Published in final edited form as:

Spine (Phila Pa 1976). 2014 November 15; 39(24): E1418–E1424. doi:10.1097/BRS.0000000000000615.

Diffuse Idiopathic Skeletal Hyperostosis Association with Thoracic Spine Kyphosis: A Cross-sectional Study for the Health Aging and Body Composition Study

Lorenzo Nardo, M.D.,

Department of Radiology, University of California San Francisco, San Francisco, CA

Nancy Lane, MD,

Center for Musculoskeletal Health, University of California at Davis School of Medicine, Sacramento, CA

Neeta Parimi, MS,

California Pacific Medical Research Center, San Francisco, CA

Peggy Cawthon, PhD,

California Pacific Medical Research Center, San Francisco, CA

Bo Fan, MD,

Department of Radiology & Biomedical Imaging, University of California San Francisco, San Francisco, CA

John A. Shepherd, PhD,

Department of Radiology & Biomedical Imaging, University of California San Francisco, San Francisco, CA

Jane A Cauley, DrPH,

Department of Epidemiology, Graduate School of Public Health, University of Pittsburgh, Pittsburgh, PA

Audrey Zucker-Levin, PT, PhD,

Department of Physical Therapy, College of Allied Health Sciences, The University of Tennessee Health Science Center, Memphis, TN

Rachel A Murphy, PhD, and

Laboratory of Epidemiology, and Population Sciences, National Institute on Aging, Bethesda, MD

Wendy B. Katzman, PT, DPTSc

Department of Physical Therapy and Rehabilitation Science, University of California, San Francisco, San Francisco, CA

Abstract

Study Design—A descriptive study of the association between diffuse idiopathic skeletal hyperostosis (DISH) and kyphosis.

Objective—To investigate the association DISH and Cobb angle of kyphosis in a large cohort of older subjects from the Health Aging and Body Composition Study.

Summary of Background Data—DISH and thoracic kyphosis are well-defined radiographic findings in spines of older individuals. Characteristics of DISH (ossifications between vertebral segments) reflect changes of spine anatomy and physiology that may be associated with Cobb angle of kyphosis.

Methods—Using data from 1172 subjects aged 70–79 years, we measured DISH and Cobb angle of kyphosis from computed tomography (CT) lateral scout scans. Characteristics of participants with and without DISH were assessed using chi-square and t-tests. Association between DISH and Cobb angle was analyzed using linear regression. Cobb angle and DISH relationship was assessed at different spine levels (thoracic and lumbar).

Results—DISH was identified on CT scout scan in 152 subjects with 101 cases in only the thoracic spine and 51 in both thoracic and lumbar spine segments. The mean Cobb angle of kyphosis in the analytic sample was 31.3° (SD=11.2). The presence of DISH was associated with greater Cobb angle of 9.1° 95%CI [5.6, 12.6] among blacks and 2.9° 95%CI [0.5, 5.2] among whites compared to no DISH. DISH in the thoracic spine alone was associated with greater Cobb angle of 10.6° 95%CI [6.5, 14.7] in blacks and 3.8° 95%CI [1.0, 6.5] in whites compared to no DISH.

Conclusions—DISH is associated with greater Cobb angle of kyphosis, especially when present in the thoracic spine alone. The association of DISH and Cobb angle is stronger within the black population.

Keywords

Cobb angle; kyphosis; hyperkyphosis; diffuse idiopathic skeletal hyperostosis; DISH; aging; spine; Computed Tomography; spine ligament; race; bone metabolism

Introduction

Diffuse idiopathic skeletal hyperostosis (DISH), often referred to as Forestier's disease (1), is a condition diagnosed by the presence of ossification of the soft tissue of the anterolateral thoracolumbar spine over at least four contiguous segments, with flowing vertebral bony bridges in absence of frank degenerative changes in the intervertebral discs (2). Currently, the etiology of DISH is unclear, however there are studies that support a genetic association with an allele variant in the COL6A1 gene, hormonal mechanisms including IGF-1 and growth hormone, medications (Vitamin A) and mechanical factors that could activate different cell signaling pathways such as Wnt-B-catenin, NFkB, bone morphogenic protein 2 (BMP2), prostaglandin I₂ (PGI₂) and endothelin (1,4). Also, studies have reported associations between DISH and diabetes mellitus type 2, obesity, hyperuricemia, and male gender (5,6).

DISH is a prevalent radiographic finding in the spines of older individuals. Other prevalent radiographic findings in older individuals include kyphosis and vertebral fractures. The spinal curvature that results in kyphosis is assessed by Cobb angle measurement obtained

from a lateral spine radiograph (4). Kyphosis increases with age and has been associated with decreased bone mineral density, (5) (6) decreased lumbar paraspinal muscle density, (7) vertebral fractures, (8) and is a predictor of poor physical function (9) (10) (11). Since both kyphosis and DISH are prevalent in aging populations, we hypothesized that the characteristic ossification of the ligaments between the vertebrae in DISH may alter the architecture of the spine and affect spinal curvature resulting in greater kyphosis. To investigate the possible association between DISH and kyphosis, we used a large cohort of older subjects from the Health Aging and Body Composition (Health ABC) Study (12).

Materials and Methods

Subjects

Health ABC is an ongoing longitudinal cohort of 3075 black (42%) and white (58%) participants, with relatively equal numbers of men (48%) and women (52%). At baseline, participants age 70–79 years old were recruited from a random sample of white Medicare-eligible residents and all age-eligible black residents of selected areas of Pittsburgh, Pennsylvania, and Memphis, Tennessee. Participants were independent in activities of daily living, able to walk ¼ of a mile and up 10 steps without resting. Protocols were approved by institutional review boards and written informed consent was collected for each participant.

Covariates

Self-reported history of vertebral fractures, doctor diagnosed gout and a medication inventory were assessed by an interviewer-administered questionnaire at the baseline visit. Osteoporosis medication use (bisphosphonates, calcitonin, raloxifene hydrochloride, and fluoride) was coded using the Iowa Drug Information System ingredient codes. Height and weight were measured using a Harpenden stadiometer and a calibrated balance beam scale. Body mass index (BMI) was calculated and reported as kilograms/meters squared. Diabetes was determined from any of the following 3 criteria: self-reported diabetes, medication use or fasting glucose ≥ 7 mmol/L. Bone mineral density (BMD) of the proximal femur was assessed by dual-energy x-ray absorptiometry (DXA) (Hologic QDR 4500A; Hologic Inc, Bedford, Massachusetts). Lumbar paraspinal muscle density was measured using a previously reported protocol (7) from axial computed tomography (CT) scans at the L4–L5 disc space on a 9800 Advantage Scanner (General Electric, Milwaukee, WI). The regions defined as left and right lumbar paraspinal muscles in the axial CT image were measured, and lumbar paraspinal muscle density was expressed as the average of these two measures. Gait speed was performed by timing participants walking at their usual pace along a 6-meter walking course twice, and reported as the average in meters per second. Chair stands were performed with arms crossed at the chest, and recorded as number of chair stands completed in 10 seconds.

The sample for this study included 1172 men and women from the Pittsburgh site for whom baseline scout CT scans and Cobb angle of kyphosis measurements were available. Of the 1172 participants with CT scans and kyphosis measurements, 1128 (96.2%) were read for presence and location of DISH, 44 scans were excluded for poor image quality and inability to assess for presence of DISH.

Radiological assessment: Cobb's angle and DISH definition

Using the scout CT of the spine (lateral view), Cobb angle (13) was calculated using a modified 6-point vertebral morphometry technique widely used for osteoporotic fracture assessment on radiographs(14). Specifically, three points were placed on the superior endplate of the fourth thoracic (T4) vertebral body, and three on the inferior endplate of T12, corresponding to the midpoint and most anterior and posterior points of the vertebra. Linear regression was used to estimate the orientation of each endplate, and then orientation lines were superimposed over the image. Cobb angle was calculated as the angle between the intersecting orientation lines (Figure 1). Repeated Cobb angle measurements from 50 scans was reproducible (ICC=0.9) (10).

DISH was assessed on the same scout CT scan. Prerequisites for the diagnosis of DISH included flowing calcification along the anterolateral aspect of at least four contiguous vertebral bodies (Figure 2) (2); preservation of the intervertebral disc height, absence of severe degenerative disease in the involved vertebral segments (15); and absence of apophyseal joint ankylosis, costovertebral joint fusion, sacroiliac joint erosions or intra-articular osseous fusion in the synovial portion of the joints (16).

Reliability of DISH readings

CT studies were read by two musculoskeletal radiologists. For intra-rater reproducibility the first reader read all scans for DISH twice, 8 weeks apart. The second reader evaluated a random sample of 490(43%) from each quartile of Cobb angle for inter-rater reproducibility. A senior rheumatologist (NEL) was consulted in cases of disagreement or doubt. Intra- and inter-rater agreement determined by calculation of kappa values was 0.9 95%CI [0.8,0.9] and 0.6 95%CI [0.5,0.7], respectively.

Statistical Methods—Characteristics of participants with and without the presence of DISH were assessed using chi-square tests for categorical variables and t-tests for continuous variables. The association between DISH and Cobb angle was analyzed using linear regression. Beta estimates and 95% confidence intervals (CI) were calculated for the difference in Cobb angle in participants with DISH compared to those without DISH. Analyses were also performed in subjects with DISH in the thoracic spine only and with DISH in both the lumbar and thoracic spine (none had DISH localized only in the lumbar spine).

Statistical models were initially adjusted for age and then further adjusted for race and sex. We tested for an interaction of DISH and age, DISH and race, and DISH and sex. All subsequent analyses presented were stratified by race. To obtain final multivariable risk estimates for the association between Cobb angle and DISH stratified by race, we added covariates to models including age, sex and BMD. Factors associated with DISH or Cobb angle at $p < 0.1$ were considered for inclusion in the final multivariable model (Table 1). Data collected from the study was compiled and analyzed using SAS software (version 9.2, Cary, NC).

Results

Demographics

Among participants with DISH measurements (n=1128), DISH was diagnosed in 152 subjects (13.5%) with 101(66%) cases located in the thoracic spine and 51(34%) in both the thoracic and lumbar regions (Table 1). Participants diagnosed with DISH were more likely to be men of older age, Caucasian, and have higher BMI, lumbar paraspinal muscle density, hip BMD and Cobb angle compared to those without DISH. Doctor diagnosed gout and diabetes were more prevalent among participants with DISH compared to those without DISH (Table 1). There were no significant differences between DISH categories in self-reported prior vertebral fractures, gait speed, chair stands and use of osteoporosis medication, $p>0.05$.

Association of DISH and Cobb Angle

There was a significant interaction of race and DISH with Cobb angle (p for interaction=0.003), and all analyses were subsequently stratified by race. The mean Cobb angle of kyphosis in the analytic sample was 31.3° (SD=11.2). In the model adjusted for age and sex, the presence of DISH among blacks was associated with an increase in Cobb angle of 8.9° 95% CI [5.4,12.4] compared to those without DISH (Table 2). This association was strengthened to 9.4° 95% CI [6.0,12.9] in models adjusted for hip BMD. The addition of other covariates to the model, including BMI, diabetes, gout, and lumbar paraspinal muscle density, did not substantially alter the association between DISH and Cobb angle (Table 2).

The association of DISH and Cobb angle among whites differed from that in blacks (Table 2). In whites, DISH was not significantly associated with Cobb angle in the age and sex adjusted model, however the results were statistically significant after further adjustment for hip BMD and the addition of clinical covariates (Table 2). Nevertheless, the magnitude of the association in blacks, 9.1° 95% CI [5.6,12.6], was substantially higher than in whites, 2.9° 95% CI [0.5,5.2], in the multivariate model.

Location of DISH and Cobb Angle

The presence of DISH in the thoracic region alone was significantly associated with an increase in Cobb angle of 10.6° 95% CI [6.5,14.7] in blacks and 3.75° 95% CI [1.0,6.5] in whites compared to those without DISH, adjusted for all covariates (Table 3). DISH in both the thoracic and lumbar regions was not associated with Cobb angle in either blacks and whites in multivariate models (Table 3).

Discussion

We found an overall 13.5% prevalence of DISH, which was higher in whites than in blacks; however, the association of DISH with the Cobb angle of kyphosis was much stronger among the black population. Our prevalence data is consistent with prior published studies where the prevalence of DISH varied from 4% to 52%, depending upon study population and the diagnostic criteria used to diagnose DISH. Most studies among men and women older than 50 years report 15% to 25% prevalence, whereas Holton described prevalence as

high as 42% (17) in the Osteoporotic Fractures in Men Study (MrOS). These discrepancies could be due to differences in race and sex of the populations studied or the criteria used to define DISH. First, the MrOS cohort is 90% white, however the Health ABC cohort is 57% white. Second, our Health ABC cohort includes both men and women, and women have lower prevalence of DISH. Also, we used the Resnick criteria (18) for defining DISH and it requires ossifications within the anterior longitudinal ligament bridging at least four consecutive vertebral bodies while other epidemiologic studies of DISH utilized the Mata criteria that require incomplete bridging between only two vertebrae to make the diagnosis (19). Thus, studies that use the Mata criteria tend to report a higher prevalence of DISH (17).

We determined that DISH is associated with greater Cobb angle of kyphosis and hypothesize that the characteristic ossification of the anterior longitudinal ligament may alter the architecture of the spine and affect spinal curvatures. Spinal involvement of DISH is characterized by bridging ossification of the anterior longitudinal ligament that is normally separated from the anterior aspect of the vertebral body by a thin radiolucent line. In DISH, the ligament becomes virtually fused to the anterior aspect of the vertebral bodies, limiting the ability to straighten the spine. Ossification of the vertebral ligaments can be seen in a large number of diseases including chondrocalcinosis, acromegaly, ochronosis, hypophosphatemia, achondroplasia and ankylosing spondylitis (AS). In particular, in AS there is ossification of the vertebral ligaments and fusion in the vertebrae resulting in a flexed-kyphtotic posture. This ossification can be explained by alterations in the mineralization of the anterior longitudinal ligament, although the reasons for this mineralization are unknown. Recent studies in mice have determined that alteration in purine metabolism affects the regulation of bio- mineralization and results in ectopic mineralization of paraspinal tissue that resembles DISH (20). It has also been theorized that mesenchymal stem cells are responsible for ossification of the ligaments and tendons observed in DISH and AS (20). Further investigation of these pathogenic pathways may help to explain the associations of DISH and kyphosis.

A stronger association between DISH and Cobb angle was demonstrated among black than among white participants. While the prevalence of DISH in our cohort is lower in blacks, the impact of DISH on Cobb angle among blacks appears to be greater. These discrepancies can be explained by anatomic differences between the two races. Whereas the anterior spinal ligament is histologically similar in both races, blacks have considerably wider and thicker anterior spine ligaments when compared to whites (21). The calcification of a wider and thicker ligament could have a greater effect on kyphosis than a narrower and thinner ligament. This hypothesis is supported by the Birnbaum et al. (22) study that reported transection of the anterior longitudinal ligament from T3 to T7 in cadavers resulted in a mean 16 degree reduction of Cobb angle.

We demonstrated that when DISH is present in both thoracic (T4–T12) and lumbar (L1–L5) spine regions, Cobb angle is not significantly changed, however when DISH is present only in the thoracic spine it is associated with greater kyphosis. In order to explain this finding, the anatomy of the spine needs to be considered. While the thoracic spine is characterized by a physiological kyphosis, an anterior curvature in the thoracic spine, the lumbar spine is characterized by a lordosis, a posterior curvature in the lumbar spine. Calcification of the

anterior ligament of the lumbar spine may produce a force that contrasts that created by calcification of the thoracic spine ligament because of the opposing concave and convex natures of thoracic and lumbar spinal curvatures.

While the gold standard measurement of kyphosis is Cobb angle from standing lateral spine radiographs, other measurements of kyphosis are used interchangeably (23–25) (26). We measured Cobb angle of kyphosis from supine CT scans because participants from the Pittsburgh site received these scans at baseline, and they have better resolution of vertebral body shape than lateral spine radiographs. Furthermore, a prior comparison of standing versus supine lateral spine radiographic measurements of Cobb angle of kyphosis reported that supine measurement underestimates the degree of kyphosis (25). Standing measures were about 4° higher than supine measures, and this difference was greater among those with the most extreme kyphosis (25). While differences might be expected because supine measurement is not effected by gravity, among those with DISH, we would expect a more rigid spine less susceptible to differences in supine and standing measurement. Regardless, any reduction of Cobb angle in those with DISH would only underestimate our findings.

Therapeutic interventions may be considered to prevent or reduce kyphosis. Given the calcification of the anterior longitudinal ligament among individuals with DISH, novel interventions may be needed that address this abnormal mineralization of soft tissue adjacent to the vertebrae. Differences in response to targeted interventions to reduce kyphosis may depend upon the etiology and warrants further investigation.

Our study is characterized by several limitations. First, selection bias may have been introduced because the Cobb angle data was available from one (Pittsburgh, PA) of the two clinical centers for Health ABC. While this limited our potential sample size to 1172, inclusion criteria were the same for both sites and the prevalence of DISH in our study sample was similar to that reported in other studies with similar aged participants. Second, Cobb angle was measured from supine scout CT, which is different from the standard Cobb angle measurement procedure from standing lateral spine radiographs; however, our measures of Cobb angle were very reproducible. Finally, the analysis was confined to well-functioning individuals aged 70–79 years and replication is needed to determine generalizability of the results in a more diverse population.

Conclusion

DISH is associated with greater Cobb angle of kyphosis in the thoracic spine of older individuals. The association of DISH and Cobb angle is stronger within the black population. These findings indicate that the presence of ossification within the anterior longitudinal ligament may alter the architecture of the spine and affect spinal curvatures. However, further investigation of this association in longitudinal studies is needed to learn whether the presence of DISH is a predictor of worsening kyphosis over time. Also, therapeutic interventions may be considered to prevent or reduce kyphosis particularly among blacks with thoracic DISH who may be at risk for increased Cobb angle of kyphosis.

Acknowledgments

The manuscript submitted does not contain information about medical device(s)/drug(s). National Institute on Aging (NIA) Contracts N01-AG-6-2101, N01-AG-6-2103, N01-AG-6-2106; NIA grants R01-AG028050, R01 AG041921; National Institute of Nursing Research (NINR) grant R01-NR-012459; NIH grants AR043052 and K24AR04884, P50 AR060752, Office of Research in Women's Health and the National Institute of Arthritis, Musculoskeletal and Skin Diseases P50 grant AR063043 funds were received in support of this work. Relevant financial activities outside the submitted work: consultancy, grants, payment for lectures.

References

1. Forestier J, Rotes-Querol J. Senile ankylosing hyperostosis of the spine. *Ann Rheum Dis.* 1950; 9(4):321–30. [PubMed: 14800245]
2. Resnick D, Shapiro RF, Wiesner KB, et al. Diffuse idiopathic skeletal hyperostosis (DISH) [ankylosing hyperostosis of Forestier and Rotes-Querol]. *Semin Arthritis Rheum.* 1978; 7(3):153–87. [PubMed: 341323]
3. Mazieres B. Diffuse idiopathic skeletal hyperostosis (Forestier-Rotes-Querol disease): what's new? *Joint Bone Spine.* 2013; 80(5):466–70. [PubMed: 23566663]
4. Langensiepen S, Semler O, Sobottke R, et al. Measuring procedures to determine the Cobb angle in idiopathic scoliosis: a systematic review. *Eur Spine J.* 2013 Nov; 22(11):2360–71. [PubMed: 23443679]
5. Ensrud KE, Black DM, Harris F, et al. The Fracture Intervention Trial Research Group. Correlates of kyphosis in older women. *J Am Geriatr Soc.* 1997; 45(6):682–7. [PubMed: 9180660]
6. Ettinger B, Black DM, Palermo L, et al. Kyphosis in older women and its relation to back pain, disability and osteopenia: the study of osteoporotic fractures. *Osteoporos Int.* 1994; 4(1):55–60. [PubMed: 8148573]
7. Katzman W, Cawthon P, Hicks GE, et al. Association of spinal muscle composition and prevalence of hyperkyphosis in healthy community-dwelling older men and women. *J Gerontol A Biol Sci Med Sci.* 2012; 67(2):191–5. [PubMed: 21878482]
8. Kado DM, Huang MH, Karlamangla AS, et al. Factors associated with kyphosis progression in older women: 15 years' experience in the study of osteoporotic fractures. *J Bone Miner Res.* 2013; 28(1): 179–87. [PubMed: 22865329]
9. Takahashi T, Ishida K, Hirose D, et al. Trunk deformity is associated with a reduction in outdoor activities of daily living and life satisfaction in community-dwelling older people. *Osteoporos Int.* 2005; 16(3):273–9. [PubMed: 15235766]
10. Katzman WB, Vittinghoff E, Kado DM. Age-related hyperkyphosis, independent of spinal osteoporosis, is associated with impaired mobility in older community-dwelling women. *Osteoporos Int.* 2011; 22(1):85–90. [PubMed: 20480146]
11. Katzman WB, Vittinghoff E, Ensrud K, et al. Increasing kyphosis predicts worsening mobility in older community-dwelling women: a prospective cohort study. *J Am Geriatr Soc.* 2011; 59(1):96–100. [PubMed: 21198460]
12. Katsiaras A, Newman AB, Kriska A, et al. Skeletal muscle fatigue, strength, and quality in the elderly: the Health ABC Study. *J Appl Physiol* (1985). 2005; 99(1):210–6. [PubMed: 15718402]
13. Keynan O, Fisher CG, Vaccaro A, et al. Radiographic measurement parameters in thoracolumbar fractures: a systematic review and consensus statement of the spine trauma study group. *Spine (Phila Pa 1976).* 2006; 31(5):E156–65. [PubMed: 16508540]
14. Black DM, Palermo L, Nevitt MC, et al. Comparison of methods for defining prevalent vertebral deformities: the Study of Osteoporotic Fractures. *J Bone Miner Res.* 1995; 10(6):890–902. [PubMed: 7572313]
15. Resnick D. Diffuse idiopathic skeletal hyperostosis. *AJR Am J Roentgenol.* 1978; 130(3):588–9. [PubMed: 415581]
16. Westerveld LA, van Bommel JC, Dhert WJ, et al. Clinical outcome after traumatic spinal fractures in patients with ankylosing spinal disorders compared with control patients. *Spine J.* 2014 May 1; 14(5):729–40. [PubMed: 23992936]

17. Holton KF, Denard PJ, Yoo JU, et al. Diffuse idiopathic skeletal hyperostosis and its relation to back pain among older men: the MrOS Study. *Semin Arthritis Rheum.* 2011; 41(2):131–8. [PubMed: 21377195]
18. Resnick D. Diffuse Idiopathic Skeletal Hyperostosis (DISH). *West J Med.* 1976; 124(5):406–7. [PubMed: 18747701]
19. Diederichs G, Engelken F, Marshall LM, et al. Diffuse idiopathic skeletal hyperostosis (DISH): relation to vertebral fractures and bone density. *Osteoporos Int.* 2011; 22(6):1789–97. [PubMed: 20882271]
20. Berthelot JM, Le Goff B, Maugars Y. Pathogenesis of hyperostosis: A key role for mesenchymatous cells? *Joint Bone Spine.* 2013; 80(6):592–6. [PubMed: 23731645]
21. Hanson P, Magnusson SP. The difference in anatomy of the lumbar anterior longitudinal ligament in young African-Americans and Scandinavians. *Arch Phys Med Rehabil.* 1998; 79(12):1545–8. [PubMed: 9862297]
22. Birnbaum K, Siebert CH, Hinkelmann J, et al. Correction of kyphotic deformity before and after transection of the anterior longitudinal ligament--a cadaver study. *Arch Orthop Trauma Surg.* 2001; 121(3):142–7. [PubMed: 11262779]
23. Goh S, Price RI, Leedman PJ, et al. A comparison of three methods for measuring thoracic kyphosis: implications for clinical studies. *Rheumatology.* 2000; 39(3):310–5. [PubMed: 10788541]
24. Greendale GA, Nili NS, Huang MH, et al. The reliability and validity of three non-radiological measures of thoracic kyphosis and their relations to the standing radiological Cobb angle. *Osteoporos Int.* 2011; 22(6):1897–905. [PubMed: 20938766]
25. Kado DM, Christianson L, Palermo L, et al. Comparing a supine radiologic versus standing clinical measurement of kyphosis in older women: the Fracture Intervention Trial. *Spine (Phila Pa 1976).* 2006; 31(4):463–7. [PubMed: 16481959]
26. Landon KM, Li AM, Bibershtein S. Interrater and intrarater reliability in the measurement of kyphosis in postmenopausal women with osteoporosis. *Spine (Phila Pa 1976).* 1998; 23(18):1978–85. [PubMed: 9779531]

Key Points

1. The prevalence of DISH is 13.5% in a cohort of well-functioning men and women aged 70–79 years.
2. DISH is associated with greater Cobb angle of kyphosis in the thoracic spine of older individuals.
3. The association of DISH and Cobb angle is stronger within the black population.

Figure 1.

Lateral scout view of the spine. T4 and T12 were automatically detected and 3 points were placed on the superior endplate of T4 and the inferior endplate of T12 (red dots), corresponding to the anterior, middle and posterior vertebra. Using linear regression to determine the best fit, these points were used to precisely draw two lines: one parallel to T4 vertebral body (T4) and one parallel to T12 vertebral body (T12); Cobb angle was calculated as the angle between these two lines.

Figure 2.

Lateral scout image. At the middle and lower thoracic spine, abnormal confluent hyperostosis (arrow) is noted in the anterior longitudinal ligaments from T9 to L1 (A); this finding is not present in the lumbar segment of the spine (B). The intervertebral disc spaces are relatively maintained (*) in both lumbar and thoracic spine. These findings are hallmarks of diffuse idiopathic skeletal hyperostosis.

Table 1

Baseline Characteristics

Baseline Characteristics	No DISH (N= 976)	DISH present (N= 152)	p-value
mean +/- SD			
Age (years)	73.5 +/- 2.9	74.2 +/- 2.9	0.01
Cobb Angle (degrees)	31.0 +/- 11.2	33.7 +/- 10.8	0.006
Gait speed (m/s)	1.2 +/- 0.3	1.2 +/- 0.3	0.69
Chair stands completed in 10 seconds (n)	3.7 +/- 1.1	3.8 +/- 1.2	0.41
BMI (kg/m ²)	27.0 +/- 4.4	28.8 +/- 4.1	<0.001
Hip BMD (g/m ²)	0.9 +/- 0.2	1.1 +/- 0.2	<0.001
Lumbar paraspinal muscle density (HU)	23.7 +/- 2.9	24.4 +/- 2.9	0.007
N (%)			
Caucasian	539 (55.2)	110 (72.4)	<0.001
Men	468 (47.9)	131 (86.2)	<0.001
Self reported vertebral fractures	24 (2.5)	6 (4)	0.28
Self reported gout	81 (8.4)	22 (14.5)	0.02
Diabetes	169 (17.3)	46 (30.3)	0.001
Osteoporosis medication use	39 (4.0)	3 (2.0)	0.22

m/s=meters/second, n=number, kg/m²=kilograms/meter², HU=Hounsfield units

Table 2

Difference in Cobb angle and presence of DISH by race

	Whites N=649 (110 with DISH)	Blacks N=479 (42 with DISH)
	Difference in Cobb angle (95% CI)	Difference in Cobb angle (95% CI)
Base model	1.8 (−0.5 to 4.1)	8.9 (5.4 to 12.4)
Base+ BMD	2.7 (0.4 to 5.0)	9.4 (6.0 to 12.9)
Multivariate model	2.9 (0.5 to 5.2)	9.1 (5.6 to 12.6)

Base model adjusted for age and sex

Multivariate model adjusted for Base, BMI, total hip BMD, diabetes, gout and lumbar paraspinal muscle density p for interaction for race and DISH in the base model=0.0028

* note that there are 9 subjects with missing lumbar paraspinal muscle density values. These include 8 without DISH and 1 with DISH. These are not included in the multivariate models.

Table 3

Difference in Cobb angle with the location of DISH by race

	Whites		Blacks	
	Thoracic only 72 with DISH, 539 No DISH Difference in Cobb angle (95%CI)	Lumbar and Thoracic 38 with DISH, 539 No DISH Difference in Cobb angle (95%CI)	Thoracic only 29 with DISH, 437 No DISH Difference in Cobb angle (95%CI)	Lumbar and Thoracic 13 with DISH, 437 No DISH Difference in Cobb angle (95%CI)
Base model	3.0 (0.3 to 5.7)	-0.5 (-4.1 to 3.1)	10.5 (6.4 to 14.6)	5.3 (-0.7 to 11.2)
Base+ BMD	3.7 (1.0 to 6.4)	0.6 (-3.0 to 4.3)	10.9 (6.8 to 14.9)	6.1 (0.2 to 12.1)
Multivariate	3.8 (1.0 to 6.5)	0.9 (-3.0 to 4.7)	10.6 (6.5 to 14.7)	5.7 (-0.3 to 11.7)

Base model adjusted for age and sex

Multivariate model adjusted for Base, total hip BMD, diabetes, gout, and lumbar paraspinal muscle density p for interaction with race and DISH location=0.0066

* note that there are 9 subjects with missing lumbar paraspinal density values. These include 8 without DISH and 1 with DISH. These are NOT included in the multivariate models.