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Title: Clinical Efficacy of Ultrasound-Assisted Scoliosis-Specific Exercise in Mild-Grade Adolescent Idiopathic Scoliosis

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Author Questionnaire

1. **Microscopy**: Does your protocol require the use of a dissecting or stereomicroscope for performing a complex dissection, microinjection technique, or something similar? **No**

2. **Software:** Does the part of your protocol being filmed include step-by-step descriptions of software usage? **Yes, all done**

3. **Filming location:** Will the filming need to take place in multiple locations? No

4. **Testimonials (optional):** Would you be open to filming two short testimonial statements **live during your JoVE shoot**? These will **not appear in your JoVE video** but may be used in JoVE's promotional materials. **NO**

Current Protocol Length
Number of Steps: 23
Number of Shots: 52 (25 SC)

Introduction

Videographer: Obtain headshots for all authors available at the filming location.

INTRODUCTION:

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~~What is the scope of your research? What questions are you trying to answer?~~

1.1. **Junjie Tong:** This study investigates mild AIS to assess ultrasound-assisted scoliosis-specific exercise's clinical efficacy.
   1.1.1. INTERVIEW: Named talent says the statement above in an interview-style shot, looking slightly off-camera.

~~What technologies are currently used to advance research in your field?~~

1.2. **Junjie Tong:** Currently, ultrasound and AI-assisted diagnosis and treatment are used to advance mild AIS research.

   1.2.1. INTERVIEW: Named talent says the statement above in an interview-style shot, looking slightly off-camera.

CONCLUSION:

~~What are the current experimental challenges?~~

1.3. **Junjie Tong:** Our main experimental challenges involve achieving standardized data collection, maintaining consistent intervention delivery, and ensuring strong adolescent adherence.
   1.3.1. INTERVIEW: Named talent says the statement above in an interview-style shot, looking slightly off-camera.

~~What significant findings have you established in your field?~~

1.4. **Junjie Tong:** Our most significant finding is that ultrasound-assisted scoliosis exercises reduce mild curve progression and improve intercostal structure and diaphragmatic mobility

1.4.1. INTERVIEW: Named talent says the statement above in an interview-style shot, looking slightly off-camera.

~~What new scientific questions have your results paved the way for?~~

1.5. **Junjie Tong:** Our results raise new questions about the long-term efficacy of ultrasound-assisted scoliosis exercises and how to individualize training parameters.

1.5.1. INTERVIEW: Named talent says the statement above in an interview-style shot, looking slightly off-camera.

Videographer: Obtain headshots for all authors available at the filming location.

Ethics Title Card

This research has been approved by the Human Research Ethics Committee of the Ninth People's Hospital of Wuxi, affiliated with Soochow University

Protocol

2. Ultrasound-Guided Intercostal Breathing Training Protocol for Scoliosis Rehabilitation

Demonstrator: Junjie Tong

2.1. To begin, gather the ultrasound device, the coupling gel, the disposable mat, and the disposable gloves **[1]**.

2.1.1. WIDE: Talent collecting the ultrasound device, coupling gel, disposable mat, and a pair of disposable gloves from a preparation table.

2.2. Inform the patient and their parents about the examination and training procedure **[1]**. Explain that the treatment area will be exposed and that coupling gel will be applied between the ribs **[2-TXT]**. Instruct the patient to observe the real-time ultrasound imaging on the screen **[3]**.

2.2.1. Talent explaining the procedure to the patient and parents using calm gestures.

2.2.2. Talent pointing to the rib area on the patient and demonstrating how the gel will be applied. **TXT: Emphasize that the procedure is radiation free and painless**

2.2.3. Talent guiding the patient to observe the real-time ultrasound

Videographer: please obtain ultrasound screen in the view

2.3. Position the patient in a seated posture or in lateral decubitus with the concave side facing up **[1]**. If in lateral decubitus, place a 5-to-10-centimeter pillow under the ribs at the level of the apical vertebra **[2]**. Ensure both feet are flat or stacked, maintain spinal neutrality **[3]**, and expose the target intercostal area **[4]**.

2.3.1. Talent assisting the patient into seated or lateral decubitus position.

2.3.2. Talent placing a 5-to-10-centimeter pillow under the ribcage at the apical vertebral level.

2.3.3. Talent adjusting the patient's legs and posture.

2.3.4. Talent uncovering the intercostal area.

2.4. Put on disposable gloves **[1]**. Apply a small amount of ultrasound coupling gel evenly over the target intercostal space **[2]**.

2.4.1. Talent wearing disposable gloves.

2.4.2. Talent applying ultrasound gel across the intercostal space using gloved fingers.

2.5. Press the **Power** button and wait about 30 seconds for the self-check to finish and the main interface to appear **[1]**.

2.5.1. Talent pressing the Power button on the ultrasound machine and self-check is

done and main interface appers.

2.6. Enter the patient's **name**, **sex, age, ID**, and **examination date** into the system **[1]**. For intercostal imaging, select **MSK Superficial** with the linear probe L10-5 *(L-Ten-Five)*, and for diaphragm imaging, select **Abdomen General** with the convex probe C5-2 *(C-Five-Two)* **[2]**.

2.6.1. SCREEN: 2.6.1.mp4. 00:10-00:24

2.6.2. SCREEN: 2.6.2.mp4. 00:03-00:17

2.7. Using palpation and anatomical landmarks, identify the concave intercostal space corresponding to the apical vertebra along the mid-axillary line **[1]**. Place the ultrasound probe over this area with the ultrasound plane perpendicular to the rib's long axis **[2]** and visualize the intercostal muscles and rib dynamics **[3]**.

2.7.1. Talent palpating anatomical landmarks such as the acromion, scapular spine, and inferior angle to identify rib levels.

2.7.2. Talent placing the probe along the mid-axillary line over the concave intercostal space with perpendicular orientation.

2.7.3. SCREEN: 2.7.3.mp4 00:05-00:20

2.8. Adjust the **Depth** knob to 2 to 4 centimeters **[1]**, set the **2D Gain** knob to clearly visualize the rib interface and fascial line **[2-TXT]**, ~~fine-tune brightness using the **TGC** sliders **[3]**,~~ and set the **Focus Position** to the intercostal muscle layer **[4]**.

2.8.1. Talent rotating the Depth knob on the ultrasound control panel.

2.8.2. Talent adjusting the 2D Gain knob to sharpen the image.
TXT: Fine tune brightness using TGC sliders

2.8.3. ~~SCREEN: Talent sliding the TGC controls to fine-tune brightness at different depths.~~
Note: Shot deleted by authors

2.8.4. SCREEN: 2.8.4.mp4 00:03-00:15

2.9. At end-expiration, press **Freeze**, then **Measure**, and choose **Distance** to measure the intercostal space width and muscle thickness in millimeters **[1]**. At end-inspiration, repeat the measurement **[2]**. Save two static images and label them **Exp** *(Expiration)* **End** and **Insp** *(Inspiration)* **End [3]**.

2.9.1. SCREEN: 2.9.2+2.9.3.mp4 00:20-00:30

2.9.2. SCREEN: 2.9.2+2.9.3.mp4 00:04-00:11

2.9.3. SCREEN: 2.9.2+2.9.3.mp4 00:12-00:29, 00:44-00:47

2.10. Now, instruct the patient to perform slow, deep breaths while observing the expansion of the concave intercostal space on the ultrasound screen **[1]**. Ask the patient to actively

control breathing by lifting the ribs to the maximal position, hold for 5 seconds, then exhale slowly through the mouth **[2-TXT]**.

2.10.1. Talent coaching the patient to breathe deeply while showing the expanding intercostal space on the ultrasound monitor.

2.10.2. Shot of the patient inhaling and exhaling. **TXT: Perform 10 breaths/set; 3 - 5 sets with 30 - 60 s rest in between sets**

2.11. Ensure that both treatment and control groups complete the same functional training procedures **[1]**.

2.11.1. Talent marking a checklist or digital record to confirm consistent training across both groups.

~~**3. Radiographic Identification of Spinal Landmarks and Cobb Angle Measurement**~~

3.1. For radiographic identification and cobb angle measurement, instruct the patient to stand up-right on an X-ray platform **[1].** Acquire a standing posteroanterior radiograph of the entire spine **[2]**. Import the radiographic image into the PACS *(P-A-C-S)* software for further analysis **[3]**.

3.1.1. Shot of the patient standing upright on a X-ray platform.

3.1.2. Shot of a posteroanterior spine radiograph being acquired.

3.1.3. SCREEN: 3.1.3.mp4 00:08-00:20

~~3.2. Locate the apical vertebra most laterally deviated from the vertical spinal midline and with the most symmetrically distant pedicles **[1]**. Identify the upper end vertebra most tilted above the apical vertebra, with a superior endplate maximally inclined toward the concavity of the curve **[2]**.~~

~~3.2.1. SCREEN: Zoom into the spine image and highlight the apical vertebra with cursor based on lateral deviation and pedicle symmetry.~~

~~3.2.2. SCREEN: 3.2.2-3.3.1-3.4.1-3.5.1-3.5.2-3.5.3.mp4 –~~

~~3.3. Then identify the lower end vertebra most tilted below the apical vertebra, with an inferior endplate maximally inclined toward the curve's concavity and transitioning to horizontal alignment below **[1]**.~~

~~3.3.1. SCREEN: 3.2.2-3.3.1-3.4.1-3.5.1-3.5.2-3.5.3.mp4 –~~

~~3.4. Draw the first reference line by placing the cursor at one end of the superior endplate of the upper end vertebra and dragging it to the opposite side along the visible cortical margin **[1]**.~~

~~3.4.1. SCREEN: 3.2.2-3.3.1-3.4.1-3.5.1-3.5.2-3.5.3.mp4 – 00:04-00:14~~

~~3.5. Draw the second reference line across the inferior endplate of the lower end vertebra **[1]**. Allow the software to automatically calculate the **Cobb angle** as the angle between~~

~~the two lines **[2]**. Confirm the selection by checking that the upper and lower end vertebrae encompass the full curve and that tilt decreases above and below them **[3]**.~~

~~3.5.1. SCREEN: 3.2.2 3.3.1 3.4.1 3.5.1 3.5.2 3.5.3.mp4 00:16-00:21~~

~~3.5.2. SCREEN: 3.2.2 3.3.1 3.4.1 3.5.1 3.5.2 3.5.3.mp4 00:22~~
~~*Video Editor: Please freeze frame here*~~

~~3.5.3. SCREEN: 3.2.2 3.3.1 3.4.1 3.5.1 3.5.2 3.5.3.mp4 00:26-00:32~~

4. Ultrasound-Based Assessment of Intercostal Space Dynamics and Muscle Thickness

4.1. Seat the subject upright on a stable examination chair or treatment bed with feet flat on the floor and arms relaxed at the sides **[1]**. Instruct the subject to maintain a natural, neutral posture without leaning forward or backward **[2]**.

4.1.1. Talent positioning the subject into an upright sitting posture with proper foot and arm placement.

4.1.2. Talent checking alignment and instructing the subject to avoid leaning or slouching.

4.2. Apply sufficient ultrasound coupling gel to the target intercostal space for optimal acoustic contact **[1]**. Use a linear ultrasound probe with frequency set between 7 and 12 megahertz in musculoskeletal or high-resolution mode **[2]** and place it longitudinally along the concave intercostal space at the mid-axillary line **[3]**.

4.2.1. Talent applying a thick layer of ultrasound gel across the intercostal region.

4.2.2. SCREEN: 4.2.2.mp4 00:03-00:25

4.2.3. Talent aligning the probe along the intercostal space and adjusting orientation.

4.3. Adjust the probe angle until the adjacent ribs and intercostal muscle layer are clearly visualized **[1]**. Instruct the subject to perform quiet breathing for orientation **[2]**, and capture images at end-expiration and end-inspiration **[3]**.

4.3.1. SCREEN: 4.3.1+4.3.2+4.3.3.mp4 00:04-00:20

4.3.2. Talent instructing the participant to perform quite breathing.

4.3.3. SCREEN: 4.3.1+4.3.2+4.3.3.mp4 00:21-00:31

4.4. Use the caliper tool to measure the intercostal space width by measuring the distance between the inner margins of two adjacent ribs **[1]**. Record the measurements at end-inspiration and end-expiration to capture dynamic changes **[2]**.

4.4.1. SCREEN: 4.4.1+4.4.2.mp4. 00:19-00:28

4.4.2. SCREEN: 4.4.1+4.4.2.mp4. 00:29-00:40

4.5. Identify the intercostal muscle layer between the ribs **[1]**. Place the calipers perpendicular to the muscle belly and measure the vertical distance between the inner

and outer fascial layers **[2]**.

4.5.1. SCREEN: 4.5.1+4.5.2.mp4. 00:04-00:10

4.5.2. SCREEN: 4.5.1+4.5.2.mp4. 00:19-00:25

4.6. Record the values at both end-inspiration and end-expiration **[1-TXT]**. Calculate and record the average value **[2]**.

4.6.1. SCREEN: 4.6.1+4.6.2.mp4. 00:01-00:02
Video Editor: Please freeze frame here
TXT: Repeat measurement 3x at each anatomical site

4.6.2. SCREEN: 4.6.1+4.6.2.mp4. 00:03-00:09

4.7. After the session, wipe off the gel with a disposable tissue **[1]** and help the patient adjust their clothing **[2]**.

4.7.1. Talent wiping the gel off the patient's side with a disposable tissue.

4.7.2. Talent helping the patient pull down their shirt and sit upright.

Results

5. Results

5.1. Both the experimental and control groups were comparable in all parameters **[1].** After treatment, the Cobb angle of the major curve was significantly lower in the treatment group than in the control group **[2]**.

5.1.1. LAB MEDIA: Table 1. *Video editor: Please sequentially highlight the columns "Control group" and "Overall sample"*

5.1.2. LAB MEDIA: Table 2. *Video editor: Highlight the rows for "Cobb angle of the major curve (mean±SD)"and emphasize the value under the "Treatment group" "19.7±2.3" and "16.2±1.7***"*

5.2. Tidal volume, inspiratory capacity, vital capacity and maximal voluntary ventilation were significantly higher in the treatment group than in the control group **[1]**.

5.2.1. LAB MEDIA: Table 2. *Video editor: Highlight the rows for "Tidal Volume (mean±SD), mL/kg" and emphasize "5.1±0.7" and "7.0±1.0***", Inspiratory Capacity (mean±SD), L" and emphasize "2.35±0.65" and "3.5±0.5***", "Vital Capacity (mean±SD), mL/kg" and emphasize "4.48±0.52" and" 5.2±0.5***"and "Maximal Voluntary Ventilation (mean±SD), L/min" and emphasize "120±15" and "150±20***"*

5.3. Patient 1 showed little change in Cobb angle and intercostal space after treatment **[1]**, whereas Patient 2 showed marked improvement in both parameters **[2]**.

5.3.1. LAB MEDIA: Table 3. *Video editor: Highlight Patient 1's row*

5.3.2. LAB MEDIA: Table 3. *Video editor: Highlight Patient 2's row*

Pronunciation Guide:

- Ultrasound-assisted

Pronunciation link: https://www.merriam-webster.com/dictionary/ultrasound
IPA: /ˈʌl.trəˌsaʊnd əˈsɪs.tɪd/
Phonetic Spelling: ul·truh·sownd uh·sis·tid

- Scoliosis

Pronunciation link: https://www.merriam-webster.com/dictionary/scoliosis
IPA: /ˌskoʊ.liˈoʊ.sɪs/
Phonetic Spelling: skoh·lee·oh·suhs

- Adolescent

Pronunciation link: https://www.merriam-webster.com/dictionary/adolescent
IPA: /ˌæd.əˈlɛs.ənt/
Phonetic Spelling: ad·uh·les·uhnt

- Idiopathic

Pronunciation link: https://www.merriam-webster.com/dictionary/idiopathic
IPA: /ˌɪd.i.oʊˈpæθ.ɪk/
Phonetic Spelling: id·ee·oh·path·ik

- Intercostal

Pronunciation link: https://www.merriam-webster.com/dictionary/intercostal
IPA: /ˌɪn.tɚˈkɑː.stəl/
Phonetic Spelling: in·ter·kah·stl

- Diaphragmatic

Pronunciation link: https://www.merriam-webster.com/dictionary/diaphragmatic
IPA: /ˌdaɪ.ə.frægˈmæt̬.ɪk/
Phonetic Spelling: dye·uh·frag·mat·ik

- Decubitus

Pronunciation link: https://www.merriam-webster.com/dictionary/decubitus
IPA: /dɪˈkjuː.bɪ.t̬əs/
Phonetic Spelling: dih·kyoo·buh·tuhs

- Apical

Pronunciation link: https://www.merriam-webster.com/dictionary/apical
IPA: /ˈeɪ.pɪ.kəl/
Phonetic Spelling: ay·pih·kuhl

- Vertebra

Pronunciation link: https://www.merriam-webster.com/dictionary/vertebra
IPA: /ˈvɝː.t̬ə.brə/
Phonetic Spelling: vur·tuh·bruh

- Mid-axillary

Pronunciation link: https://www.merriam-webster.com/dictionary/axillary
IPA: /ˌæks.əˈlɛr.i/
Phonetic Spelling: ak·suh·lair·ee

- Palpation

Pronunciation link: https://www.merriam-webster.com/dictionary/palpation
IPA: /pælˈpeɪ.ʃən/
Phonetic Spelling: pal·pay·shuhn

- Musculoskeletal

Pronunciation link: https://www.merriam-webster.com/dictionary/musculoskeletal
IPA: /ˌmʌs.kjə.loʊˈskɛl.ɪ.ɾəl/
Phonetic Spelling: mus·kyuh·loh·skel·ih·tl

- Megahertz

Pronunciation link: https://www.merriam-webster.com/dictionary/megahertz
IPA: /ˈmɛg.əˌhɝːts/
Phonetic Spelling: meg·uh·hurts

- Posteroanterior

Pronunciation link: https://www.merriam-webster.com/dictionary/posteroanterior
IPA: /ˌpɑː.stɚ.oʊ.ænˈtɪr.i.ɚ/
Phonetic Spelling: pah·ster·oh·an·teer·ee·er

- Radiograph

Pronunciation link: https://www.merriam-webster.com/dictionary/radiograph
IPA: /ˈreɪ.di.oʊˌgræf/
Phonetic Spelling: ray·dee·oh·graf

- PACS

Pronunciation link: https://www.merriam-webster.com/dictionary/PACS
IPA: /pæks/
Phonetic Spelling: paks

- Cobb angle

Pronunciation link: https://www.merriam-webster.com/dictionary/Cobb%20angle
IPA: /kɑːb ˈæŋ.gəl/
Phonetic Spelling: kob ang·guhl

- Inspiratory

Pronunciation link: https://www.merriam-webster.com/dictionary/inspiratory
IPA: /ɪnˈspaɪr.əˌtɔːr.i/
Phonetic Spelling: in·spy·ruh·tor·ee

- Tidal volume

Pronunciation link: https://www.merriam-webster.com/dictionary/tidal%20volume
IPA: /ˈtaɪ.dəl ˈvɑː.ljuːm/
Phonetic Spelling: ty·duhl vol·yoom

- Vital capacity

Pronunciation link: https://www.merriam-webster.com/dictionary/vital%20capacity
IPA: /ˈvaɪ.ɾəl kəˈpæs.ə.ɾi/