Research Article *Open Access*

Journal of Pediatric Growth & Health Perspectives

DOI: doi.org/10.63721/26JPGHP0106

Persistent Postural Landmark Incoherence During School-Based Monitoring in Children Aged 8–10 Years: A Retrospective Longitudinal Observational Study

Mirko Zisi 1*, Valentina Solfrini 2 and Vincenzo Canali 3

1Habitus et Motus, Via Nazionale 144, 40046 Alto Reno Terme, Italy
2Former Director, Alto Reno Health District, Local Health Authority of Bologna, Italy
3Postura e Sport Srl, Via Alberto Savinio 26F; 43123 Parma, Italy

Citation: *Mirko Zisi, Valentina Solfrini, Vincenzo Canali (2026) Persistent Postural Landmark Incoherence During School-Based Monitoring in Children Aged 8–10 Years: A Retrospective Longitudinal Observational Study. J. of Pre Gro and Hea Pre 1(3), 1-13. WMJ/JPGHP-106*

Abstract

Background/Objectives: *School-based musculoskeletal screening frequently identifies postural asymmetries that are often transient and related to normal growth. Distinguishing physiological developmental variability from persistent clinical findings requiring closer surveillance remains a challenge. This retrospective longitudinal observational study evaluated whether repeated assessment of predefined postural landmarks could improve the identification of children requiring further clinical follow up.*

Methods: *A total of 340 children aged 8–10 years participating in a school-based musculoskeletal surveillance program underwent six standardized postural assessments during one academic year. Clinical observations were repeated under different biomechanical conditions (standing, sitting, supine, prone and forward bending when indicated) to distinguish transient from persistent alterations in predefined postural landmark relationships. Children showing persistent findings were referred for further specialist evaluation according to routine clinical practice.*

Results: *Repeated longitudinal assessment differentiated transient postural variations from persistent clinical findings. Overall, 102 of 340 children (30.0%) demonstrated persistent postural landmark incoherence and were referred for further specialist evaluation. Radiographic examinations were performed only when clinically indicated and identified 44 structural spinal alterations requiring continued clinical follow-up in a proportion of referred children. Because imaging was not systematically performed in all participants, diagnostic accuracy, sensitivity, specificity and predictive values were not evaluated.*

Conclusions: *Repeated longitudinal observation of predefined postural landmark relationships may represent a useful non-invasive strategy for school-based musculoskeletal surveillance. Persistent postural landmark incoherence should not be interpreted as a diagnosis of scoliosis but as a clinical finding that*

may justify closer observation and specialist assessment during growth. Prospective multicenter studies with standardized radiographic follow-up are required to confirm the clinical utility of this observational approach.

***Corresponding author**: Mirko Zisi, Habitus et Motus, Via Nazionale 144, 40046 Alto Reno Terme, Italy.

Submitted: 21.07.2026 **Accepted**: 27.06.2026 **Published**: 01.08.2026

Keywords: Scoliosis, School Screening, Posture, Musculoskeletal Assessment, Child, Longitudinal Studies, Follow-up Studies, Physical Examination, Observational Study, Postural Assessment

Highlights

What are the main findings?

Longitudinal observation of postural landmarks over one academic year distinguished persistent alteration in the relationships among predefined postural landmarks from transient postural asymmetries in school-aged children. Children presenting persistent postural landmark incoherence were considered for further clinical assessment and follow-up, when clinically indicated, to investigate possible underlying spinal conditions.

What are the implications of the main findings?

Repeated assessment of postural landmark relationships may support non-invasive school-based monitoring by helping identify children who could benefit from closer clinical surveillance during growth. Persistent postural landmark incoherence should not be interpreted as evidence of scoliosis but as a clinical finding that warrants appropriate follow-up within a comprehensive musculoskeletal assessment.

Introduction

Adolescent idiopathic scoliosis (AIS) is the most common structural spinal deformity in otherwise healthy children and adolescents, affecting approximately 2–3% of the pediatric population [1-3]. Although many spinal curves remain mild, progressive deformities may result in cosmetic concerns, pain, reduced physical function, impaired quality of life, and, in severe cases, cardiopulmonary complications. Because curve progression is closely associated with skeletal growth, identifying children who require closer clinical surveillance before significant progression occurs remains an important objective of pediatric musculoskeletal care. School-based screening programs have been introduced in several countries to facilitate the early recognition of children who may require orthopedic evaluation [4-7]. Current screening strategies primarily rely on clinical observation, including visual inspection of body symmetry, the Adams Forward Bend Test, trunk rotation assessment, and, when appropriate, scoliometer measurements. These methods are inexpensive, non-invasive, and suitable for large populations; however, they are intended to identify children who may benefit from further evaluation rather than to establish a diagnosis. Radiographic examination remains the reference standard for confirming scoliosis but is not appropriate as a first-line screening tool because of radiation exposure, cost, and practical limitations.

An important limitation of school-based screening is that postural asymmetry is frequently observed during childhood and does not necessarily reflect structural spinal deformity [8]. Normal growth, biological variability, temporary musculoskeletal adaptations, limb-length discrepancy, pelvic obliquity, sports participation, neuromuscular conditions, and other orthopedic factors may all influence body alignment without indicating scoliosis. Consequently, isolated postural asymmetries should not automatically prompt diagnostic conclusions or radiographic referral. Clinical musculoskeletal examination is traditionally based on the systematic observation of anatomical landmarks to evaluate body symmetry, segmental alignment, and movement patterns [9,10].

The relative position of the shoulders, scapulae, thoracic cage, pelvis, waist triangles, and trunk represents an essential component of routine orthopedic and postural

assessment. However, these observations are generally performed during a single examination, making it difficult to distinguish temporary developmental variations from persistent findings that may deserve closer attention. From a clinical perspective, repeated observation over time may provide information that cannot be obtained from a single assessment [11].

Persistent alterations in the relationships among predefined postural landmarks observed under different biomechanical conditions may represent stable clinical findings, whereas inconsistencies that disappear over repeated evaluations are more likely to reflect transient developmental variability. Therefore, longitudinal observation may support clinical decision-making by helping clinicians distinguish children who simply present physiological postural variations from those who may benefit from closer follow-up during growth.

Importantly, these findings should not be interpreted as evidence of scoliosis but rather as clinical observations that may justify continued surveillance within a comprehensive musculoskeletal assessment.

The present study was conducted within a school-based longitudinal postural monitoring program involving repeated standardized clinical evaluations over one academic year. Rather than proposing a new diagnostic method or replacing established orthopedic assessment, this study explores whether persistent alterations in the relationships among predefined postural landmarks are associated with the need for further clinical evaluation during routine practice.

The aim of this retrospective longitudinal observational study was to investigate whether repeated assessment of predefined postural landmarks could support the identification of school-aged children who may benefit from further clinical follow-up during growth. The proposed approach is intended exclusively as a non-invasive observational strategy to support clinical surveillance and should not be considered a diagnostic method for scoliosis.

Materials and Methods

Study Design

This retrospective longitudinal observational study was conducted to evaluate whether repeated standardized clinical observation of postural landmarks during routine school-based monitoring could support the identification of children who may benefit from further clinical follow-up during growth.

The study was based on data collected during a structured postural monitoring program carried out in five primary schools in the Emilia-Romagna region (Italy). Rather than evaluating postural findings at a single time point, the monitoring protocol included repeated clinical assessments performed throughout one academic year to distinguish persistent findings from transient postural variations commonly observed during childhood.

The study was observational in nature and did not involve any experimental intervention or modification of routine clinical practice. Radiographic examinations were not performed for research purposes but were requested exclusively when considered clinically appropriate following the clinical evaluation, according to routine medical practice. Because radiographic assessment was not systematically performed in the entire study population, the study was not designed to determine diagnostic accuracy, sensitivity, specificity, or predictive values. Instead, its purpose was to investigate the potential clinical usefulness of repeated longitudinal observation of postural landmarks as a strategy to support musculoskeletal surveillance during childhood.

Participants

The study population consisted of 340 school-aged children aged 8–10 years who participated in a school-based longitudinal musculoskeletal surveillance program conducted in five primary schools in the Emilia-Romagna region, Italy, over one academic year (Table1).

Table 1: Demographic Characteristics of the Study Population

Variable	N	%
Total participants	340	100
Female	180	52.9
Male	160	47.1
Sport participants	289	85
Sedentary	51	15

Children were eligible for inclusion if they were enrolled in one of the participating schools, were between 8 and 10 years of age at baseline, completed

the scheduled longitudinal clinical assessments throughout the school year, and had written informed consent provided by a parent or legal guardian. Children with conditions known to substantially affect posture independently of spinal development were excluded. Specifically, exclusion criteria included previously diagnosed congenital spinal deformities, neuromuscular disorders, syndromic conditions associated with spinal deformity, previous spinal surgeryzor any medical condition that could interfere with standardized clinical musculoskeletal assessment.

The selected age range was chosen to evaluate children during the prepubertal developmental stage, before the period of rapid skeletal growth when the risk of scoliosis progression is known to increase. Longitudinal observation during this phase provides an opportunity to distinguish persistent clinical findings from transient postural variations associated with normal growth and maturation. Accordingly, the purpose of including this age group was not to diagnose adolescent idiopathic scoliosis at an earlier age, but to investigate whether repeated standardized clinical observations could support the identification of children who may benefit from closer musculoskeletal surveillance and, when clinically indicated, further specialist assessment during subsequent growth.

At baseline, demographic and clinical characteristics, including age, sex, participation inorganized sports, and relevant musculoskeletal history, were collected using standardized questionnaires completed by parents or legal guardians. These variables were recorded to characterize the study population and to identify potential factors that might influence postural development during the observation period.

Standardized Longitudinal Clinical Assessment

Eachparticipant underwent a standardized longitudinal clinical musculoskeletal assessment on six occasions over one academic year. Assessments were performed at regular intervals usingthe same examinationprotocol and standardized observation procedures throughout the study period.

All clinical assessments were performed by trained examiners who had received standardized instruction in the assessment protocol. To ensure consistency throughout the longitudinal observation period, each child was evaluated by the same examiner at every scheduled assessment. This approach was adopted to minimize inter-observer variability and to improve the consistency of repeated clinical observations over time.

All examiners followed identical examination procedures and used standardized data collection forms during every evaluation. The clinical examination consisted of systematic observation of predefined anatomical landmarks commonly evaluated during routine musculoskeletal assessment, including the thoracic cage, pelvis, scapulae, waist triangles, and trunk alignment. Rather than interpreting each anatomical landmark independently, the examination focused on the relationships among these regions and on the consistency of their spatial organization during repeated observations.

To evaluate postural behavior under different biomechanical conditions, each participant was examined in standing, sitting, supine, and prone positions. The Adams Forward Bend Test was additionally performed whenever clinically indicated as part of the routine musculoskeletal examination to assess trunk asymmetry and rotational prominence.

The principal objective of the longitudinal assessment was not to establish a diagnosis during a single examination but to determine whether alterations in the relationships among predefined postural landmarks remained stable or changed over repeated observations throughout the school year. Findings that persisted across multiple assessments were considered stable clinical observations, whereas findings that resolved or varied over time were interpreted as transient postural adaptations commonly associated with normal growth and day-to-day musculoskeletal variability.

The standardized longitudinal assessment was designed to support clinical decision making by distinguishing children presenting persistent alterations in postural landmark relationships that could justify closer musculoskeletal surveillance from those demonstrating physiological postural variability during development. Consequently, this observational approach was intended exclusively to support decisions regarding clinical follow-up and should not be interpreted as a diagnostic procedure for scoliosis.

Clinical Observation of Postural Landmarks

Clinical assessment was based on the standardized visual observation of predefined anatomical landmarks routinely evaluated during musculoskeletal examination. The evaluation included the thoracic cage, pelvis, scapulae, waist triangles, trunk alignment, andtrunk rotational prominence when clinically indicated. Allobservations were performed according to the same standardized examination protocol throughout the study.

Rather than interpreting each anatomical landmark as an isolated clinical finding, the assessment focused on the relationships among the different anatomical regions and on their behaviour under the various examination conditions. This approach was intended to provide a comprehensive description of overall postural organization rather than to evaluate individual asymmetries independently. Particular attention was given to the persistence of alterations in the relationships among predefined postural landmarks across repeated longitudinal assessments.

Isolated or inconsistent findings observed during a single examination were considered compatible with the physiological variability commonly encountered during growth and were not regarded as sufficient to justify further clinical investigation. Conversely, alterations that remained reproducible over time and under different biomechanical conditions were considered clinically relevant and were taken into account during the subsequent surveillance process.

No anatomical displacement or postural asymmetry was quantified in absolute units of measurement. The assessment was based exclusively on standardized clinical observation using predefined evaluation criteria designed to ensure consistency throughout the longitudinal follow-up. Consequently, the examination was intended to support clinical judgment within a structured musculoskeletal surveillance program and was not designed as a quantitative measurement system or as a diagnostic test for scoliosis.

Clinical Criteria for Longitudinal Follow-up

The primary objective of the longitudinal musculoskeletal surveillance program was not to establish a diagnosis of scoliosis, but to identify children presenting persistent patterns of postural findings that might justify closer clinical observation during growth. Clinical decisions were based on the persistence and reproducibility of postural findings observed across repeated standardized assessments rather than on isolated observations obtained during a single examination. Because postural asymmetries are frequently encountered during childhood and may reflect normal developmental variability, temporary musculoskeletal adaptations, or other non-structural conditions, isolated findings were not considered sufficient to recommend further specialist evaluation.

Instead, the decision to continue musculoskeletal surveillance or to recommend additional clinical assessment was based on the overall pattern of repeated observations recorded throughout the surveillance period. Particular attention was given to findings that remained consistent over time and were reproducible under different standardized examination conditions, as these were considered more likely to represent stable clinical features than transient developmental variations.

The decision to refer a child for further specialist evaluation was always made according to clinical judgment and integrated the complete longitudinal clinical history obtained during the surveillance program. No automated decision-making process or diagnostic algorithm was used to determine referral, and no single clinical finding was considered sufficient to establish the need for further investigation.

Accordingly, the longitudinal assessment was intended to support clinical decision-making by identifying children whose persistent postural findings warranted closer musculoskeletal surveillance or specialist evaluation during growth. This observational approach should not be interpreted as a diagnostic procedure for scoliosis but rather as a structured strategy to guide clinical follow-up within a school-based musculoskeletal surveillance program.

Radiographic Evaluation

Radiographic evaluation was not included as part of the study protocol and was not performed for research purposes. Instead, spinal radiographs were requested exclusively when considered clinically appropriate following the longitudinal musculoskeletal surveillance program, in accordance with routine clinicalpractice. The decisionto recommend radiographic evaluation was

based on the overall clinical assessment and integrated the persistence and reproducibility of postural findings observed across repeated standardized examinations together with the clinician's judgment. No participant underwent radiographic examination solely on the basis of an isolated postural asymmetry identified during a single assessment.

When performed, radiographic examination was undertaken to investigate the possible presence of structural spinal alterations and to support subsequent clinical management. Radiographs were interpreted by qualified physicians according to routine clinical practice, and the results were considered complementary clinical information rather than asystematic validation of the observational assessment.

Because radiographic examinations were performed only when clinically indicated and were not systematically obtained for the entire study population, the present study was not designed to determine diagnostic accuracy, sensitivity, specificity, positive predictive value, or negative predictive value. Consequently, the radiographic findings should be interpreted as complementary evidence obtained during routine clinical care and not as proof of the diagnostic performance of the longitudinal clinical assessment described in this study.

Standardization of Clinical Assessment and Inter-Examiner Reliability

Before the implementation of the school-based musculoskeletal surveillance program, all examiners completed a standardized training program designed to ensure uniform application of the clinical assessment protocol. Training included theoretical instruction, practical demonstrations, and supervised assessment sessions focusing on the identification and recording of the predefined postural landmarks according to standardized examination procedures.

To evaluate the consistency of the standardized assessment protocol among examiners, apreliminary inter-examiner reliability exercise was conducted during the training phase. Thirty trained examiners independently evaluated the same participant under identical examination conditions using the standardized clinical assessment protocol and the same data collection procedures. Each examiner performed the assessment independently without access to the observations recorded by the other examiners. The preliminary analysis demonstrated an overall agreement of approximately 90% in the identification and recording of the predefined clinical observations, indicating satisfactory consistency among trained examiners when applying the standardized assessment protocol.

This preliminary reliability exercise was performed exclusively to standardize the clinical observation procedures before implementation of the surveillance program and to minimize variability among examiners. It should not be interpreted as a formal validation of the assessment approach but rather as evidence supporting the reproducibility of the standardized clinical examination procedures used throughout the study.

Statistical Analysis

Descriptive statistics were used to summarize the demographic and clinical characteristics of the study population. Continuous variables are presented as means and standard deviations or medians and interquartile ranges, as appropriate, whereas categorical variables are presented as frequencies and percentages.

Because radiographic examinations were performed only when clinically indicated and were not systematically obtained for all participants, no analyses of diagnostic accuracy, sensitivity, specificity, positive predictive value, or negative predictive value were performed. The objective of the statistical analysis was descriptive and exploratory, with the purpose of characterizing the study population and describing the longitudinal clinical observations recorded during the surveillance program.

Results

Study Population

A total of 340 children aged 8–10 years completed the longitudinal musculoskeletal surveillance program and met all eligibility criteria for inclusion in the study. The study population included 180 females (53%) and 160 males (47%). Among all participants, 289 children (85.0%) regularly participated in organized sports activities, whereas 51 children (15.0%) did not participate in structured physical activity. The distribution of sports participation differed between males and females and is presented in **Table 2 and 3**.

Table 2: Distribution of Sports Participation Among Male Participants

Sport	%
Football	45
Skiing	15
Tennis	12
Swimming	9
Karate	6
Sedentary	6
Judo	4
Boxe	3

Table 3: Distribution of Sports Participation Among Female Participants

Sport	%
Volleyball	39
Sedentary	36
Aerial tissues	11
Equitation	8
Football	3
Gymanstics arts	3

Football was the most frequently practiced sport among male participants, whereas volleyball represented the most common organized sport amon female participants. No participant was excluded after enrollment because of incomplete follow-up, and allenrolled children completed the six scheduled clinical assessments performed throughout the observation period

Longitudinal Clinical Observations

The repeated standardized clinical assessments demonstrated that postural findings did not remain constant throughout the observation period in all participants **(Table 4).** While many children exhibited minor postural asymmetries during individual examinations, a considerable proportion showed spontaneous changes or complete resolution of these findings during subsequent assessments. Conversely, a subgroup of participants presented persistent patterns of postural findings that remained reproducible throughout the longitudinal observation period and under different standardized examination conditions.

Table 4: Longitudinal Evolutionof Clinical Observational

Longitudinal finding	Interpretation
Finding disappeared during follow up	Transient postural variation
Finding changed between assessments	Developmental variability
Finding remains stable across repeated as-sessment	Persistent clinical finding requiring closer surveillance

These findings were characterized by stable alterations in the relationships among predefined anatomical landmarks rather than by isolated postural asymmetries observed during a single examination. The longitudinal assessment therefore enabled differentiation between transient postural variations, which were commonly observed during growth, and persistent clinical findings that remained consistent over repeated evaluations. Children presenting persistent findings were subsequently considered for closer clinical surveillance and, when judged clinically appropriate, referral for specialist evaluation according to the observational protocol described in the Materials and Methods.

No attempt was made to interpret isolated postural asymmetries as evidence of scoliosis. 356 Instead, the longitudinal observation process emphasized the persistence and reproducibility of clinical findings over time as the principal criterion supporting continued clinical follow-up.

Children Referred for Further Clinical Evaluation

Among the 340 children included in the surveillance program, a subgroup presented persistent patterns of postural findings that remained reproducible throughout repeated standardized assessments. Based on the overall longitudinal clinical evaluation, these children were considered to require closer musculoskeletal surveillance.

When persistent clinical findings remained stable over time and were judged clinically relevant by the examining clinician, referral for specialist evaluation was recommended according to routine clinical practice. The decision to refer was based on the overall longitudinal pattern of observations rather than on any isolated postural finding identified during a single assessment.

Overall, 102 children (30.0%) were referred for further specialist clinical evaluation during or following completion of the surveillance period. Referral did not constitute a diagnosis of scoliosis but represented a precautionary clinical decision intended to allow further investigation whenever persistent musculoskeletal findings were considered to justify additional assessment. Children who did not demonstrate persistent findings during repeated evaluations continued routine surveillance without further specialist referral.

Radiographic Findings

Following specialist clinical evaluation, radiographic examinations were performed only in children for whom imaging was considered clinically appropriate as part of routine patient care. Consequently, radiographic data were available exclusively for this subgroup and were not systematically obtained for the entire study population.

Radiographic assessment identified structural spinal findings of varying severity, ranging from minor spinal asymmetries to radiographic features consistent with scoliosis according to routine specialist interpretation. The radiographic examinations provided additional clinical information to guide subsequent patient management and follow-up but were not performed to validate the observational assessment protocol described in this study.

Because imaging was requested solely on clinical grounds after longitudinal surveillance, the present study does not permit conclusions regarding the diagnostic performance of the clinical assessment protocol. In particular, no estimates of diagnostic accuracy, sensitivity, specificity, positive predictive value, or negative predictive value can be derived from these data, as radiographic evaluation was not systematically performed in all participants.

Overall, the radiographic findings supported the clinical decision to continue specialist follow-up in the examined children. These observations are consistent with the concept that persistent patterns of postural findings identified during repeated standardized clinical assessments may represent an indication for further specialist evaluation.

However, the present results do not demonstrate that such clinical findings are specific for scoliosis, nor should they be interpreted as evidence of a direct diagnostic relationship. Instead, they support the potential value of longitudinal clinical surveillance as a non-invasive strategy for identifying children who may benefit from closer musculoskeletal monitoring during growth.

Summary of Longitudinal Clinical Findings

The longitudinal surveillance program demonstrated that repeated standardized clinical assessment allowed differentiation between transient postural variations and persistent patterns of postural findings observed over time. Most participants exhibited physiological variability during growth, whereas a subgroup presented stable clinical findings that remained reproducible throughout repeated assessments and under different examination conditions.

Children presenting persistent postural findings were considered for further specialist evaluation according to routine clinical judgment. When radiographic examination was clinically indicated, imaging provided complementary information to support subsequent clinical management. Taken together, these findings support the feasibility of a standardized longitudinal musculoskeletal surveillance approach for identifying children who may benefit from closer clinical follow-up during growth.

Discussion

Principal Findings

The present study investigated whether repeated standardized clinical observation of postural landmarks could contribute to the longitudinal musculoskeletal surveillance of school-aged children. Unlike conventional cross-sectional screening approaches, the proposed surveillance strategy emphasized the persistence of clinical findings over time rather than the interpretation of isolated postural asymmetries observed during a single examination.

The principal finding of this study is that repeated longitudinal assessment allowed differentiation between transient postural variations, which were frequently observed during growth, and persistent patterns of postural findings that remained reproducible throughout successive examinations. This distinction may be clinically relevant because

transient asymmetries are common during childhood and often resolve spontaneously as part of normal musculoskeletal development [12,13].

Importantly, the present findings should not be interpreted as evidence that persistent postural findings are diagnostic of scoliosis or represent a validated biomarker of structural spinal deformity. Rather, they suggest that children demonstrating persistent clinical findings over time may represent a subgroup for whom closer musculoskeletal surveillance and, when clinically appropriate, specialist evaluation could be justified.

Accordingly, the results support the concept that longitudinal clinical observation may complement routine musculoskeletal assessment by helping clinicians distinguish between physiological developmental variability and stable clinical findings requiring continued follow-up. However, confirmation of the clinical utility of this observational approach requires prospective multicenter studies with standardized radiographic follow-up.

Comparison with Previous Literature

Several professional societies and previous studies have emphasized both the potential benefits and the limitations of school-based scoliosis screening [14,15]. While early recognition of spinal deformities may allow timely specialist management, concerns remain regarding false-positive findings, unnecessary radiographic exposure, over-referral, and the lack of standardized screening strategies. Consequently, current recommendations generally encourage careful clinical evaluation while recognizing the need for additional evidence supporting screening approaches.

The findings of the present study are consistent with this perspective. Rather than proposing a new diagnostic test, the present observational approach focuses on repeated standardized clinical assessment performed over time [16]. The results suggest that longitudinal observation may provide additional clinical information beyond that obtained during a single examination by allowing differentiation between transient developmental postural variations and persistent patterns of clinical findings.

This concept is also consistent with current understanding of musculoskeletal development during childhood. Postural asymmetries are relatively common in growing children and may reflect physiological growth, temporary functional adaptations, sports participation, or other non-structural musculoskeletal factors. Consequently, isolated postural findings should be interpreted with caution and should not automatically prompt specialist referral or radiographic investigation.

The present study extends this concept by suggesting that the persistence of clinical findings observed over repeated standardized examinations may represent a more clinically meaningful criterion for determining which children warrant closer musculoskeletal surveillance [17,18]. This interpretation remains observational and should not be considered evidence that persistent postural findings are specific for scoliosis.

Rather, the findings support the rationale for prospective studies investigating whether longitudinal clinical observation can improve the efficiency of school-based musculoskeletal surveillance while reducing unnecessary referrals.

Clinical Implications

The findings of the present study have potential implications for routine musculoskeletal surveillance in school-aged children [19]. Rather than supporting the introduction of a new diagnostic procedure, the proposed longitudinal observational approach may provide clinicians with additional information for deciding which children could benefit from closer follow-up during growth.

Current school-based screening strategies are generally based on single cross-sectional examinations [20]. However, isolated postural asymmetries are common during childhood and may reflect physiological growth, temporary functional adaptations, sports participation, or other non-structural musculoskeletal conditions. Consequently, referral decisions based solely on a single clinical observation may increase unnecessary specialist consultations and imaging examinations.

The longitudinal surveillance model described in the present study emphasizes repeated standardized clinical observation over time. Within this framework, persistent and reproducible patterns of postural findings

may represent a more clinically meaningful indication for continued surveillance than isolated observations obtained during a single examination. This approach does not replace specialist evaluation or radiographic investigation but may contribute to improving the selection of children who warrant closer clinical monitoring.

From a practical perspective, repeated clinical assessment is inexpensive, non-invasive, radiation-free, and easily applicable within school-based health surveillance programs [21]. If confirmed by prospective multicenter studies with standardized clinical and radiographic follow-up, this observational strategy could complement existing musculoskeletal screening protocols by supporting more individualized follow-up pathways while potentially reducing unnecessary referrals and radiographic exposure.

Strengths and Limitations

The present study has several strengths. To our knowledge, it is among the first investigations to evaluate the potential contribution of repeated standardized clinical observation of postural landmarks within a longitudinal school-based musculoskeletal surveillance program. Unlike conventional cross-sectional screening approaches, the study was designed to monitor the evolution of clinical findings over time, allowing differentiation between transient postural variations and persistent patterns of postural findings observed throughout growth.

Furthermore, all participants underwent repeated assessments according to the same standardized examination protocol, and each child was evaluated by the same examiner throughout the surveillance period, thereby reducing interexaminer variability during longitudinal follow-up.

Nevertheless, several limitations should be acknowledged. First, this was a retrospective observational study and, therefore, no causal relationship between persistent postural findings and structural spinal deformity can be established [22]. Second, radiographic examinations were performed only when clinically indicated as part of routine patient care and were not systematically obtained for the entire study population. Consequently, the study was not designed to evaluate diagnostic accuracy or to calculate sensitivity, specificity, positive predictive value, or negative predictive value.

In addition, although the clinical assessment protocol was standardized and examiner training demonstrated satisfactory agreement, the observational approach has not yet undergone formal external validation in independent populations. Future studies should include standardized reliability analyses using established statistical methods and should evaluate reproducibility across multiple clinical settings [23].

Finally, the study population was recruited from a single geographical region, which may limit the generalizability of the findings. Prospective multicenter studies involving larger and more diverse pediatric populations, together with standardized longitudinal clinical and radiographic follow-up, will be necessary to determine the broader applicability and clinical utility of this surveillance strategy.

Future Perspectives

The findings of the present study provide the basis for future prospective investigations aimed at evaluating the clinical utility of longitudinal musculoskeletal surveillance during childhood. Although the present results suggest that persistent patterns of postural findings may assist in identifying children who warrant closer clinical follow-up, larger prospective studies are required before this observational approach can be incorporated into routine screening strategies.

Future research should include multicenter cohorts with standardized assessment protocols and systematic longitudinal clinical and radiographic follow-up. Such studies should evaluate the reproducibility of repeated clinical observations across different examiners and clinical settings and should determine whether longitudinal assessment improves the identification of children at risk of developing clinically relevant structural spinal deformities.

An additional area for future investigation will be the integration of standardized clinical observation with quantitative technologies, including surface topography, three-dimensional optical imaging, ultrasound-based assessment, and other non-ionizing imaging techniques [24,25]. Combining repeated clinical assessment with objective instrumental measurements may improve

understanding of postural development during growth while minimizing unnecessary exposure to ionizing radiation.

Future studies should also investigate the relationship between persistent postural findings and biological growth indicators, skeletal maturation, physical activity, and other musculoskeletal factors that may influence postural development throughout childhood and adolescence [26]. Such investigations may contribute to a more comprehensive understanding of the natural evolution of postural changes during growth.

Ultimately, prospective longitudinal studies with predefined clinical outcomes and standardized imaging protocols will be necessary to determine the clinical value, reproducibility, and generalizability of this observational approach. Until such evidence becomes available, the present findings should be interpreted as supporting a structured strategy for longitudinal musculoskeletal surveillance rather than as validation of a diagnostic method for scoliosis.

Conclusions

This retrospective longitudinal study suggests that repeated standardized clinical observation of postural landmarks may represent a valuable component of musculoskeletal surveillance in school-aged children. Monitoring the persistence of clinical findings overtime, rather than relying on isolated cross-sectional observations, may assist clinicians in distinguishing physiological developmental variability from persistent postural findings that justify closer clinical follow-up during growth.

The proposed observational approach is not intended to diagnose scoliosis, predict the development of structural spinal deformities, or replace specialist clinical evaluation or radiographic assessment. Instead, it should be regarded as a non-invasive clinical surveillance strategy that may help identify children who could benefit from continued observation and, when clinically indicated, further specialist evaluation.

Although the present findings are encouraging, they should be interpreted within the limitations inherent to a retrospective observational study. Prospective multicenter investigations with standardized clinical protocols, systematic radiographic follow-up, external validation, and comprehensive reliability analyses are required to determine the reproducibility, generalizability, and clinical utility of this longitudinal surveillance approach.

Overall, the present study supports the concept that repeated clinical observation of postural landmarks may contribute to a more structured and individualized musculoskeletal surveillance strategy during childhood, while emphasizing that further evidence is required before its broader implementation in clinical practice.

Patents

None.

Supplementary Materials: The following supporting information can be downloaded at the journal website: Supplementary File S1: Parental informed consent form used for participation in the school-based musculoskeletal surveillance program and for the anonymous use of clinical data for research purposes.

Author Contributions: "Conceptualization, M.Z. and V.C.; methodology, V.C.; investigation, M.Z.;formal analysis, M.Z.; data curation, M.Z.; writing—original draft preparation, M.Z.; writing—re- 585 view and editing, M.Z.; visualization, M.Z.; supervision, V.C and V.S.; project administration, M.Z.; funding acquisition, M.Z. All authors have read and agreed to the published version of the manuscript." Please turn to the CRediT taxonomy for the term explanation. Authorship must be limited to those who have contributed substantially to the work reported.

Funding: This research received no external funding.

Institutional Review Board Statement: This retrospective observational study analyzed anonymized data collected during a routine school-based musculoskeletal surveillance and prevention program. The program was authorized by the participating schools, and no additional procedures or interventions were introduced for research purposes. Written informed consent was obtained from the parents or legal guardians of all participating children, including consent for the anonymous use of clinical data for research purposes. The study was conducted in accordance with the ethical principles of the Declaration of Helsinki.

Informed Consent Statement: Informed Consent Statement: Written informed consent was obtained from the parents or legal guardians of all participating children for participation in the musculoskeletal surveillance program and for the anonymous use of clinical data for research purposes.

Data Availability Statement: The datasets generated and analyzed during the current study are not publicly available because they contain anonymized data from minors and are subject to privacy and ethical restrictions. Data are available from the corresponding author upon reasonable request.

Acknowledgments: The authors sincerely thank the participating children and their families for their trust and collaboration. The authors also acknowledge the principals, teachers, and staff of the participating primary schools for facilitating the implementation of the longitudinal musculoskeletal surveillance program.

Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

MDPI	Multidisciplinary Digital Publishing Institute
DOAJ	Directory of open access journals
TLA	Three letter acronym
LD	Linear dichroism

References

1. Janicki J A, Alman B. (2007) Scoliosis: Review of Diagnosis and Treatment. Paediatr. Child Health 12: 771-776.
2. Hresko M T. (2013) Idiopathic Scoliosis in Adolescents. N. Engl. J. Med 368: 834-841.
3. Weinstein SL, Dolan LA, Wright JG, Dobbs MB. (2013) Effects of Bracing in Adolescents with Idiopathic Scoliosis. N.Engl.J. Med 369: 1512-1521.
4. Daniel Yee Tak Fong, Chun Fan Lee, Kenneth Man Chee Cheung, Jack Chun Yiu Cheng, Bobby Kin Wah Ng, et al. (2010) A Meta-Analysis of the Clinical Effectiveness of School Scoliosis Screening. Spine 35: 1061-1071.
5. Dunn J, Henrikson NB, Morrison CC, Paula R Blasi, Matt Nguyen, et al. (2018) Screening for Adolescent Idiopathic Scoliosis: Evidence Report and System-atic Review for the US Preventive Services Task Force. JAMA 319: 173-187.
6. US Preventive Services Task Force. (2018) Screening for Adolescent Idiopathic Scoliosis: US Preventive Services Task Force Recommendation Statement. JAMA 319: 165-172.
7. Stefano Negrini, Sabrina Donzelli, Angelo Gabriele Aulisa, Dariusz Czaprowski, Sanja Schreiber, et al. (2018) 2016 SOSORT Guidelines: Orthopaedic and Rehabilitation Treatment of Idiopathic Scoliosis During Growth. Scoliosis Spinal Disord 10:13:3 https://pubmed.ncbi.nlm.nih.gov/29435499/ .
8. Romano M, Negrini S. (2005) Manual evaluation of posture in children: reliability and clinical interpretation. Vigevano (PV): GSS Gruppo di Studio della Scoliosi e delle Deformità Vertebrali; 2005.
9. Magee DJ, Manske RC. (2020) Orthopedic Physical Assessment. 7th ed. St. Louis (MO): Elsevier https://shop.elsevier.com/books/orthopedic-physical-assessment/magee/978-0-323-52299-1 .
10. Kendall FP, McCreary EK, Provance PG, Rodgers MM, Romani WA. (2005) Muscles: Testing and Function with Posture and Pain.5th ed. Baltimore (MD): Lippincott Williams&Wilkins https://pt.lwwhealthlibrary.com/book.aspx?bookid=1059
11. Saverio Sabina, Daria Monteleone, Pierpaolo Mincarone, Patrizia Maiorano, Roberto Guarino, et al. (2025) A quasiexperimental controlled study to evaluate the effects of a kinesiologic approach—the Canali Postural Method—to posturerepro-6 gramming for non-specific low back pain. Healthcare 13:869 https://pubmed.ncbi.nlm.nih.gov/40281817/ .
12. Hans Rudolf Weiss, Sarah Seibel (2018) Hemidystrophic Thorax Mimicking Scoliosis. Open Orthop J 12:252-260.
13. Negrini S, Negrini A. (2007) Postural Effects of Symmetrical and Asymmetrical Loads on the Spines of Schoolchildren. Scoliosis https://pubmed.ncbi.nlm.nih.gov/17620121/ .
14. US Preventive Services Task Force: David C Grossman, Susan J Curry, Douglas K Owens, Michael J Barry, et al. (2018) Screening for Adolescent Idiopathic Scoliosis: US Preventive Services Task Force Recommendation Statement. JAMA 319: 165-172.

15. Fong DYT, Lee CF, Cheung KMC, Cheng JCY, Ng BKW, et al. (2010) A Meta Analysis of the Clinical Effectiveness of School Scoliosis Screening. Spine 35: 1061-1071.
16. Weinstein SL, Dolan LA, Wright JG, Dobbs MB. (2013) Effects of Bracing in Adolescents with Idiopathic Scoliosis. N. Engl.J. Med 369: 1512-1521.
17. Bunnell WP. (1984) An Objective Criterion for Scoliosis Screening. J. Bone Joint Surg. Am 66: 1381-1387.
18. Goldberg CJ, Dowling FE, Fogarty EE, Moore DP. (1995) School Scoliosis Screening and the United States Preventive ServicesTask Force. Spine 20: 1368-1374.
19. Mingyang Li, Jiaying Liu ,Zeping Jiang, Qilong Nie. (2024) Prevalence of Scoliosis in Children and Adolescents: A Systematic Review and Meta-Analysis. Front. Pediatr 12: 1399049.
20. Altaf F, Drinkwater J, Phan K, Cree A K. (2017) Systematic Review of School Scoliosis Screening. Spine Deform 5: 303-309.
21. Federico Roggio, Luca Petrigna, Veronica Filetti, Ermanno Vitale, Venerando Rapisarda, et al. (2023) Infrared Thermography for the Evaluation of Adolescent and Juvenile Idiopathic Scoliosis: A Systematic Review. J. Therm. Biol 113: 103524 https://pubmed.ncbi.nlm.nih.gov/37055128/ .
22. von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, et al. (2007) STROBE Initiative. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement: Guidelines for Reporting Observational Studies. PLoS Med 335: 806-808.
23. Koo TK, Li MY. (2016) A Guideline of Selecting and Reporting Intraclass Correlation Coefficients for Reliability Research. J.Chiropr. Med 15:155-163.
24. Grivas TB, Vasiliadis E, Koulgis V, Soutos K, Kaspiris A. (2010) A review of the trunk surface metrics used as Scoliosis and other deformities evaluation indices. Scoliosis 5:12 https://pmc.ncbi.nlm.nih.gov/articles/PMC2906414/ .
25. Cheung JPY, Cheung PWH, Samartzis D, Luk KDK. (2019) Three-dimensional optical imaging for assessment of adolescent idiopathic scoliosis: a systematic review. Spine Deform 7:701-707.
26. Sanders JO, Khoury JG, Kishan S, Browne RH, Mooney JF, et al. (2008) Predictingscoliosis progression from skeletal maturity: a simplified classification during adolescence. J Bone Joint Surg Am 90: 540-553.