Evaluating the Impact of Adult Thoracic Scoliosis on Pulmonary Function and Chronic Disease in Aging Adults

Sonya Singh[1]; Eun Bi Kim[1]; Nancy Hadley-Miller[1]; Kaleb Taylor[1]; Harry Smith[1]; Syed Ahmed Nadeem[2]; Klane White[1]; David Ou-Yang[1]; Punam K. Saha[2]; Elizabeth A. Regan[3]; Patrick M. Carry[1]

[1]University of Colorado Anschutz Medical Campus; [2]University of Iowa; [3]National Jewish Health

Disclosures: The authors do not have any disclosures relevant to the current work

INTRODUCTION: Scoliosis is a three-dimensional spinal curve. The impact of scoliosis on lung function and the risk of major cardiovascular events in older adults has not been well studied. Mild or moderate scoliosis curves are assumed to be at low risk for long term health issues. Recent work from the UK Biobank[1], however, has challenged this notion based on the significant association between scoliosis, abnormal cardiac compression, and increased risk of major cardiovascular events. The long-term impact of thoracic scoliosis related spine deformities on other vital organs in the thorax, such as the lungs, and their connection to pulmonary disease has not been rigorously evaluated. Therefore, we aimed to study the impact of thoracic scoliosis on lung and cardiovascular disease in COPDGene, a multi-institutional NHLBI funded study of the genetic epidemiology of chronic obstructive pulmonary disease.

METHODS: We screened the IRB approved COPDGene study population to identify scoliosis cases. Screening was performed in two phases. In phase I, collaborators at the University of Iowa and National Jewish manually reviewed 3,231 chest CT scans to identify scoliosis cases. This dataset was split into training (n=450) and test (n=2461) samples. A novel deep segmentation algorithm was used to segment the spine based on the CT scans and measure the orientation of vertebral segments which were used as inputs for a full-connected Bayesian neural network model that was used to predict the presence of scoliosis. The model demonstrated high accuracy (sensitivity, 90.5%, and specificity, 94.25%). In phase II, this model was used to predict scoliosis cases in the full population, n=10,305 participants. Three independent raters manually reviewed presumed cases (n=1832) to confirm the presence of scoliosis, defined as Cobb angle>20 degrees with rotation. Raters reviewed curve pattern and medical history to differentiate scoliosis subtypes, idiopathic, degenerative, traumatic, congenital, or other. Chi-square and student's t-tests were used to test for differences in the distribution of demographic variables in confirmed scoliosis group vs the non-scoliosis comparison group. Multivariable linear mixed models were used to test for differences in quantitative CT scan measures, spirometry measures, and lung dimensions. For all CT scan-based measures, random intercepts were used to account for clustering due to CT scanner type and study site. For all other variables, random effects were used to account for study site only. Multivariable generalized logistic regression models were used to test for differences in the prevalence of prior major adverse cardiovascular events (MACE, congestive heart failure, myocardial infarction, or stroke) as well as chronic disease outcomes. All statistical models were adjusted for age, sex, race/ethnicity, smoking history, and height.

RESULTS: The prevalence of scoliosis was 2.4% (243/10,305). Among participants with scoliosis, idiopathic scoliosis (127/243) was most common subtype followed by degenerative (66/243), other/unknown (42/243), congenital (5/243) and traumatic (3/243) scoliosis. The median cobb angle was 23.6 (interquartile range (IQR): 21 to 28). Curves were identified in identified in the thoracic region. The median apex of the curve occurred at T7 (IQR: T5 to T9). The scoliosis group included a higher proportion of female participants (56% vs 47%, p=0.0036), was older (61.4 ±9.6yrs vs 59.5 ±9.0 yrs, p=0.0030) and had a lower average BMI (26.6 ±5.4 vs 28.9 ±6.3 p<0.001) compared to the group without scoliosis. There was no difference in the distribution of race/ethnicity (p=0.1835) or smoking status (p=0.0612) between groups. Average lung width was significantly decreased in the scoliosis group (adjusted mean difference: -4.11mm, 95% CI: -6.25 to -2.08mm, p<0.0001). There was no difference in lung height (p=0.1716) or depth (p=0.3271) between groups. Among the pulmonary measures, FEV1 and FEV1/FVC were significantly decreased in scoliosis cases (see Table 1). Percent emphysema and percent gas trapping were significantly increased in scoliosis cases (Table 1). In relation to the self-reported chronic disease endpoints, there was no difference in the prevalence of prior MACE (Odds Ratio (OR): 0.84, 95% CI: 0.49-1.39, p=0.4658), osteoarthritis (OR: 1.26, 95% CI: 0.93-1.72,p=0.1363), rheumatoid arthritis (OR: 1.08, 95% CI: 0.67-1.73, p=0.7487) or gastroesophageal reflux (OR: 1.13, 95% CI: 0.84-1.51,p=0.4260). Osteoporosis was more common in scoliosis cases (OR: 1.66, 95% CI: 1.14-2.40, p=0.0079), whereas diabetes was less common (OR: 0.42, 95% CI: 0.25-0.72, p=0.0014) in scoliosis cases.

Table 1. Scoliosis and pulmonary outcomes at study enrollment

	Difference*	95% CI	p-value
FEV1†	-0.10	-0.19 to -0.01	0.0228
Functional Vital Capacity†	-0.04	-0.13 to +0.04	0.2997
FEV1/FVC†	-0.02	-0.04 to -0.01	0.0089
Functional residual capacity	+0.10	-0.02 to +0.22	0.1087
Total Lung Capacity	-0.06	-0.18 to +0.06	0.3301
Airway wall thickness	-0.01	-0.09 to +0.06	0.7392
Percent Emphysema	+1.69	+0.59 to +2.78	0.0027
Percent Gas Trapping	+3.52	+1.25 to +5.79	0.0024

*Mean difference between scoliosis vs. non-scoliosis groups, adjusted for age, sex, smoking status, height, study site and, if appropriate, CT scanner model, †All spirometry measurements were obtained post-bronchodilator

DISCUSSION: Thoracic scoliosis was positively associated with osteoporosis and inversely associated with diabetes. Although inconsistent findings have been noted, decreased bone mass has been previously associated with scoliosis[2]. The decreased prevalence of diabetes in the scoliosis group may reflect lower BMI among scoliosis cases in our study, a finding that has also been noted in relationship to adolescent idiopathic scoliosis[3]. After adjusting for demographic variables and smoking history, we found significant associations between scoliosis and both emphysema and pulmonary function in this cohort of smokers. Individuals with scoliosis exhibited reduced FEV_1 and FEV_1/FVC ratios, consistent with an obstructive pattern of pulmonary impairment. Additional work is needed to determine whether the long-term persistence of a thoracic spinal curve creates abnormal mechanical forces within the thorax that contribute to obstructive pulmonary dysfunction, particularly in older adults at elevated risk for lung disease. The current study evaluated the association between thoracic scoliosis and the prevalence of chronic disease at study enrollment. Additional work is needed to evaluate the impact of scoliosis on these outcomes during longitudinal follow-up.

SIGNIFICANCE/CLINICAL RELEVANCE: Scoliosis is a common spine condition in adults. Understanding the contribution of scoliosis to health conditions across the lifespan is essential for guiding the clinical management of complex spine conditions in aging populations. We confirmed that adult thoracic scoliosis is associated with alterations in lung dimensions and pulmonary function in cohort of smokers at high risk for lung disease. Additional work is needed to review the clinical relevance of our findings, confirm associations between scoliosis and pulmonary function in non-smokers, and to study the potential impact of interventions aimed at improving respiratory outcomes in older adults with thoracic scoliosis.

REFERENCES:

1.Quintero Santofimio V, Clement A, O'Regan DP, Ware JS, McGurk KA. Identification of an increased lifetime risk of major adverse cardiovascular events in UK Biobank participants with scoliosis. *Open Heart*. May 2023;10(1)doi:10.1136/openhrt-2022-002224

2.Sadat-Ali M, Al-Othman A, Bubshait D, Al-Dakheel D. Does scoliosis causes low bone mass? A comparative study between siblings. *Eur Spine J*. Jul 2008;17(7):944-7. doi:10.1007/s00586-008-0671-4

3.Otomo N, Khanshour AM, Koido M, et al. Evidence of causality of low body mass index on risk of adolescent idiopathic scoliosis: a Mendelian randomization study. *Front Endocrinol (Lausanne)*. 2023;14:1089414. doi:10.3389/fendo.2023.1089414