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ORIGINAL RESEARCH

# Trunk asymmetry is associated with dominance preference: results from a cross-sectional study of 1029 children

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**KEYWORDS**
Spinal posture;
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**Abstract**
*Background:* In some studies, an association has been reported between laterality of the curve in scoliotic adolescents and hand dominance; however, additional studies have to be performed to confirm these findings.
*Objective:* The objective of this study is to evaluate the prevalence between trunk asymmetry and side dominance in hand, foot and visual laterality in adolescents.
*Methods:* This was a cross-sectional study secondary analysis. In total, 1029 children (491 females) were enrolled from the Secondary School of Brescia, Italy, with a mean age of 12 (SD = 0.9 years). All subjects underwent a screening program divided into three phases: Phase 1, collection of demographic and clinical characteristics; Phase 2, spine evaluation with a plumb line and Bunnell Scoliometer; and Phase 3, evaluation of side dominance of the eye, hand and foot with a 4-item survey.
*Results:* Our data showed a prevalence of 0.43%, 1.01% and 0.87% for thoracic, thoracolumbar and lumbar curves, respectively, with a right-side dominance and a prevalence of 2.72%, 2.54% and 0.65% for thoracic, thoracolumbar and lumbar curves, respectively, with a left-side dominance.
*Conclusion:* The left-side dominance could have a prevalence on trunk asymmetry in thoracic and thoraco-lumbar curves. Our study suggests that the clinical evaluation of trunk asymmetry should be associated with the evaluation of laterality.


*Abbreviations:* TA, trunk asymmetry; SD, side dominance; ATR, angle of trunk rotation; PPV, sensitivity, specificity, positive; NPV, negative predictive values; TP, true positive; FP, false positive; TN, true negative; FN, false negative.

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## Introduction

Trunk asymmetry (TA) is defined as a clinical expression of scoliosis[1] and appears to correlate with the prediction of future scoliosis in adolescents; however, it is not a sensitive clinical sign of scoliosis.[2–4] Changes in TA mainly develops during the pubertal growth spurt in girls and boys and shows a strong surface-spine relation with scoliosis.[5–7]

The aetiology of scoliosis is multi-factorial, and includes genetic, tissue, hormonal, and neurosensorial factors.[8] Side dominance (SD), one of the behavioural markers of early neurodevelopment, can be defined as preference or hand-differences in task performance and represents an expression of the motor cortex asymmetry of the brain.[9] A positive association has been reported between laterality of the curve in scoliotic adolescents and hand dominance,[10] but further studies are needed to confirm this. One of the hypotheses involves the cerebral cortex functioning as an aetiopathogenic factor for the development of TA.[11] In other studies, a correlation between SD and the scoliotic curve has a prevalence in right thoracic scoliosis and right-handed patients.[12] The obvious predominance of right convex thoracic curve patterns in scoliosis has always suggested a parallel with hand preference and with other patterns of cerebral lateralisation.[13] This has prompted hypotheses that associate the two, either with the dominant side causing scoliosis or the reverse, scoliosis determining SD, but curve convexity itself is not a major predictive sign.[1,14]

For some authors, the laterality evaluation should form an integral part of the scoliotic patient's assessment; the majority of these studies have only evaluated the graphic manual laterality,[15] but the development of laterality is a complex process that involves a different part of the cortex.[9,16] For this reason, it is preferable to use an evaluation of the hand, podal and visual laterality in subjects to verify a possible aetiopathogenesis hypothesis of side dominance.[17] Therefore, the objective of this study is to evaluate the prevalence between TA and side dominance in hand, foot and visual laterality in adolescents.

## Methods

### Ethical statement

The authors declare no conflict of interest, and no commercial or other source of funding was received. This study was conducted in accordance with the Declaration of Helsinki, with written informed consent obtained from the parents of adolescents; the study was specifically approved by the IRCCS Don Gnocchi Foundation Ethical Committee in Milan (8/12 December 2012).

### Study design

Full details about the cross-sectional study design and primary analysis are available in the study by Arienti et al.[18] The main part of the study design is summarised as follows.

### Setting

Recruitment was performed in a secondary school, located in a town in the North of Italy, in the gym of the school, during gym lessons, from February to April 2014. We evaluated a total of 47 school classes with a postural examination, which was included in the school scoliosis screening program.

### Participants

The inclusion criterion was age between 11 and 14 years. Exclusion criteria were physical and cognitive disability, genetic polymorphism and bone growth disease.

### Procedure

The evaluation was based on a postural examination divided into three phases, performed once by two different physical therapist examiners. Phase 1 involved anthropometric data collection and Phase 2 was the clinical evaluation of the spine in all planes; these phases have been previously reported in the study by Arienti et al.[18] That study focused on correlations between the morphology of the spine and the face, while the current study focused on a totally different aspect: the possible correlation between a neurological phenomenon (side preference) and the morphology of the spine.

Phase 3 was the evaluation of SD, which was performed through a protocol with a checklist completed for each child, where handedness was included. The children's hand, eye and foot preferences were documented by asking the child which hand, eye and foot they prefer for everyday activities, especially writing, eating, throwing an object or performing fine motor skills. For those children where hand preference for performing diverse types of manual tasks varied, hand preference was determined by the number of tasks performed by each hand.

### Outcome measures

Patients were evaluated for trunk asymmetry[18] and dominance through clinical assessment.

The evaluation of SD was based on a specific evaluation protocol to evaluate hand, eye, and foot dominance preference. The examiner had a clear picture of each child's hand, eye, and foot preference, so no demonstration was needed. Each child was classified objectively as having right- or left-dominance.[11]

### Statistical analysis and sample size

Linear regression was performed to estimate the effect of trunk asymmetry and side dominance on the angle of trunk rotation (ATR). The sample size was calculated to require at least 30 patients with idiopathic scoliosis. Since the prevalence of scoliosis (more than 7° of ATR) is between 2% and 3%,[19] we aimed to recruit 1000 schoolchildren. The study was powered for a $p$ value set to 0.05, assuming 80% power, and an effect size where the difference between means is 50% of the standard deviation within groups.

**Table 1** Baseline demographic characteristics.

| Variable | Participants($n = 1029$) |
|---|---|
| *Demographic characteristics* | |
| Age (years) | $12.4 \pm 0.9$ |
| Gender, female [*n* (%)] | 491 (47.7%) |
| Weight (m) | $49.0 \pm 11.0$ |
| Height (m) | $157.4 \pm 10.2$ |
| *Predominant side* | |
| Write, right [*n* (%)] | 923 (89.7%) |
| Throw, right [*n* (%)] | 952 (92.5%) |
| Foot, right [*n* (%)] | 905 (87.9%) |
| Eyes, right [*n* (%)] | 768 (74.6%) |
| *Trunk asymmetry >4°* | |
| Thoracic | 53 (5.2%); $4.8 \pm 1.1$ |
| Thoraco-lumbar | 81 (7.9%); $5.3 \pm 1.6$ |
| Lumbar | 74 (7.2%); $5.1 \pm 1.5$ |
| *Trunk asymmetry ≥7°* | |
| Thoracic | 6 (0.6%) |
| Gender, female [*n* (%)] | 2 (0.2%) |
| Thoraco-lumbar | 13 (1.3%) |
| Gender, female [*n* (%)] | 10 (1.0%) |
| Lumbar | 9 (0.9%) |
| Gender, female [*n* (%)] | 8 (0.8%) |

Data were analysed using SPSS version 20.0 (SPSS Inc., Chicago, IL, USA). The results are expressed as means, standard deviations, and/or 95% confidence intervals. Sensitivity, specificity, positive (PPV) and negative predictive values (NPV), accuracy, and positive likelihood ratio (LR = sensitivity/1-specificity) of each manoeuvre to detect handedness and trunk asymmetry was calculated using a two-by-two table, using as cut-off ATR≥4°. $p < 0.05$ was considered statistically significant.

## Results

The overall characteristics of the included population are reported in Table 1 Table 1.

Of the 1029 subjects included, 79.9% were symmetric (ATR <4°), 18.0% were asymmetric with an ATR between 4° and 7°, and 2.1% were asymmetric with an ATR ≥7°. Overall, 89.5% of the sample showed right-side dominance, 6.7% reported left-side dominance and 3.8% were ambidextrous. In total, 96.1% of boys and 93.5% of girls were symmetric in the thoracic region; for the thoracolumbar and lumbar regions, the corresponding percentages were 94.6–89.4% and 96.1–89.2%, respectively. ATR mean values in the subjects with TA were $4.8 \pm 1.1$, $5.3 \pm 1.6$ and $5.1 \pm 1.5$ in the thoracic, thoraco-lumbar and lumbar spine, respectively, as shown in Table 1. No significant differences were detected between subjects with or without a SD and TA with respect to gender.

The association of right-side dominance with TA was estimated to have a prevalence of 0.43%, 1.01% and 0.87% for right thoracic, right thoracolumbar and left lumbar curves, respectively. It was not possible to consider the right-side dominance as a predictor of TA and vice versa, due to the very low sensitivity, specificity, positive and negative predictive values and likelihood ratios (Table 2 Table 2).

The association of left-side dominance with TA was estimated to have a prevalence of 2.72%, 2.54% and 0.65% for right thoracic, right thoracolumbar and left lumbar curves, respectively. It was possible to consider a prevalence of left-side dominance in TA in thoracic and thoraco-lumbar curves and vice versa due to the high sensitivity, specificity, positive and negative predictive values and likelihood ratios (Table 3).

## Discussion

The present study investigated the correlation between TA and SD with evaluations of the hand, foot and visual laterality in 1029 adolescents. The results showed a prevalence of left-side dominance in TA with the possibility of considering the left-side dominance as a predictor of TA in thoracic and thoraco-lumbar curves and vice versa.

We expect these results to be generalisable since these data refer to a general population in which no specific selection processes were applied. Some of the schools involved were in a large town, while others where in a nearby rural area. Obviously, the population refers to Italy, so it is possible that the results could be different in other countries, even if there are no real physiological reasons why this would happen. In terms of the prevalence of trunk asymmetries, our data corresponded to previous results.[18]

The literature showed that the normal spine has a slight rotation and curvature with the same laterality as TA, which may explain why the laterality of the curve pattern may

**Table 2** Physical examination findings in predominant side (right).

| Result | 2 × 2 Table | Sensitivity | Specificity | PPV | NPV | OR (95% CI) | +LR (95% CI) | −LR (95% CI) | |
|---|---|---|---|---|---|---|---|---|---|
| Trunk asymmetry | TP[a] | FP[a] | | | | | | | |
| | TN[a] | FN[a] | | | | | | | |
| Thoracic | 25 | 28 | 47.2 | 32.6 | 3.7 | 91.9 | 0.43 (0.25–0.75) | 0.7 (0.52–0.93) | 1.62 (1.24–2.12) |
| | 658 | 318 | | | | | | | |
| Thoraco | 54 | 27 | 66.7 | 33.6 | 7.9 | 92.2 | 1.01 (0.63–1.64) | 1.0 (0.86–1.18) | 0.99 (0.72–1.37) |
| Lumbar | 629 | 319 | | | | | | | |
| Lumbar | 47 | 27 | 63.5 | 33.4 | 6.9 | 92.2 | 0.87 (0.53–1.43) | 0.95 (0.8–1.14) | 1.09 (0.8–1.5) |
| | 636 | 319 | | | | | | | |

[a] Legend: T = Right side dominance; P = Right side convexity curve; F = No right-side dominance; N = No right-side convexity

**Table 3** Physical examination findings in the predominant side (left).

| Result | 2 × 2 Table | Sensitivity | Specificity | PPV | NPV | OR (95% CI) | +LR (95% CI) | −LR (95% CI) |
|---|---|---|---|---|---|---|---|---|
| Trunk asymmetry | TP<br>TN | FP<br>FN | | | | | | |
| Thoracic | 5<br>36 | 48<br>940 | 9.4 | 96.3 | 12.2 | 95.1 | 2.72 (1.02–7.24) | 2.51 (1.02–7.24) | 0.92 (0.82–1.04) |
| Thoraco Lumbar | 7<br>34 | 74<br>914 | 8.6 | 96.4 | 17.1 | 92.5 | 2.54 (1.09–5.93) | 2.28 (1.12–4.63) | 0.9 (0.78–1.03) |
| Lumbar | 2<br>39 | 72<br>916 | 2.7 | 95.9 | 4.9 | 92.8 | 0.65 (0.15–2.76) | 0.67 (0.17–2.63) | 1.03 (0.96–1.1) |

T = Left side dominance; P = Left side convexity curve; F = No left side dominance; N = No left side convexity.

differ from the pathogenesis of TA and scoliosis.[20] The superficial extrinsic back muscles on the right side, which contribute to the movement of the upper limbs, should be stronger than those on the left side as they should help to restrict the tendency of flexion and rotation of the spine. Humans will most likely use the right upper limb as it seems to be lighter due to the stronger superficial extrinsic back muscles. This may be the reason for the right laterality of handedness.[14,21] As a result of the trend of right flexion and rotation of the spine in most right-handed people, the right convex curve pattern is frequent. The same mechanism might be valid for left SD related to TA. Milenkovic et al.[22] showed that left-handedness might be significantly related to scoliosis in females during early adolescence.[22] In addition, genetical and environmental factors, such as lateralisation of cerebral motor cortex function[11] and carrying a backpack in an asymmetrical manner,[23] may affect the spine in the age near the growth spurt and influence the correlation between SD and TA.[10]

Consequently, the previous management of TA is very important to prevent its progression because it may cause painful spine degenerative processes[24,25] and finally, cardiovascular[26] and respiratory complications requiring operative treatment. It is important to consider the left SD as a possible predictor of TA in the screening process of adolescents, and to plan in-depth sessions for them. For left-sided adolescents, there are also many important specific preventive measures concerning board adjustment, writing technique, body posture while writing, and left-side dominance specific school supplies that can be used before puberty.[27]

This study has some limitations, such as the screening procedures used which precluded a real study of the bones; the low prevalence of scoliosis and asymmetries in our sample yielded only a few scoliosis subjects, even though it was reported to be representative of a general population. Also, poor vision was not considered an exclusion criterion.

## Conclusion

This study showed a prevalence of left-side dominance in trunk asymmetry in thoracic and thoraco-lumbar curves and vice versa. This is a crucial point for the prompt treatment of trunk asymmetry and the prevention of further progression. Further studies are necessary to investigate the development of SD in TA in adolescents.

## Declarations

### Ethics approval and consent to participate

The study was conducted in accordance with the Helsinki Declaration; written informed consent was obtained from the parents of the children and was specifically approved by the IRCCS Don Gnocchi Foundation Ethic Committee in Milan.

### Consent for publication

Consent for publication was obtained from the parents of the children.

### Availability of data and materials

The datasets used and analysed during the current study are available from the corresponding author upon reasonable request.

### Funding

Not applicable.

## Conflicts of interest

The author declares no conflicts of interest.

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