Systematic Review of Postural Assessment in Individuals With Obstructive Respiratory Conditions

MEASUREMENT AND CLINICAL ASSOCIATIONS

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■ **PURPOSE:** Changes in posture in individuals with an obstructive respiratory disease have been reported, but the extent of these deviations and their clinical significance is not well understood. This study aimed to systematically review the literature of the skeletal structural alignment in children and adults with an obstructive respiratory disease, describe the measurement techniques used, and determine the clinical relevance of any alternations.

■ **METHODS:** Observational cohort or cross-sectional studies of postural assessment were identified, with 2 reviewers independently assessing study quality.

■ **RESULTS:** A total of 18 studies were included, 12 in cystic fibrosis (CF), 5 in asthma, and 1 in chronic obstructive pulmonary disease (COPD). The overall quality assessment rating was 12.6 out of 16. Increased thoracic kyphosis or scoliosis was found in both children and adults with CF. Increased shoulder protraction and elevation were evident in asthma and COPD, although changes in spinal curvature were variable. The clinical impact of postural changes was diverse, with an inconsistent influence on lung function. A mix of methods was applied for postural assessment.

■ **CONCLUSIONS:** Skeletal structural malalignment appears to be present in some individuals with an obstructive respiratory disease, although the extent of alterations and its clinical impact is variable. Photogrammetry is used to provide a comprehensive assessment of posture in these populations.

K E Y W O R D S

lung function

obstructive respiratory disease

postural assessment

skeletal structural alignment

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In individuals diagnosed with an obstructive respiratory disease, such as chronic obstructive pulmonary disease (COPD), cystic fibrosis (CF), asthma, and bronchiectasis, common symptoms include dyspnea, fatigue, and reduced health-related quality of life (HRQOL).[1-4] Recent reports of the clinical profile of these diseases have also identified pain as a comorbidity.[5-10] Common pain regions include the lower back/lumbar spine, upper to mid-back/thoracic spine, neck/cervical spine, and chest.[5-7,9-11] While the precise etiology of pain within these areas is unclear, several hypotheses have been proposed. With increased respiratory muscle workload characteristic of obstructive respiratory diseases,[1-4] muscle hypertonicity with shortened chest wall and upper limb muscles has been reported.[12-14] These may result in reduced flexibility, the development of soft tissue contractures, and muscle imbalance, which have been linked to postural abnormalities in individuals with asthma,[10,15] CF,[12,16] and COPD.[17,18] From a clinical perspective, these postural changes may induce excessive strain on the musculoskeletal system, which may present clinically as spinal pain[19,20] or reduced physical function.[21] Pain may also be related to the concomitant musculoskeletal conditions, such as osteoarthritis and osteoporosis,[6,19,22-26] which have been linked to vertebral fractures in COPD, CF, and asthma.[10,14,22] The additional physical stress imposed by fractures on mechanically less robust vertebral bodies has also been linked to postural deviations in asthma.[10]

Posture is the balanced arrangement of body structures. It is a measure of the position of body segments, with joints and muscles in a state of equilibrium, which involves minimal effort and load and maximal efficiency of the musculoskeletal system.[27] There are numerous techniques that may be applied to gain an accurate measurement of skeletal structural alignment and the presence of any deviations or asymmetry, including radiographic measurements, goniometry, flexicurve, 2- or 3-dimensional surface topography, and landmark digitalization using motion capture systems.[28,29] A range of measurements within the sagittal and coronal planes is obtained from these methods, providing information on spinal curvatures (degree of cervical and lumbar lordosis and thoracic kyphosis), shoulder and pelvic girdle positions, and trunk alignment. These techniques have been used in postural assessment in healthy older individuals.[30,31]

Clinically, postural changes in individuals with obstructive respiratory conditions have the potential to negatively influence pulmonary function, HRQOL, and physical activity. However, an overview of the measurement techniques of skeletal structural alignment, the extent of any deviations, and the clinical associations of changes in posture has not been systematically reviewed in this respiratory population.

Therefore, the primary aim of this study was to (1) systematically review the literature that describes skeletal structural alignment in individuals with obstructive respiratory diseases and (2) examine the relationship between any changes in alignment and clinical parameters. A secondary objective was to describe the measurement techniques applied to assess skeletal structural alignment in obstructive respiratory diseases. This review was registered with PROSPERO (Number: CRD42015016646).

METHODS

Search Strategy

The primary search strategy used electronic databases of MEDLINE, CINAHL, EMBASE, AMED, PubMed, Cochrane Database of systematic reviews, and Physiotherapy Evidence Database (PEDro) from inception to December 2014. An update was conducted in February 2015. The key terms derived using MeSH headings included "pulmonary disease-chronic obstructive" OR "chronic bronchitis" OR "emphysema" OR "asbestosis" OR "asthma" OR "cystic fibrosis" OR "cystic fibr*" OR "CF" OR "bronchiectasis" AND "Posture" OR "posture assess*" OR "Posture balance" OR "posture align*" OR "spinal disease" OR "spinal curvature" OR "lordosis" OR "kyphosis" OR "scoliosis" OR "posture measure*." The search strategy applied in MEDLINE was adapted for other databases. Reference lists of included papers were reviewed to identify other potentially suitable studies.

Inclusion and Exclusion Criteria

Two reviewers reviewed titles and abstracts independently and potentially relevant articles were identified and retrieved in full text for independent assessment using the inclusion criteria. Any disagreements were resolved in consultation with a third reviewer when necessary. Inclusion criteria for this review included (1) children or adults with a diagnosis of COPD, chronic bronchitis, asthma, bronchiectasis or CF, and cross-sectional or cohort studies that may have included comparisons with control participants were eligible for inclusion; (2) objective assessment of skeletal structural alignment using noninvasive techniques including radiographic measures, goniometry, plumb line, skin surface contour methods (flexicurve ruler), torso scans, landmark digitalization/photogrammetry (identification of anatomical landmarks with photographic record or provision of 2- or 3-dimensional coordinates); (3) assessment of at least 1 of the following skeletal structural alignments including degree of thoracic kyphosis; cervical and lumbar lordosis; relevant angles related to head and neck/cervical alignment; scapula position; pelvic position; and thoracic cage/lumbar alignment; (4) association of postural measurements to clinical and demographic detail, including lung function, age, physical activity, HRQOL, pain or functional capacity; and (5) articles published in English.

Exclusion criteria were studies of individuals with restrictive respiratory conditions such as interstitial lung diseases, thoracic restriction, or neuromuscular disease. Papers written in a language other than English or only available in abstract form or conference proceedings were also excluded because of the difficulty in determining quality assessment and limited information to identify whether the inclusion criteria were met.

Data Extraction and Quality Assessment

Data extraction of study characteristics was performed by 1 reviewer and confirmed by a second reviewer using a standardized template. Authors were contacted when necessary to obtain further information. Study quality was assessed by 2 reviewers who independently completed the quality appraisal using the Critical Review Form–Quantitative Studies.[32] This tool evaluates method rigor and bias, with a total score of 16. Any disagreement between the 2 reviewers was resolved by consensus.

Statistical Analysis

Results of the included studies were narratively reported. The associations between postural measurements and clinical parameters were reported as the Pearson correlation coefficient or the Spearman rho as stated in the source articles.

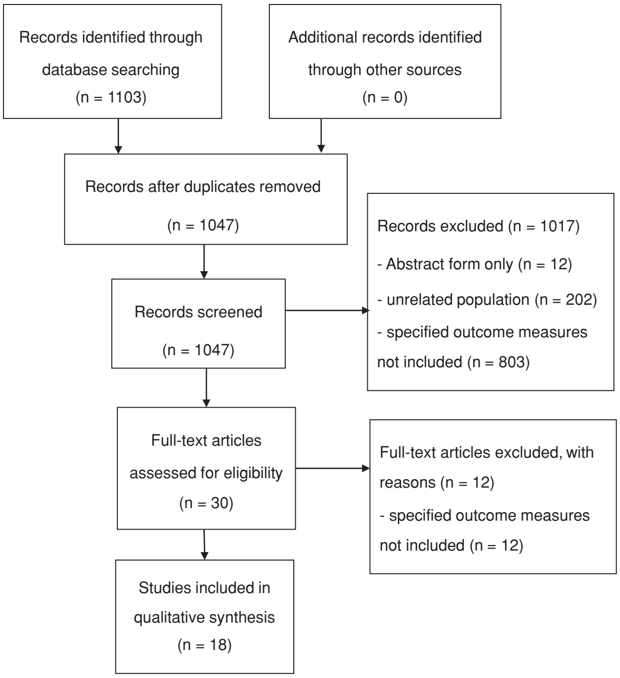

Figure. Flow diagram of study selection process.

RESULTS

A total of 1103 records were found. After deleting duplicates (n = 56), a total of 1047 studies were screened. Overall, a total of 30 studies were reviewed for inclusion using full text, with a total of 18 meeting the inclusion criteria (Figure). A total of 12 studies involved persons with CF,[22,33-43] 5 with asthma,[10,15,44-46] and 1 with COPD.[17] All participants were assessed in a clinically stable condition. Ten studies compared postural assessment in CF or asthma with aged-matched, healthy control participants.[10,17,22,33,35,37,43-46] Details of the study characteristics are outlined in Table 1.

Quality Assessment

The mean ± SD quality scores of quantitative studies was 12.6 ± 2.3 out of 16 (Table 2). Common methodological flaws were a lack of sample size justification, inconsistent use of valid or reliable measurement tools, and an absence of discussion of study limitations.

Measurements of Posture

Of the 12 CF studies, 8 measured Cobb angle from lateral or anteroposterior/posteroanterior chest x-ray films,[22,33-35,37,38,41] with measurement of the degree of thoracic kyphosis[22,33,35,37,40,41] and/or scoliosis.[34,35,38,40] Three studies used photogrammetry[36,39,43] to measure a variety of different angles pertinent to postural assessment, while 1 study used a flexicurve ruler for measurement of thoracic index.[42]

In asthma studies, goniometry to determine specific angles related to the degree of cervical protraction, shoulder girdle, and lumbar spine position was used in 2 studies.[10,45] Photogrammetry was applied in 2 studies to determine the extent of spinal curvature change and other variables.[15,44] Shoulder position measurement ratio was used in 1 study to identify the degree of scapula protraction.[46] In COPD, photogrammetry was used to assess extent of thoracic kyphosis, cervical lordosis, and shoulder girdle position.[17] Descriptions of these techniques are outlined in Table 3.

The anatomical landmarks and the precise angles reported in degrees (°) used to determine cervical and lumbar lordosis, thoracic kyphosis, degree of pelvic tilt, and vertical alignment of the trunk and chest from studies using goniometry[10,45] and photogrammetry[15,36,39,43,44] and those using radiographic techniques[22,33,35,37,38,40,41] are outlined in Table 4.

Postural Findings

The key findings of postural measurements are summarized in Table 5. In CF, the increase in thoracic kyphosis angles ranged from 3% to 62%[22,33,37,40,41,43] and was greater compared to healthy controls.[22,33,42] No difference was evident between males and

Table 1 • Characteristics of Clinical Studies

	Study Design	n	Age; Gender (% Male)	Disease Severity ($FEV_{1\%}$ pred)	Measurement Tools for Postural Assessment
Cystic Fibrosis					
Erkkila et al (1978)[40]	Cross-sectional	203	Age: 3 mo-32 yr; gender NR	NR	Cobb angle (>35°) from lateral CXR (thoracic kyphosis) and scoliosis (>90°)
Denton et al (1981)[33]	Cross-sectional	CF: 91 Control: NR	CF: age; gender NR Control: age; gender NR	CF: NR	Cobb angle (>40°) from lateral CXR (thoracic kyphosis)
Paling and Spasovsky-Chernick (1982)[38]	Cross-sectional	183	Age: NR; gender (60%)	NR	Cobb angle (lower limit of 10° of lateral curvature of spine) from CXR (scoliosis)
Logvinoff et al (1984)[37]	Cross-sectional	CF: 37 Control: 212	CF: age: 6-36 yr; gender (43%) Control: age: 6-40 yr; gender (55%)	NR	Cobb angle from PA and lateral CXR (thoracic kyphosis)
Kumar et al (2004)[35]	Cross-sectional	316 (children = 132; adults = 184)	Children: age: 0-16 yr[a]; gender (47%) Adults: age: 16-43 yr; gender (52%)	NR	Cobb angle (T3-T12) from AP and lateral CXR (thoracic kyphosis) Scoliosis diagnosed on the basis of ≥10° lateral curvature
Sandsund et al (2011)[42]	Randomized controlled	20	Age: 25-34 yr; gender (50%)	1.4-2.6 L[a]	Flexicurve for Thoracic index as a reflection of kyphosis (thoracic width/thoracic length × 100)
Penafortes et al (2013)[39]	Cross-sectional	14	Age: 25 yr (22-34)[b]; gender (57%)	54% pred (40.3-76.8)[b]	Photogrammetry using landmark digitalization with anatomical points of R and L tragus, acromion, greater trochanter, spinous process of C7, ASIS, tibial tuberosity and lateral malleolus
Fainardi et al (2013)[34]	Cross-sectional	319	Age: 11 yr (1-18)[b]; gender (47%)	NR	Cobb angle > 10% in coronal plane from CXR (scoliosis). Curvature classed as cervical (C2-C6), cervicothoracic (C7-T1), thoracic (T2-T11), thoracolumbar (T12-L1) Scoliosis progression defined by ↑ within 6 mo of a minimum of 10° curvature with Cobb angle <20° and of at least 5° for curvature with Cobb angle ≥20°
Aris et al (1998)[22]	Cross-sectional	CF: 70 Control: 32	CF: age: 18-39 yr; gender: (49%) Control: NR	27%-40% pred[a]	Cobb angle (T2/3-T12) from PA and lateral CXR (thoracic kyphosis)
Barker et al (2014)[41]	Cross-sectional	74	Age: 8-16[a] yr; gender (41%)	93% pred (79-99.7)[b]	Alternative Cobb angle (T4-T9) from lateral CXR, defined as angle >35° (thoracic kyphosis)
Lima et al (2014)[36]	Cross-sectional	14	Age: 25 yr (20-34)[b]; gender (57%)	NR	Photogrammetry using landmark digitalization with anatomical landmarks of R and L tragus, acromion, greater trochanter and C7SP and T3SP
Schindel et al (2015)[43]	Cross-sectional	CF: 34 Control: 34	CF: age: 13 ± 3 yr; gender (59%) Control: age 13 ± 3 yr; gender (59%)	Control: 99 ± 24% pred	Photogrammetry using landmark digitalization with anatomical landmarks of R and L tragus, inferior angle of scapula, C7SP, T3SP, T7SP, L1SP, ASIS, PSIS, greater trochanter, tibial tuberosity, lateral malleolus, medial malleolus, and calcaneum. Cervical and lumbar lordosis

(*Continues*)

Table 1 • Characteristics of Clinical Studies (*Continued*)

	Study Design	n	Age; Gender (% Male)	Disease Severity ($FEV_{1\%}$ pred)	Measurement Tools for Postural Assessment
Asthma					
Robles-Ribeiro et al (2005)[46]	Cross-sectional	Asthma: 19	Asthma: age: 32 ± 8 yr; gender (79%)	Asthma: NR	Shoulder position measurement ratios (outermost point of each scapula marked and distance measured front and back, with ratio calculated)
		Control: 20	Control: age: 31 ± 9 yr; gender (65%)	Control: NR	
Lopes et al (2007)[45]	Cross-sectional	Asthma: 40	Asthma: age: 11 yr (7-12)[c]; gender (100%)	Asthma: 84% pred (52-113)[c]	Goniometry using anatomical landmarks of R and L mastoid process, acromion, suprasternal notch, lateral humeral epicondyles, C7SP, PSIS and SP of sacrum
		Control: 20	Control: age: 11 yr (7-12)[c]; gender (100%)	Control: 100% pred (85-112)[c]	Measurement of shoulder girdle elevation, shoulder girdle protraction, head protraction, elbow inflection position, occiput-to-wall distance and change in lumbar curve
Belli et al (2009)[44]	Cross-sectional	Asthma: 30	Asthma: age: 10 ± 10 yr; gender (53%)	1.88 L (1.74-2.02)[d]	Photogrammetry using landmark digitalization with anatomical landmarks including R and L external orbicularis, commissura labiorum, acromioclavicular joint, sternoclavicular joint, ear lobe, ASIS, PSIS, PIIS, and inferior angle of scapula
		Control: 30	Control: age: 10 ± 3 yr; gender NR		Cervical lordosis, thoracic kyphosis, lumbar lordosis, forward head position and sternal angles
Lunardi et al (2011)[10]	Cross-sectional	Asthma: 30	Asthma: age 37 yr (21-55)[e]; gender (80%)	NR	Goniometry using anatomical landmarks of R and L acromion, suprasternal notch, lateral humeral epicondyles, C7SP, PSIS, spinous process of sacrum, right mastoid
		Control: 15	Control: 29 yr (24-47)[e]; gender (53%)		Measurement of shoulder girdle protraction, shoulder girdle elevation, and internal shoulder rotation
Almeida et al (2013)[15]	Cross-sectional	50	Age: 33 yr (24-40)[b]; gender (28%)	74% pred (53-87)[b]	Photogrammetry using landmark digitalization with plum line with anatomical landmarks of R and L tragus, acromion, inferior angle of scapula, ASIS, PSIS, greater trochanter, C7SP and T3SP
COPD					
Dias et al (2009)[17]	Cross-sectional	COPD: 19	COPD: age: 74 ± 5 yr; gender (100%)	NR	Photogrammetry with anatomical landmarks of R and L tragus, root of spine of scapula, inferior angle of scapula, acromion, sternoclavicular joint, T1SP, T7SP, and T12SP
		Control: 19	Control: age 72 ± 5 yr; gender (100%)		Measurements included scapula upward rotation, anterior tilt, internal rotation, elevation and abduction, thoracic kyphosis, and protraction of head and shoulders

Abbreviations: AP, anterioposterior; ASIS, anterior superior iliac spine; CF, cystic fibrosis; CXR, chest x-ray; C2, second cervical vertebra; C6, sixth cervical vertebra; C7, seventh cervical vertebra; FEV_1, forced expiratory volume in 1 second; L, left; L1, first lumbar vertebra; ML, mediolateral; NR, not reported; PA, posteroanterior; PIIS, posterior inferior iliac spine; PSIS, posterior superior iliac spine; R, right; SP, spinous process; T1, first thoracic vertebra 1; T2, second thoracic vertebra; T3, third thoracic vertebra; T4, fourth thoracic vertebra; T11, eleventh thoracic vertebra; T12, twelfth thoracic vertebra; ↑, increased. Data are reported as mean ± standard deviation or [a]minimum to maximum or [b]median (interquartile range) or [c]median (95% confidence intervals) or [d]mean (95% confidence intervals) or [e]mean (minimum to maximum).

Table 2 • Quality Assessment of Observational Studies

	Quality Appraisal Score[a]																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total Score
Cystic fibrosis																	
Erkkila et al (1978)[40]	1	1	1	1	0	0	1	0	0	1	1	0	1	1	1	0	10
Denton et al (1981)[33]	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	0	12
Paling and Spasovsky-Chernick (1982)[38]	1	1	1	1	1	0	0	0	0	1	1	0	1	1	1	0	10
Logvinoff et al (1984)[37]	1	1	1	1	1	0	0	0	0	1	1	0	1	1	1	0	10
Kumar et al (2004)[35]	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	15
Sandsund et al (2011)[42]	1	1	1	1	1	0	0	0	1	0	1	0	1	1	1	1	11
Penafortes et al (2013)[39]	1	1	1	1	1	0	0	0	0	1	1	0	1	1	1	1	11
Fainardi et al (2013)[34]	1	1	1	1	1	0	0	1	1	0	1	1	1	1	1	0	12
Aris et al (1998)[22]	1	1	1	1	1	0	0	0	0	1	1	0	1	1	1	1	11
Barker et al (2014)[41]	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	15
Lima et al (2014)[36]	1	1	1	1	1	0	1	0	0	1	1	1	1	1	1	1	13
Schindel et al (2015)[43]	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	16
Asthma																	
Robles-Ribeiro et al (2005)[46]	1	1	1	1	0	1	0	0	0	1	1	1	1	1	1	0	11
Lopes et al (2007)[45]	1	1	1	1	1	0	1	0	0	1	1	0	1	1	1	1	12
Belli et al (2009)[44]	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	15
Lunardi et al (2011)[10]	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	15
Almeida et al (2013)[15]	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	16
Chronic obstructive pulmonary disease																	
Dias et al (2009)[17]	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	14
Mean ± SD	12.6 ± 2.3																

[a]Law et al[32]; 1 for yes, 0 for no, except biases (0 for yes, 1 for no). 1—Was the study purpose stated clearly?; 2—Was relevant background literature reviewed?; 3—Was the design appropriate for the study question?; 4—Were there any biases present (minimum response rate of 80% for sample bias, blinding of investigators when physical measures were taken)?; 5—Was the sample size justified?; 6—Was the sample described in detail? (had to include the number of participants by gender, age, and a description of where the cohort was sampled from); 7—Was informed consent obtained? (if not described, assume no); 8—Were the outcome measures valid? (if all not described, assume no); 9—Were the outcome measures reliable? (if all not described, assume no); 10—Results were reported in terms of statistical significance?; 11—Dropouts were reported?; 12—Clinical importance was reported?; 13—Were the statistical analysis methods appropriate?; 14—Conclusions were appropriate given the study methods?; 15—Are there implications for clinical practice given the results of the study (based on the experience of the reviewers)?; 16—Were limitations of the study acknowledged and described by the authors?

females,[22] although 2 studies found that the angle increased with age[37,40] and was associated with vertebral fractures.[22] Scoliosis was found in 3% to 11% of individuals with CF,[34,35,38,40] with the scoliosis located within the cervical,[38] upper and lower thoracic,[35,38,40] and lumbar regions.[38]

In asthma, deviation in spinal curvatures was variable. While 1 study found no change in cervical, thoracic, or lumbar curves,[44] an increase in cervical lordosis[10,45] and a decrease in thoracic kyphosis[45] compared with controls was evident in 3 studies. Increased shoulder protraction was found through a variety of measurement methods[10,45,46] and was accompanied by heightened shoulder elevation[45,46] and greater internal rotation of the shoulder girdle.[10]

In those with moderate to severe COPD, shoulder elevation was greater than that in controls, although there was no difference in scapula position or angulation or the degree of thoracic kyphosis, cervical lordosis, or shoulder protraction.[17]

Clinical Associations of Postural Changes

In CF, Denton et al[33] found that an increase in thoracic kyphosis was associated with more extensive

Table 3 • Descriptions of Postural Measurement Techniques Used in Included Studies

	Description
Cobb angle	Angle formed between a line drawn parallel to the superior endplate of 1 vertebra above the fracture and a line drawn parallel to the inferior endplate of the vertebra 1 level below the fracture. Measured in the sagittal or coronal plane (A-P/P-A or lateral chest x-ray)
Flexicurve or flexible ruler	A 60-cm-long flexible piece of lead covered durable plastic that is molded to the contour of the spine. It is used to measure both thoracic and lumbar postural curves in the sagittal plane. With the subject standing in an upright position, the flexicurve is placed over the spinous processes of the thoracic and lumbar spine and shaped to fit the contours of these spinal curves. The instrument is removed and traced onto a piece of plain white paper. A vertical line was drawn to connect the C7 and S1 landmarks. The point where this line intersected the traced curve marked the transition between the thoracic and lumbar curves. The maximum width and the total length of each curve were measured in centimeters, with an Index of Kyphosis and Index of Lordosis calculated.
Goniometry	A goniometer is an instrument that either measures an angle or allows an object to be rotated to a precise angular position. It is used to measure the total amount of available motion at a specific joint.
Shoulder position measurement ratio	The skin of the subject was marked at the outermost point of each scapula and the distance in centimeters between the 2 marks was measured, front and back, using a measuring tape. The ratio representing the relationship between the front and back measurements is then calculated.
Photogrammetry	Photogrammetry provides a measure of posture using photographic images. Digital photographs of the subjects are taken in frontal or sagittal plane with a camera that is mounted on a leveled tripod stand, positioned at a specific distance from the subject. Prior to the photography, specific anatomical landmarks are marked using adhesive tags or reflective markers. The photographs obtained are transferred to a computer system. Angles are then drawn between the markers by drawing horizontal and/or vertical lines to calculate postural angles. This method is used to calculate head posture, shoulder posture, cervical lordosis, thoracic kyphosis, lumbar lordosis, lower limb posture, and pelvic tilt

Abbreviations: A-P, anterior-posterior; C7, seventh cervical spine; P-A, posterior-anterior; S1, first sacral spine.

pulmonary disease, while Kumar et al[35] found a weak correlation between pulmonary function and heightened thoracic kyphosis. In contrast, 3 other studies did not find a relationship between pulmonary function and degree of thoracic kyphosis.[34,37,40] Changes in chest vertical alignment were associated with poorer physical function, reduced lung function, and limited exercise capacity.[39]

In asthma, clinical associations of postural deviations were reported in 3 studies.[10,15,46] Increased shoulder protraction was linked to greater airflow obstruction.[46] The increase in cervical lordosis, shoulder protraction, internal rotation, and elevation was associated with chronic pain in the lower thoracic spine in 50% of patients; in the cervical spine in 22% of patients; and in the shoulder in 29% of patients.[10] In the only study in COPD, no clinical associations were explored.[17]

DISCUSSION

The findings of this review are that multiple techniques for postural measurement have been applied in studies of individuals with obstructive respiratory conditions, which included radiographic approaches, photogrammetry, and stabilometry. While changes in normal spinal curvature have been noted in children and adults with CF or asthma, the extent of postural deviation is variable. In individuals with asthma and COPD, some changes in the position of the shoulder girdle were evident.[10,17,45,46] The associations between postural abnormalities and clinical parameters of lung function, physical function, and pain were inconsistent within and between respiratory conditions.

In CF, the prevalence of postural deviations with a specific focus on increased thoracic kyphosis and scoliosis was inconsistent. This is likely to be due to the use of differing criteria for an abnormal thoracic kyphosis, ranging from Cobb angle measurements of $>35°$ or $>40°$,[33,40,41] alternate angles with differing landmarks derived from photogrammetry[36,39,43] or unspecified angles.[22,37] With only 4 studies comparing findings in CF to a healthy control population,[22,33,37,43] the ability to identify the most suitable criteria for detecting an increased thoracic kyphosis was limited. In contrast, a diagnosis of scoliosis was based on the same criteria in all 5 studies ($\geq 10°$ lateral curvature),[34,35,37,38,40] with deviations identified throughout all spinal regions.[34,35,37]

In asthma and COPD, reports were also inconsistent; some studies found an increase in upper cervical

Table 4 • Commonly Measured Postural Variables and Their Corresponding Anatomical Descriptors From Included Studies

	Descriptors of Anatomical Points and Angles Used for Measurement
Cervical lordosis	Lines between occipital protuberance and C7SP and that intersects the horizontal line between C4 and the true vertical line[44]
	Angle between tragus, C7SP, and acromion[43]
Head-horizontal alignment: position of head in degree of flexion/extension	Angle formed between the line linking C7 vertebra, tragus, and a horizontal line[17,28]
	Angle formed between vertical line, C7 vertebra, and mastoid process[45]
Pelvic horizontal alignment: degree of anterior/posterior tilt	Angle between the line linking the ASIS and PSIS and a horizontal line[28]
Vertical alignment of the body; anteroposterior inclination of the body	Angle formed between the line linking the acromion and lateral malleolus and a vertical line[28]
Vertical alignment of the chest	Angle between the acromion and greater trochanter and a vertical line[29]
Thoracic kyphosis	Angle formed by the straight lines between C7 and T12SP[22,44,33-35,37,38] or T4sp and T9SP[41] and that intersect the horizontal line between T7SP and the true vertical line
	Upper thoracic kyphosis: angle formed by interaction of straight line over T1 and a marker positioned 9 cm below T1 with vertical axis. Lower thoracic kyphosis: angle formed by interaction of a straight line passing over T12 and a marker positioned 9 cm above T12 with the vertical axis[17]
Lumbar lordosis	Angle formed by the straight lines between T12SP and L5SP and that intersect the horizontal line between L3 and the true vertical line[22]
	Angle formed by straight lines between L1SP, ASIS, and greater trochanter[43]

Abbreviations: ASIS, anterior superior iliac spine; C4, fourth cervical vertebra; C7, seventh cervical vertebra; L1, first lumbar vertebra; L3, third lumbar vertebra; L5, fifth lumbar vertebra; PSIS, posterior superior iliac spine; SP, spinous process; T1, first thoracic vertebra; T4,fourth thoracic vertebra; T7, seventh thoracic vertebra; T9, ninth thoracic vertebra; T12, twelfth thoracic vertebra; S1, first sacrum vertebra.

protraction[10,45]; others found no difference in this measure or any other spinal curvatures.[15,17,44] These findings may be due to the severity of lung disease; despite different methods of reporting lung function, increased deviations in spinal curvature was evident in those with moderate[10] or severe asthma.[45] Diverse definitions and quantitative methods may also account for the variation between studies.

Postural changes presenting as an increased thoracic kyphosis, upper cervical lordosis, or scoliosis in children and adults with CF may be associated with the higher rate of osteoporosis in CF,[22,25] predisposing to vertebral compression fractures and wedging[12,47] that are more prevalent in adolescents and adults.[35,40,41] As trunk muscles serve both respiration and postural support,[48] an increased demand imposed by worsening lung function may negatively impact on postural support.[41] Moreover, in an effort to relieve dyspnea, individuals with CF frequently assume a forward leaning posture, which may be reflected in 1 study by a greater anterior orientation in the chest wall alignment.[39] Repeated adoption of this position encourages recruitment of accessory muscles of respiration, the prolonged use of which may result in ligamentous strain, muscle and joint imbalance, and an altered posture.[14,16] These postural changes may be aggravated by increased coughing.[14] Symptoms of pain can cause ineffective neuromotor recruitment of the core trunk stabilizers, the same muscles that support respiration and posture.[49] Postural deviations may contribute to the back pain frequently reported in children and adults with CF.

In asthma, changes in cervical lordosis, thoracic kyphosis, pelvic tilt, and scapula position, albeit inconsistent, may be associated with a higher prevalence of osteoporosis,[50-52] which has been linked to thoracic pain.[10] Lung hyperinflation alters the length-tension relationship of the respiratory muscles,[53] with the ribs shifted from an oblique orientation to a more horizontal position.[54,55] These alterations in respiratory mechanics are similar to those observed in CF and may account for the reduced thoracic and lumbar flexibility and the increased cervical lordosis and shoulder girdle protraction in asthma.[10,45,46]

Although the physiology of COPD differs from the above, changes in bone mineral density[23] and respiratory mechanics[3] may also account for the increased shoulder elevation and scapula protraction.[17] In COPD, age may contribute to muscle weakness of the passive and active stabilizers of the spine,[30,56]

Table 5 • Findings of Postural Measurements and Clinical Associations

	Postural Measurements	Clinical Associations
Cystic fibrosis		
Erkkila et al (1978)[40]	Kyphosis in 22% (increased with age); average angle 42° (range 40°-44°) located in T2-T12	No relationship between kyphosis or scoliosis and lung function based on spirometry (r or ρ values NR)
	Scoliosis of 5% (12% if age >15 yr); angle 10°-28°	
Denton et al (1981)[33]	Kyphosis in 15% compared with 6% in controls ($P < .05$)	Kyphosis associated with worse lung function (lower Taussig score, FEV_1 and FVC) (r or ρ values NR)
Paling and Spasovsky-Chernick (1982)[38]	Scoliosis in 10% of those aged ≥4 yr; higher prevalence compared to general population ($P < .01$); angle of curvature from 9° to 32°, with locations in C6-T8 (n = 1), T1/2/3/4-T7/8/9 (n = 7), T5/6-T10/11/12 (n = 8), L1-L5 (n = 2)	No relationship between scoliosis and lung function based on spirometry (r or ρ values NR)
Logvinoff et al (1984)[37]	Kyphosis in 22%; in females, degree of kyphosis increased significantly in those >12 yr ($P < .018$)	No relationship between kyphosis and lung function based on spirometry (r or ρ values NR)
Aris et al (1998)[22]	Kyphosis in 62% (angle > 40°); no differences between genders; kyphosis angles associated with spinal fractures ($r = 0.31$; $P = .02$)	NR
Kumar et al (2004)[35]	Scoliosis in 11% in 0- to 4-yr-olds, 16% in 4- to 16-yr-olds, 10% in 16- to 43-yr-olds	No relationship between Cobb angle and Chrispin-Norman score (r or ρ value NR)
	Progression of curve in 21% in 4- to 16-yr-olds, 11% in 16- to 43-yr-olds	Weak correlation between Shwachman-Kulzychi score and Cobb angle ($R^2 = 0.04$; $P = .007$)
Sandsund et al (2011)[42]	Increased thoracic kyphosis compared to healthy controls (thoracic index ranged from median of 10.1 and 14.4) (IQR 8.2-16.3) compared with normal mean of 9.2 ± 3.7	NR
Penafortes et al (2013)[39]	Increased upper cervical lordosis	Vertical alignment of the chest and physical domain of the CFQ ($\rho = -0.74$; $P < .01$)
	Increased anterior alignment of the body and increased chest vertical alignment	Reduced lung function (FEV_1: $\rho = -0.57$, $P < .05$; and TLC: $\rho = 0.54$, $P < .05$) and increased airway resistance ($\rho = 0.67$; $P < .01$) was associated with vertical alignment of the chest
		Reduced 6MWD associated with vertical alignment of the chest ($\rho = -0.65$; $P < .01$)
		No other relationships between postural and lung function, quality of life, and exercise capacity
Fainardi et al (2013)[34]	Scoliosis in 2.2%; primary curves in thoracic, right-sided and apices between T7 and T10	No relationship between Cobb angle or scoliosis and lung function based on spirometry (r or ρ values NR)
	Single curve with Cobb angle <20° (n = 5); double curve with primary curve Cobb angle 23°-37° and secondary curve between T4-T5 and 23°-26°	

(*Continued*)

Table 5 • Findings of Postural Measurements and Clinical Associations (*Continued*)

	Postural Measurements	Clinical Associations
Barker et al (2014)[41]	3% with abnormal thoracic kyphosis	FVC correlated with Cobb angle ($P = .004$); for every 1% decrease in FVC, Cobb angle increased 0.26°
		No relationship between thoracic kyphosis, age, gender, FEV_1, or Shwachman score (r or ρ values NR)
Lima et al (2014)[36]	Increase in upper cervical lordosis	NR
Schindel et al (2015)[43]	Increase in cervical lordosis (62° vs 52°; $P = .001$), but not thoracic kyphosis or lumbar lordosis vs control	NR
	Increase in scapula girdle tilt (1.8° vs 1.1°; $P = .015$) and pelvic tilt (2.4° vs 1.0°; $P = .001$) vs control	
Asthma		
Robles-Ribeiro et al (2005)[46]	Increased shoulder protraction in asthma compared to control (ratio of 0.88 vs 0.97; $P < .001$)	Lower PEFR associated with greater shoulder protraction ($r = 0.8$; $P < .001$)
Lopes et al (2007)[45]	Increase in head protraction in severe asthma vs control (9.5° vs 5.5°; $P < .05$)	NR
	Increase in shoulder girdle protraction (0.885° vs 0.94°; $P < .01$) and shoulder girdle elevation (4.0° vs 1.5°) vs control	
	Reduced thoracic kyphosis in severe asthma vs control (8.2 cm vs 9.0 cm; $P < .01$)	
Belli et al (2009)[44]	No between-group differences in cervical lordosis, forward head posture, thoracic kyphosis, and lumbar lordosis	NR
Lunardi et al (2011)[10]	Increase in shoulder protraction and internal rotation compared to controls ($P < .01$)	Chronic pain in lower thoracic spine, cervical spine, or shoulder region in 47% of asthmatic patients
	Increased forward head position (8° vs 6°; $P < .05$) in moderately severe asthma and increased shoulder elevation in severe asthma (9° vs 6°; $P = .03$)	
Almeida et al (2013)[15]	Normal cervical lordosis and vertical alignment of the body. Increase in pelvic alignment-anterior tilt	NR
COPD		
Dias et al (2009)[17]	No between-group differences in upper rotation, internal rotation, anterior tilt of the scapula, upper cervical lordosis, shoulder protraction, thoracic kyphosis or thoracic cage	NR
	Greater shoulder elevation compared to control (11.58-12.39 cm vs 13.11-13.60 cm; $P < .05$)	

Abbreviations: CF, cystic fibrosis; CFQ, cystic fibrosis questionnaire; COPD, chronic obstructive pulmonary disease; C6, sixth cervical vertebra; FEV_1, forced expiratory capacity in 1 second; FVC, forced vital capacity; L1, first lumbar vertebra; L5, fifth lumbar vertebra; NR, not reported; ρ, Spearman rho; PEFR, peak expiratory flow rate; r, Pearson correlation coefficient; TLC, total lung capacity; T1, first thoracic vertebra; T2, second thoracic vertebra; T3, third thoracic vertebra; T4, fourth thoracic vertebra; T5, fifth thoracic vertebra; T6, sixth thoracic vertebra; T7, seventh thoracic vertebra; T8, eighth thoracic vertebra; T9, ninth thoracic vertebra; T10, tenth thoracic vertebra; T12, twelfth thoracic vertebra; 6MWD, 6-minute walk distance.

superimposed on age-related degenerative spinal processes in those older than 60 years.[56]

Deviations in normal spinal curvature may inhibit ventilation[57] and could contribute to reduced lung function,[16,58] although this was inconsistently demonstrated in CF. With limited or a lack of exploration of this relationship in asthma and COPD, the precise impact of any postural changes on respiratory mechanics requires more comprehensive and simultaneous evaluation of posture and respiration in each of these respiratory conditions.

A mix of measurement techniques was applied in these studies. While calculation of the Cobb angle from chest x-ray films was most frequently used in CF, it only provides a measure of thoracic kyphosis and scoliosis. Given the other postural deviations in CF, other techniques such as goniometry may be more applicable. This measures shoulder position and protraction but does not measure spinal curvature. Both the flexicurve ruler and photogrammetry require skill in identifying specific anatomical landmarks and in interpretation of the measures with no exposure to radiation. Photogrammetry provides a comprehensive measure of spinal curvatures as well as scapula and pelvic positions. Further research is necessary to determine the validity and reliability of these techniques in each of these respiratory conditions.

Postural disorders can be addressed by treatment programs and rehabilitation techniques, including a combination of stretching for the shoulder girdle, upper and lower limbs and trunk, thoracic mobility exercises, and mobilization techniques in individuals with CF.[14,43,59] These are associated with reduction in pain, dyspnea, and improvement in posture.[42,43,59] In COPD, these are often prescribed immediately prior to endurance and resistance training.[60] In CF, these management strategies that focus on maintenance of postural alignment may reduce the risk of lumbar pain and vertebral complications.[61] Gaining an understanding of approaches to assessing posture may advance the overall specificity of treatment.

This review is limited by our inclusion of several obstructive respiratory conditions, heterogeneous methodologies, and adults as well as children. With a mix of techniques applied in both adults and children, more information is required as to the association between age and measurement sensitivities. The differing definitions and landmarks used to determine skeletal structural alignment highlight the need for clarification of criteria as well as more controlled studies. Recommendations as to which methodologies can be used to assess posture in respiratory disease must be preceded by a better understanding of their measurement properties such as validity and reliability. While radiographic measurements are considered the gold standard, the Cobb method has been identified to have some weaknesses, particularly in the adult population.[62,63] This is related to the effect of altered end plate angle on the measured kyphotic angle, minimal in children but it may become more of an issue for individuals of increased age. Applying a non-fixed range for thoracic kyphosis may be more appropriate in adults, as a single upper limit of normality does not account for the normal variation in thoracic kyphosis with age and may generate false abnormal values in older individuals.[64]

In conclusion, some individuals with an obstructive respiratory condition experience changes in their skeletal structural alignment. The extent to which these changes occur as well as their impact on respiratory function is variable. Photogrammetry can be used to provide a comprehensive assessment of posture. The clinical application of a postural evaluation and the relationship between postural changes and pain remain to be clarified.

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