention has been paid to investigate overweight patients affected by spinal deformities.^{9,10} On the contrary, more evidence in literature can

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<https://doi.org/10.1016/j.jor.2020.08.011>

Received 18 June 2020; Accepted 11 August 2020

Available online 18 August 2020

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be found in studies highlighting the relationship between scoliosis and hand dominance, the method of transporting school supplies or spine flexibilization.^{11–13} Aim of this work is to investigate different parameters as obesity, gender, presence of scoliotic posture/hump, flexibility, in order to develop a relationship with the presence of lateral spinal deviations.

2. Materials and methods

Prevalence of spine asymmetries was investigated, between March and May 2015, in a population of subjects (from 11 to 14 years), living in Messina (Italy). An informational meeting was held to explain the methodology of the research, and application forms were delivered to each participant in order to collect anamnesis data and authorize the treatment of sensitive personal data. The current study was examined and approved by the Ethics Committee of the University of Messina. The average error of measurements, carried on the gibbonometer and scolimeter, was estimated in 3 mm. Clinical examination has been designed to be quick-run and easily repeatable, and subjects were examined with their underwear or swimsuit. The assessment included: inspection of the spine in the upright position, lateral deviation from the plumb line, index of kyphosis and lordosis, Adam's test (Forward Bending Test), ATR test by Bunnell scolimeter® and sizing of humps by gibbometer. Humps with ATR $\geq 5^\circ$ and/or height ≥ 5 mm were considered clinically relevant, according to the Italian Guidelines. More detailed data concerning population are reported in Table 1.

Adams' test is one of the most widely used techniques for detection of orthopaedic spinal alterations, able to distinguish between scoliotic attitude and structured scoliosis. It consists in measuring an increase of the relief lateral to the spinal axis, when the patient makes a 50 to 65° forward flexion of the trunk. If a hump or prominence is found patient is defined positive otherwise negative.

The body mass index, BMI, is defined as eq. (1):

$$\text{BMI} = W / \sqrt{h} \quad [1]$$

Where:

W = weight in kg; h = height in cm

Table 1

Demographic and anthropometric characteristics of the sample.

	Unit [.]	Total Sample (n° 478)	Male (n° 226)	Female (n° 252)
Age Min - Max	[years]	11,5 – 14,6	11,5 – 14,6	11,5 – 14,6
Mean Age (Std. Dev.)	[years]	12,6 (± 0,4)	12,4 (± 0,4)	12,6 (± 0,4)
High Min - Max	[cm]	133,5 – 179,4	133,5 – 179,3	134,2 – 173,6
Mean High (Std. Dev.)	[cm]	154,1 (± 8,1)	154,6 (± 8,8)	153,7 (± 7,2)
Weight Min - Max	[kg]	26,0 – 108,8	29,5 – 108,8	26,6 – 89,8
Mean Weight (Std. Dev.)	[kg]	51,1 (± 11,7)	52 (± 12,9)	50,2 (± 10,3)
BMI Min - Max	/	13,1 – 36,2	14,2 – 36,2	13,1 – 35,2
Mean BMI (Std. Dev.)	/	21,4 (± 3,8)	21,1 (± 3,9)	21,2 (± 3,6)

Four categories are established: low weight, normal weight, overweight and obesity.

The BMI-for-age percentile growth charts are the most commonly used indicator to measure the size and growth patterns of children and teens in the United States. BMI-for-age weight status categories and the corresponding percentiles were based on expert committee recommendations and are shown in Table 2.

To determine spinal flexibility, the deep trunk flexion test was performed, already used in other studies.^{11,14} The subject must squat on marks indicated on the floor, having legs separated by a distance

Table 2

BMI for age weight status categories and the corresponding percentiles.

Weight Status Category	Percentile Range
Underweight	Less than the 5th percentile
Normal or Healthy Weight	5th percentile to less than the 85th percentile
Overweight	85th to less than the 95th percentile
Obese	Equal to or greater than the 95th percentile

Fig. 1. RX image showing scolios deformation.

equivalent to the shoulder's width, and has to slide both hands held together by the palms, as far as possible between the legs, in the backwards direction pushing a marker within a ruler registering the reached distance. A Statistical analysis was carried out using the SPSS 20.0 software for Windows. The statistical technique used was descriptive (frequencies and means), organized by contingency tables of chi-square test, a multivariate binary logistic regression analysis, with scoliosis as dependent variable and age as independent variable. In this model, sex, BMI, and flexibility variables were included, see Table 3.

3. Results

A population of 478 students was involved in this research, results of Bunnel scoliometer and gibbometer analyses are reported in Table 4. As it is possible to notice table include three areas of investigation located in the thoracic, toraco-lumbar, and lumbar zones. The lumbar zone results as the most subjected to humps (about 49%) with the higher presence of $ATR \geq 5^\circ$. On the other hand, the ATR maximum value is registered on the thoracic zone (17°). Moreover, the compared gibbometer analysis confirms previous results evidencing 93 cases in lumbar zone with size of humps ≥ 5 mm. In addition, in this case the maximum value of 25 mm measured for the hump is reached on the thoracic area, results are reported in Table 5 and Fig. 2.

In Table 6 is reported the statistical analysis and chi-square test. As it is possible to notice significant differences can be argued ($p < 0.005$) by comparing scoliosis with gender; female (48%) appears more subjected to spinal deformities than male (27%). Results confirm an increasing tendency to develop scoliotic deformation of the spinal column with the age of the subject. Percentages aging from 38 to 44% were found in students between 13 and 14 years of age. The obesity seems to play an important role in scoliosis as a percentage of about 40% was estimated to be present in these subjects. On the other hand, also low weight students show a similar trend with a percentage of 33%. Finally, flexibility data confirm better results in subject having the presence of scoliotic deformities then the healthy ones. Most participants were right-handed (93,5%).

4. Discussion

In the literature, the prevalence of scoliosis after radiological diagnosis is highly variable: most of the papers reported are between 0.47% and 5.2%.⁶ Also, the prevalence of clinical asymmetries referral to a possible scoliosis, shows considerable differences according to the parameters examined. In fact, using as cut-off an $ATR \geq 5^\circ$ there is a 12% positivity, which is reduced to 3% with a cut-off $\geq 7^\circ$.^{7,8} Considering instead, the height of the hump, for values between 3 mm and 7 mm, shows a positivity of 65.5%, while there is a positivity of 26.2% for values ≥ 8 mm.⁹ The data collected in this study confirm that the prevalence of clinically positive subjects varies considerably with the variation of the cut-offs adopted. By choosing an ATR of $\geq 5^\circ$ or a height of the hump ≥ 5 mm as a parameter for a clinical positivity, the

Table 3
Descriptive analysis of the analyzed variables.

Scoliosis	Number	[%]
Present	194	41%
Absent	284	59%
Weight	Number	[%]
Low weight	112	23,4%
Normal weight	248	51,8%
overweight	56	11,7%
obesity	62	12,9%
Flexibility	Mean Distance [cm]	Std dev
	17,6	5478

Table 4

Number and location of the hump detected by scoliometer and gibbometer (level).

	Unit [.]	BUNNELL® SCOLIOMETER ANALYSES			
		Total Sample	Thoracic	Toraco- Lumbar	Lumbar
Number of humps	/	414 (86,61%)	135 (32,60%)	85 (20,53%)	194 (46,85%)
Location ATR $\geq 5^\circ$	[°]	100 (20,92%)	26 (26,34%)	26 (26,34%)	48 (48%)
ATR Min - Max	[°]	1–17	1–17	1–10	1–10
Mean ATR (Std. Dev.)	[°]	3,3 ($\pm 1,9$)	3,3 ($\pm 1,9$)	3,6 ($\pm 2,3$)	3,5 ($\pm 1,7$)
	Unit [.]	GIBBOMETER ANALYSES			
		Total Sample	Thoracic	Toraco- Lumbar	Lumbar
Number of humps	/	413 (86,40%)	133 (32,20%)	86 (20,82%)	194 (46,97%)
Size of humps ≥ 5 mm	[mm]	194 (40,58%)	64 (32,98%)	37 (19,07%)	93 (47,93%)
Humps height Min - Max	[mm]	1–25	1–25	1–20	1–14
Mean height (Std. Dev.)	[mm]	4,1 ($\pm 3,1$)	4,8 ($\pm 3,2$)	4,4 ($\pm 2,9$)	4,7 ($\pm 2,6$)

Table 5

Location of humps with $5^\circ \leq ATR \leq 7^\circ$ and $5 \text{ mm} \leq \text{height} \leq 10 \text{ mm}$.

	ATR $\geq 5^\circ$	ATR $\geq 6^\circ$	ATR $\geq 7^\circ$	ATR 5°	ATR 6°	ATR $\geq 7^\circ$
Thoracic	26	8	5	18	3	5
Toraco-lumbar	26	12	5	14	7	5
Lumbar	48	22	7	26	15	7
Total Humps	100	42	17	58	25	17
	Height 5–7 mm		Height 8–9 mm		Height ≥ 10 mm	
Thoracic	41		15		8	
Thoraco-lumbar	27		7		3	
Lumbar	62		21		10	
Total Humps	130		43		21	

percentage of patients to be subjected to a second level examination ranging

from 20.9%, considering ATR, to 40.5%, considering the height of the hump. Using more restrictive inclusion parameters, $ATR \geq 6^\circ$ or a height ≥ 8 mm, the number of patients on which to continue the diagnostic procedure is reduced, varying from 8.7% for the ATR assessment to 13.3% for the assessment of height. A further reduction in the number of patients to be addressed to a deepening can be obtained by using a cut-off value of $ATR \geq 7^\circ$ or a height of hump ≥ 10 mm, with percentages ranging from 4.3% based on the millimeter estimation, to 3.5%, based on the ATR value. Considering both the ATR and the height estimation, a total reduction in subjects can be observed with positive results at the first evaluation, indicating an increase in specificity. In addition, with differential cut-offs for the thoracic or thoraco-lumbar region and for the lumbar region, a variation in the percentages of clinical positives may be observed. The need to adopt different cut-off height between the thoracic area/thoraco-lumbar and lumbar region is justified by the different morphology of the hump in the various locations: the lumbar hump is determined by rising transverse processes from the side of the convexity, while at the thoracic level is determined by the elevation of the costal arch. In this last case, the greater distance of the apex of the hump from the rotation center, located on the midline, determines a greater height with equal degrees of rotation (ATR).

As reported in many cases of literature conducted in children populations,^{15–18} more than a third of the children show positive sign on the

Fig. 2. Graph of size distribution vs anatomical location of the humps.

Table 6

Relationships between the scoliosis and the selected variables.

	Frequencies	Percentage	χ^2	(p = .)
Gender				
Male	226	27,0%	64,245	(p = 0,001)
Female	252	48,0%		
Age				
Years 11	141	32,5%	28,568	(p = 0,004)
Years 12	116	35,8%		
Years 13	129	38,2%		
Years 14	92	44,7%		
Weight				
Low weight	17	33,1%	12,458	(p = 0,005)
Normal weight	25	29,6%		
overweight	8	26,8%		
obesity	12	39,9%		
Flexibility				
Presence of deformity mean distance [cm]	17,3	Std dev 5689		(p = 0.001)
Absence of deformity mean distance [cm]	15,9	Std dev 5553		

Adams test (scoliosis hump), also if this percentage doesn't agree with the other screening techniques. Other studies¹⁹ demonstrate as almost 40% of positive subjects do not show any kind of abnormality if analyzed by radiologic and orthopedic test.

In this research a sample of 478 students, 226 male and 252 female, aging from 11 to 14 years of age were analyzed in order to detect spinal deformities or scoliotic attitudes. Most participants were right-handed, with identical values to those found in other studies.^{20,21} A Statistical descriptive analysis was carried out, performing chi-square test and multivariate binary logistic regression analysis. Results show a more evident tendency of female students to develop scoliosis, in accordance with other studies,^{22,23} which refer larger proportions of curves greater than 20° in girls. In particular, the multivariate binary logistic regression analysis girls were found to have a two-fold higher risk of developing a hump compared with boys, at similar age, and BMI category, as confirmed by literature.^{24,25}

Regarding the age in relationship with scoliosis, studies confirm pathology is born in the middle or by the end of the childhood period and is increased upon puberty arrival.²⁶ In accordance with this phenomenon, probably due to incorrect postures protracted for a longer period in a particular phase of the bony growing, our data show the higher frequencies corresponding to the 14 and 13 years of age,

respectively 44,7% and 38,2%.

Obese subjects show higher scoliotic deformities, about 40% of frequencies were found in this kind of subjects. These data confirm those in the reviewed literature,^{27,28} which establish comparisons of scoliosis with sedentary habits, bad ergonomic attitudes, and abnormalities in spinal postures.

Another interesting consideration can be due regarding low weight subjects, in this category a frequency of about 33% was found regarding the scoliosis.

Flexor capability was found to be higher in individuals with scoliotic tendency; differences of about 1,4 cm were found between healthy subjects and scoliotic ones. This could be explained by supposing that higher flexibility would stabilize the spine to a lesser extent, and that this would result in more deformity.

Further research will be carried on to investigate the stress shielding on spinal column in case of deformities. For this purpose Many FE models^{29–40} have been developed in order to investigate from a different point of view what surgical interventions could provoke inside bony and soft tissue.

5. Conclusions

The detected data highlight the extreme variability in the prevalence of spine clinical asymmetries suggestive of scoliosis, varying the considered parameters. For the purpose of early diagnosis and considering the expected percentage of patients with adolescent idiopathic scoliosis, it is advisable to use multiple measurements during the first level examination in order to make the evaluation more specific. An association between ATR $\geq 6^\circ$ valid for the entire spine and of differentiated height of the hump according to the site, ≥ 5 mm ≥ 8 mm lumbar and thoracic/thoraco-lumbar, could be the recommended value. In conclusion more than a third of subjects aging from 11 to 14 present spinal deformities. Female have more risks than male, and the increasing age can influence the arising of this pathology. Obesity results to be significant to encourage scoliosis appearance and flexibility is higher in those individuals with spinal disorders. Finally, further research will be carried on to investigate the relationship between the variables influencing scoliosis.

Declaration of competing interest

I certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

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