Effects of Respiratory-Muscle Exercise on Spinal Curvature

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Design: Randomized controlled study. Setting: Laboratory. Participants: 26 healthy swimmers randomly assigned to an exercise (n = 13; Ex) or control group (n = 13; Cont). Intervention: The Ex group performed respiratory-muscle exercises for 10 min thrice a week for 4 wk. Context: Respiratory-muscle exercises are used not only in the rehabilitation of patients with respiratory disease but also in endurance training for athletes. Respiration involves the back and abdominal muscles. These muscles are 1 of the elements responsible for posture control, which is integral to injury prevention and physical performance. However, the effects of respiratory-muscle exercise on posture remain unclear. Objective: To examine the potential of respiratory-muscle exercise for improving posture. Main Outcome Measures: Spinal curvature, pulmonary function, and trunk-muscle strength were measured for both the groups at baseline and after 4 wk. The data were compared between the Ex and Cont groups with Mann–Whitney U test and preintervention and postintervention within groups with a Wilcoxon signed rank-sum test. Results and Conclusion: The spinal curvature was significantly different in the Ex group, indicating a decrease in the thoracic (–13.1%, P < .01) and lumbar (–17.7%, P < .05) angles. The Ex group presented with lower thoracic (–8.6%) and lumbar (–20.9%) angles at postexercise than the Cont group (P < .05). With respect to trunk-muscle strength, only trunk-flexion strength significantly increased from pretest to posttest in the Ex group (P < .05). For pulmonary function, forced vital capacity and forced expiratory volume in 1.0 s were significantly increased after 4 wk in the Ex group (P < .05). The results suggest that respiratory-muscle exercise straightened the spine, leading to good posture control, possibly because of contraction of abdominal muscles.

Keywords: trunk-muscle training, spinal alignment, low back pain

In competitive sports, the spine of young athletes can have excess thoracic kyphosis and lumbar lordosis because it is the conduit for transferring mechanical power between the upper and lower extremities during rapid and forceful movements. Consequently, it is subjected to large 3-dimensional bending moments in flexion, extension, and axial rotation, with concomitantly large compression and shear forces. Under the influence of these forces, athletes have much degeneration of the intervertebral disks, and the loss of disk height with denaturation is associated with increased spine curvature. Thoracic kyphosis and lumbar lordosis contribute to back pain. Much inclined thoracic kyphosis lessens or increases lumbar lordosis. The loss or increase of lumbar lordosis correlates well with the incidence of chronic low back pain. In addition, thoracic kyphosis leads to shoulder pain. In swimming, shoulder pain termed swimmer’s shoulder occurs frequently. The major cause of swimmer’s shoulder has been thought to be impingement of the subacromial structures. Scapular-motion abnormalities result from several factors such as inadequate serratus anterior activation, excess upper trapezius activation, pectoralis minor tightness, posterior capsule tightness, inadequate rotator-cuff activation or partial tearing, pectoralis major tightness, and thoracic kyphosis or flexed posture. In particular, thoracic hyperkyphosis encumbers motions of the scapulothoracic joint—for example, greater scapular internal rotation and anterior tilt and lesser scapular upward rotation. Swimming-stroke motions require great range of motion in the shoulder joint. When thoracic hyperkyphosis and decreased motion of the scapulothoracic joint occur, the glenohumeral joint covers the gaps of motion in the swimming stroke. Thus, the glenohumeral joint is used more than it usually would be, leading to swimmer’s shoulder. Spinal-alignment control is essential for preventing various injuries. Alignment depends on muscle strength and balance, muscle tightness, and skeletal structure.

The trunk muscles are grouped into 2 categories: global and local stabilizers. The global stabilizers comprise superficial muscles such as the rectus abdominis and longissimus muscles, and the local stabilizers are deep muscles, for example, the transverse abdominal and multifidus muscles. Cholewicki et al reported that the
contraction of local stabilizers is indispensable to trunk stability; that is, the trunk becomes unstable in the case of contraction of global stabilizers alone. The unstable trunk increases stress to the ligament and bone that control the end of motion and cause pain such as back pain.12

Exercises for local stabilizers are performed by athletes for injury prevention13 and improved sport performance.14 Alternatively, stabilizing exercises like Pilates15,16 and yoga17 lead to good posture. However, local stabilizing exercises entail certain problems. For beginners attempting the exercise, it is difficult to selectively contract the local stabilizers, and most individuals contract the global stabilizer muscles instead. It can lead to injury during sports activities, so exercises that stimulate local stabilizers selectively and easily need to be developed.

Respiratory-muscle exercises are used in the rehabilitation of chronic obstructive pulmonary disease18 and endurance exercise for athletes.19 The muscles comprise the diaphragm, intercostal muscles, and the accessory muscles of respiration.20 The accessory muscles of respiration consist of several of the trunk muscles, including local stabilizers. Therefore, this study focused on exercises for the respiratory muscles, which have the advantage that the load can be accurately set by regulating frequency and depth of breathing. We hypothesized that respiratory-muscle exercises would stimulate the local stabilizers, alter spinal curvature, and straighten postural alignment. This original study is the first to examine the potential of respiratory-muscle exercises for improving postural control in spinal curvature.

Methods

Participants

We recruited 26 healthy swimmers from 2 swim teams. Swimmers who had had severe respiratory dysfunction (eg, asthma or pneumonia) or spinal injury were excluded for the study. Participants were randomly assigned to an exercise or control group (each \( n = 13 \), 8 males and 5 females; Table 1). No smokers were included; all the participants were under age.

Procedure

Spinal curvature was measured with the SpinalMouse (Idiag Co, Switzerland; Figure 1), an electronic computer-aided measuring device, which measures sagittal-spinal ROM and intersegmental angles in a noninvasive way, a so-called surface-based technique. This device can measure the angle between the vertebral bodies from C7 to S3, with data corresponding to those obtained from X-rays.21 After basic data are obtained for the patient, including height, weight, gender, and age, the SpinalMouse is run paravertebrally along the spinal column from C7 to S3. When manually guided paravertebrally along the spine of a subject, the system records the outline of the skin over the spinal column in the sagittal plane. The local angle or inclination relative to a perpendicular line is given at any position by an internal pendulum connected to a potentiometer. An intelligent recursive algorithm computes information concerning the relative position of the vertebral bodies of the underlying bony spinal column. Raw data of the SpinalMouse measurements are the superficial back length from C7 to S3 and the local angle of each point of this length relative to the plumb line. In this manner, spinal curvature and 17 segments (Th1/2–L5/S1) are evaluated. Based on the measurements, this study defined the total C7–L1 angle as tho thoracic kyphosis angle (TH angle) and the total T12–S1 angle as the lumbar lordosis angle (L angle).21

Pulmonary function was measured by Autospiro AS-407 (Minato Medical Science Co, Japan) to confirm the effect of respiratory-muscle exercise. To evaluate pulmonary function, we measured forced vital capacity (FVC) and forced expiratory volume in 1.0 second (FEV1.0). Subjects performed 3 familiarization trials before measurements.

Trunk-muscle strength was measured by Isoforce GT-350 (OG Giken Co, Ltd, Japan), for which high reliability and validity are attested.22 Subjects were asked to sit on a chair in 90° flexion at the hip and knee joints and perform 3 trials of isometric trunk extension and flexion with maximal voluntary effort. The average of 3 trials was used as the measurement value.

The exercise group performed the respiratory-muscle exercises with the Spiro Tiger (Idiag Co, Switzerland; Figure 2), a device consisting of a handheld unit with a respiratory pouch and a base station. The device allows for personalized respiratory exercises through maximal inspirations and expirations without hypocarbia. Individual exercise target values are entered into the base unit and are used to monitor breathing frequency and depth during exercise. The base station in the handheld computer monitors breathing frequency, sets threshold limits for breathing patterns, and displays visual and acoustic feedback to enable the subject to breathe within the threshold values for isocapnia.23 The base station also stores the time and frequency of each exercise session. This device trains both inspiration and expiration muscles by resistance of a magnetic splint inside a respiratory tube and geared for strength and endurance of the respiratory muscles. The exercise group exercised for 10 minutes thrice a week for 4 weeks. Typically, respiratory-muscle exercises in endurance exercise for athletes are performed for ~15 minutes.24,25 However, the intervention time was 10 minutes in this study, because we were investigating not endurance but muscle function. The frequency and the intervention period followed those of a previous study.26,27

Table 1  Subject Characteristics, Mean ± SD

<table>
<thead>
<tr>
<th>Group</th>
<th>Gender, M:F</th>
<th>Age, y</th>
<th>Height, cm</th>
<th>Weight, kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exercise</td>
<td>8:5</td>
<td>16.1 ± 0.6</td>
<td>166.3 ± 8.6</td>
<td>57.8 ± 9.2</td>
</tr>
<tr>
<td>Control</td>
<td>8:5</td>
<td>17.6 ± 1.8</td>
<td>169.2 ± 5.9</td>
<td>60.2 ± 7.6</td>
</tr>
</tbody>
</table>
Personal training target values are entered into the base unit and used to monitor breathing frequency (1.5 × the rest time frequency; average 28.1 times/min) and depth (the respiratory pouch the nearest to 50%FVC, 2.0-L pouch, 5 swimmers; 2.3-L pouch, 8 swimmers) during training. The exercise group was instructed to inflate and deflate the respiratory pouch completely and breathe according to the tempo of a sound from the base station. The training target was constant throughout intervention. Participants in both groups continued swim training throughout the intervention. After 4 weeks, spinal curvature and pulmonary function were measured again for both the exercise and control groups. The data were compared preexercise and postexercise between the groups.

This study was approved by the Hiroshima University Department of Physical Therapy and Occupational Therapy Sciences ethical review board. We obtained informed consent from all the subjects and their parents before the study. No research grants contributed to the study.

**Statistical Analyses**

A Wilcoxon signed rank-sum test was used to compare preexercise and postexercise values, and a Mann–Whitney U test was used to compare the exercise and control groups, with the significance level of <5%. StatView 5.0 (SAS Institute, Cary, NC) was used for data analysis.

**Results**

The spinal-curvature angles are shown in Table 2. Statistical analysis revealed a significant difference within the exercise group for the preexercise to postexercise values for all parameters measured, indicating a decrease in the TH (–13.1%) and L (–17.7%) angles after the intervention. The muscle strengths for trunk flexion and extension are shown in Table 3. These results indicated a significant increase only in trunk-flexion strength from preexercise to postexercise in the exercise group (+10.6%, P < .05).

There was no significant difference in trunk strength (P < .05). There are no differences in initial dates between the groups. However, the exercise group presented with lower TH (–8.6%) and L (–20.9%) angles postexercise than the control group (P < .05).
between the groups with respect to the preexercise and postexercise values.

The pulmonary-function values are shown in Table 4. FVC (+4.5%) and FEV1.0 (+8.8%) were significantly increased after 4 weeks for the exercise group ($P < .01$). There were no differences in the FVC and FEV1.0 values for the 2 groups.

### Discussion

Swimmers can be plagued by joint pain and dysfunction, which are attributed to several factors including posture.\(^7\) For example, thoracic hyperkyphosis encumbers motions of the scapulothoracic joint\(^8\) and leads to swimmer’s shoulder.\(^6\) Improvement in posture is essential to prevent and treat injury.\(^28\) This study examined the effects of a 4-week respiratory-muscle exercise intervention on spinal curvature and trunk-muscle strength. Our results indicated that the exercise significantly decreased the TH and L angles and increased trunk-flexion-muscle strength and pulmonary function. Decreased spinal curvature leads to adaptive changes in the pelvis and lower limbs and improves posture.\(^29\) Therefore, we believe that the exercises targeted muscles that contribute to improved posture. Furthermore, we observed between-groups differences for thoracic kyphosis and lumbar lordosis after the intervention. Increased spine curvature is responsible for low back pain\(^4,5\) and swimmer’s shoulder,\(^6\) so respiratory-muscle exercise may prevent these dysfunctions.

In this study, FVC and FEV1.0 values were elevated in the exercise group at the end of the intervention. Similar results have been demonstrated by a previous study without FEV1.0.\(^30\) This confirms the effect of respiratory-muscle exercise in improving pulmonary function.

The preexercise thoracic and lumbar curvatures in this study are similar to those in another Japanese study,\(^31\) and the postexercise curves in the exercise group are better than that. These results showed that curvatures improved. The postexercise thoracic and lumbar curvatures were smaller than the preexercise curvatures. Because muscle strength for trunk flexion was noted to increase only in the exercise group, we conclude that the exercises strongly affected the abdominal muscles. Abe et al.\(^32\) reported that the transverse abdominal muscle is the most powerful in the abdominal muscle group with respect to respiration. The transverse abdominal muscle may have been specifically targeted in this exercise. This important muscle is a key local stabilizer. Contraction of the transverse abdominis increases intra-abdominal pressure, which leads to lumbar

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**Table 2** Change in Spinal Curvature, Mean ± SD

<table>
<thead>
<tr>
<th>Group</th>
<th>Thoracic Angle, °</th>
<th>Lumbar Angle, °</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Preexercise</td>
<td>Postexercise</td>
</tr>
<tr>
<td>Exercise</td>
<td>41.7 ± 5.1**</td>
<td>36.2 ± 5.1**†</td>
</tr>
<tr>
<td>Control</td>
<td>39.4 ± 3.4</td>
<td>39.6 ± 5.5†</td>
</tr>
</tbody>
</table>

*Pre vs post, $P < .05$; **pre vs post, $P < .01$; †ex vs cont, $P < .05$.

**Table 3** Changes in Trunk-Muscle Strength, Mean ± SD

<table>
<thead>
<tr>
<th>Group</th>
<th>Trunk Flexion, N</th>
<th>Trunk Extension, N</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Preexercise</td>
<td>Postexercise</td>
</tr>
<tr>
<td>Exercise</td>
<td>695.4 ± 175.2*</td>
<td>769.2 ± 179.7*</td>
</tr>
<tr>
<td>Control</td>
<td>687.6 ± 113.6</td>
<td>681.0 ± 95.3</td>
</tr>
</tbody>
</table>

*Pre vs post, $P < .05$.

**Table 4** Changes in Pulmonary Function, Mean ± SD

<table>
<thead>
<tr>
<th>Group</th>
<th>Forced Vital Capacity, L</th>
<th>Forced Expiratory Volume in 1.0 s, L</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Preexercise</td>
<td>Postexercise</td>
</tr>
<tr>
<td>Exercise</td>
<td>4.1 ± 0.7**</td>
<td>4.3 ± 0.8**</td>
</tr>
<tr>
<td>Control</td>
<td>4.2 ± 0.7</td>
<td>4.2 ± 0.8</td>
</tr>
</tbody>
</table>

**Pre vs post, $P < .01$; †ex vs cont, $P < .05$.**
straightening. In addition, a rise in intra-abdominal pressure presses the rib cage upward and effectively allows the extension of the thoracic vertebrae. In a previous study, Izumizaki et al. reported that thoracic capacity and rib-cage movement were changed by thixotropy, which is the exercise of maximal expiration from maximum inspiration. The stiffness of the rib cage leads to thoracic kyphosis. In this study, repetitive deep breathing resolved the stiffness of the rib cage and straightened thoracic kyphosis. This process may be responsible for altering the spinal curvature.

In contrast, trunk-extension-muscle strength was not altered. In quiet breathing, inspiration requires muscle contractions. However, expiration occurs naturally via the elasticity of the respiratory apparatus. Our subjects respired faster and deeper than in common respiration during the respiratory exercises. The respiratory-muscle exercise may thus affect abdominal muscles that do not normally play a role in breathing at rest, and it may not have any effect on back muscles that typically work in breathing at rest.

Emery et al. reported that subjects showed smaller static thoracic kyphosis during quiet sitting and greater abdominal strength after 12 weeks of Pilates training, and Scannell and McGill noted that the lumbar curvature of their subjects with hyperlordosis became less lordotic, decreasing their standing lumbar lordosis by 10° after 12 weeks of trunk-muscle training. These training methods require a long period of 12 weeks for improvement. By contrast, our intervention period was 4 weeks, so spinal alignment may be improved in a much shorter period. In addition, if respiratory-muscle exercise is combined with stretching used in the previous study, further effects may be expected.

Our study has certain limitations: (1) The reason underlying the altered alignment is a matter of speculation because muscle function was not measured. (2) The effect of changes in curvature on performance or injury treatment or prevention remains unclear. (3) There was no placebo group. (4) There was no measure of respiratory-muscle strength or endurance. (5) The authors were not blinded to the study. Further studies are required to clarify these issues.

**Conclusion**

Our study examined the effectiveness of respiratory-muscle exercise to both increase trunk-muscle strength and correct spinal curvature in adolescent swimmers. The results suggest that respiratory-muscle exercise straightens the spine, possibly by stimulating the local stabilizers.

**References**


