Assessment of idiopathic scoliosis among adolescents and associated factors in Palestine

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ABSTRACT

Purpose: This study aimed to investigate adolescent idiopathic scoliosis (AIS) and its related risk factors, including body mass index (BMI), physical activity (PA), gender, time of the first menstrual cycle, transportation, backpack weight and the way of carrying a backpack.

Design and method: a cross-sectional quantitative design was utilized. A convenient sample of adolescent students in grades seven through ten was included in the study. A self-reported questionnaire with three sections: demographic data; physical data including height, weight and PA; and Adam's forward bend test to determine each student's spine's Cobb angle by measuring the angle of trunk rotation using a scoliometer. The data were analyzed using SPSS version 25, with confidence intervals of 95%.

Results: A total of 820 schoolchildren participated in the study; 53.7% were female and 46.3% were male. Only 22% of these students engaged in vigorous exercise, compared to 36.7% who engaged in low PA; additionally, 10% of the adolescents had a low BMI. After the analysis, it was found that 5.4% of participants had AIS. Low PA ($p = 0.001$), being underweight ($p = 0.038$), and time of first menstrual period ($p = 0.033$) were significantly associated with AIS, while gender, backpack weight, and way of carrying were not statistically related to AIS. Binary logistic regression identified low PA as an independent predictor of AIS (OR = 7.22, 95%CI [1.64, 31.79]).

Conclusions: The frequency of AIS in Palestine was significant, which highlighted the importance of this issue at a national and global level. There was an association between AIS and BMI, PA, and the time of the first menstrual cycle, which signifies the importance of early detection of the problem to limit its burden later in life.

Practice implications: Teachers, teenagers, and their parents should be provided with programs that educate and clarify AIS, and a specific protocol should be established for scoliosis screening in schools.

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Introduction

Adolescent idiopathic scoliosis (AIS) accounts for 80% of all scoliosis cases, with a range of 1–3% worldwide (Cheng et al., 2015; WHO, 2017). AIS is characterized by a 10° or more lateral curvature of the spine in adolescents aged 13 to 18 with no definite congenital or neuromuscular etiology measured using the Cobb angle method on a coronal radiograph (Kuznia et al., 2020). Different factors contribute to increasing the incidence of AIS, including physical activity (PA), gender, backpack, and body mass index (BMI) (Tahirbegolli et al., 2021; Teles et al., 2020; van Sluijs et al., 2021; Zou et al., 2022). AIS affects the child not only physically but also in many other life sectors, such as psychologically, emotionally, and mentally (Makino et al., 2019). Thus, professionals

from all around the world have been interested in studying the risk factors for AIS.

Adolescents go through phases of rapid changes and growth during their maturation. As a student, this could be impacted by daily habits like carrying extra weight, wearing a backpack asymmetrically, and engaging in little PA (Dahl et al., 2018). These moments may offer the chance to significantly influence their developmental trajectories, such as spinal growth, which results in spinal deformity, including AIS (Cheng et al., 2015). In fact, according to Labelle et al. (2013), scoliosis screening is a crucial preventive measure to avert the advancement of such deformity (Labelle et al., 2013). Therefore, scoliosis screening seems to be a useful and significant technique to identify students with undiagnosed scoliosis at an early stage (Grivas et al., 2008).

Scoliosis is a condition where the spine rotates and curves to an unnatural degree; the word "scoliosis" is a Greek word that means "crooked" (Choudhry et al., 2016). Instead of having a straight spine, a person who has scoliosis will have a "C/S"-shaped spine; a scoliotic

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spine typically resembles a letter "C" (or a reverse letter "C," depending on the direction of the curve); however, some patients have two curves, resulting in an S-shaped spine (Jada et al., 2017). Due to the extensive screening procedures employed in schools, several countries around the world, including China (Du et al., 2016; Hu et al., 2022), Turkey (Yılmaz et al., 2020), and Sweden (Płaszewski et al., 2020), have access to epidemiological data. Unfortunately, there are inadequate national screening guidelines for AIS in Palestine.

The physical health of a person is negatively impacted by AIS in a variety of forms, including breathing problems (Kempen et al., 2022) that are caused by the distortion of the spine and rib cage (Wozniczka et al., 2017), back pain, and sleep disorders such as insomnia (Wong et al., 2019). Additionally, psychological issues and a poor sense of self may develop as a result of a visible deformity (Makino et al., 2019). Scoliosis can be controlled, and the problem will not get worse if it is examined and detected early on with the proper instructions to avoid or halt its appearance (Glavaš et al., 2022). To keep an adolescent from experiencing AIS and its difficulties or repercussions, it is important to understand the factors that increase the likelihood of having AIS (Abdelaal et al., 2018). Therefore, the main purpose of the study was to evaluate AIS in Palestine and identify the relationship between AIS and the selected variables of BMI, gender, PA, backpack weight, and backpack carrying method in order to establish a foundation for developing preventative measures and promoting modifications in lifestyles in adolescents.

Methods

Research design

The current study utilized a quantitative cross-sectional correlation study design, including an Adam test, to screen adolescents' schoolchildren who lived in the Ramallah governorate area of Palestine.

Setting

This study was conducted at secondary schools in Ramallah Governorate, Palestine. Ramallah governorate was selected because it is geographically in the center of Palestine. Furthermore, it serves as Palestine's main administrative and economic center, making it appear vital to start there in order to have an impact on the rest of the country. Additionally, Ramallah is the city where people from many sections of the country live. Ramallah is thought of as a smaller version of Palestine because it is home to all of the country's citizens. The current study covered all schoolchildren aged 13–18 enrolled in Ramallah's private secondary school for the academic year 2022–2023.

Sampling

In Palestine, there are 400,000 teenagers aged 13 to 18, according to the Palestinian Central Bureau of Statistics (PCBS, 2022), as well as 3142 schools. To estimate the sample size required for determining the AIS rate, the prevalence formula was employed $n = \frac{Z^2 P(1-P)}{d^2}$ (Daniel, 1999), where n = required sample size, Z = confidence level at 95% (standard value of 1.96), and P = estimated prevalence of AIS in the study area (19.1%) (Assiri et al., 2019). d = precision (5%) (Pourhoseingholi et al., 2013). Taking into consideration all the values presented above, the sample size was calculated to be 292 participants. Furthermore, an additional 58 adolescents were included in the sample size since a 20% non-response rate was anticipated to prevent type II error (Bujang, 2021). The minimum calculated sample was 350. A total of 870 students were recruited from six secondary schools in Ramallah governorate using a convenient non-random sampling process. A total of 820 participants met the eligibility criteria, and their mothers consented to participate in the study (Fig. 1).

Inclusion: All adolescent schoolchildren aged 13 to 18 who were enrolled in a private school for the academic year 2023 in the Ramallah governorate were included, regardless of regional or economic representation. Children who could stand while carrying a bag of supplies and bend forward to execute Adam's forward bending test (AFBT) were included in the study.

Exclusion: Students with known congenital or structural defects or those who use wheelchairs or other mobility aids were excluded.

Instruments/tools

Researchers developed a 21-item questionnaire with three sections to evaluate study variables. The first section was about socio-demographic data. The second section, the International Physical Activity Questionnaire (IPAQ) (Craig et al., 2017), was utilized for evaluating adolescents PA. It was structured with 7 questions that the student was supposed to answer as required, and then the researcher had to calculate the metabolic equivalent of the task (MET-min per week): MET value (3.3 for walking, which means mild PA, 4 for moderate PA, and 8 for vigorous high PA). The last section, the Adam test (AFBT), is a clinical examination that examines the rotational component of AIS and is considered the primary screening test for AIS due to its simplicity and being relatively inexpensive, with the sensitivity ranging from 74 to 100% and the specificity ranging from 60 to 99%, depending on the position and amplitude of the curve, allowing an assessment of the potential for scoliosis (Karachalios et al., 1999). The Adams test falls into the category of "functional tests." It is a quick, painless, non-invasive test that involves a scoliometer tool that calculates the angle of trunk rotation (ATR) (Karpiel et al., 2021). The scoliometer used for this study was tested for the intra-rater and inter-observer reliability of ATR for the upper, lower thorax, and lumbar spine. The observed intra-rater reliability values for the upper and lower thorax and lumbar segments of the subjects ranged from very good to excellent (ICC = 0.84 to 0.95) (Bonagamba et al., 2010). A validated correlation existed between the ATR angle and the radiographic Cobb angle (Morrison et al., 2015). The value of at least 5° of the scoliometer was chosen as indicative of a Cobb angle of 10° or more, which is the cut-off angle for diagnosing scoliosis (Bunnell, 2006). During the examination, the children were instructed to bend forward while the examiner stood close behind them and scanned the horizontal plane of the spine for deviations in the curve. The scoliometer was placed on the apex of the lower (lumbar), middle (thoracic-lumbar), and upper (thoracic) backs to measure the ATR. Idiopathic scoliosis was defined as an ATR value ≥5° in at least one of the spinal regions (thoracic, thoracolumbar, or lumbar). (Bunnell, 2006).

Data collection

Researchers contacted the principals of each selected school after receiving IRB approval from the Birzeit University (BZU) committee (No. BZUPNH2220). The school's principal, together with the teachers, served as liaisons, made the initial contact with the mothers, and sent a cover letter in Arabic outlining the purpose of the study and comprehensive information about the screening process. The mothers were informed to return written consent to the school principal within a week. Adolescents' assent was required and obtained prior to study activities beginning, following a thorough description of every step involved in the data collection process. Between April 1 and May 30, 2023, data were collected from adolescent students in grades 7 through 10 at various schools in the Ramallah governorate. Asking them to complete a questionnaire that was created by the researchers and pertains to both their socio-demographic characteristics and the level of PA they engage in. This took about 10 min, and researchers responded to any participant who may have a question concerning the questionnaire or any other aspect of the study. The second and third parts of the
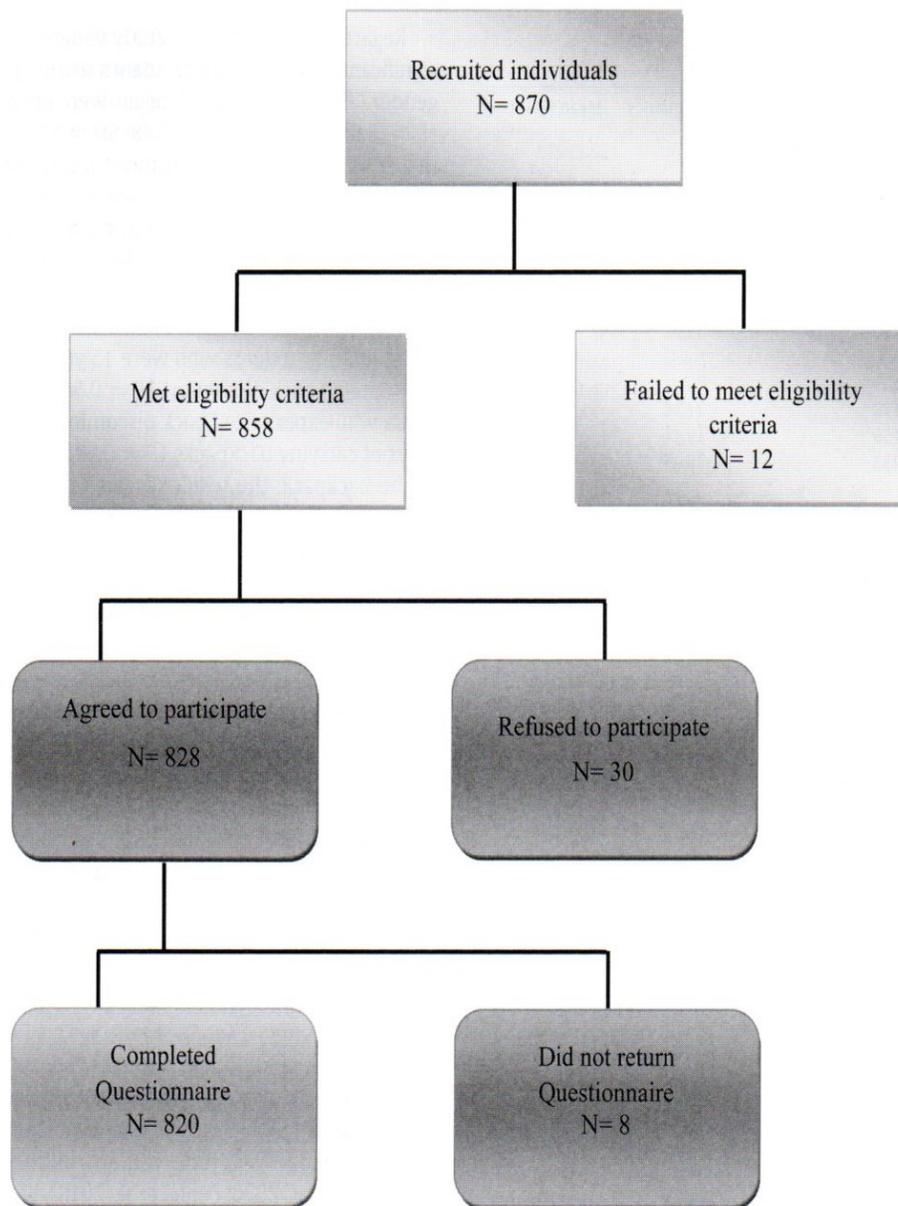
Fig. 1. Participants selection flow diagram.

questionnaire included the researcher's role in assessing height and weight, calculating BMI (kg/m2), and using the Adam test to determine the ATR by scoliometer. These measurements were taken by the researchers in a private room under the direct supervision of their supervisor, a pediatric nursing professional.

Ethical consideration

Informed consent for participation in the study was obtained from the parents of the participants. This study preserved the participant's privacy as Adam's test was done in a private room, information was used for research only, and participants achieved anonymity by keeping data in a safe place until the end of the study and then discarding it. The collected data contained only the study identification number without any personally identifiable information. In the event that the test reveals scoliosis in any of the participants, the researchers will advise that these students be referred to a specialist.

Data analysis

All statistical analyses were conducted using SPSS version 25. The researcher described the variables by using frequencies (n) and percentages (%) for categorical variables, while for continuous variables, the mean ± standard deviation (SD) appropriately, a *t*-test (for two groups), and an ANOVA (for more than two groups) were used to detect the relationship between risk factors (BMI, PA, backpack weight and carrying way, and gender) and AIS. Binary logistic regression was utilized to identify the predictors of AIS. Confidence intervals (CIs) were calculated at the 95% level.

Results

Table 1 demonstrates the demographic characteristics of the participants. A total of 820 adolescents were split between males and females ($N = 380$; 46.3%; and $N = 440$; 53.7%, respectively). They ranged in age from 13 to 18 years old, with ($N = 253$, 40%) of them in seventh grade, and most of them used a bus or car to go to school ($N = 643$, 77%). About two-thirds had a normal range BMI ($N = 509$, 62.1%), and ($N = 224$, 7.3%) of the students were overweight or obese. The majority of students had moderate physical exercise ($N = 339$, 41.3%), and in terms of age of first menstrual period, the mean age for menstrual periods was 12.47 (SD = 1.06), with the majority having their first menstrual periods at 13 years of age and older ($N = 186$, 42.2%). As for backpack carrying, most participants carried the bag on two shoulders ($N = 493$, 60.1%), and approximately half of them experienced back pain while carrying it ($N = 372$, 42%). Of these, three-quarters of students carried bags that weighed <10% of their body weight ($N = 202$, 75.4%).

Table 1
Sociodemographic characteristics of the Participants.

Demographic characteristics	Number of participants (N)	Frequency (%)	Mean (SD)
Age (in years)			14.01 (1.043)
14 and less	548	66%	
15 and more	272	33%	
Gender			
Male	380	46.3%	
Female	440	53.7%	
Educational level			
Seventh grade	253	30.9%	
Eight grade	175	21.3%	
Ninth grade	159	19.4%	
Tenth grade	233	28.4%	
Transportation			
Car or bus	634	77.6%	
Walking	186	22.7%	
BMI			23.25 (4.29)
Underweight	87	10.6%	
Normal weight	509	62.1%	
Overweight & obesity	224	27.3%	
Physical activity			
Low PA	301	36.7%	
Moderate PA	339	41.3%	
High PA	180	22%	
Age of first menstrual	N = 440		12.47 (1.06)
Not yet	95	21.5%	
12 & less	159	36.1%	
13 & more	186	42.2%	
Time of first menstrual	N = 440		
Not yet	95	21.5%	
2 years & less	256	58.2%	
3 years & more	89	20.2%	
Backpack carrying			
One shoulder	327	39.9%	
Two shoulders	493	60.1%	
Back pain			
Yes	372	45.4%	
No	448	54.6%	
School bags to body weight			
10% and less	582	70.9%	
More10%	238	29%	
Total	820		

Regarding the percentage of AIS, Adam scores showed that 5.4% of participants (N = 44) had scoliosis (positive Adam's test), as indicated in Table 2.

Association between the Adam test mean score and study variables

The result of the analysis showed a significant relationship between Adam's scores and the following study variables: PA (F = 7.531, P = 0.001), the Bonferroni post-hoc test showed a significant difference in mean high PA over low and moderate PA; adolescence with high PA showed a lower mean of Adam's scores (M = 7.20, SD = 1.33); time of first menstrual cycle (P = 0.033), the mean of whom had menses 3 years ago and more were >2 years and less (M = 7.71, M = 7.34); finally, BMI (P = 0.038), underweight had the highest mean (M = 7.9, SD = 1.8) of the other categories; in general, results indicated that a mean of Adam's sores increased as their weight decreased (Table 3).

Table 2
the percentage of adolescent idiopathic scoliosis.

	Percent	Frequency	Cumulative percent
Scoliosis	5.4%	44	5.4
No Scoliosis	94.6%	776	100
Total	100%	820	

Regarding the remaining study variables, there was no statistically significant relationship with Adam's scores (*p*-value <0.05), including: gender (P = 0.075), males' means were greater than those of females (M = 7.67; SD = 1.49; M = 7.48; SD = 1.55, respectively); transportation (P = 0.177), the walking mean was higher than car and bus (M = 7.7, SD = 1.53); the age of first menstrual period (P = 0.23), having had a period at 12 years old or younger has a higher mean AIS (M = 7.54, SD =1.6); and educational levels (P = 0.26), the tenth grade had the greatest mean (M = 7.68, SD = 1.47). Also, there was no significant relationship with Adam's scores in terms of age (P = 0.3), with a higher mean among students who were 15 years of age or older (M = 7.65, SD = 1.46); back discomfort (P = 0.50), with a higher mean for students who experienced back discomfort (M = 7.61, SD = 1.43); and ways of carrying backpacks (P = 0.52); Finally, regarding the weight of the backpack, the result revealed no significant association with Adam's mean scores (P = 0.47), with a greater mean for students carrying bags of >10% of their body weight (M = 7.61, SD = 1.51). (Table 3).

Predictors of adolescence idiopathic scoliosis

The variables at the bivariate level that were significantly associated with AIS were entered in the Binary logistic regression model, including the PA level, time of the first menstrual cycle, and BMI. The logistic regression model was statistically significant: χ^2 (7, N = 820) = 18.35, $p < 0.01$. The model explained 6.5% of the variance in AIS and correctly classified 94.1% of cases. The results indicated that low PA adolescents were more likely to have AIS compared to high PA adolescents (OR = 7.22, 95%CI [1.64, 31.79]). Although BMI and time of the first menstrual cycle were correlated to AIS, they were not significant predictors of AIS (all *p* values >0.001). (Table 4).

Discussion

The current study's findings indicated a significantly higher percentage of AIS (5.4%) than the global average (1–3%) and other countries including China (3.9%), Turkey (1.1%), and Brazil (1.5%) (Cheng et al., 2015; Kim et al., 2020; Penha et al., 2018), but a significantly lower percentage than Saudi Arabia (19.1%) (Assiri et al., 2019). This rise may be a result of insufficient systematic screening procedures for schoolchildren's developmental aspects in Palestine (Almahmoud & Abushaikha, 2023). In light of this, many cases of scoliosis may go undetected and untreated. This may be caused by the absence of an early diagnosis of scoliosis in its early stages.

The findings showed that low PA is a substantial risk factor and an independent predictor of the emergence of AIS. These findings were consistent with those of earlier research (de Assis et al., 2021; McMaster et al., 2015), which found that adolescents who are inactive or get little exercise are more likely to acquire AIS than active adolescents. According to McMaster et al. (2015), this may be interpreted as increased physical activity resulting in improved muscle mass and flexibility, supporting the spine, and decreasing the risk of developing AIS (McMaster et al., 2015). However, other research (Watanabe et al., 2017) does not reach the same conclusion and demonstrates that there is no link between exercise and AIS.

Low BMI was a second factor that had a strong correlation with the development of AIS. This conclusion is consistent with findings from other studies that showed adolescents with low BMI have an increased risk of having AIS (Dantas et al., 2021; Hengwei et al., 2016; Jeon & Kim, 2021; Zou et al., 2022). On the other hand, other researchers indicated that individuals who were obese or overweight frequently had a large AIS curve (Ciaccia et al., 2017; Matusik et al., 2016), or a high BMI may have a higher risk of a late diagnosis of advanced-stage AIS, hypothesizing that their body mass could hide the vertebral rotation, making the diagnostic process more challenging (Scaturro et al., 2021). This intense debate was a sign that there were more unmeasured elements that have had an impact on the emergence of AIS.

Table 3
Association between Adam test mean score and participants' characteristic.

Variables	Categories	Mean (SD)	F/T value	p- value
Physical Activity (PA)	Low PA	7.75 (1.52)	F = 7.531	P = 0.001
	Moderate PA	7.61 (1.59)		
	High PA	7.20 (1.33)		
Time of first menstrual cycle	Not yet	7.66 (1.53)	F = 2.93	P = 0.033
	2 years &less	7.34 (1.52)		
	3 years &more	7.71 (1.62)		
BMI	Underweight	7.9 (1.8)	F = 3.271	P = 0.038
	Normal weight	7.58 (1.46)		
	Overweight/obesity	7.42 (1.54)		
Gender	Male	7.67 (1.49)	T = 1.783	P = 0.075
	Female	7.48 (1.55)		
Transportation	Car& bus	7.53 (1.52)	T = 1.35	P = 0.17
	Walking	7.71 (1.53)		
Age of First menstrual cycle	Not yet	7.66 (1.53)	F = 1.46	P = 0.232
	12&less	7.54 (1.6)		
	13&more	7.34 (1.51)		
Level of education	Seventh grade	7.54 (1.57)	F = 1.335	P = 0.262
	Eighth grade	7.40 (1.61)		
	Ninth grade	7.66 (1.39)		
	Tenth grade	7.68 (1.47)		
Age	14 and less	7.53 (1.55)	T = 1.05	P = 0.305
	15 and more	7.65 (1.46)		
Back pain	Yes	7.61 (1.43)	T = 0.66	P = 0.508
	No	7.54 (1.59)		
Backpack carrying	One shoulder	7.53 (1.51)	T = 0.63	P = 0.52
	Two shoulders	7.61 (1.53)		
Bag weight	10%and less	7.5 (1.54)	T = 0.51	P = 0.47
	More than10%	7.61 (1.51)		

Note: F; one-way ANOVA test, T; an independent T-test, SD: Standard Deviation; the P value ≤0.05 indicates significance.

Furthermore, the results of the current study showed a significant association between AIS and the onset of puberty, with a higher mean among teenagers whose cycle started three years ago or more. This might be connected to the fact that once puberty started, the impact of hormones on spinal growth increased (Penha et al., 2018). Our investigation revealed a significant correlation that was unclear in earlier literature and highlighted the need for additional research to fully comprehend this association.

Our findings contradict earlier findings regarding the relationship between gender and the development of scoliosis (Hu et al., 2022; Yılmaz et al., 2020; Zou et al., 2022). Moreover, in terms of transportation type, our results contradict earlier findings (Schmid et al., 2020). This may be interpreted as the majority of study participants commuting to school by car or bus, making it difficult to interpret these results. Our findings disagreed with those of Kim et al. (2020), who found that the AIS rate increased significantly as students got older (Kim et al., 2020). The results of our research, however, revealed that students in the 10th grade (15 years and older) had a high mean of Adam's scores. Finally, our results were consistent with those of other studies (Kim et al., 2020; Tahirbegolli et al., 2021) about backpacking carrying and bag weight (10% of body weight). In conclusion, the researchers

observed that AIS cannot be attributed to a single factor, as the study had demonstrated; hence, the disorder is referred to as being multifactorial.

Limitations and strengths

Our study's limitations stemmed from our inability to obtain permission to collect data from government schools in accordance with the policies of the Palestinian Ministry of Education. As a result, our study was restricted to private schools where social and economic conditions are different and may affect the heterogeneity of the study sample, making it difficult to find a significant correlation with some study variables. This research is the first study in Palestine to assess the percentage of AIS and its related factors. We employed a measurement tool (scoliometer) that has been validated and has excellent intra- and inter-observer reliability. But, as the study utilized a screening tool, it is important to proceed with caution when drawing conclusions from the results. For future studies, it is preferable to employ X-rays for confirmation and diagnosis of AIS after identifying children with AIS by scoliometer testing.

Recommendations

- Employing a qualitative research design: It is recommended that future studies analyze adolescent habits that contributed to AIS using a qualitative method. This would offer insightful information on the elements impacting their spine development.
- Increased research efforts on AIS should entail looking into possible risk factors, finding preventive measures as screening program, and examining effective interventions that incorporate the involvement of the Palestinian Ministries of Education and Health, given the paucity of research on AIS in Palestine.
- Promote a healthy adolescent lifestyle: We recommended focusing on workshops and educational activities initiated by school nurses. Adolescents, parents, and teachers should be included in these programs, and they should be given the necessary knowledge and direction to prevent AIS.

Table 4
Binary Logistic Regression Analysis of Factors Associated with AIS.

Factors		OR	95% CI for OR
Physical Activity	High PA	1	1
	Moderate PA	1.90	0.66–5.51
	Low PA	7.221	1.640–31.797
First menstrual	Not yet	1	1
	2 years and less	0.682	0.320–1.454
	3 years and more	1.559	0.649–3.747
BMI	Overweight/Obesity	1	1
	Underweight	2.589	0.962–6.968
	Normal weight	1.071	0.500–2.295

Notes: variables with significant OR at $p < 0.05$ were shown in bold formatting.

- Continuous training for healthcare professionals: Since healthcare professionals play a crucial role as a primary source of information for adolescents and their parents regarding the importance of PA and nutritional and other modifiable factors, this ensures accurate and up-to-date knowledge on AIS and healthy musculoskeletal practices.
- Create a trustworthy online platform: Since social media has been acknowledged as a major source of information across the globe, it is recommended to establish a trustworthy website or specific social media page focused on adolescent health. The Palestinian Health Ministry should be in charge of running this platform, which would offer important updates on AIS, proper physical exercise, and other pertinent teen-related information. Adolescents would be sure to get access to reliable information in this way.

Implications for practice and research

The school nurse plays an important role in AIS. First, educate adolescents, their parents and teachers about the main risk factors for developing scoliosis through educational programs. Second, begin a screening program for the early diagnosis of scoliosis using a planned screening profile between the ages of 13 and 18. Thirdly, actively engage in research and policy-making pertaining to adolescent health and work as a change agent to create a screening protocol for boosting adolescent health across the country. Finally, as a communicator with a multidisciplinary team, the school nurse should take part in scoliosis screening as well as therapeutic interventions, including the transfer and follow-up of adolescents who are suspected of developing the condition to specialists.

Conclusion

The frequency of AIS in Palestine was significant (5.4%), which highlighted the importance of this issue at a national and global level. The study determined an association between AIS and BMI, PA, and the time of the first menstrual cycle. However, characteristics related to the school, like the weight of the backpack, and those related to the adolescent, such as gender and how they carried the backpack, did not appear to have a significant impact. These findings signify the importance of early detection of the problem to limit its burden later in life.

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CRediT authorship contribution statement

Omar H. Almahmoud: Writing – original draft, Conceptualization, Methodology, Formal analysis, Software, Supervision, Writing – review & editing. **Baraa Baniodeh:** Data curation, Writing – original draft. **Reem Musleh:** Visualization, Investigation. **Sanabel Asmar:** Writing – review & editing. **Mohammed Zyada:** Software, Validation. **Hadeel Qattousah:** Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

Abdelaal, A. A. M., Abd El Kafy, E. M. A. E. S., Elayat, M. S. E. M., Sabbahi, M., & Badghish, M. S. S. (2018). Changes in pulmonary function and functional capacity in adolescents with mild idiopathic scoliosis: Observational cohort study. *Journal of International Medical Research, 46*(1), 381–391. https://doi.org/10.1177/0300060517715375.

Almahmoud, O. H., & Abushaikha, L. (2023). Prevalence and risk factors of developmental disabilities among preschool children in the Arab world: A narrative literature review. *Child Health Nursing Research, 29*(2), 101–110. https://doi.org/10.4094/CHNR. 2023.29.2.101.

Assiri, A., Ahmed, A. M., Nabil, J. A., Ahmed, Y. A., Medhat, S., Ahmed, A., & Alsabaani, A. (2019). School screening for scoliosis among male adolescents in Abha city, Southwestern Saudi Arabia. *International Journal of Medical Research & Health Sciences, 8* (4), 190–195. https://www.indianjournals.com/ijor.aspx?target=ijor: ijmrhs&volume=8&issue=4&article=024.

de Assis, S. J. C., Sanchis, G. J. B., de Souza, C. G., & Roncalli, A. G. (2021). Influence of physical activity and postural habits in schoolchildren with scoliosis. *Archives of Public Health, 79*(1). https://doi.org/10.1186/S13690-021-00584-6.

Bonagamba, G. H., Coelho, D. M., & Oliveira, A. S. (2010). Inter and intra-rater reliability of the scoliometer. *Brazilian Journal of Physical Therapy, 14*(5), 432–438. https://doi.org/ 10.1590/S1413-35552010005000025.

Bujang, M. A. (2021). A step-by-step process on sample size determination for medical research. *The Malaysian Journal of Medical Sciences, 28*(2), 15. https://doi.org/10.21315/ MJMS2021.28.2.2.

Bunnell, W. P. (2006). Selective screening for scoliosis. *Clinical Orthopaedics and Related Research, 445*, 278–279. https://doi.org/10.1097/01.BLO.0000205905.36480.91.

Cheng, J. C., Castelein, R. M., Chu, W. C., Danielsson, A. J., Dobbs, M. B., Grivas, T. B., ... Burwell, R. G. (2015). Adolescent idiopathic scoliosis. *Nature Reviews. Disease Primers.* https://doi.org/10.1038/nrdp.2015.30.

Choudhry, M. N., Ahmad, Z., & Verma, R. (2016). Adolescent idiopathic scoliosis. *The Open Orthopaedics Journal, 10*(1), 143–154. https://doi.org/10.2174/ 1874325001610010143.

Ciaccia, M. C. C., De Castro, J. S., Rahal, M. A., Penatti, B. S., Selegatto, I. B., Giampietro, J. L. M., & Rullo, V. E. V. (2017). Prevalence of scoliosis in public elementary school students. *Revista Paulista de Pediatria, 35*(2), 191. https://doi.org/10.1590/1984-0462/; 2017;35;2;00008.

Craig, C., Marshall, A., Sjostrom, M., Bauman, A., Lee, P., Macfarlane, D., & Stewart, S. (2017). International physical activity questionnaire-short form. *Journal of American College Health, 65*(7), 492–501. https://doi.org/10.2165/11531930-000000000.

Dahl, R. E., Allen, N. B., Wilbrecht, L, & Suleiman, A. B. (2018). Importance of investing in adolescence from a developmental science perspective. *Nature, 554*(7693), 441–450. https://doi.org/10.1038/NATURE25770.

Daniel, W. (1999). *Biostatistics: A foundation for analysis in the health sciences* (7th ed.). New York: Wiley. https://scholar.google.com/scholar?hl=ar&as_sdt=0%2C5&q= Daniel%2C+W.+%281999%29.+Biostatistics%3A+A+Foundation+for+analysis +in+the+health+sciences%2C+7th+edR+Wiley.+New+York%2C+141-142. +&btnG=.

Dantas, M. G. B., Aquino, A. N., Correia, H. J., Ferreira, K. P., Nascimento, B. B., Silva, L., ... João, S. M. A. (2021). Prevalence of Back pain and idiopathic scoliosis in adolescents from the semiarid region of Brazil: A cross-sectional study. *Journal of Chiropractic Medicine, 20*(3), 97–107. https://doi.org/10.1016/J.JCM.2021.12.004.

Du, Q., Zhou, X., Negrini, S., Chen, N., Yang, X., Liang, J., & Sun, K. (2016). Scoliosis epidemiology is not similar all over the world: A study from a scoliosis school screening on Chongming Island (China). *BMC Musculoskeletal Disorders, 17*(1). https://doi.org/ 10.1186/S12891-016-1140-6.

Glavaš, J., Rumboldt, M., Karin, Ž., Matković, R., Kresina, S., Dragaš-Zubalj, N., & Aljinović, J. (2022). The role of school medicine in the early detection and management of adolescent idiopathic scoliosis. *Wiener Klinische Wochenschrift, 135*(11-12), 273–281. https://doi.org/10.1007/S00508-022-02092-1.

Grivas, T. B., Vasiliadis, E. S., Rodopoulos, G., & Kovanis, I. (2008). School screening as a research tool in epidemiology, natural history and aetiology of idiopathic scoliosis. *Studies in Health Technology and Informatics, 135*, 84–93. https://pubmed.ncbi.nlm. nih.gov/18401083/.

Hengwei, F., Zifang, H., Qifei, W., Weiqing, T., Nali, D., Ping, Y., & Junlin, Y. (2016). Prevalence of idiopathic scoliosis in Chinese schoolchildren. *Spine, 41*(3), 259–264. https:// doi.org/10.1097/BRS.0000000000001197.

Hu, M., Zhang, Z., Zhou, X., Gao, R., Wang, C., Ma, J., Meng, Y., & Zhou, X. (2022). Prevalence and determinants of adolescent idiopathic scoliosis from school screening in Huangpu district, Shanghai, China. *American Journal of Translational Research, 14*(6), 4132–4138. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9274610/.

Jada, A., Mackel, C. E., Hwang, S. W., Samdani, A. F., Stephen, J. H., Bennett, J. T., & Baaj, A. A. (2017). Evaluation and management of adolescent idiopathic scoliosis: A review. *Neurosurgical Focus, 43*(4). https://doi.org/10.3171/2017.7.FOCUS17297.

Jeon, K. K., & Kim, D. I. (2021). Low body mass index levels and idiopathic scoliosis in Korean children: A cross-sectional study. *Children, 8*(7), 570. https://doi.org/10.3390/ CHILDREN8070570.

Karachalios, T., Sofianos, J., Roidis, N., Sapkas, G., Korres, D., & Nikolopoulos, K. (1999). Ten-year follow-up evaluation of a school screening program for scoliosis. Is the forward-bending test an accurate diagnostic criterion for the screening of scoliosis? *Spine, 24*(22), 2318–2324. https://doi.org/10.1097/00007632-199911150-00006.

Karpiel, I., Ziębiński, A., Kluszczyński, M., & Feige, D. (2021). A survey of methods and technologies used for diagnosis of scoliosis. *Sensors, 21*(24). https://doi.org/10.3390/ S21248410.

Kempen, D. H. R., Heemskerk, J. L., Kaçmaz, G., Reesink, H. J., Vanhommerig, J. W., & Willigenburg, N. W. (2022). Pulmonary function in children and adolescents with untreated idiopathic scoliosis: A systematic review with meta-regression analysis. *The Spine Journal, 22*(7), 1178–1190. https://doi.org/10.1016/j.spinee. 2021.12.011.

Kim, S., Uhm, J. Y., Chae, D. H., & Park, Y. (2020). Low body mass index for early screening of adolescent idiopathic scoliosis: A comparison based on standardized body mass

index classifications. *Asian Nursing Research, 14*(1), 24–29. https://doi.org/10.1016/j.anr.2019.12.003.

Kuznia, A., Hernandez, A., & Physician, L. L. (2020). *Adolescent idiopathic scoliosis: Common questions and answers.* Aafp.Org.

Labelle, H., Richards, S. B., De Kleuver, M., Grivas, T. B., Luk, K. D. K., Wong, H. K., ... Fong, D. Y. T. (2013). Screening for adolescent idiopathic scoliosis: An information statement by the scoliosis research society international task force. *Scoliosis, 8*(1). https://doi.org/10.1186/1748-7161-8-17.

Makino, T., Kaito, T., Sakai, Y., Takenaka, S., & Yoshikawa, H. (2019). Health-related quality of life and postural changes of spinal alignment in female adolescents associated with back pain in adolescent idiopathic scoliosis. *Spine, 44*(14), E833–E840. https://doi.org/10.1097/BRS.0000000000002996.

Matusik, E., Durmala, J., & Matusik, P. (2016). Association of Body Composition with curve severity in children and adolescents with idiopathic scoliosis (IS). *Nutrients, 8*(2). https://doi.org/10.3390/NU8020071.

McMaster, M. E., Lee, A. J., & Burwell, R. G. (2015). Physical activities of patients with adolescent idiopathic scoliosis (AIS): Preliminary longitudinal case-control study historical evaluation of possible risk factors. *Scoliosis, 10*(1). https://doi.org/10.1186/S13013-015-0029-8.

Morrison, D. G., Chan, A., Hill, D., Parent, E. C., & Lou, E. H. M. (2015). Correlation between Cobb angle, spinous process angle (SPA) and apical vertebrae rotation (AVR) on posteroanterior radiographs in adolescent idiopathic scoliosis (AIS). *European Spine Journal, 24*(2), 306–312. https://doi.org/10.1007/S00586-014-3684-1.

PCBS (2022). PCBS | PCBS: Demonstrating the situation of youth in the Palestinian society, on the Eve of the International Youth Day, 2022/08/12. https://www.pcbs.gov.ps/post.aspx?lang=en&ItemID=4296.

Penha, P. J., Ramos, N. L. J. P., de Carvalho, B. K. G., Andrade, R. M., Schmitt, A. C. B., & João, S. M. A. (2018). Prevalence of adolescent idiopathic scoliosis in the state of São Paulo, Brazil. *Spine, 43*(24), 1710–1718. https://doi.org/10.1097/BRS.0000000000002725.

Płaszewski, M., Grantham, W., & Jespersen, E. (2020). Screening for scoliosis - new recommendations, old dilemmas, no straight solutions. *World Journal of Orthopedics, 11*(9), 364–379. https://doi.org/10.5312/WJO.V11.I9.364.

Pourhoseingholi, M. A., Vahedi, M., & Rahimzadeh, M. (2013). Sample size calculation in medical studies. *Gastroenterology and Hepatology From Bed to Bench, 6*(1), 14.

Scaturro, D., Costantino, C., Terrana, P., Vitagliani, F., Falco, V., Cuntrera, D., ... Mauro, G. L. (2021). Risk factors, lifestyle and prevention among adolescents with idiopathic juvenile scoliosis: A cross sectional study in eleven first-grade secondary schools of Palermo Province, Italy. *International Journal of Environmental Research and Public Health, 18*(23), 12335. https://doi.org/10.3390/IJERPH182312335.

Schmid, S., Burkhart, K. A., Allaire, B. T., Grindle, D., Bassani, T., Galbusera, F., & Anderson, D. E. (2020). Spinal compressive forces in adolescent idiopathic scoliosis with and without carrying loads: A musculoskeletal modeling study. *Frontiers in Bioengineering and Biotechnology, 8,* Article 520855. https://doi.org/10.3389/FBIOE.2020.00159/BIBTEX.

van Sluijs, E. M. F., Ekelund, U., Crochemore-Silva, I., Guthold, R., Ha, A., Lubans, D., ... Katzmarzyk, P. T. (2021). Physical activity behaviours in adolescence: Current evidence and opportunities for intervention. *The Lancet, 398*(10298), 429–442. https://doi.org/10.1016/S0140-6736(21)01259-9.

Tahirbegolli, B., Obertinca, R., Bytyqi, A., Kryeziu, B., Hyseni, B., Taganoviq, B., & Shabani, B. (2021). Factors affecting the prevalence of idiopathic scoliosis among children aged 8–15 years in Prishtina, Kosovo. *Scientific Reports, 11*(1), 16786. https://doi.org/10.1038/s41598-021-96398-1.

Teles, A. R., St-Georges, M., Abduljabbar, F., Simões, L., Jiang, F., Saran, N., ... Ferland, C. E. (2020). Back pain in adolescents with idiopathic scoliosis: The contribution of morphological and psychological factors. *European Spine Journal, 29*(8), 1959–1971. https://doi.org/10.1007/S00586-020-06489-2/METRICS.

Watanabe, K., Michikawa, T., Yonezawa, I., Takaso, M., Minami, S., Soshi, S., Tsuji, T., Okada, E., Abe, K., Takahashi, M., Asakura, K., Nishiwaki, Y., & Matsumoto, M. (2017). Physical activities and lifestyle factors related to adolescent idiopathic scoliosis. *Journal of Bone and Joint Surgery - American, 99*(4), 284–294. https://doi.org/10.2106/JBJS.16.00459.

WHO (2017). *Spotlight on adolescent health and well-being. Findings from the 2017.* World Health Organization. https://apps.who.int/iris/handle/10665/332104.

Wong, A. Y. L., Samartzis, D., Cheung, P. W. H., & Cheung, J. P. Y. (2019). How common is back pain and what biopsychosocial factors are associated with back pain in patients with adolescent idiopathic scoliosis? *Clinical Orthopaedics and Related Research, 477*(4), 676–686. https://doi.org/10.1097/CORR.0000000000000569.

Wozniczka, J., Ledonio, C., & D. P. (2017). Adolescent idiopathic scoliosis thoracic volume modeling: The effect of surgical correction. *Journal of Pediatric Orthopedics, 37*(8), e512–e518. https://doi.org/10.1097/BPO.0000000000000728.

Yılmaz, H., Zateri, C., Ozkan, A., Kayalar, G., & Berk, H. (2020). Prevalence of adolescent idiopathic scoliosis in Turkey: An epidemiological study. *The Spine Journal, 20*(6), 947–955. https://doi.org/10.1016/j.spinee.2020.01.00.

Zou, Y., Lin, Y., Meng, J., Li, J., Gu, F., & Zhang, R. (2022). The prevalence of scoliosis screening positive and its influencing factors: A school-based cross-sectional study in Zhejiang Province, China. *Frontiers in Public Health, 10,* Article 773594. https://doi.org/10.3389/FPUBH.2022.773594/BIBTEX.