Paraspinal Muscle Activity During Symmetrical and Asymmetrical Weight Training in Idiopathic Scoliosis

Annina B. Schmid, Linda Dyer, Thomas Böni, Ulrike Held, and Florian Brunner

Context: Various studies report decreased muscle activation in the concavity of the curve in patients with scoliosis. Such decreased muscle-performance capacity could lead to sustained postural deficits. Objective: To investigate whether specific asymmetrical sports therapy exercises rather than symmetrical back strengthening can increase EMG amplitudes of paraspinal muscles in the concavity of the curve. Design: Cross-sectional. Setting: Laboratory. Participants: 16 patients with idiopathic scoliosis. Interventions: Patients performed 4 back-strengthening exercises (front press, lat pull-down, roman chair, bent-over barbell row) during 1 test session. Each exercise was performed in a symmetrical and asymmetrical variant and repeated 3 times. Main Outcome Measure: EMG amplitudes of the paraspinal muscles were recorded in the thoracic and lumbar apexes of the scoliotic curve during each exercise. Ratios of convex- to concave-side EMG activity were calculated. Results: Statistical analysis revealed that the asymmetrical variants of front press at the lumbar level (P = .002) and roman chair and bent-over barbell row at the thoracic level (P < .0001, .001 respectively) were superior in increasing EMG amplitudes in the concavity of the scoliotic curve. Conclusions: Specific asymmetrical exercises increase EMG amplitudes of paraspinal muscles in the concavity. If confirmed in longitudinal studies measuring improvements of postural deficits, these exercises may advance care of patients with scoliosis.

Keywords: exercise therapy, resistance training, low back pain, physical therapy
Recent studies confirm that muscle morphology is most affected on the concave side of the scoliotic curve.\textsuperscript{11–13} Histological evaluation of muscle tissue in the concavity indicates a lower proportion of oxidative slow-twitch (type 1) fibers.\textsuperscript{12} Because healthy paraspinal muscles are mainly postural muscles with a predominance of type 1 muscle fibers,\textsuperscript{14} a smaller area of type 1 muscle fibers in patients with scoliosis may indicate the presence of decreased tonic activity in the concavity of the curve. Some authors have hypothesized that this may lead to a reduced ability to sustain tonic contractions for prolonged periods of time and cause sustained postural deficits in patients with IS.\textsuperscript{15}

Weight training is commonly used in sports therapy to improve postural performance capacity of the paraspinal muscles. These exercises are normally performed symmetrically. Considering the decreased tonic capacity of the muscles in the concavity of the scoliotic curve with a subsequent overactivation of the convex muscles, symmetrical exercises may carry the risk of aggravating the existing imbalance in patients with IS. Ideally, strengthening programs in patients with scoliosis should be targeted to the weaker concave side rather than the already activated convex side. However, it is not known whether asymmetrical exercises targeting the concave side are feasible and effective in patients with IS.

This study therefore aimed to investigate whether asymmetric weight training focusing on the concave side of the scoliotic curve is feasible in patients with IS and whether this training increases electromyographic (EMG) activity of the concave side.

### Methods

**Design**

Our study used a cross-sectional, within-subject design. The participants attended a single testing session where we measured electromyographic activity of their paraspinal muscles during different exercises.

**Participants**

Sixteen female participants with IS were recruited through the outpatient clinic of a university hospital and through community-based physiotherapists specializing in the treatment of patients with scoliosis (see Table 1 for demographic data). We

<table>
<thead>
<tr>
<th>Table 1 Demographic Data</th>
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<tbody>
<tr>
<td>Characteristic</td>
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<tr>
<td>Age, median (interquartile range)</td>
</tr>
<tr>
<td>Visual analog score, mean (95% confidence interval)</td>
</tr>
<tr>
<td>Cobb angle, mean (95% confidence interval)</td>
</tr>
<tr>
<td>Main curve thoracic</td>
</tr>
<tr>
<td>Main curve lumbar</td>
</tr>
<tr>
<td>Main curve thoracolumbar</td>
</tr>
<tr>
<td>Double major</td>
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</table>
included female patients with IS and a Cobb angle of $\geq 30^\circ$ because patients with smaller Cobb angles may not present with muscle asymmetries. Spinal curves (according to Cobb) were obtained from radiographs. Exclusion criteria were back-pain intensity $>4$ on a visual analog scale, pregnancy or corset bracing during the last 12 months, previous spinal surgery, systemic diseases, and neurological symptoms or signs.

We obtained ethics approval from the university institutional ethics committee, and all subjects gave their informed written consent to participate in the study.

**Exercises**

A physiotherapist specializing in scoliosis treatment and sports therapy instructed each participant in how to perform 4 symmetrical exercises (see Figure 1). These symmetrical exercises are commonly used in sports therapy and public fitness centers to strengthen the paraspinal muscles and improve core stability. We developed an asymmetrical variant of each exercise targeted to favoring paraspinal muscle activity in the concavity of the scoliotic curve (see Figure 1). All participants were given the same weight irrespective of their maximum voluntary contraction because we were not interested in the overall extent of paraspinal muscle activation but in the ratio of convex- to concave-side EMG activation. Patients performed all exercises symmetrically and asymmetrically in a randomized order.

Front press was performed pressing two 1-kg weights overhead in the frontal plane. The asymmetrical front press resembles the muscle cylinder that is commonly used in conservative management of patients with scoliosis.

Lat pull-down was performed pulling a 10-kg handle from overhead to the cranial part of the sternum. In the asymmetrical lat pull-down, the patient positioned her left leg on a box, which was individually adapted in height to prevent her right hip joint from sliding laterally (as frequently seen in patients with scoliosis). Hence, the asymmetrical variant was designed to counteract the scoliotic curvature by correcting the pelvic position. Lat pull-down and front press are designed to improve postural trunk control during a dynamic arm task.

For the roman chair, the patients were instructed to start in an inclined position with their back stabilized in a neutral position. They then bent the trunk forward by flexing the hip joints to reach the horizontal plane. The only difference between the symmetrical and asymmetrical roman chairs was the position of the arms, as shown in Figure 1, which should facilitate the activation of the concave-side muscles. The roman chair is designed to strengthen the paraspinal muscles, with a focus on the lumbar area.

The bent-over barbell row was performed with the patient in a squatting position, ensuring that the back was stabilized in a neutral position. During the symmetrical exercise, the patients pulled a 6-kg barbell with 1 additional kg on each side toward their sternum. During the asymmetrical task, we used an imbalanced barbell by adding 2 additional kg on the left side and none on the right. This exercise facilitates core stability in an inclined position, which is important for daily activities such as lifting or bending.

**EMG Recordings**

EMG activity of the paraspinal muscles was recorded during each exercise. Four pairs of surface electrodes were placed 2 cm apart on the superficial erector spinae
<table>
<thead>
<tr>
<th>Symmetrical</th>
<th>Asymmetrical</th>
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<tbody>
<tr>
<td><img src="image1" alt="Front press" /></td>
<td><img src="image2" alt="Front press" /></td>
</tr>
<tr>
<td>(1 kg dumbbell each side)</td>
<td></td>
</tr>
<tr>
<td><img src="image3" alt="Lat pull down" /></td>
<td><img src="image4" alt="Lat pull down" /></td>
</tr>
<tr>
<td>(7.5 kg)</td>
<td></td>
</tr>
<tr>
<td><img src="image5" alt="Roman chair" /></td>
<td><img src="image6" alt="Roman chair" /></td>
</tr>
<tr>
<td>(no weight)</td>
<td></td>
</tr>
<tr>
<td><img src="image7" alt="Bent over barbell row" /></td>
<td><img src="image8" alt="Bent over barbell row" /></td>
</tr>
<tr>
<td>(6 kg barbell + 2 x 1 kg on both sides or on left side only)</td>
<td></td>
</tr>
</tbody>
</table>

**Figure 1** — Symmetrical training exercises with corresponding asymmetrical variants.
Paraspinal Muscle Activity in Scoliosis

muscles, 3 cm from the midline and parallel to the spinous processes. The levels of the electrodes corresponded with the thoracic and lumbar apex as determined on the radiographs. The ground electrode was placed on the spinous process of T1 (see Figure 2).

EMG signals were amplified and sampled at 1000 Hz using Solea software (Alea Solutions, Zurich, Switzerland). The raw EMG data were filtered for electrocardiogram contamination using a high-pass Butterworth filter with a cutoff frequency of 30 Hz. According to the trigger signal, the EMG signal of each exercise was divided into 3 sequences. Each sequence was normalized for time, after which the average EMG signal was calculated. The root mean square (RMS) quantified the EMG amplitude of this averaged signal. Ratios of convex- to concave-side EMG amplitudes were then calculated by dividing the RMS of the convex side by the RMS of the concave side of the scoliotic curve. We interpret a ratio <1 as a greater EMG amplitude on the concave side and a ratio >1 as a greater amplitude on the convex side of the scoliotic curve.

Procedure

Surface EMG was first recorded twice for 10 seconds in the relaxed standing position to determine differences in muscle activation of the paraspinal muscles. The participants then performed each exercise 3 times in a randomized order. The investigator ensured a standardized rhythm of performance by counting in seconds and by visually controlling the accuracy of timing. The start and end of each of the 3

Figure 2 — Surface electrode placement at the thoracic and lumbar apexes of the scoliotic curve.
repetitions of the exercise were marked by the investigator by activating a handheld trigger. A rest of 3 minutes was allowed between exercises to avoid muscle fatigue.

**Statistical Analysis**

The statistical package SPSS, version 15 (SPSS Inc, Chicago, IL), was used for all analyses. We used the Wilcoxon signed-ranks test to compare the ratio of the symmetrical exercise with the ratio of the asymmetrical exercise in both the thoracic apex and the lumbar apex of the curve.

We analyzed the intertester reliability with intraclass correlation coefficients (ICC; 2-way random model with absolute agreement) for the convex:concave ratio for each exercise (symmetrical and asymmetrical) to assess the degree of standardization of the measurement procedure.

The ICCs for the EMG values were high for all exercises (from .871 to .996) except the asymmetrical front press on the thoracic level, which showed only fair agreement with an ICC of .615 (lower- and upper-bound confidence intervals .129 and .860, respectively). Lower- and upper-bound confidence intervals for all other exercises ranged from .706 to .999, indicating a high level of reliability.

**Results**

Comparison of the convex and concave sides of the scoliotic curve in standing revealed a median ratio of the convex-side EMG over the concave-side EMG of 2.3 (interquartile range 0.8–4.9) for the lumbar curve and a ratio of 1.3 (interquartile range 0.7–2.0) for the thoracic curve, suggesting that the convex side of the curve may be more active both in the lumbar and in the thoracic curve. Because there was no difference in preferential muscle activation depending on the scoliotic curve type, we report group results.

**Table 2 EMG Ratios for the Exercises**

<table>
<thead>
<tr>
<th>Exercise</th>
<th>Symmetrical</th>
<th>Asymmetrical</th>
<th>P</th>
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<tbody>
<tr>
<td><strong>Thoracic curve</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Front press</td>
<td>1.23 (0.87–2.05)</td>
<td>1.93 (1.52–1.93)</td>
<td>.049</td>
</tr>
<tr>
<td>Roman chair</td>
<td>1.10 (0.79–1.49)</td>
<td>0.33 (0.26–0.57)</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Lat pull-down</td>
<td>0.93 (0.70–1.24)</td>
<td>1.14 (0.83–1.71)</td>
<td>.041</td>
</tr>
<tr>
<td>Bent-over row</td>
<td>1.12 (0.80–1.43)</td>
<td>0.72 (0.57–0.84)</td>
<td>.001</td>
</tr>
<tr>
<td><strong>Lumbar curve</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Front press</td>
<td>1.69 (0.58–3.47)</td>
<td>0.20 (0.13–0.39)</td>
<td>.002</td>
</tr>
<tr>
<td>Roman chair</td>
<td>1.68 (0.91–2.58)</td>
<td>1.68 (0.95–2.19)</td>
<td>.163</td>
</tr>
<tr>
<td>Lat pull-down</td>
<td>0.86 (0.66–2.73)</td>
<td>1.09 (0.58–2.37)</td>
<td>.191</td>
</tr>
<tr>
<td>Bent-over row</td>
<td>1.64 (0.95–2.45)</td>
<td>1.38 (0.84–1.77)</td>
<td>.013</td>
</tr>
</tbody>
</table>

Ratio <1 indicates preferential activation of the concave side. Ratio >1 indicates preferential activation of the convex side.
Table 2 outlines the ratios during symmetrical and asymmetrical exercises. The following asymmetric exercises showed statistically significantly different ratios favoring the concavity of the scoliotic curve: front press at the lumbar level \((P = .002)\) and bent-over barbell row at the lumbar level \((P = .013)\). Roman chair \((P < .0001)\) and bent-over barbell row \((P = .001)\) reached statistically significantly different ratios in the thoracic level. Front press and lat pull-down reached statistical significance at the thoracic level \((.049\) and \(.041\), respectively\). However, these 2 exercises favor the concavity of the scoliotic curve if performed symmetrically. See Figures 3(a–d) for examples of EMG data during the exercises that enhance concave-side EMG activity.

**Figure 3(a)** — Examples of electromyographic (EMG) data of a representative patient during the bent-over barbell row for the lumbar spine (normalized for time) Gray: convex-side EMG in microvolts. Black: concave-side EMG in microvolts.
Figure 3(b) — Examples of electromyographic (EMG) data of a representative patient during the bent-over barbell row for the thoracic spine (normalized for time) Gray: convex-side EMG in microvolts. Black: concave-side EMG in microvolts.

Discussion

Main Findings

We found that the front press and bent-over barbell row can increase EMG amplitudes in the concavity of the lumbar scoliotic curve when performed asymmetrically. In the thoracic curve, the asymmetric roman chair and bent-over barbell row increased the concave-side EMG amplitudes. The lat pull-down and front press, however, activated the concavity of the thoracic curve more strongly when performed symmetrically.
Results in the Context of the Existing Literature

Our findings confirm previous reports describing decreased EMG amplitudes of the concave musculature of the scoliotic curve during relaxed standing. Even though many studies reported this imbalance in static positions, there are not many that investigated scoliotic paraspinal EMG activity during dynamic back-strengthening exercises. Two studies investigated the effect of 4 months of weight training including torso rotation. Even though the rotation exercise was performed in both directions, identical resistance was used in both studies, which presumably challenges the weaker concave side more. In one study, this exercise regimen was efficient in correcting asymmetrical strength in patients with IS, which was associated with around 20% improvement of the scoliotic curvature in most patients. In the other study, training reduced curve progression at 8 months but not 24 months in patients with a Cobb angle of 20° to 40°. We hypothesize that these findings might be a
result of improved muscle-performance capacity of the paraspinal muscles, which addresses the functional component of the scoliotic curve. Similarly, Weiss\textsuperscript{15} has shown that an intensive inpatient rehabilitation program based on asymmetrical exercises\textsuperscript{22} can improve the postural performance capacity of the paraspinal muscles. The author suggested that improved postural-performance capacity might lead to a functional correction of the scoliotic curve.\textsuperscript{15} The mentioned studies advocate specifically targeted asymmetrical interventions for patients with IS. It is therefore crucial to evaluate the activation pattern of exercises used in rehabilitation of patients with scoliosis.

Besides individual physiotherapeutic rehabilitation, recent literature highlights the importance of core-strengthening exercises in patients with scoliosis who wish to participate in sports.\textsuperscript{23} Having the alterations of the paraspinal muscles in mind, it seems that commonly used symmetrical back-strengthening exercises may not be suitable for patients with scoliosis.
Our results demonstrate that some asymmetrical exercises target the lumbar concavity and others primarily favor the thoracic curve. Commonly used back-strengthening exercises may therefore be specifically adapted for patients with scoliosis to optimize training.

**Strength and Limitations**

This study focused on the development and evaluation of exercises that preferentially activate the concave muscles in patients with scoliosis. Our participants therefore only attended 1 training session, and because no long-term effect was expected, no attempt was made to measure the effect of these exercises on functional curve correction.

We used standardized weights that allowed each participant to perform the exercises correctly and without fatigue. Gaudreault et al.\(^2\) have shown that the RMS force relationships of patients with scoliosis and healthy people, as well as between the concave and the convex, are comparable at 10% to 80% of their maximum voluntary contraction. Standardized weights may therefore not differentially influence the concave and the convex side of the scoliotic curve. In clinical practice and future longitudinal studies, however, the weights should be individually adapted for each patient to achieve maximum training adaptations.

To our knowledge, this is the first study investigating the potential of these asymmetrically performed sports-therapeutic exercises to increase EMG amplitudes in the concavity of the scoliotic curve. Sport therapy alone, however, does not replace specialized individual physiotherapy appointments that offer comprehensive educational and postural management. Our set of exercises is designed to optimize back-strengthening programs such as those performed in sport therapy or in a fitness center as an adjunct to individual physiotherapy sessions.

**Implications for Research**

Future longitudinal studies with a bigger patient population are necessary to confirm our results and to investigate the long-term effects of these exercises on muscle-performance capacity and possibly curve progression of patients with scoliosis. Moreover, their influence on level of disability and participation should be taken into consideration in future longitudinal studies.

**Implications for Practice**

The different convex:concave EMG ratios of the thoracic and lumbar curves among the different exercises suggest that exercise selection may be based on the type of the scoliotic curve. For patients with a main thoracic curve, the asymmetrical roman chair may be most suitable, whereas the asymmetrical bent-over barbell row might be especially useful to train both the lumbar and thoracic concavities. This latter exercise reflects inclined activities such as bending and lifting and may therefore improve performance capacity during these activities.

The asymmetrical front press seems to be suitable for patients with a main lumbar curve. Nevertheless, this exercise together with the lat pull-down generated statistically significantly smaller thoracic EMG ratios when performed symmetrically. This suggests that the lat pull-down and front press may be superior
in activating the thoracic concavity if performed symmetrically. Nevertheless, the large interquartile range of the symmetrical front press and the inability to reverse thoracic EMG ratio indicates that these results should be interpreted with caution in clinical practice.

Because of the complexity of muscle activation during these exercises, we suggest that a suitable training program be instructed by a physiotherapist with experience treating patients with scoliosis.

**Conclusion**

Our study suggests that asymmetric back-strengthening exercises that activate the lumbar or thoracic concavity of the scoliotic curve are feasible in patients with idiopathic scoliosis. Specifically, the asymmetric front press and bent-over barbell row increase EMG amplitudes in the lumbar concavity, and the roman chair and bent-over barbell row target the thoracic concavity. If confirmed in longitudinal studies measuring improvements in postural deficits, these exercises may advance care of patients with scoliosis.

**Acknowledgments**

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**References**