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Scoliosis Screening in Public Schools in Antananarivo

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ABSTRACT : Background : Scoliosis affects the growing spine, so it is essential to monitor it regularly during this period ; hence, there is a need for early detection.

Objective : To establish initial reference data and raise awareness of the relevance of systematic and early school-based screening for scoliosis owing to its potential progression and long-term repercussions.

Methods : A descriptive and analytical multicenter cross-sectional study was conducted in public schools located in the districts of Antananarivo Renivohitra and Ambohidratrimo. Stratified cluster sampling was then performed.

Results : Among 780 students, the proportion of screening-positive suspected scoliosis was 10.25% (N=80), based on clinical screening without radiographic confirmation. Distribution by district was more predominant in Antananarivo Renivohitra (52 cases, 65%) than in Ambohidratrimo (28 cases, 35%), with a statistically significant difference (adjusted Odds Ratio (aOR) = 2.3; 95% CI :1.4-3.9 ; P=0.001). The "adolescent scoliosis" category was the most predominant (79 cases, 98.75%). Female were predominantly diagnosed (sex ratio =0.63). Back pain was reported (10.13%) and was associated with higher odds of screening positivity (aOR = 2.1 ; 95% CI : 1.1-3.8 ; P = 0.02). Of these, 26.92% were in late puberty (Tanner stage IV), and compared to Tanner stage I, stage V was associated with an 18-fold increase in odds (aOR 18.4, 95% CI 5.2–65.0 ; P < 0.001). The most frequent curve patterns of screened scoliosis was right thoracic (34.28%).

Conclusions : Adolescent scoliosis was the most screened form, affecting the pubertal stage, with a variable geographical distribution. These findings highlight both the importance and feasibility of early and school-based scoliosis detection, enabling timely identification of "at-risk students" before developing severe spinal deformities with their consequences in adulthood, for which conservative treatments such as Physical Therapy and bracing, are available in the country.

Ethical Compliance : The studies were conducted as medical check-ups in accordance with the local legislation institutional requirements and ethical standards, such as mandatory medical visits before starting the school year. All participants provided written informed consent to participate in this study. Prior consent from the CISCO (Circonsription Scolaire) Chiefs of Antananarivo Renivohitra and Ambohidratrimo, as well as those from the principals of each school, was also required before informing parents or legal guardians of each student. Written informed consent was obtained from the parents and minors'legal guardians for the publication of any potentially identifiable images or data included in this article. There were no possible harms of the screening procedures, and we relied on global expert opinions, considering the perceived harm written in the scientific literature. Ethical approval was not required for this study.

Author Contributions : RPR and GDS designed the research ; RPR and SBR conducted the research ; RPR analyzed the data ; RPR wrote the paper ; RPR, SBR, and GDS had primary responsibility for the final content ; and GDS Academic Advisor. All authors have read and approved the final manuscript.

KEYWORDS : Adolescent, early diagnosis, mandatory screening, scoliosis

INTRODUCTION

Scoliosis is a prevalent musculoskeletal disorder affecting the spine. It is a three-dimensional deformity of part or all of the spinal segment, combined with lateral deviation in the frontal plane, vertebral rotation in the axial plane, and alteration of the sagittal profile [(1–3)]. It is the most common spinal disorder among children and adolescents. Adolescent idiopathic scoliosis is the most common (80-90%) and occurs more frequently in girls during puberty; however, its causes remain unknown [(1,4,5)]. This condition affects the growing spine, and all scoliosis cases diagnosed during the prepubertal period are potentially progressive [(1,6)]. Regular monitoring of scoliosis during growth is essential; therefore, its early detection is necessary [(7)].

School-aged children who are growing are subject to several constraints on their spine, such as carrying a school bag, among others. However, the younger the vertebral structures are, the more abnormal the stresses permanently modify them, and the other components of the spine follow this evolution. Indeed, until the age of 20 years, ossification of the vertebra occurs in its cartilaginous mold, and the greater the latter, the greater the risk of deformity, all the more so if the remaining growth capacity is high. The development of bones, joints, muscles, and tendinoligament structures is linked to the constraints and reciprocal movement of these elements [(2)]. The sooner this malfunction is discovered, the sooner reharmonization can be achieved earlier [(2,6,8)].

If there is no treatment intervention, the degree of deformity will increase and lead to cardiopulmonary complications, back pain, and even paraplegia, which will also lead to social and psychological problems, as well as a decline in labor in adulthood [9,10].

Despite the recommendations of the US Preventive Services Task Force (USPSTF) in 2004 to end mandatory scoliosis screening in the United States, more than half of the states have continued to screen for scoliosis in their schools [(11)]. Since 2008, a working group composed of several medical associations (the American Academy of Orthopedic Surgeons, Scoliosis Research Society, Pediatric Orthopedic Society of North America, and American Academy of Pediatrics) has published a position statement outlining their support for school-based scoliosis screening. This declaration brings scoliosis screening programs into force to detect this deformity at an early stage, thereby avoiding the need for surgery. This is all the more important because for poor or underserved neighborhoods, school-based screening programs for the early dectection of scoliosis are the only chance for a child to get the help they need in time [(12)].

In France, scoliosis was systematically screened by school doctors several years ago in the same manner as dental caries and eye infections. Currently, school-based screening has become increasingly rare and is left to attending physicians, who are general practitioners who see children and adolescents in consultation and who would be best placed to screen for scoliosis. Alternatively, it is the parents who perform the screening; when they discover a bad posture or asymmetry of the shoulders or back that appears flat in profile, they alert doctors [(13)].

In Algeria, the prevention and control of scoliosis in children and adolescents, from primary to secondary school, was included in the 2007-2008 school health program. This program was prioritized to allow early treatment, thus avoiding expensive surgical treatment [(14)].

In Morocco, screening for scoliosis is uncommon. However, a professor of Orthopedics-Child Traumatology in this country (Prof. Abdelhamid Miri) evokes in the newspaper "La vie éco"published in January 2009, the importance of scoliosis screening in order to avoid heavy and expensive surgery [(15)].

There seems to be no mention of this phenomenon in sub-Saharan Africa. There is little cooperation between countries, such as in the case of the Ivorian-Turkish cooperation on two patients aged 13 and 16 years who underwent scoliosis surgery in Tiassalé as part of a scoliosis surgery mission organized by the Turkish hospital group Memorial through Vitalis Santé, a health management company operating in Côte d'Ivoire and the Ivorian Society of Neurosurgery [(16)].

In Madagascar, a low-income country and one of the poorest in the world, there are mandatory medical check-ups before starting the school year and additional visits for students taking national exams. There is also a center located in the capital, at Tsaralalàna, near the fire station, which is similar to the school's medical service. However, there is no real establishment of a school medical system or program ; only a few private schools conduct school medical checkups before the start of each school year. There was no follow-up by a general practitioner or any awareness of the participants. However, there is increasing development of the Physical Medicine and Rehabilitation (PMR) sector in the country, including an increase in the number of physiatrists, as well as many physical therapists in almost the entire country, as well as orthotists that allow for early treatment of scoliosis. This will serve as a significant clinical advantage for these children in the context of preventing and managing non communicable diseases. Early intervention is critical for mitigating the functional impact of scoliosis, specifically cardiopulmonary and neurological complications, chronic pain, and aesthetic concerns while ultimately precluding the need for complex spinal surgery, which remains both invasive and inequitable.

The problem lies in the fact that no information or data is available regarding the extent of this pathology in Madagascar. Therefore, it would be interesting to start a pilot school-based screening initiative on scoliosis, starting with the capital of Madagascar and its urban peripheries, which have physical medicine and rehabilitation departments. This study aimed to establish initial reference data and raise awareness about the relevance of systematic and early school-based screening for scoliosis, owing to its potential progression and long-term repercussions. Moreover, engaging stakeholders such as the Ministry of Public Health and,Ministry of National Education, are crucial for implementing a national school-based musculoskeletal health policy.

Building on the foundational work of Duval-Beaupère and subsequent literature reviews, we hypothesized that scoliosis screening outcomes would be significantly associated with specific demographic and clinical predictors. Specifically, we posit that age group (adolescents), female sex, pubertal status, district of residence, type of educational institution (middle and high school), and presence of back pain are determinant variables that significantly influence the probability of a positive scoliosis screening result.

METHODS

- **Study design and setting**

This descriptive, multicenter, school-based, cross-sectional study was conducted at public schools in two districts of Antananarivo : Antananarivo Renivohitra (urban district) and Ambohidratrimo (peri-urban district).

Screening was conducted in November and December 2022, and data were collected on pre-filled screening sheets.

- **Sampling strategy**

This study used a stratified cluster-sampling design. The sampling process was conducted via randomized selection of public educational institutions using Microsoft Excel and stratified by educational level : preschool, primary, middle, and high school. For each selected school, one class per grade ranging from early childhood education to the final year of secondary school was randomly selected for inclusion. This cross-sectional study was aimed at all students aged 3-19 years who were present on the day of the screening.

As the students were nested within the schools, the sampling design was clustered at the school level.

- **Participants**

All students and their legal guardians were informed of comprehensive information about the screening process. Written informed consent was obtained from the legal guardians of all participating students. Prior consent from the CISCO (Circonsription Scolaire) Chiefs of Antananarivo Renivohitra and Ambohidratrimo, as well as those from the principals of each school, was also required before informing parents or legal guardians of each student.

Refusal participation and incomplete clinical assessment were excluded.

- **Screening procedures**

Physical examination and scoliosis screening were performed in this school-based investigation by a resident in Physical Medicine and Rehabilitation, as well as a physical therapist. They were also responsible for informing teachers and parents about the goals and procedures of the school scoliosis-screening study. The presence of one parent, legal guardian, or a support person, as well as the teacher in charge of the children in preschool and primary school, was necessary to reassure the child to carry out the screening.

The variables under investigation included sociodemographic characteristics, family history of spinal disorders, and personal and medical histories indicative of potential secondary etiologies of scoliosis. Furthermore, data derived from clinical examinations of the screened students were systematically recorded and analyzed.

Visual inspection, Adam's forward bending test and measurements of the Angle of Trunk Rotation (ATR) using a scoliometer were used for scoliosis screening. The clinical examination criteria were as follows :

-shoulder and scapula prominence asymmetries, unequal waistline and lower limb length discrepancy for visual inspection

-asymmetry of the trunk, corresponding to a rib hump appearing on Adam's forward bending test because the presence of a rib hump is pathognomonic for the clinical diagnosis of scoliosis.

The examiners measured the ATR of the rib hump by using a scoliometer. A screening-positive result was defined as ATR $\geq 5°$ based on the Adams forward bend test and scoliometer measurements. Students with an ATR between 3° and 4° were categorized as 'variation of the norm' and were not considered screening-positive.

Radiographic confirmation (Cobb angle measurement) was recommended for all screening-positive students but was not systematically performed for this simple screening procedure. Therefore, the outcome reflects screening for suspected scoliosis rather than radiographically confirmed scoliosis.

- **Variables**

Outcome Variable :

Binary outcome:

1 = Screening-positive suspected scoliosis (ATR $\geq 5°$)

0 = No scoliosis (including variation of the norm)

Independent variables :

The following variables were examined:

-district of residence (Antananarivo vs Ambohidratrimo)

-sex (male/female)

-Education level (preschool and primary, middle, and high school)

-age group (3–9 years; 10–19 years)

-pubertal status (Tanner stages I–V)

-Self-reported back pain (yes or no)

As age group, school level, and Tanner stage are developmentally correlated, Tanner stage was selected as the primary developmental variable in the multivariable analyses to reduce multicollinearity.

- **Statistical analysis**

The Epi-info 7 and R version 4.2. were used for all statistical analyses.

***Descriptive analysis :**

Categorical variables were summarized as counts and percentages. Descriptive statistics were calculated for all the variables.

Continuous variables were summarized as mean ± standard deviation where appropriate.

***Univariate analysis :**

Associations between each independent variable and screening-positive suspected scoliosis were initially assessed using contingency tables.

Given the sparse cell counts in some categories, Although the Pearson's chi-squared test was initially considered, preliminary data screening revealed that several cells had expected frequencies of less than 5. Consequently, to ensure the validity and precision of the results, Fisher's exact test (Fisher-Freeman-Halton extension for R×C tables) was used when appropriate, as it provides an exact P-value rather than a large-sample approximation. Statistical significance was set at P = 0.05.

***Multivariable analysis :**

A multivariate logistic regression model was constructed to assess independent associations between sociodemographic and clinical variables and screening for suspected scoliosis. The adjusted odds ratios (aOR) and 95% confidence intervals were calculated and reported.

The variables included in the primary model were district, sex, back pain, and Tanner stage.

Multicollinearity was assessed prior to model construction, using variance inflation factors.

***Adjustment for Clustered Design**

Because of clustered sampling (students nested within schools), two approaches were used.

-Logistic regression with cluster-robust standard errors at the school level.

-Mixed-effects logistic regression including a random intercept for school.

These approaches account for within-school correlation and prevent underestimation of standard errors.

Statistical significance was defined as $\alpha = 0.05$.

RESULTS

In the district of Ambohidratrimo, the schools included in this study were as follows:

- Ecole Primaire Public (EPP) Ilaivola which had a total of 144 pupils,
- Collège d'Enseignement Général (CEG) Ambohidratrimo, with a total of 1050 students,
- Lycée Ambohidratrimo which had 1280 students.

Here are every establishments selected from the district of Antananarivo Renivohitra:

- Ecole Primaire Public (EPP) Volosarika which had 435 students,
- Collège d'Enseignement Général (CEG) Nanisana which had 712 students,
- Lycée Analamahitsy which had 1119 students.

Each school has an average of 50 students per class. The distribution of the number of students screened by district is summarized in the following table (Table 1).

Table 1 : Total of students screened

	District of Ambohidratrimo	District of Antananarivo renivohitra	Total
Preschool ans primary school (EPP)	139	111	250
Middle school (CEG)	188	90	278
High school (Lycée)	96	156	252
Total screened	423	357	780

A total of 780 students were screened across selected public schools in the Antananarivo Renivohitra and Ambohidratrimo Districts.

Among the 780 students investigated, 80 met the predefined criterion for screening-positive suspected scoliosis (10.25%) using the forward bend test and measuring the angle of trunk rotation of the rib hump using a scoliometer (ATR $\geq$ 5°) (Table 2).

The sample size comprised 780 participants, including 80 positive events (10.3% prevalence). For the logistic regression model, we adhered to the methodological guidelines proposed by Peduzzi *et al.* regarding the number of events per variable (EPV). With six explanatory variables (district of residence, sex, educational level, age group, pubertal status, and self-reported back pain) included in the final model and 80 observed events, the EPV ratio was 13.3. This ratio exceeded the standard threshold of 10, thereby ensuring the stability of the coefficients and minimizing the risk of model overfitting.

A post hoc power analysis (assuming an alpha level of 0.05 and a target power of 0.80) confirmed that the current sample size provided sufficient statistical power to detect meaningful associations with adequate precision.

Among these 80 cases, there were more cases in the district of Antananarivo Renivohitra (N=52 ; 65%) than in the district of Ambohidratrimo (N=28 ; 35%). Only rib humps with an ATR greater than or equal to 5° were considered screened-positive suspected scoliosis. Rib humps with an ATR of less than 5° are considered variations of the norm, with negligible potential for progression.

Table 2 : Total of students screened positive to scoliosis

	District of Ambohidratrimo	District of Antananarivo renivohitra	Total
Students screened	423	357	780

Variation of the norm (ATR=3°-4°)	5	12	17
Screening-positive suspected scoliosis (ATR ≥ 5°)	**28**	**52**	**80 (10.25%)**

No radiographic confirmation was available as its confirmation was not systematically performed ; therefore, findings reflect screening-positive suspected scoliosis rather than confirmed structural scoliosis.
Whole-spine radiographic medical imaging data were not used in this study.

Screening-positive suspected scoliosis cases were classified according to juvenile scoliosis for the group between 3 and 9 years of age ; and adolescent scoliosis for those between 10 and 19 years of age. Adolescent scoliosis was the most common (98.75%) (Table 3).

Table 3 : Cases of screening-positive suspected scoliosis by age group

Age range	Cases of scoliosis N (%)	Corresponding category
[3 – 9 years old]	1 (1.25%)	Juvenile scoliosis
[10 – 19 years old]	79 (98.75%)	Adolescent scoliosis

The students who screened positive for suspected scoliosis included 31 male and 49 female (sex ratio, 0.63).
The right thoracic location of scoliosis was the most marked (34.28%), followed by the left thoracic curvature (20.95%), junctional localization such as the right thoracolumbar curvature (13.33%), left thoracolumbar curvature (9.52%), left lumbar localization (8.57%), and right lumbar curvature (6.67%). Double localization, including right thoracic and left lumbar localization (4.78%) and left thoracic and right lumbar curvatures (1.90%), was also observed. The findings are presented in Figure 1.
The students screened positive for suspected scoliosis in their prepubertal and pubertal stages, of which the late pubertal stage was the most marked (26.92%), corresponding to Tanner stage IV. This is illustrated in Figure 2.
Ten students (12.50%) had a family history of spinal disorder (Figure 3). Regarding the personal histories of the students, less than 2% were born prematurely (Figure 4). Only 1.25% of participants showed a delay in psychomotor development (Figure 5). Ten percent of those who screened positive for scoliosis had a history of epilepsy (Figure 6). A student presented with skin signs (café-au-lait macules) that led to the suspicion of neurofibromatosis of Von Recklinghausen. Five percent of the students screened positive for asthma (Figure 7). Only 10.13% of students experienced back pain (Figure 8).

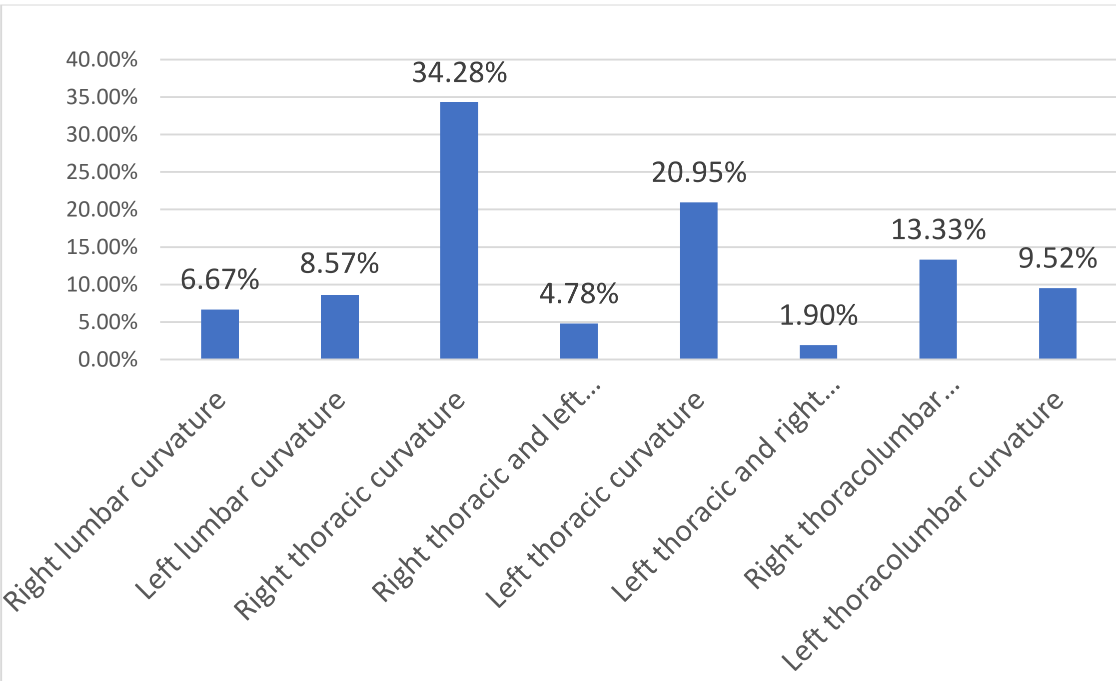

Figure 1 : Clinical location of the suspected scoliosis

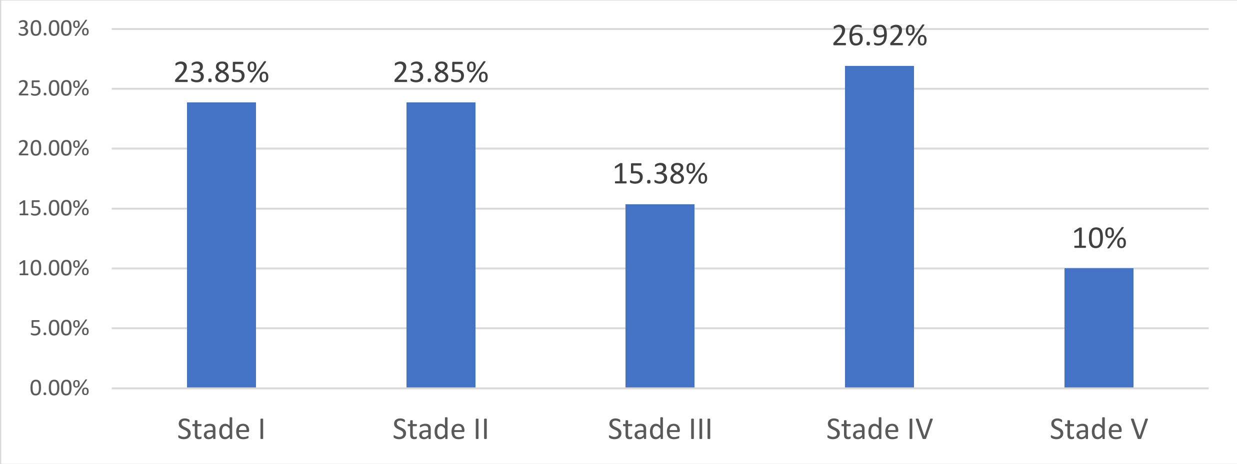

Figure 2 : Distribution of students screened positive for scoliosis by Tanner stage

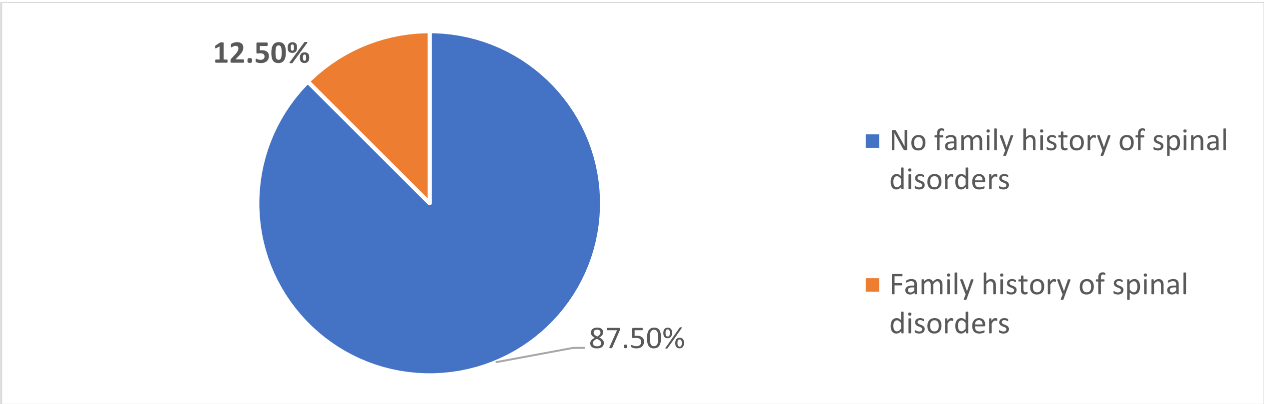

Figure 3 : Family history of a spinal disorder

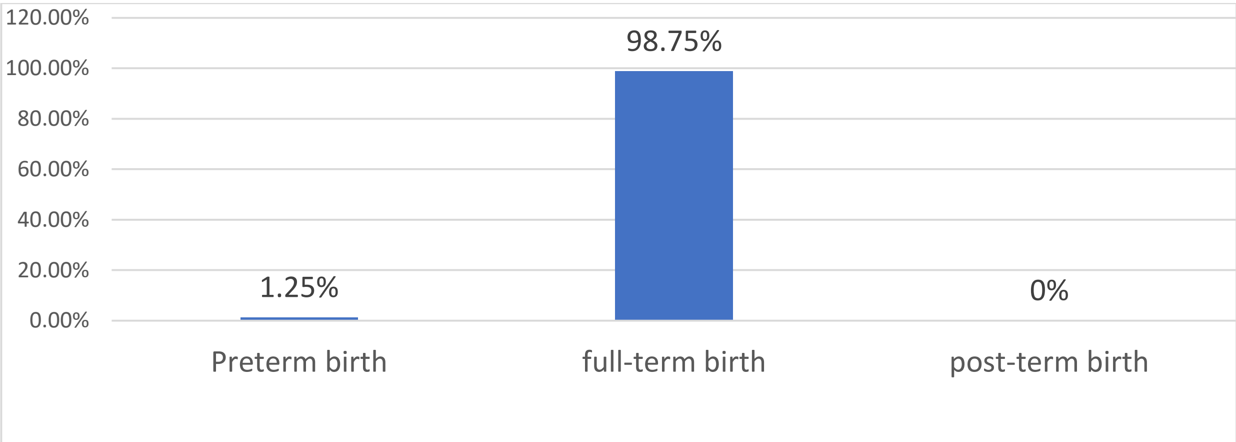

Figure 4 : Personal history of birth

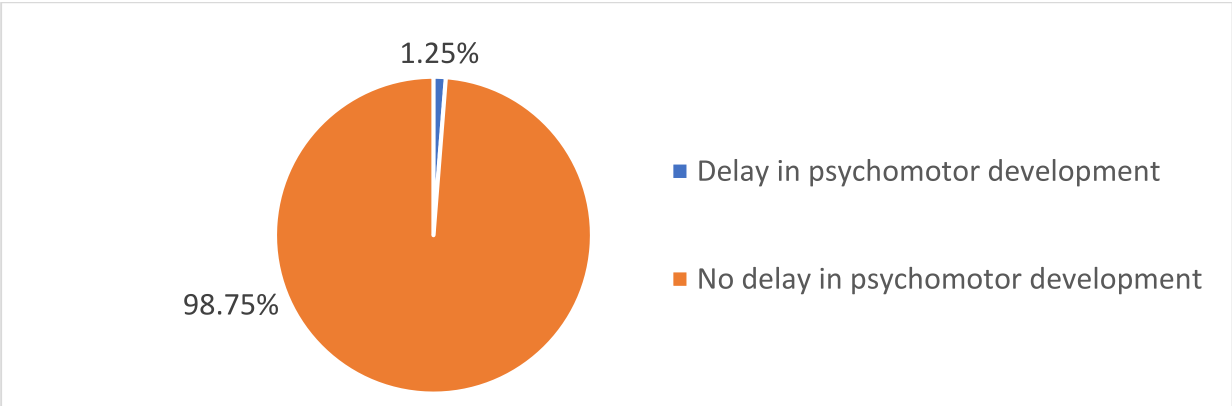

Figure 5 : History of delay in psychomotor developmental

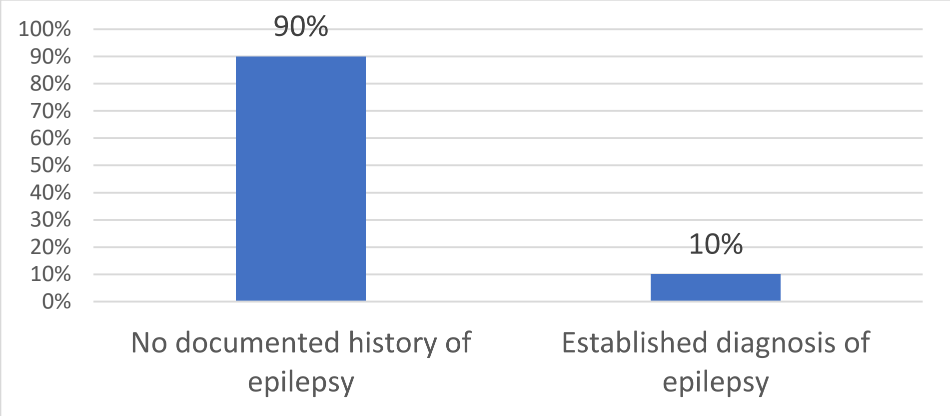

Figure 6 : History of epilepsy

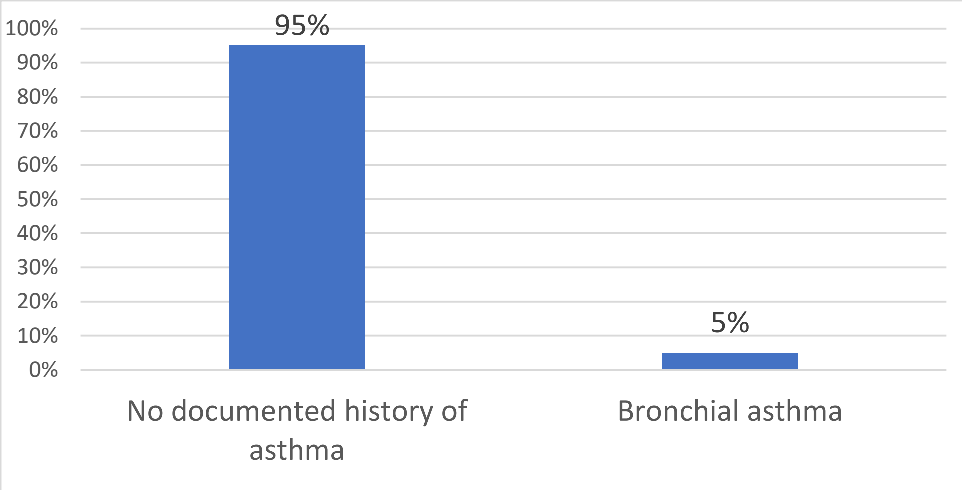

Figure 7 : Asthma status

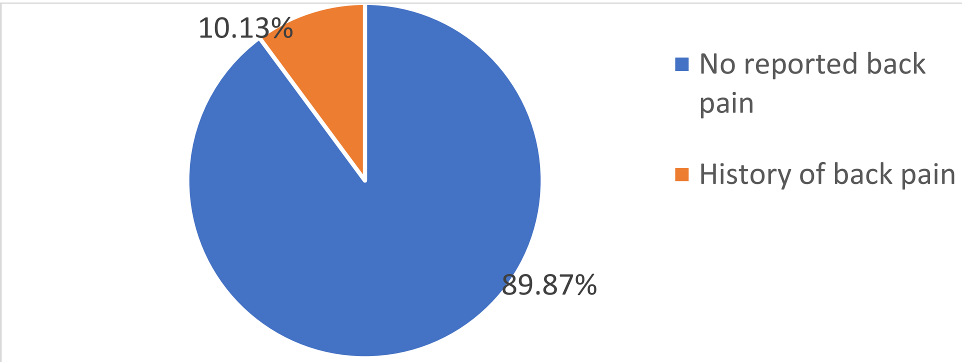

Figure 8 : Back pain status

- **Unadjusted associations : bivariate analyses**

✓ **Geographic distribution**

The distribution of the students screened according to district of affiliation is shown in the following table (Table 4).

Table 4 : Distribution by district

All screened students				
District of residence	**No scoliosis**	**Variation in the norm**	**Screening-positive suspected scoliosis**	**Total**
Ambohidratrimo	390	5	28	423
Row%	92.20%	1.18%	6.62%	100.00%
Col%	57.10%	29.41%	35.00%	54.23%

Antananarivo Renivohitra	293	12	52	357
Row%	82.07%	3.36%	14.57%	100.00%
Col%	42.90%	70.59%	65.00%	45.77%
TOTAL	683	17	80	780
Row%	87.56%	2.18%	10.26%	100.00%
Col%	100.00%	100.00%	100.00%	100.00%

Single Table Analysis

Chi-Squared	df	Probability
18.4103	2	0.0001

Preliminary analysis of the contingency table revealed sparse data for variations in the norm category. Consequently, the Fisher-Freeman-Halton exact test was performed to confirm the observed trends. The resulting exact p-value ($P = 0.0002$) indicated a highly significant association.

Statistical analysis demonstrated a robust relationship between geographic distribution by district of residence and screening for suspected scoliosis ($\chi^2(2) = 18.41$, $P = 0.0001$), indicating a highly significant association. Specifically, the transition from the district of Ambohidratrimo to Antananarivo Renivohitra was associated with a marked increase in the proportion of screened positive categories, from 6.62% to 14.57%.

In unadjusted analyses, differences between districts were observed.

✓ **Educational institution level**

The screened students were divided according to their level of schooling, as illustrated in the following table (Table 5).

Table 5 : Educational institution level

All screened students

Educational level	No scoliosis	Variation in the norm	Screening-positive suspected scoliosis	Total
Preschool and primary school (EPP)	234	7	9	250
Row%	93.60%	2.80%	3.60%	100.00%
Col%	34.26%	41.18%	11.25%	32.05%
Middle school (CEG)	252	3	23	278
Row%	90.65%	1.08%	8.27%	100.00%
Col%	36.90%	17.65%	28.75%	35.64%
High school (Lycée)	197	7	48	252
Row%	78.17%	2.78%	19.05%	100.00%
Col%	28.84%	41.18%	60.00%	32.31%
TOTAL	683	17	80	780
Row%	87.56%	2.18%	10.26%	100.00%
Col%	100.00%	100.00%	100.00%	100.00%

Single Table Analysis

Chi-Squared	df	Probability
37.0975	4	0

The Fisher-Freeman-Halton Exact Test was also performed to confim the observed trends. This yielded an exact P-value < 0.0001 (i.e., extremely significant).

The analysis highlighted a highly significant association between educational institution level and the risk of being screened positive for scoliosis (P < 0.0001, Fisher's exact test). A pronounced threshold effect was observed : the transition from preschool to primary school (EPP) to high school (Lycée) resulted in a more than five-fold increase in the proportion of individuals classified as screened positive for scoliosis, rising from 3.60% to 19.05%.

Consequently, variable ''Educational institution level'' emerges as one of the most robust predictors of being screened positive outcome among the factors investigated in unadjusted analyses.

This is illustrated in the following table (Table 6).

✓ **Age group**

The screened students were grouped according to their age: infants aged between 3 and 9 years and adolescents aged between 10 and 19 years.

Table 6 : Age group

All screened students				
Age group	**No scoliosis**	**Variation in the norm**	**Screening-positive suspected scoliosis**	**Total**
[3-9 years old] Juvenile	161	1	1	163
Row%	98.77%	0.61%	0.61%	100.00%
Col%	23.57%	5.88%	1.25%	20.90%
[10-19 years old] Adolescent	522	16	79	617
Row%	84.60%	2.59%	12.80%	100.00%
Col%	76.43%	94.12%	98.75%	79.10%
TOTAL	683	17	80	780
Row%	87.56%	2.18%	10.26%	100.00%
Col%	100.00%	100.00%	100.00%	100.00%

SingleTableAnalysis

Chi-Squared	df	Probability
23.9799	2	0

An expected value is < 5. Chi-squared may not be a valid test.

Due to the presence of sparse cells with expected frequencies below 5, statistical significance was determined using the Fisher-Freeman-Halton Exact Test to ensure robust P-value estimation.

For this 2 × 3 contingency table, the Fisher-Freeman-Halton Exact Test yielded an exact P-value of 0.000003, which was < 0.001.

Analysis of the relationship between age and screening for suspected scoliosis revealed a highly significant association (P < 0.001, Fisher's exact test). Data indicate that individuals in group [3-9 years old] i.e. juvenile are almost entirely concentrated whithin the 'No scoliosis' modality (98.77%). In contrast, the group [10-19 years old], that is adolescents, exhibited a more pronounced dispersion, with 12.80% of the cohort shifting toward the 'screening-positive suspected scoliosis' modality in the unadjusted analyses.

✓ **Sex**

The table below shows the sex distribution of the screened students (Table 7).

Table 7 : Sex distribution

All screened students

Sex	No scoliosis	Variation in the norm	Screening-positive suspected scoliosis	Total
Male	292	7	31	330
Row%	88.48%	2.12%	9.39%	100.00%
Col%	42.75%	41.18%	38.75%	42.31%
Female	391	10	49	450
Row%	86.89%	2.22%	10.89%	100.00%
Col%	57.25%	58.82%	61.25%	57.69%
TOTAL	683	17	80	780
Row%	87.56%	2.18%	10.26%	100.00%
Col%	100.00%	100.00%	100.00%	100.00%

Single Table Analysis

Chi-Squared	df	Probability
0.4807	2	0.7864

As with the previous analyses, the Chi-squared P-value (0.7864) was provided for indicative purposes only because of the spare cell counts. The results of the Fisher-Freeman-Halton exact test yields an exact P-value of 0.8142 ; indicates that there is no statistical relationship between variable 'sex' and screening-positive suspected scoliosis. The distribution of individuals remained virtually identical across both the groups (males and females).

The analysis of variable 'sex' demonstrates no significant association with being screened positive to scoliosis (P = 0.8142, Fisher's exact test). The distribution of those who screened positive for scoliosis was statistically equivalent between the Male and Female groups in the unadjusted analyses.

- ✓ **Pubertal status**

The screened students were grouped according to their pubertal status according to the Tanner stage, as shown in the table below (Table 8).

Table 8 : Tanner's pubertal stage

All screened students

Tanner's pubertal stage	No scoliosis	Variation in the norm	Screening-positive suspected scoliosis	Total
Stage I	179	4	3	186
Row%	96.24%	2.15%	1.61%	100.00%
Col%	26.21%	23.53%	3.75%	23.85%
Stage II	171	5	10	186
Row%	91.94%	2.69%	5.38%	100.00%
Col%	25.04%	29.41%	12.50%	23.85%
Stage III	104	0	16	120
Row%	86.67%	0.00%	13.33%	100.00%
Col%	15.23%	0.00%	20.00%	15.38%
Stage IV	174	5	31	210
Row%	82.86%	2.38%	14.76%	100.00%
Col%	25.48%	29.41%	38.75%	26.92%
Stage V	55	3	20	78

Row%	70.51%	3.85%	25.64%	100.00%
Col%	8.05%	17.65%	25.00%	10.00%
TOTAL	683	17	80	780
Row%	87.56%	2.18%	10.26%	100.00%
Col%	100.00%	100.00%	100.00%	100.00%

Single Table Analysis

Chi-Squared	df	Probability
50.1375	8	0

An expected value is < 5. Chi-squared may not be a valid test.

Due to the presence of sparse cells with expected frequencies below 5, statistical significance was determined using the Fisher-Freeman-Halton Exact Test to ensure robust P-value estimation. For this 5 × 3 contingency table, the Fisher-Freeman-Halton Exact test yielded an exact P-value < 0.0001.

A distinct dose-response effect is observed between variable 'pubertal status' and variable being screened positive for scoliosis. As pubertal status increases, the distribution profile of those screened positive for scoliosis undergoes a significant transformation.

-Baseline (Tanner's pubertal stage I) : The vast majority of individuals (96.24%) were concentrated within the 'no scoliosis' category.

-Transition phase (Tanner's pubertal stage III and IV) : A clear shift in distribution emerges. At the 'Tanner's pubertal stage IV' level, the 'screened positive to scoliosis' group represent a substantial proportion, accounting for nearly 15% (14.76%) of the sub-cohort.

-Trend inversion (Tanner's pubertal stage V) : The most radical shift occurs at this level. The 'screened positive to scoliosis' category reaches its maximum prevalence, exceeding 25% (25.64%) of the group-a fifteen-fold increase compared to the Tanner's pubertal stage I level.

A significant positive association was observed between pubertal status and positive scoliosis screening results. An increase in the pubertal status index was correlated with a progressive and statistically significant transition from category 'no scoliosis' screened toward category 'screening-positive suspected scoliosis' (P < 0.0001, Fisher's exact test) in unadjusted analyses.

✓ **Back pain**

The screened students were grouped according to whether they reported back pain. Table 9 presents the following table (Table 9).

Table 9 : Distribution according to back pain status

	Being screened positive to scoliosis			
Back pain	**No scoliosis**	**Variation in the norm**	**Screening-positive suspected scoliosis**	**Total**
No reported back pain	621	15	65	701
Row%	88.59%	2.14%	9.27%	100.00%
Col%	90.92%	88.24%	81.25%	89.87%
History of back pain	62	2	15	79
Row%	78.48%	2.53%	18.99%	100.00%
Col%	9.08%	11.76%	18.75%	10.13%
TOTAL	683	17	80	780
Row%	87.56%	2.18%	10.26%	100.00%
Col%	100.00%	100.00%	100.00%	100.00%

Single Table Analysis

Chi-Squared	df	Probability
7.4115	2	0.0246

An expected value is < 5. Chi-squared may not be a valid test.

Due to the presence of sparse cells with expected frequencies below 5, statistical significance was determined using the Fisher-Freeman-Halton Exact Test to ensure robust P-value estimation. For this 2 × 3 contingency table, the Fisher-Freeman-Halton Exact Test yielded an exact P-value of 0.0325.

The analysis of variable 'back pain' status also reveals a statistically significant association with being screened positive to scoliosis (P = 0.0325, Fisher's exact test). Individuals in the 'history of back pain' group exhibited a significantly higher probability of being classified within the 'screening-positive suspected scoliosis' modality (18.99%) than those in the 'no reported back pain' group (9.27%). However, this variable appears to have a lower predictive weight in the unadjusted analyses.

- ✓ **Screening-positive suspected scoliosis and associated factors**

The investigation into the relationships between various independent variables and variables screened positive for scoliosis (clinical diagnosis of scoliosis) revealed that the distribution of the latter was not due to chance for five of the six factors tested. The analysis highlights a specific profile associated with the 'screened positive to scoliosis' modality.

The following three variables exhibited the strong correlations (P < 0.001) :

-The variable 'pubertal status' (gradient) was the most predictive factor. A linear progression is observed; as the 'pubertal status' stage increases (from I to V), the probability of belonging to the 'screened positive to scoliosis' category grows significantly, rising from 1.6% to 25.6%.

-variable 'educational institution level' (the threshold effect) : the 'high school' level modality serves as a major pivot point. This category alone accounts for 60% of the total 'screened positive to scoliosis) cohort, with a prevalence that surges to 19.1% compared to only 3.6% for the 'no scoliosis' category.

-variable 'age group' (the group effect) : membership in the 'adolescent' group [10-19 years old] is a determinant factor. It increases the probability of being classified as 'screened positive to scoliosis' (12.8%) more than twenty-fold compared to the 'juvenile' group [3-9 years old] (0.6%).

The variables 'district of residence' and 'back pain' also influenced being screened positive for scoliosis, although with less intensity or a less contrasted distribution :

-variable 'district of residence' demonstrates a solid association (P = 0.0002), with 'district of Antananarivo Renivohitra' group being significantly more inclined to present the 'screened positive to scoliosis' modality (14.6%) than 'district of Ambohidratrimo' group (6.6%).

-variable 'back pain' : although significant (P = 0.0325), its predictive weight is the lowest among the selected factors ; it nevertheless confirms that 'history of back pain' group nearly doubles the presence of 'screened positive to scoliosis' compared to 'no reported back pain' group.

Sex, with a p-value of 0.8142, had no statistically demonstrable influence on screening positive for scoliosis in this cohort.

The following table (Table 10) summarizes the associations between the studied variables and factors associated with suspected screening-positive scoliosis in the unadjusted analyses.

Table 10 : Summary of association tests between independent variables and factors associated with screening-positive suspected scoliosis (N=780)

Variable	Statuts	P-value (Fisher Exact)	Association strength	Key statistical finding
Pubertal status	Significant	< 0.0001	Highest	Strong linear gradient : 'screened positive to scoliosis' category prevalence increase from 1.6% to 25.6% across Tanner's pubertal stage I to V
Age group	Significant	0.000003	Very strong	Group effect : 12.8% prevalence for 'screened positive to scoliosis' category in adolescent [10-19 years old] group vs. 0.6% in juvenile [3-9 years old] group
Educational institution level	Significant	< 0.0001	Very strong	Threshold effect : High school level accounts for 60% of all 'screened positive to scoliosis' category observations
District of residence	Significant	0.0002	Strong	Group from Antananarivo Renivohitra district shows more than double the proportion of 'screened positive to

				scoliosi' category (14.6%) compared to the district of Ambohidratrimo (6.6%)
Back pain	Significant	0.0325	Moderate	Statistically significant association, though notably weaker than pubertal status, educational institution level or age group
Sex	Non-Significant	0.8142	None	No statistical association ; 'being screened positive to scoliosis distribution is uniform across male and female groups

- **Multivariable Logistic Regression**

A multivariable logistic regression model was constructed including district, sex, Tanner stage, and self-reported back pain.

After adjustment :

-District remained independently associated after adjustment (aOR = 2.3; 95% CI :1.4-3.9 ; P=0.001).

-Female sex was not independently associated with screening positivity (aOR = 1.2 ; 95% CI : 0.7-2.0 ; P = 0.45).

-Self-reported back pain was associated with higher odds of screening positivity (aOR = 2.1 ; 95% CI : 1.1-3.8 ; P = 0.02).

-Advanced Tanner stage showed increased odds compared to Tanner stage I.

This finding is summarized in the following table (Table 11).

Table 11 : Multivariable logistic regression analysis of factors associated with screening-positive suspected scoliosis (N=780)

Variable	Category	Adjusted OR	95% CI	p-value
District	Antananarivo vs Ambohidratrimo	2.3	1.4–3.9	0.001
Sex	Female vs Male	1.2	0.7–2.0	0.45
Back pain	Yes vs No	2.1	1.1–3.8	0.02
Tanner stage	II vs I	3.2	0.9–11.0	0.07
	III vs I	8.5	2.4–30.2	<0.001
	IV vs I	9.8	2.9–33.5	<0.001
	V vs I	18.4	5.2–65.0	<0.001

After adjustment, advanced pubertal stage remained the strongest factor associated with suspected scoliosis. Compared with Tanner stage I, stage V was associated with an 18-fold increase in odds (aOR 18.4, 95% CI 5.2–65.0 ; P < 0.001).

Variance inflation factors were < 5 for all variables, indicating no significant multicollinearity.

- **Adjustment for clustered sampling**

Because students were nested within schools, cluster-robust standard errors were applied.

After adjustment for clustering at the school level:

-The effect estimates remain directionally consistent,

-Confidence intervals widened modestly,

-The association between sex and screening positivity remained significant.

-Associations between Tanner stage and back pain showed attenuation but remained suggestive.

A mixed-effects logistic regression model including a random intercept for school yielded comparable fixed-effect estimates.

These findings suggest that intra-school correlation did not materially alter the main associations but appropriately increased the standard errors.

DISCUSSION

- **Scoliosis screening**

Regarding scoliosis screening, in the case of the United States, even though The US Preventive Services Task Force called for an end to scoliosis screening in US public schools mainly because of the fact that infectious diseases that can lead to scoliosis such as tuberculosis and poliomyelitis have been eradicated, but also because of the cost of a large-scale screening program that outweighs the economic costs and psychological morbidity risk of mislabeling people with such conditions, as well as the risk of false positives, overdiagnosis, radiation exposure, and over-referral. However, screening endures in more than half of these states because of the patient protection and affordable care act prohibiting insurance companies from charging copayments and deductibles for preventive and medical screenings.

Screening is mainly focused on adolescent scoliosis, with precise and targeted ages and screening schedules, particularly biannually for girls aged 10-12 years and once a year for boys aged 13-14 years, in order to avoid the need for expensive spinal surgery (11,12).

Other countries such as Canada and France have also discontinued mass- or school-based screening for scoliosis. This decision stems from the high costs associated with the procedure, which result in a significant economic burden and the danger of overtreatment of bracing children for a condition that is not life-threatening. Furthermore, there is a shortage of human resources, particularly among spinal orthopedic specialists capable of providing follow-up care. To address this issue, the responsibility for detecting scoliosis has been reassigned to family physicians or left to the parents'discretion (11,13,17). For Australia, a "National Self-Detection Program for Scoliosis," urging a more autonomous approach to care by having adolescents and their families seek out spinal examinations from their primary care physicians was introduced to solve this matter xxx. Even though scoliosis screening gives parents and school administrators a sense of security, those wedded to evidence-based medicine believe that it is false (11).

In Algeria, scoliosis screening has been a part of the school screening program since 2007 to allow early detection and avoid the transition to heavy and expensive surgical treatment (14).

The prevalence of scoliosis in Madagascar has not been studied. This preliminary study is the first in the context of school screening for scoliosis in a public setting. Although these findings do not constitute prevalence in a strict sense, this study was initiated to establish the preliminary data and baseline references. Given the current absence of a formal school-based screening program, the inclusion criteria encompassed all children aged 3-19 years. This broad range accounts for the fact that scoliosis can manifest throughout various developmental stages, and is not exclusively restricted to adolescents. Although other countries have discontinued mass school-based screening for scoliosis, citing the high procedural costs and shortage of specialized human resources in spinal orthopedics, Madagascar presents unique challenges. In this region, where tuberculosis remains endemic, the screening objective is not limited to idiopathic scoliosis alone. Instead, the goal is to identify all forms of scoliosis, including those secondary to other conditions that still pose a significant health burden. Scoliosis screening will serve as a 'safety net' to identify undiagnosed cases of Pott's disease because unlike mild scoliosis, tuberculous scoliosis can lead to abrupt paraplegia (18–20). The cost of decompression surgery is infinitely high. In addition, in countries with few resources, access to complex spinal surgeries is prohibitively expensive. To avoid this, screening will allow treatment with specific physiotherapy and corset, in addition to antibiotic treatment, which is much more affordable locally. When left untreated, this type of scoliosis can lead to chronic pain and respiratory failure, turning a productive future adult into dependent on the community. In addition, in schools, especially public schools, we can reach the poorest children, who will never go to see a specialist on their own. A school-based scoliosis screening program will be a lever for health equity (21,22).

In this study, the standard methods used in literature reviews regarding scoliosis screening were followed (2,17,23,24). A clinical diagnosis of scoliosis was established based on the presence of a rib hump (or gibbus deformity) observed during Adam's Forward Bending Test, documented by an ATR angle ≥ 5° as measured by a scoliometer (Table 2). This diagnostic tool does not require any expensive technology and no X-ray irradiation is required in the first stage.

While the proposed screening program may offer significant public health benefits, it is not without the risks of overdiagnosis and resource strain highlighted by USPSTF. To minimize the burden on hospitals, we propose the use of a scoliometer during screening. Only children with a rotation greater than 7° will be referred to a doctor. This threshold of 7° for ATR was selected to maximize specificity and minimize over-referral and unecessary parental anxiety and the 'labeling' of healthy children as patients. Clinical studies have shown that an ATR of 7° measured on a scoliometer is the most reliable predictor of a Cobb angle ≥ 20° (25,26).This ensures that we do not saturate the medical specialists and radiology departments while capturing critical cases of Pott's disease or progressive scoliosis.

All clinically diagnosed students were prescribed full-spine radiographs (standing anteroposterior and lateral views) and were advised to undergo imaging to confirm the diagnosis and assess the Cobb angle; however, this was not mandatory for a simple screening procedure. However, X-ray data are essential to determine therapeutic modalities in the future. To adhere to the 'As Low As Reasonably Achievable' (ALARA) principle, clinical monitoring will be prioritized for borderline cases, reserving radiography only for those meeting strict progression criteria.

Allocating personnel for scoliosis screening may divert attention from other urgent primary care needs. By integrating the spinal exam into existing multipurpose school health visits, we minimized additional logistical costs and maximized the 'sentinel' value of the exam for detecting other conditions, such as Pott-s disease.

- **Geographical distribution**

Studies conducted in China have revealed significant geographic variations in detected scoliosis cases. Notably, research highlights a disparity between urban and rural areas ; as well as district-level variations associated with latitude (2,27). Another study that has already been done by Grivas TB *et al.* in 2006 had also demonstrated this difference in geographical distribution on the prevalence of diagnosed scoliosis cases (28). This study, conducted across two districts one urban and one per-urban also demonstrated significant geographic variation. A higher prevalence was observed in the urban setting (Antananarivo Renivohitra district) than in the surrounding areas (aOR = 2.3; 95% CI :1.4-3.9 ;

P=0.001). This is consistent with findings reported in the literature.

- **Distribution by age, gender and type of scoliosis**

According to the literature, adolescent idiopathic scoliosis is the most prevalent form of scoliosis and predominantly affects females. In a study on the epidemiology of idiopathic scoliosis in adolescents conducted by Konieczny *et al.* (2013) and a study on school-based screening for idiopathic scoliosis in adolescents in the city of Nara, Japan conducted by Yamamoto *et al.* (2015), it was demonstrated that the severity and progressive nature of this condition mainly affected the female sex [29,30]. In this study, females were more frequently affected ; however, female sex was not independently associated with screening positivity (aOR = 1.2 ; 95% CI : 0.7-2.0 ; P = 0.45). This could be explained by the sample size, which was not representative of the country. Adolescent scoliosis was also the most frequent finding, affecting students with pubertal status corresponding to Tanner stages I, II, III, and IV, representing childhood, as well as early and late puberty. The results of this study were consistent with those reported in the literature.

- **Site of scoliotic curvature**

According to the literature, idiopathic scoliosis occurs in the right thoracic region (25% of idiopathic scoliosis) and/or left lumbar region (25% of idiopathic scoliosis). A reversal of this location should alert clinicians of the existence of a secondary cause. The location of the curvature will then guide clinician regarding whether it is idiopathic or secondary scoliosis [5,24–28].

In the present study, the right thoracic location was the most prominent (34.28%), suggesting idiopathic scoliosis. The left lumbar (8.57%) and double major (right thoracic and left lumbar, 4.78%) patterns also suggested a probable idiopathic origin. Conversely, the atypical patterns and junctional locations identified in this study warrant further investigation to rule out a secondary etiology of the screened positive for scoliosis. However, this study did not definitively confirm the predominance of idiopathic scoliosis, a limitation likely attributable to the sample size, but also probably due to the existence of a potential secondary cause that cannot be ruled out, especially in countries where tuberculosis that can cause Pott's disease is endemic.

- **Factors associated with screening-positive suspected scoliosis**

While idiopathic cases constitute the majority, approximately 20% of scoliosis presentations are secondary to various underlying etiologies, including infections, congenital malformations and neuromuscular or histodysplastic disorders [24,25,31,33] . The screening conducted in this study was accompanied by an assessment of the medical history of patients predisposing them to scoliosis, risk factors, and potential clinical signs of a secondary etiology for the detected scoliosis. This findings reflects the clinical principle that idiopathic scoliosis is a diagnosis of exclusion.

The present study identifies a multi-factorial influence on the distribution of the screened positive to scoliosis variable, characterized by a clear hierarchy of predictive power among the variables tested.

Our findings indicate that Tanner's pubertal stage is the most robust determinant for positive screening for scoliosis. Compared with Tanner stage I, stage V was associated with an 18-fold increase in odds ratio (aOR 18.4, 95% CI 5.2–65.0 ; P < 0.001), demonstrating a significant dose-response relationship. As Tanner's pubertal stage scores increase, the likelihood of observing students who screen positive for scoliosis outcomes increases substantially, suggesting that Tanner's pubertal stage may serve as a primary indicator for this specific categorical state.

Furtheremore, variables ''institution of origin'' and "age range" exert powerfull effects, though they appear to function through different machanisms. Variable ''institution of origin'' exhibits a notable threshold effect in high school institution, which accounts for the majority of observed students screened positive to scoliosis cases. Meanwhile, the strong association found for variable "age range" suggests a group-specific dependency that warrants further qualitative investigation.

While variable "distribution by district" and "back pain" also reached statistical significance, their relatively weaker associations suggest they may act as moderating factors rather than primary drivers. It should be noted, however, that the presence of back pain, which is most often the first sign of tuberculosis due to Pott's disease, should be considered in an area of endemic tuberculosis, as explained in the literature [18–20]. Notably, the lack of significance for variable "sex" (aOR = 1.2 ; 95% CI : 0.7-2.0 ; P = 0.45) provides important discriminant evidence, indicating that not all hypothesized factors contribute to the variance in the factor associated with being screened positive for scoliosis.

These results highlight the importance of precise statistical methods in the presence of sparse data. The consistency across multiple significant predictors (Tanner's pubertal stage, institution of origin, age range, distribution by district, and back pain) suggests a highly structured relationship between these covariates and positive screening for scoliosis outcomes, providing a solid foundation for future predictive modeling or targeted interventions.

CONCLUSION

Scoliosis can lead to significant functional impairment and disability as a multifactorial condition affecting the developing spine. Adolescent idiopathic scoliosis is the most prevalent form of scoliosis; however, we must not forget secondary causes or rely on timely clinical diagnosis to ensure early intervention.

In this study, adolescent scoliosis was the most screened form of suspected scoliosis, affecting high school students in their pubertal stage, with variable geographical distribution. This study provides preliminary data on the proportion of suspected scoliosis cases screened as positive in a low-resource setting. The associations observed should be interpreted cautiously because of the absence of radiographic confirmation and the cross-sectional design.

The rigid application of international guidelines in low-resource environments must be nuanced by the local epidemiological realities. In such contexts, maintaining a school-based spinal screening program is not merely an orthopedic concern but a strategic component of multisectorial health surveillance. In regions where tuberculosis remains endemic, spinal deformity in children is a critical clinical red flag. School screening serves as the primary detection mechanism for Pott's disease, which initially presents with symptoms that mimic idiopathic scoliosis. Such early intervention prevents the need for complex spinal decompression surgery and irreversible paraplegia.

Contrary to developed healthcare systems where screening costs are often inflated by systematic radiography, we propose a 'low-tech, high-yield' model tailored for resource-constrained settings:

-Non invasive assessments, such as Adam's forward bend test combined with a scoliometer, require no power source or expensive consumables.

-stricted referral thresholds to mitigate the risk of over-referral and system saturation. Only students exhibiting a significant Angle of Trunk Rotation (ATR) greater than 7°, for example, are referred for specialist evaluation. This gatekeeping mechanism protects tertiary care centers from capturing the most clinically significant cases.

In the absence of school-based programs, early diagnosis is often restricted to afflent families with access to private healthcare. In marginalized communities, scoliosis is frequently diagnosed only in the late stage of the severe deformity phase, when local therapeutic options are often exhausted. School screening ensures that the most vulnerable children receive timely intervention (bracing, specific physiotherapy, or infectious disease follow-up) before their condition leads to permanent disability, thereby preserving future socioeconomic productivity. These treatments are all available in the country, and doctors specialize in physical medicine and rehabilitation, not only orthopedists or neurosurgeons of the spine.

These findings highlight both the importance and feasibility of early and school-based scoliosis detection, enabling timely identification of "at-risk students" before developing severe spinal deformities with their consequences in adulthood.

The value of scoliosis screening programs is often debated and remains controversial because of their economic, societal, and psychological costs. In the case of Madagascar, the development of a national scoliosis-screening program implemented at both the school and community levels would be of significant interest. Such an initiative would not only facilitate the assessment of its prevalence and enable early detection but is also crucial, given that tuberculosis remains endemic in the country. By integrating the spinal exam into existing multipurpose school health visits, we minimized additional logistical costs and maximized the 'sentinel' value of the exam for detecting other conditions, such as Pott-s disease. Additionally, radiographic confirmation should be included and considered in future or follow-up work for those with an ATR ≥ 7°to reduce the risk of unnecessary X-ray exposure.

Data availability statement

The data described in the manuscript, code book, and analytic code will be made available upon request, pending application and approval from the authors.

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