symmetry

MDPI

Article

Lateralization Direction, Strength, and Consistency in Juvenile and Adolescent Idiopathic Scoliosis: A Case Control Pilot Study

Barbara Dobies-Krześniak [1,*], Agnieszka Werblińska [1] and Beata Tarnacka [2]

[1] Rehabilitation Clinic, 1st Faculty of Medicine, Medical University of Warsaw, Spartańska 1, 02-637 Warsaw, Poland; klinreh@wum.edu.pl
[2] Rehabilitation Clinic, National Institute of Geriatrics, Rheumatology and Rehabilitation, Spartańska 1, 02-637 Warsaw, Poland; klinika.rehabilitacji@spartanska.pl
* Correspondence: bdobies@wum.edu.pl; Tel.: +48-22-6709481

Abstract: The aim of this study was to assess the hypothesis that functional laterality features are associated with scoliosis incidence. The study included 59 patients with radiologically confirmed idiopathic scoliosis (mean age 13 years, 41 girls and 18 boys) and 55 controls (mean age 10.5 years, 38 girls and 17 boys). Side dominance was determined by the Lateral Preference Inventory. Direction, strength, and consistency of lateral dominance was obtained. Continuous data were compared by Student's t-test or U Mann-Whitney test where appropriate. Categorical data were compared by chi-squared test and Fisher's exact test. Groups were significantly different in terms of age ($p < 0.001$) and dependent variables: height ($p < 0.001$) and weight ($p < 0.001$). Lateralization analysis showed some trends, but the results obtained were not statistically significant. Statistical significance of lateralization direction are respectively: for hand ($p = 0.364$); leg ($p = 0.277$); eye ($p = 0.804$); ear ($p = 0.938$); number of right/left sided participants $p = 0.492$; $p = 0.274$; $p = 0.387$; $p = 0.839$, and right/mixed/left sided participants $p = 0.930$; $p = 0.233$; $p = 0.691$; $p = 0.804$. For laterality consistency depending on definition used, $p = 0.105$; $p = 0.108$; $p = 0.380$. The relationship between scoliosis and laterality is not a simple causal relationship and needs further investigation.

Keywords: handedness; sidedness; brain asymmetry; children posture; side dominance

check for updates

Citation: Dobies-Krześniak, B.; Werblińska, A.; Tarnacka, B. Lateralization Direction, Strength, and Consistency in Juvenile and Adolescent Idiopathic Scoliosis: A Case Control Pilot Study. *Symmetry* **2022**, *14*, 888. https://doi.org/10.3390/sym14050888

Academic Editor: Thierry Paillard

Received: 1 March 2022
Accepted: 20 April 2022
Published: 26 April 2022

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Copyright: © 2022 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

1. Introduction

The human body is built on the principle of lateral symmetry. There are exceptions to this principle both in the structure of the body and in the functions of individual organs. Typically, there is clear distribution of functions between sides. Laterality or side dominance is described as a clear advantage of one side of the body over the other in terms of usability, precision, and coordination [1]. Laterality is a characteristic that develops gradually with age and general motor development. The final sensory and motor side dominance is determined around the age of 7 [1,2]. A reliable and valid assessment of laterality is important. There are many definitions of lateralization, and often even within a single definition we may encounter several interpretations [3].

The current literature mainly uses three types of lateralization assessment tools: performance tasks, preference tasks, and self-report questionnaires. Performance tasks compare the quality of tasks performed with both left and right sides. Preference tasks are elicitation of motor responses as an indicator of laterality. Self-report questionnaires gather information about preferences in various motor activities [3]. Due to the heterogeneity of approaches, no standardized examples of "best practices" for assessing laterality dominance are available, nor is there a single definition of "laterality" [3]. Self-report questionnaires are the easiest and most commonly used form of lateralization testing [3].

Asymmetrical spinal load associated with lateral preference is often highlighted as passible contributing factor to scoliosis pathogenesis [4]. Scoliosis is a tri-planar deformity of the spine with Cobb angle lateral curvature of at least 10 degrees (according to Cobb angle), rotation and deformation of the vertebrae. When no cause for the defect can be identified, a diagnosis of idiopathic scoliosis (IS) is made. The baseline prevalence of IS is 2 to 3%. It is more common in girls (♀:♂1.4:1 for angles 10–20° to 7.2:1 for angles >30°) [4]. The etiopathogenesis of IS is still a topic of exploration. Familial incidence suggests a genetic etiology. Among possible causes are abnormalities in estrogen receptor structure and function, mucopolysaccharide, lipoprotein, melatonin or calmodulin synthesis, matrix metalloproteinase-3 (MMP-3) and interleukin-6 (IL-6) promoter polymorphisms, and increased expression of the basonuclin 2 (BNC2) gene [4].

Some prior investigations indicate a significant correlation between direction of hand preference, strength of the asymmetry direction or side preference consistency and incidence of trunk asymmetry, scoliosis, or curve pattern of scoliosis convexity in children and adolescents [5–10]. Others did not confirm these observations [11]. Furthermore, there is no literature on the association between crossed laterality and scoliosis. Crossed laterality can be identified in people who have dominant organs located on opposite sides of the body [1]. This property requires intense cooperation between the hemispheres and can contribute to functional imbalance [1].

This study was designed to try to answer the question: can a significantly different level of lateralization traits (direction, strength and consistency) be identified in children with scoliosis?

2. Materials and Methods

2.1. Study and Control Group Background

The study group was recruited among patients of the Orthopedic and Rehabilitation Centre for Children and Youth admitted between January 2018 and July 2019. The study included children and adolescents aged 7–18 years. Patients with IS with Cobb angle $\geq$10° and vertebral rotation on anteroposterior radiograph taken in the last 6 months without connective tissue disorder in medical history and their legal guardians were approached. Informed written consent was obtained.

The control group aged 7–15 was recruited from volunteers from St. Francis School in Warsaw, Poland and was examined from April to June 2019. Children with abnormal posture diagnosed prior to study inclusion (abnormalities in spinal shape with suggestion of therapeutic intervention) were excluded. The study protocol was approved by the Warsaw Medical University Ethic Committee and was conducted in accordance with the Declaration of Helsinki principles. Study and control groups were matched by sex ratio [8,9].

The demographic and medical data (including medical history, age, sex, weight, hight) was collected from both groups.

No a priori sample estimation was performed.

2.2. Scoliosis Angular Value

To assess scoliosis in the study group, lateral spinal curve size was measured using the Cobb method [12]. BDK, using the Radiant Dicom Viewer computer program, drew lines parallel to the upper border of the upper vertebral body and the lower border of the body of the lowest vertebra of the structural arch (the vertebra most deviated from vertical), obtaining the angular value of the scoliosis.

2.3. Lateral Preference Inventory (LPI)

Side dominance was determined by the Lateral Preference Inventory (LPI) [13]. The Polish version of LPI was translated by the first author and approved by the other authors. The survey, which consists of items to assess hand, foot, eye, and ear preference was filled by the subjects. Each item requires the response of “left”, “right”, or “either” [13].

2.3.1. Side Dominance Direction and Strength

To analyze the data from the study, we scored 1 for each “right”, “0” for “either”, and “-1” for “left” answer, giving a score for each four-item scale from -4 to 4, with

−4 meaning consistent left-sidedness and 4 meaning consistent right-sidedness for any index. Then, laterality data were categorized as a dichotomy (R/L; right/left), where R is the number of "right" responses (1 to 4) and L is the number of "left" (0 to −4), and a trichotomy (right/ mixed/left; R/M/L) where "R" describes consistent right laterality with score of 4, "M"—mixed or weak laterality—from 3 to −3, and "L"—consistent left with score of −4.

2.3.2. Side Dominance Consistency

To compare the prevalence of crossed laterality, study participants were grouped based on using the opposite sides of the body while performing different tasks with any combination of hand, eye, foot, or ear [14]. We considered three used definitions of crossed laterality. Consistent (absolute) crossed laterality with at least one score of consistent right (=4), and at least one consistent left (score of −4). Secondly, we compared prevalence of strong crossed laterality with at least one result of strong right (3/4 tests marked "1") and at least one strong left (3/4 tests marked "−1") in both groups. Thirdly, simple (relative) crossed laterality with at least one "R" (scored from 4 to 1) and one "L" (from 0 to −4) item was compared between groups.

2.4. Statistics

For statistical analysis, mean value and standard deviation (SD) were used to present continuous data. Categorical data were presented as a percentage. The Kolmogorov-Smirnov test was used to verify normal distribution. Continuous data were compared by Student's *t*-test or U Mann-Whitney test where appropriate. Categorical data were compared by chi-squared test and Fisher's exact test. For statistical significance, p value less than 0.05 was considered. The statistician used IBM SPSS Statistics for Windows, v21 (IBM Corp., Armonk, NY, USA)

G*Power software v.3.1.9.4 was used to determine the effect size and conduct a post hoc analysis of the power of the study.

3. Results

3.1. Basic Statistics of the Studied Groups

The study group consisted of 59 patients with radiologically confirmed IS (mean age 13 years, 41 girls and 18 boys). A control group with 55 subjects (mean age 10.5 years, 38 girls and 17 boys) participated in this study. Basic parameters comparing both groups are shown in Table 1.

Table 1. Basic parameters of the study and the control groups.

	Study Group (n = 59)	Control Group (n = 55)	p (<0.05)
Age (years)	13.0 ± 2.4	10.5 ± 2.1	<0.001
Male sex (%)	18 (30.5)	17 (30.9)	0.963
Female sex (%)	41 (69.5)	38 (69.1)	0.972
Weight (kg)	52.3 ± 16.2	35.5 ± 10.4	<0.001
Height (cm)	160.3 ± 13.9	144.3 ± 13.3	<0.001

3.2. Comparative Analysis of Direction of Laterality between the Study Group and the Control Group

Table 2 shows the comparison between the study group and the control group in terms of laterality for each item and for the summed mean total numerical score (from −4 to 4) for each four-item scale. In general, we can see a tendency to laterally shift to the left in the study group for handedness and footedness. This effect did not reach the level of statistical significance in our study. The only item with statistical significance (identifying the ear with which the child would listen to the heartbeat) indicates a less pronounced dominance of the left ear in the scoliosis group.

Table 2. Comparative analysis of LPI items and mean for each scale.

Lateral Preference Inventory	Study Group n = 59 (100%)			Control Group n = 55 (100%)			p (<0.05)	Effect Size
	1	0	−1	1	0	−1		
Drawing	54 (91.5)	1 (1.7)	4 (6.8)	51 (92.7)	3 (5.5)	1 (1.8)	0.253	
Hit a target	40 (67.8)	15 (25.4)	4 (6.8)	43 (78.2)	9 (16.4)	3 (5.5)	0.446	
Eraser	47 (79.7)	6 (10.2)	6 (10.2)	49 (89.1)	2 (3.6)	4 (7.3)	0.316	
Dealing cards	46 (78.0)	6 (10.2)	7(11.9)	41 (74.5)	8 (14.5)	6 (10.9)	0.775	
Handedness		2.8 ± 1.8			3.1 ± 1.4		0.364	d = 0.186
Kicking a ball	46 (78.0)	10 (16.9)	3 (5.1)	42 (76.4)	8 (14.5)	5 (9.1)	0.682	
Pick up a pebble	29 (49.2)	27 (45.8)	3 (5.1)	37 (67.3)	15 (27.3)	3 (5.5)	0.119	
Stepping on a bug	33 (55.9)	22 (37.3)	4 (6.8)	36 (65.5)	14 (25.5)	5 (9.1)	0.390	
Stepping up	45 (76.3)	8 (13.6)	6(10.2)	49 (89.1)	1 (1.8)	5 (9.1)	0.062	
Footedness		2.3 ± 1.6			2.7 ± 1.7		0.277	d = 0.242
Telescope	39 (66.1)	9 (15.3)	11 (18.6)	34 (61.8)	6 (10.9)	15 (27.3)	0.492	
Looking into	38 (64.4)	8 (13.6)	13 (22.0)	41 (75.5)	4 (7.3)	10 (18.2)	0.427	
Keyhole	44 (74.6)	3 (5.1)	12 (20.3)	38(69.1)	1 (1.8)	16 (29.1)	0.392	
Sighting a rifle	36 (61.0)	14 (23.7)	9 (15.3)	37 (67.3)	6 (10.9)	12 (21.8)	0.173	
Eyedness		1.9 ± 2.7			1.8 ± 3.1		0.804	d = 0.034
Eavesdropping	33 (55.9)	17 (28.8)	9 (15.3)	35 (63.6)	12 (21.8)	8 (14.5)	0.657	
Earphone	37 (62.7)	17 (28.8)	5 (8.5)	34 (61.8)	15 (27.3)	6 (10.9)	0.904	
Heartbeat	34 (57.6)	19 (32.2)	6 (10.2)	29 (52.7)	11 (20.0)	15 (27.3)	0.044	
Clock in the box	37 (62.7)	14 (23.7)	8 (13.6)	42 (76.4)	9 (16.4)	4 (7.3)	0.273	
Earedness		1.9 ± 1.9			1.9 ± 2.2		0.938	d = 0.000

In dichotomized groups R/L (Table 3), hand and foot dominance items tested showed a trend to shift to the left in the study group, and eye and ear tended to shift to the right. Again, these effects did not achieve statistical significance.

Table 3. Comparative analysis of direction of laterality.

Dominance	Study Group n = 59 (100%)		Control Group n = 55 (100%)		p (<0.05)
	R	L	R	L	
Hand	53 (89.8)	6 (10.2)	52 (94.5)	3 (5.5)	0.492
Leg	51 (86.4)	8 (13.6)	51 (92.7)	4 (7.3)	0.274
Eye	46 (78.0)	13 (22.0)	39 (70.9)	16 (29.1)	0.387
Ear	46 (78.0)	13 (22.0)	42 (76.4)	13 (23.6)	0.839

3.3. Comparative Analysis of Strength of Laterality between the Study Group and the Control Group

The influence of laterality strength on the occurrence of scoliosis was assessed. The trichotomy R/M/L considering patients with pure right or left laterality for hand, leg, eye, or ear was analyzed. For all four subdomains, more subjects with weak laterality could be found in the scoliosis group (Table 4), but the effect observed is not statistically significant.

Table 4. Comparative analysis of strength of laterality.

Dominance:	Study Group n = 59 (100%)			Control Group n = 55 (100%)			p (<0.05)
	R	M	L	R	M	L	
Hand	28 (47.5)	30 (50.8)	1 (1.7)	28 (50.9)	26 (47.3)	1 (1.8)	0.930
Leg	15 (25.4)	43 (72.9)	1 (1.7)	21 (38.2)	34 (61.8)	0 (0.0)	0.233
Eye	27 (45.8)	26 (44.1)	6 (10.2)	28 (50.9)	20 (36.4)	7 (12.7)	0.691
Ear	15 (25.4)	43 (72.9)	1 (1.7)	17 (30.9)	37 (67.3)	1 (1.8)	0.804

3.4. Comparative Analysis of Crossed Laterality between the Study Group and the Control Group

When analyzing the consistency in preference, we can see a general trend towards more frequent crossed laterality prevalence in the control group. This observation does not have statistical significance (Table 5).

Table 5. Comparative analysis of crossed laterality.

Crossed Laterality	Study Group n = 59 (100%)	Control Group n = 55 (100%)	p (<0.05)
Consistent	1 (1.7)	5 (9.1)	0.105
Strong	8 (13.6)	14 (25.5)	0.108
Simple	21 (35.6)	24 (43.6)	0.380

4. Discussion

To our knowledge, our study is the only one that examines the prevalence and characteristics of not only hand and leg, but also eye and ear laterality using multi-item inventory in radiologically confirmed scoliotic patients with a control group.

The prevalence of left-handedness is reported between 1% and 30% depending on age, sex, handedness testing method, nationality, and sociological characteristics [3]. In our study, the frequency of left-handedness was 10.2% for the study group and 5.5% for the control group (Table 3), but the difference was not statistically significant (p = 0.492). The effect sizes of summed mean total numerical score for hand and leg laterality were d = 0.186 and d = 0.242 (small effect) and for eye and ear d = 0.034 and d = 0.000 (neglectable effect). Based on the values obtained, a post hoc analysis of the power of the study was performed, giving values of ~0.75 for hand and leg and >0.85 for eye and ear.

The main issue may not be the direction of preference alone, but the strength of laterality. Dominance appears weaker lateralized among younger respondents [15–17]. Children with clear hand dominance show less coordination problems than their poorly lateralized peers [18]. Also, early development of strong dominance (regardless of dominating side) correlate with better coordination [19]. In our study, children with pure laterality for all items tested appeared more frequently in the control group, despite their younger age (Table 4). Again, this observation was not supported by statistical significance and is opposite to observation from the study of Goldberg and Dowling [5].

Crossed laterality is a topic that needs a closer look. Inconsistencies in any pair of lateral preferences can be noted in 69.2% of healthy adults [15]. Consistency in preference across different domains increases among older respondents [15–17].

In our study, more subjects with crossed laterality of any dominance pair can be found in the control group, irrespective of the definition of crossed laterality adopted. This tendency did not achieve statistical significance (Table 5).

Results should be considered, keeping in mind the age difference in our study. The study group would be even more left lateralized and even less strongly lateralized when considering a younger population. In turn, the lateralization intersection difference would likely lose value when the groups were equalized by age.

There is no consensus in the literature whether the occurrence of scoliosis is directly related to the side and strength of lateral dominance [5–11].

Grivas et al. examined 8245 children 6 to 18 years old. Significant correlation between handedness and trunk asymmetry in the group of 2–7° mid-thoracic asymmetry was noted [10]. Chiara et al. examined 1029 Italian children aged 11–14 years. The left-side dominance was marked as a possible predictor of trunk asymmetry in thoracic and thoracolumbar curves [9].

Milenkovic et al. investigated a group of 2546 children 11 to 14 years old. Co-occurrence of left-handedness and scoliosis was statistically significant in girls [8]. Goldberg and Dowling studied 254 girls for scoliosis convexity association with handedness. The correlation of curve pattern and handedness was noted in 82% of the cases and was statistically significant.

However, in comparison to normal population proportion of left-handers among IS patients was typical [6]. The two authors have continued the topic in 1991, examining 159 children with IS using the questionnaire by Porac and Coren for hand and leg preference. They concluded that scoliotic patients tend to be more strongly lateralized than healthy peers [5]. In 2006, they published large study of 1636 children, of whom 673 had IS. The work showed a significant correlation between hand preference and scoliosis pattern [7].

All the papers mentioned differ from ours in terms of methodology. Some identify scoliosis only in terms of an abnormal Adams test result [8–11] or lateral curvature in radiogram as low as 5 degrees [6]. Such planning of the studies was probably aimed at obtaining a larger study group without the burden of the radiological examination.

There is a possibility, that lefthanders trying to adapt to a right-handed world during their daily activities at home, school, or in their social environment adopt incorrect postures developing trunk asymmetries with abnormal Adams test, but this effect does not lead to changes in bone structure of the spine [6].

Identification of dominant side is also inconsistent among studies. It could be caused by multiplicity of diagnostic methods and the heterogeneity of nomenclature.

In most previous works, only dominant (or writing) hand was identified. The identification was typically based on a question to the child or parent of which hand is preferred [6–10]. In only two papers the authors used a survey questionnaire to determine lateralization. [5,11]. This simplification allowed for larger study groups to be recruited.

In the recommendations, we can find a suggestion that multi-item inventory should be used [15]. Also, response categories consisting of 'right', 'left', and 'no preference' are considered sufficiently accurate for the assessment of lateral preferences [15]. LPI was the only survey indicated to be reliable [15].

Limitations

The most important limitation of the study is the age difference between the two groups because the mixed-siders are generally younger than both right- and left-siders [15], but this trend is most relevant when considering children under 7 years of age [16].

The age difference between the groups also explains the statistically significant differences in weight and height.

For this topic, sample size and survey power are challenging due to the high asymmetry of the lateral preference itself and the skewed distributions of consistency and strength of lateral preference. Cobb angle measurement for the study group was performed by one researcher (BDK) in a single measurement. The intra-rater reliability for this investigator was 0.706 when assuming a $\pm 1^{\circ}$ range and 0.941 when assuming a $\pm 2^{\circ}$ range.

There is a methodological problem across the studies—a lack of agreement for the definition, instruments, and methods to assess lateral preference.

5. Conclusions

The relationship between radiologically confirmed scoliosis and laterality is inconclusive.

Our study, due to the lack of statistical significance of the observations made, does not provide clinically relevant conclusions. However, it shows trends that require further observation in larger study groups, from our calculations for 0.8 power of the study and $p = 0.05$ for hand and leg lateralization minimum 359 participants in each group, keeping in mind the age difference in our study.

Author Contributions: Conceptualization, B.D.-K.; data curation, B.D.-K. and A.W.; formal analysis, B.D.-K.; funding acquisition, B.D.-K.; investigation, B.D.-K. and A.W.; methodology, B.D.-K. and B.T.; project administration, B.D.-K.; resources, B.D.-K.; supervision, B.D.-K. and B.T.; visualization, B.D.-K.; writing—original draft, B.D.-K.; writing—review and editing, B.D.-K., A.W. and B.T. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki and acknowledged by the Ethics Committee of Warsaw Medical University (KB/38/2017 from 7 March 2017).

Informed Consent Statement: The informed written consent to participate in the study was obtained from all subjects and their legal guardians. All data is anonymized. Individual consent for publication is not required.

Data Availability Statement: The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Acknowledgments: Piotr Tederko, Justyna Frasuńska.

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

Abbreviations

IS—idiopathic scoliosis.

References

1. Osiński, W. *Antropomotoryka*, 2nd ed.; AWF Poznań: Poznań, Poland, 2003; pp. 286–295.
2. Bondi, D.; Prete, G.; Malatesta, G.; Robazza, C. Laterality in Children: Evidence for Task-Dependent Lateralization of Motor Functions. *Int. J. Environ. Res. Public Health* **2020**, *17*, 6705. [CrossRef] [PubMed]
3. Utesch, T.; Mentzel, S.; Strauss, B.; Büsch, D. Chapter 4—Measurement of laterality and its relevance for sports. In *Laterality in Sports. Theories and Applications*; Loffing, F., Hagemann, N., Strauss, B., MacMahon, C., Eds.; Elsevier: Amsterdam, The Netherlands; Academic Press: Cambridge, MA, USA, 2016; pp. 65–86. [CrossRef]
4. Negrini, S.; Donzelli, S.; Aulisa, A.G.; Czaprowski, D.; Schreiber, S.; de Mauroy, J.C.; Diers, H.; Grivas, T.B.; Knott, P.; Kotwicki, T.; et al. 2016 SOSORT guidelines: Orthopaedic and rehabilitation treatment of idiopathic scoliosis during growth. *Scoliosis Spinal Disord.* **2018**, *13*, 3. [CrossRef] [PubMed]
5. Goldberg, C.J.; Dowling, F.E. Idiopathic scoliosis and asymmetry of form and function. *Spine* **1991**, *16*, 84–87. [CrossRef] [PubMed]
6. Goldberg, C.; Dowling, F.E. Handedness and scoliosis convexity: A reappraisal. *Spine* **1990**, *15*, 61–64. [CrossRef] [PubMed]
7. Goldberg, C.J.; Moore, D.P.; Fogarty, E.E.; Dowling, F.E. Handedness and spinal deformity. *Stud. Health Technol. Inform.* **2006**, *123*, 442–448. [PubMed]
8. Milenkovic, S.; Kocijancic, R.; Belojevic, G. Left handedness and spine deformities in early adolescence. *Eur. J. Epidemiol.* **2004**, *19*, 969–972. [CrossRef] [PubMed]
9. Arienti, C.; Buraschi, R.; Donzelli, S.; Zaina, F.; Pollet, J.; Negrini, S. Trunk asymmetry is associated with dominance preference: Results from a cross-sectional study of 1029 children. *Braz. J. Phys. Ther.* **2019**, *23*, 324–328. [CrossRef] [PubMed]
10. Grivas, T.B.; Vasiliadis, E.S.; Polyzois, V.D.; Mouzakis, V. Trunk asymmetry and handedness in 8245 school children. *Pediatr. Rehabil.* **2006**, *9*, 259–266. [CrossRef] [PubMed]
11. Fernandez, M.; Fernandez, R.; Zurita, F.; Jimenez, C.; Almagia, A.; Yuing, T.; Curilem, C. Relationship between Scoliosis, Sex and Handedness in a Sample of Schoolchildren. *Int. J. Morphol.* **2015**, *33*, 24–30.
12. Cobb, J.R. The problem of the primary curve. *J. Bone Joint Surg. Am.* **1960**, *42*, 1413–1425. [CrossRef] [PubMed]
13. Coren, S. The Lateral Preference Inventory for measurement of handedness, footedness, eyedness, and earedness: Norms for young adults. *Bull. Psychon. Soc.* **1993**, *31*, 1–3. [CrossRef]
14. Ferrero, M.; West, G.; Vadillo, M.A. Is crossed laterality associated with academic achievement and intelligence? A systematic review and meta-analysis. *PLoS ONE* **2017**, *12*, e0183618. [CrossRef]
15. Tran, U.S.; Stieger, S.; Voracek, M. Evidence for general right-, mixed-, and left-sidedness in self-reported handedness, footedness, eyedness, and earedness, and a primacy of footedness in a large-sample latent variable analysis. *Neuropsychologia* **2014**, *62*, 220–232. [CrossRef] [PubMed]
16. Greenwood, J.G.; Greenwood, J.J.; McCullagh, J.F.; Beggs, J.; Murphy, C.A. A survey of sidedness in Northern Irish schoolchildren: The interaction of sex, age, and task. *Laterality* **2007**, *12*, 1–18. [CrossRef] [PubMed]
17. Suar, D.; Mandal, M.K.; Misra, I.; Suman, S. Lifespan trends of side bias in India. *Laterality* **2007**, *12*, 302–320. [CrossRef] [PubMed]
18. Hill, E.L.; Bishop, D.V. A reaching test reveals weak hand preference in specific language impairment and developmental co-ordination disorder. *Laterality* **1998**, *3*, 295–310. [CrossRef] [PubMed]
19. Gabbard, C.; Hart, S.; Kanipe, D. Hand preference consistency and fine motor performance in young children. *Cortex* **1993**, *29*, 749–753. [CrossRef]