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ORIGINAL ARTICLE

Spine fracture prevalence in a nationally representative sample of US women and men aged ≥40 years: results from the National Health and Nutrition Examination Survey (NHANES) 2013-2014

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Abstract
Summary Spine fracture prevalence is similar in men and women, increasing from <5 % in those <60 to 11 % in those 70–79 and 18 % in those ≥80 years. Prevalence was higher with age, lower bone mineral density (BMD), and in those meeting criteria for spine imaging. Most subjects with spine fractures were unaware of them.

Introduction Spine fractures have substantial medical significance but are seldom recognized. This study collected contemporary nationally representative spine fracture prevalence data.
Methods Cross-sectional analysis of 3330 US adults aged ≥40 years participating in NHANES 2013–2014 with evaluable Vertebral Fracture Assessment (VFA). VFA was graded by semiquantitative measurement. BMD and an osteoporosis questionnaire were collected.
Results Overall spine fracture prevalence was 5.4 % and similar in men and women. Prevalence increased with age from <5 % in those <60 to 11 % in those 70–79 and 18 % in those ≥80 years. Fractures were more common in non-Hispanic whites and in people with lower body mass index and BMD. Among subjects with spine fracture, 26 % met BMD criteria for osteoporosis. Prevalence was higher in subjects who met National Osteoporosis Foundation (NOF) criteria for spine imaging (14 vs 4.7 %, $P < 0.001$). Only 8 % of people with a spine fracture diagnosed by VFA had a self-reported fracture, and among those who self-reported a spine fracture, only 21 % were diagnosed with fracture by VFA.
Conclusion Spine fracture prevalence is similar in women and men and increases with age and lower BMD, although most subjects with spine fracture do not meet BMD criteria for osteoporosis. Since most (>90 %) individuals were unaware of their spine fractures, lateral spine imaging is needed to identify these women and men. Spine fracture prevalence was threefold higher in individuals meeting NOF criteria for spine imaging (~1 in 7 undergoing VFA). Identifying spine fractures as part of comprehensive risk assessment may improve clinical decision making.

Keywords Osteoporosis · Prevalence · Screening · Spine fracture · Vertebral Fracture Assessment (VFA)

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Required disclaimer
The findings and conclusions in this report are those of the authors and not necessarily those of the Centers for Disease Control and Prevention.

Previous disclosure
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Introduction

Approximately two million Americans suffered an osteoporosis-related fracture in 2005, and this incidence is projected to increase to more than three million by 2025 [1]. Health care professionals frequently fail to diagnose and treat osteoporosis even after major fractures [2].

The presence of osteoporotic fractures indicates that the skeleton has deteriorated and is unable to sustain day-to-day loads. Clinical and morphometric spine fractures are associated with increased mortality [3], chronic pain, and impaired quality of life [4, 5]. Spine fractures are often the first osteoporotic fractures [6] and are associated with substantially elevated risk for subsequent vertebral [7] and nonvertebral fractures including those of the hip [8]. Accordingly, recognition of these fractures as sentinel events may trigger assessments and interventions that potentially could prevent additional fractures [9–12]. However, spine fractures often do not come to clinical attention at the time of the event and so patients with spine fractures are usually not identified. As a result, criteria for proactive spine imaging with radiography or VFA have recently been recommended by the National Osteoporosis Foundation (NOF). Although these criteria were intended to identify individuals with increased spine fracture prevalence, the prevalence in individuals meeting these criteria is unknown [10].

In the USA, five previous studies have provided prevalence data on spine fractures by lateral spine radiography. These studies were not nationally representative, did not include both men and women or a broad age range, or did not comprehensively discriminate fractures from nonfracture deformities [13–17]. Over a decade ago, the Surgeon General's Report on Bone Health and Osteoporosis highlighted the need for national-level data on spine fracture prevalence obtained through VFA [9]. Compared to lateral lumbar and thoracic spine radiographs, VFA includes a single image of the spine, has reduced resolution and higher noise, but less projection distortion (parallax) and lower radiation exposure, with nearly comparable accuracy in identifying vertebral fractures [18–25].

The National Health and Nutrition Examination Survey (NHANES) has provided information regarding BMD of US citizens, and the NHANES III database is the reference database for hip BMD [26]. The goals of this study were to define the prevalence of spine fractures in men and women aged ≥40 years using VFA data collected in NHANES 2013–2014, to assess characteristics of subjects with spine fractures, to compare self-report of spine fracture with VFA diagnosis, and to assess prevalence in those meeting NOF spine imaging criteria based on age, BMD, and previous fracture [10].

Methods

Study design and sample

The NHANES is conducted by the National Center for Health Statistics (NCHS) to assess the health and nutritional status of a representative sample of the noninstitutionalized, civilian US population. Details about the plan, operation, and design of the survey are described elsewhere [27]. NHANES participants underwent a home interview followed by assessments at a mobile examination center. All procedures in NHANES 2013–2014 were approved by the NCHS Research Ethics Review Board; written informed consent was obtained from subjects.

The percentage of subjects aged ≥40 years who came to the mobile examination center relative to the number selected to participate was 61.2 %. Of 3708 adults, 378 (10 %) did not undergo VFA due to pregnancy, body weight > 450 lb (204 kg), history of radiographic contrast material exposure in the past week, or presence of Harrington rod in the spine, or had scans excluded because of movement artifacts. The VFA sample included 3330 subjects.

Assessments

VFA using lateral spine imaging IVA™ mode and BMD of posterior–anterior lumbar spine (LS) and proximal femur with Hologic Discovery® A densitometers (Hologic Inc., Marlborough, MA) were performed in the supine position. BMD was analyzed using APEX™ Version 4.0. Images of T4–L4 were viewed and results were stored using Optasia Medical SpineAnalyzer™ 4.0 software (Cheadle Hulme, UK). Each vertebra was graded using a semiquantitative method [28] by a physician trained by the expert musculoskeletal radiologist (Genant) at the NHANES DXA quality control center at the University of California, San Francisco (UCSF) as normal or mild, moderate, or severe fracture. Spine images of "fracture" cases identified by the UCSF reader were reread by Dr. Genant to confirm the findings; this rereading was limited to putative fracture cases because discrimination of fracture from nonfracture deformity is challenging, whereas discriminating deformity from non-deformity is relatively easy. Of 274 participants initially identified to have a "fracture," 88 (32 %) were not confirmed; these were mostly mild wedge deformities, without evident endplate or cortical wall displacement, thought to represent deformity related to chronic mechanical loading or degenerative remodeling. As described by Genant et al. in 1993 [28], the readings included inspection for vertebral body height loss and morphology out of step with adjacent vertebrae and for buckling or bowing of the endplates and/or anterior cortical walls. Also, deformities related to degenerative change identified by intact and sometimes sclerotic endplates with accompanying adjacent disc space narrowing were not diagnosed as fractures, and deformities such as Scheuermann's disease or congenital vertebral fusion were also not diagnosed as fractures [28]. Subject status was defined as "normal" if no fracture was observed and at least 9 of 10 vertebral bodies from T7–L4 were evaluable; T4–T6 were not required to be evaluable since they are not always well visualized and only a small proportion of vertebral fractures occur at these levels [19]. Status was considered "fractured" if a fracture was observed in T4–L4, regardless if there were unevaluable levels elsewhere. Status was "uninterpretable" for participants not meeting above criteria.

Procedures for assessment of BMD of the lumbar spine (LSBMD), total hip (TOTBMD), and femoral neck (FNBMD) have been described elsewhere [29, 30]. LSBMD was calculated as the average of individual lumbar vertebra in subjects with at least two valid vertebrae between L1 and L4 [31]. T-scores were calculated per the 2013 recommendations from the International Society for Clinical Densitometry [31].

Self-reported race/ethnicity and previous fracture history were assessed by questionnaire. Prior low trauma fractures were defined as self-reported fractures that occurred at age ≥50 years due to a fall from standing height or less, a trip/slip, or a fall out of bed (hip, wrist, spine) or at age ≥20 years and not due to severe trauma such as a car accident, hard fall down steps, or from a ladder (fractures other than hip, wrist, spine).

The prevalence of spine fractures in men and women aged ≥50 years was compared in those meeting vs not meeting the following NOF criteria for spine imaging [10]: (a) women aged 65–69 and men aged 70–79 years whose FNBMD, TOTBMD, or LSBMD T-score was ≤ −1.5; (b) women aged ≥70 and men aged ≥80 years whose FNBMD, TOTBMD, or LSBMD T-score was ≤ −1.0; and (c) men and women who reported a prior low trauma fracture that occurred after age ≥50 years. Data on additional conditions that define eligibility for spine imaging, such as glucocorticoid use and historical height loss, were not yet publicly released.

Statistical analyses

Analyses were conducted with PC-SAS (Version 9.3, SAS Institute, Cary, NC) and SUDAAN (Version 11.0.1, Research Triangle Institute, Cary, NC). All analyses used the examination sample weights and accounted for the complex survey design when performing statistical tests. Statistical tests were *t* tests or chi-square analyses for unadjusted results. For age-adjusted results, age was included as an independent variable in a regression model, and means or proportions for the variable of interest were calculated by group after setting the value for age equal to the average age of the sample being modeled (57 years in the present study).

Because 10 % of the examined sample were not included in the final VFA sample, nonresponse bias analyses were conducted. Excluded respondents were more likely to be older, female, nonwhite, have higher BMI, report their health as fair or poor, and report more sedentary time than respondents in the analytic sample. To examine for potential nonresponse bias, the publicly released examination sample weights were adjusted for item nonresponse by age, sex, and race/Hispanic origin using the PROC WTADJUST procedure in SUDAAN. The sample weights adjusted for nonresponse for these three characteristics resulted in conclusions similar to those when the publicly released sample weights were used.

Results

The VFA sample included 1602 males and 1728 females. The weighted demographic characteristics of the VFA sample reflect those of the noninstitutionalized US population aged ≥40, and mean age was 57 years. Specifically, the race/ethnic composition after applying the sample weights was 71 % non-Hispanic white, 11 % Hispanic, 10 % non-Hispanic black, 5 % non-Hispanic Asian, and 2 % other race. Mean BMI was 29 kg/m^2 and mean BMD values were within the normal range (T-score > −1) at FNBMD, TOTBMD, or LSBMD in both genders.

Overall, 5.4 % of US adults aged ≥40 had spine fractures, including 6.2 % of males and 4.6 % of females (Table 1). There was a significant increase in the prevalence of spine fractures by age in both genders ($P = 0.03$ for all). The prevalence increased from 3–5 % in men and women <60 years old to 16–21 % in those aged ≥80 years. Overall, the prevalence of mild fractures was 2.3 % and of moderate/severe fractures was 3.3 %. The prevalence of moderate/severe fractures was 1.9 % in those aged <65 years and 14.5 % among those ≥80, with similar age-related increases in men and women (Table 2). Among fracture cases, the proportion with moderate/ severe fracture was higher in those aged ≥65 years (66 %; 95 % CI 55–76 %) than in those <65 (51 %; 95 % CI 35–67 %) ($P = 0.03$; data not shown).

Gender distribution for normal vs fractured adults was similar. Adults with fracture were older, more likely to be non-Hispanic white, had lower BMI and BMD at all sites, and a higher proportion met BMD criteria for osteoporosis (T-score ≤ −2.5) at the LS or FN (26.4 vs 9.9 %) (Table 3). In those ≥65 years old with vertebral fracture, 38 % had osteoporosis in at least one site compared to 14 % of those without fracture, and 22 % had normal BMD at both sites compared to 35 % of the nonfracture population.

Spine status showed fracture in 1 % by both VFA and self-report, 2 % by self-report with normal VFA, and 5 % by VFA diagnosis with no fracture self-report. Only 8 % of those with a VFA diagnosis were aware of their fracture. Furthermore, only 21 % of those who self-reported fracture had a proven VFA diagnosis (Table 4).

Table 1 Vertebral fracture prevalence by age and sex in US adults aged ≥40 years

1a.		Fracture[a]		Normal[a]		Uninterpretable[a, b]	
Sex	Age (years)	*n*	% [95 % CI]	*n*	% [95 % CI]	*n*	% [95 % CI]
Both sexes	≥40	186	5.4 [4.6, 6.3]	3038	91.4 [89.9, 92.8]	106	3.2 [2.3, 4.4]
	40–49	13	2.1 [1.2, 3.4]	905	96.1 [94.9, 97.0]	19	1.9 [1.1, 2.9]
	50–59	33	4.2 [2.9, 6.0]	785	93.3 [91.0, 95.2]	19	2.5 [1.2, 4.5]
	60–69	43	5.4 [3.6, 7.8]	762	90.0 [86.7, 92.8]	36	4.6 [2.8, 7.0]
	70–79	53	10.5 [7.1, 14.8]	399	85.7 [80.5, 90.0]	15	3.8 [1.9, 6.7]
	≥80	44	18.0 [13.4, 23.3]	187	74.7 [68.3, 80.5]	17	7.3 [2.4, 16.3][d]
	P age trend	0.03					
Men	≥40	105	6.2 [4.8, 8.0]	1455	91.3 [89.3, 93.0]	42	2.5 [1.8, 3.3]
	40–49	10	3.5 [1.8, 6.1]	423	94.9 [92.5, 96.7]	9	1.6 [0.8, 2.8]
	50–59	23	5.2 [2.9, 8.5]	383	92.6 [89.4, 95.1]	9	2.2 [0.7. 5.2][d]
	60–69	24	6.3 [2.8, 11.9][c]	364	89.8 [84.5, 93.7]	15	3.9 [1.5, 8.0][c]
	70–79	26	10.3 [5.3, 17.6]	198	87.8 [79.1, 93.8]	3	– [–][e]
	≥80	22	20.7 [13.3, 29.8]	87	73.8 [64.5, 81.7]	6	– [–][e]
	P age trend	0.01					
Women	≥40	81	4.6 [3.5, 5.9]	1583	91.6 [88.9, 93.7]	64	3.9 [2.5, 5.7]
	40–49	3	– [–][e]	482	97.2 [94.2, 98.9]	10	2.1 [0.7, 5.1][d]
	50–59	10	3.3 [1.8, 5.3]	402	94.0 [90.4, 96.5]	10	2.8 [1.0, 6.1][c]
	60–69	19	4.6 [2.0, 8.9][c]	398	90.2 [85.4, 93.9]	21	5.1 [2.8, 8.5]
	70–79	27	10.6 [6.4, 16.2]	201	84.0 [76.5, 89.8]	12	5.4 [2.8, 9.3]
	≥80	22	16.3 [8.8, 26.5]	100	75.3 [64.9, 83.9]	11	8.4 [2.5, 19.6][d]
	P age trend	<0.001					

[a] Sample sizes are unweighted while prevalences are weighted

[b] No fracture, ≥1 uninterpretable vertebra in T7–L4

May be statistically unreliable for the following reason(s): [c] Relative standard error = 30–39 %; [d] Relative standard error = 40–49 %; [e] Relative standard error ≥ 50 %

Common locations for fractures in both genders were the mid-thoracic region and thoracolumbar junction. Fracture frequency appeared to be similar in men and women at most levels, but fractures appeared to be more common in men at some levels, including T11 and T12 (Fig. 1).

The prevalence of spine fracture was higher in subjects meeting NOF criteria for spine imaging overall (14.0 vs 4.7 % in adults not meeting criteria, $P < 0.001$) and considering men (20.1 vs 5.6 %, $P = 0.003$) and women (12.4 vs 3.6 %, $P < 0.001$) separately (Table 5).

Discussion

These data from NHANES 2013–2014 provide the first nationally representative estimates of spine fracture prevalence in US men and women aged ≥40 years. VFA-diagnosed spine fracture prevalence was very low in subjects 40–49 but increased to 11 % in those aged 70–79 and 18 % in those aged ≥80 years. Among fracture cases, a higher proportion of individuals ≥65 years old vs younger adults had fractures of at least moderate severity. Prevalence was similar in men and women. Beyond the association with age, those with vertebral fractures had lower BMI and BMD. Among participants aged ≥65 years with vertebral fractures, the proportion with osteoporosis by BMD criteria was 38 % and the proportion with normal BMD (T-score > −1.0 at both skeletal sites) was 22 %. The Study of Osteoporotic Fractures (SOF) study showed that 58 % of hip fracture patients had osteoporosis at the LS or FN [32]. Thus, among older people with spine or hip fractures, roughly 40–60 % of subjects meet BMD criteria for osteoporosis.

Five previous studies of spine fracture prevalence in the US, all based on lateral spine radiography, have been published [13–17]. The first included women ≥50 years old in Rochester, MN [13]. Prevalence of deformity by quantitative morphometry (QM), a method that does not discriminate fracture from nonfracture deformity, increased from 7.6 % among women aged 50–54 to 45.5 % in women 80–84. The second study included 899 women and 529 men ≥50 years old in Saunders County, NE and also assessed deformity by QM [14]. Prevalence of spine deformity increased with age, from

Table 2 Fracture severity by age and sex in US adults aged ≥40 years in NHANES 2013–2014, excluding subjects with uninterpretable spine images

Sex	Age	*n*[a]	No fracture[a] % [95 % CI]	Mild[a] % [95 % CI]	Moderate/severe[a] % [95 % CI]
Both	≥40	3224	94.3 [93.5–95.3]	2.3 [1.8–3.0]	3.3 [2.4–4.3]
	40–64	2183	96.2 [94.8–97.3]	1.9 [1.3–2.5]	1.9 [1.0–3.3]
	65–79	810	92.0 [89.1–94.3]	3.2 [1.8–5.3]	4.8 [3.2–7.0]
	≥80	231	80.6 [75.4–85.2]	4.9 [1.9–10.0]	14.5 [9.7–20.4]
Men	≥40	1560	93.6 [91.8–95.1]	2.8 [1.9–3.9]	3.7 [2.4–5.6]
	40–64	1057	95.1 [93.0–96.8]	2.1 [1.2–3.4]	2.8 [1.4–5.0]
	65–79	394	91.5 [86.6–95.1]	4.4 [2.4–7.4]	4.1[b] [1.7–9.2]
	≥80	109	78.1 [68.9–85.6]	–[d]	15.8 [8.0–26.9]
Women	≥40	1664	95.2 [93.8–96.4]	1.9 [1.1–3.0]	2.9 [2.0–4.1]
	40–64	1126	97.3 [95.3–98.6]	1.7[b][0.8–3.1]	1.1[c] [0.3–2.8]
	65–79	416	92.4 [88.6–95.2]	2.1[b] [0.7–4.6]	5.5 [3.3–8.6]
	≥80	122	82.2 [71.8–90.1]	4.2[b] [1.6–8.7]	13.6 [6.8–23.5]

[a] Sample sizes are unweighted while prevalences are weighted

May be statistically unreliable for the following reason(s): [b] Relative standard error = 30–39 %; [c] Relative standard error = 40–49 %; [d] Relative standard error ≥ 50 %

10 % of women in their 50s to 45 % of women in their 80s and from 29 % of men in their 50s to 39 % of men in their 80s. The SOF included 9575 Caucasian women aged ≥65 years from four metropolitan areas, again using QM, reported prevalence of vertebral deformities to be 20 %, without prevalence reported by age [15]. By a visual semiquantitative methodology, the prevalence of deformity in 704 women and men in the Framingham Study with mean age 53–54 years was 14 % with no effect of age or sex on prevalence, although the authors suggested that some deformities may have been a result of remote trauma, stress, sports, physical activity, or degenerative remodeling, rather than osteoporosis [16]. Finally, in the MrOS Study, prevalence in 5958 men aged ≥65 years from six locations in the US was 12 % by semiquantitative methodology (mildly deformed vertebrae had to have endplate depression or cortical buckling to be considered fractured) [17]. In studies from Canada, Japan, and Europe, spine fracture prevalence rates varied from 4 to 25 %, based on the population age, gender distribution, geography, ascertainment technique, and other factors [7, 8, 33–38].

The methodology for the evaluation of the VFA images was the rigorous semiquantitative method as described by Genant [28]. While this methodology is sometimes misapplied to include only an assessment of approximate height and shape, the method described by Genant et al. includes evaluation of qualitative features including endplate deformity, buckling of cortices, lack of parallelism of endplates, and loss of vertical continuity of vertebral shape to define fracture and assessment for presence of characteristic nonfracture deformities to rule out fracture [28]. Training slide decks on this methodology are available from the International Osteoporosis Foundation website https://www.iofbonehealth.org/what-we-do/training-and-education/educational-slide-kits/vertebral-fracture-teaching-program. The lower prevalence of spine fractures in this contemporary study may be due to the rigorous methodology for defining fractures, since in most prevalence studies in the USA, visual assessments for degenerative change or nonfracture deformities were conducted incompletely or not at all [13–16]. In some European studies that included a stricter definition of spine fractures, prevalence was more similar to that seen here [8, 37, 39]. Another system for defining spine fracture prevalence called the Algorithm-Based Qualitative (ABQ) method defines spine fracture by presence of endplate depression without consideration of vertebral height reduction with a detailed algorithm for identifying nonfracture deformity [40]. Depending on how the SQ vs ABQ method is implemented by individual readers and investigators, these methods are likely to show different prevalences [22, 41]. In addition to the reading methodology, it is possible that spine fracture prevalence may have declined, similar to the decline in hip fracture since the 1990s [42–44].

We endeavored to rigorously differentiate fractures from nonfracture deformities such as stress and degenerative remodeling. These latter deformities often occur at T7–T8 and T12–L1 where flexion compression force may be maximal and suggest a chronic or intermittent stress-related phenomenon, rather than an acute fracture [45]. Multiple negative consequences have been associated with spine fractures defined by a variety of methodologies, usually by criteria less strict than those in this study [3, 4, 7, 8, 15, 46]. The clinical and prognostic significance of spine fractures by our strict criteria

Table 3 Selected age-adjusted characteristics of US adults aged ≥40 years by VFA fracture status, NHANES 2013–2014

	No fracture[a]		Fracture[a]		*P* value
	n	Mean or % [95 % CI]	*n*	Mean or % [95 % CI]	
Age (unadjusted mean, years)	3038	56.7 [56.2, 57.3]	186	65.6 [63.6, 67.7]	<0.001
Sex (%)					0.08
Men	1455	47.9 [46.0, 49.8]	105	57.0 [46.9, 66.5]	
Women	1583	52.1 [50.2, 54.0]	81	43.0 [33.5, 53.2]	
Race and Hispanic origin (%)					0.01
Non-Hispanic white	1295	70.8 [63.8, 76.9]	127	80.0 [70.3, 87.2]	
Non-Hispanic black	628	10.5 [7.8, 14.1]	20	5.2 [3.1, 8.6]	
Hispanic	693	11.5 [7.8, 16.7]	24	7.7 [3.8, 15.0][d]	
Non-Hispanic Asian	356	5.0 [3.7, 6.9]	13	4.0 [2.2, 7.3]	
Other	66	2.1 [1.5, 3.1]	2	– [–][e]	
Self-reported spine fracture (%)	3036	1.8 [1.2, 2.7]	186	9.3 [4.6, 18.0]	<0.001
BMI (mean, kg/m^2)	3017	29.2 [28.8, 29.5]	183	27.8 [26.6, 29.0]	0.02
Femur neck BMD (mean, g/cm^2)	2859	0.783 [0.777, 0.790]	172	0.722 [0.702, 0.743]	<0.001
Total femur BMD (mean, g/cm^2)	2859	0.953 [0.944, 0.963]	172	0.881 [0.852, 0.911]	<0.001
Lumbar spine BMD (mean, g/cm^2)	2841	1.023 [1.015, 1.031]	164	0.966 [0.936, 0.997]	0.002
Femoral neck T-score (mean)[b]	1989	−0.85 [−0.90, −0.80]	159	−1.37 [−1.58, −1.15]	<0.001
Total femur T-score (mean)[b]	1989	−0.07 [−0.15, 0.02]	159	−0.68 [−0.93, −0.44]	<0.001
Lumbar spine T-score (mean)[b]	1938	−0.32 [−0.38, −0.25]	152	−0.92 [−1.20, −0.64]	<0.001
Lumbar spine and femoral neck status[c]					
Age ≥ 50					
Osteoporosis (%)[b]	199	9.9 [8.5, 11.2]	40	26.4 [16.2, 36.5]	<0.001
Low bone mass (%)[b]	794	45.0 [42.7, 47.2]	64	38.6 [26.8, 50.4]	0.29
Normal (%)[b]	817	45.2 [42.7, 47.7]	37	35 [23.8, 46.3]	0.06
Age ≥ 65					
Osteoporosis (%)[b]	107	13.8 [10.7, 16.9]	33	37.9 [28.2, 47.6]	<0.001
Low bone mass (%)[b]	359	50.9 [46.8, 55.0]	41	39.6 [29.3, 49.9]	0.03
Normal (%)[b]	277	35.3 [32.5, 38.2]	18	22.4 [11.8, 33.1]	0.02

Linear or logistic regression was used to adjust results for comparison between groups that differed significantly in age. Specifically, age was included as an independent variable in the regression model, and means or proportions for the variable of interest were calculated by group after setting the value for age equal to the average age of the sample being modeled (57 years in the present study).

BMD bone mineral density, *BMI* body mass index, *VFA* vertebral fracture assessment

[a] Sample sizes are unweighted while mean or percent is weighted

[b] Respondents aged ≥50 only

[c] Subjects classified based on the lowest T-score from lumbar spine or femoral neck: "osteoporosis" = T-score ≤ −2.5 at either site; "low bone mass" = T-score between −1 and −2.5 at one or both sites; "normal" = T-score ≥ −1.0 at both sites

May be statistically unreliable for the following reason(s): [d] Relative standard error = 30–39 %; [e] Relative standard error ≥ 50 %

might be even more important. Further studies of the consequences of nonfracture vertebral deformities are warranted.

Over 90 % of subjects with a positive VFA diagnosis did not self-report a fracture, and most subjects who self-reported a fracture did not have a VFA diagnosis. Similarly, in another study, 93 % of subjects with radiographic spine fractures were unaware of the fracture [47]. Vertebral fractures are associated with an increased risk (2–5-fold) for subsequent vertebral and other fractures [46]; indeed, a high proportion (perhaps up to 50 %) of patients with hip fracture have vertebral fractures found on routine spine imaging [48]. The identification of spine fractures as sentinel events could potentially reduce the risk of having subsequent hip or other fracture [9, 10, 12, 49].

The prevalence of vertebral fracture was 14.0 % (one in seven individuals) in individuals meeting NOF criteria for screening spine imaging based on age and BMD or on previous fragility fracture [10], compared to 4.7 % in those not meeting criteria. Thus, the NOF criteria indeed identified subjects with approximately threefold increased prevalence of

Table 4 Relationship between VFA spine fracture and self-reported spine fracture US adults aged ≥40 years, NHANES 2013–2014

	n^a	% [95 % CI][a]
Spine fracture status		
Both VFA and self-reported spine fracture	14	0.5 [0.2, 1.0][c]
Self-reported spine fracture, no VFA spine fracture	45	1.8 [1.2, 2.6]
VFA spine fracture, no self-reported spine fracture	172	5.1 [4.5, 5.8]
No VFA or self-reported spine fracture	2991	92.7 [91.5, 93.7]
Self-reported spine fracture status among those with VFA spine fracture		
Yes	14	8.2 [3.3, 16.3][b]
No	172	91.8 [83.7, 96.7]
VFA spine fracture status among those with self-reported spine fracture		
Yes	14	20.7 [8.1, 39.4][b, d]
No	45	79.3 [60.6, 91.9][d]

VFA Vertebral Fracture Assessment

[a] Sample sizes are unweighted while prevalences are weighted

May be statistically unreliable for the following reason(s): [b] Relative standard error = 30-39 %; [c] Relative standard error = 40-49 %; [d] <12 df

vertebral fracture. At the time of these analyses, some data from NHANES 2013–2014, such as glucocorticoid use and historical height loss, were not yet publicly available. When this information is available, future analyses may help to refine the NOF screening criteria.

In those aged <50 years, very few of the females but approximately 3.5 % of the males had spine fractures. The cause of fractures in younger males is unknown, although athletic and work-related trauma or repetitive stresses are possible etiologies [34]. Also, some of these subjects may have had glucocorticoid exposure during young adulthood, as glucocorticoids are known to contribute risk for fracture independently of BMD [50]. Future analyses including glucocorticoid use will help address at least one of these possibilities.

This is the first study to assess the prevalence of spine fractures in a nationally representative sample. The study included men and nonwhite groups and a wide range of ages. The study used VFA and strict criteria were utilized for diagnosis. The agreement between VFA performed with a Hologic Discovery A in the supine lateral position, as used in this study, and radiographs has been independently evaluated by two studies including a total of 679 older men and women. The studies found very good agreement with kappas of 0.73 and 0.84 [19, 51]. A large volume of additional data, including multisite BMD assessment and fracture history, were collected. A possible limitation is potential nonresponse bias in the estimates, although results from analyses re-weighted to address nonresponse by age, sex, and race/ethnicity were similar to those obtained when the publicly released sample weights were used, suggesting that nonresponse bias associated with these particular demographic variables is unlikely. Another limitation is lower statistical reliability of some of the estimates as evidenced by wide CI. Finally, institutionalized persons, a group with a high prevalence of osteoporosis [52], were not included.

In conclusion, this study establishes the prevalence of spine fracture by VFA using a rigorous definition of fracture in a nationally representative sample of men and women. The prevalence was lower than in previous US studies which defined fractures less rigorously, suggesting that visual assessment is necessary to evaluate for nonfracture deformities. Spine fracture prevalence was higher with increasing age, lower BMD, or previous fracture. Even so, most subjects with spine fracture did not meet BMD criteria for osteoporosis. Few US citizens (less than 10 %) with documented vertebral fracture were aware of their fracture and those reporting a

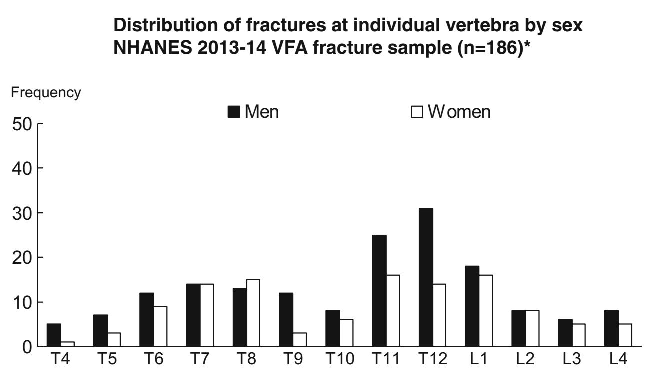

Fig. 1 Distribution of fractures at individual vertebra by sex, NHANES 2013–2014 VFA fracture sample (n = 186). The distribution of fractures at each level from T4 through L4 is shown for the 186 subjects found to have one or more vertebral fractures. Results are presented as frequency of fracture at each vertebral level. Note the precision of this information may be low at some levels, and these data are provided to illustrate distribution rather than exact prevalence at each level. As an additional caveat, visualization of T4–T6 was inadequate in some subjects, although only a small proportion of vertebral fractures occur at these levels [19]

Table 5 Vertebral fracture prevalence by NOF spine imaging criteria status among adults aged ≥50 years, NHANES 2013–2014

Sex	Met NOF spine imaging criteria[a, b]		Did not meet NOF spine imaging criteria[b]		Met vs did not meet criteria
	n	% [95 % CI]	*n*	% [95 % CI]	*P* value
Both sexes	482	14.0 [11.7, 16.7]	1467	4.7 [3.2, 6.8]	<0.001
Men	115	20.1 [13.2, 29.3]	835	5.6 [3.5, 8.7]	0.003
Women	367	12.4 [9.7, 15.6]	632	3.6 [2.2, 6.0]	<0.001

These results were not adjusted for age differences between the groups being compared because the objective was to test the impact of all the criteria, including age

NOF National Osteoporosis Foundation, *VFA* Vertebral Fracture Assessment, *FN_T* femoral neck T-score, *TOTHIP_T* total femur T-score, *LS_T* lumbar spine T-score

[a] Criteria used are as follows: (i) women aged ≥70 and men ≥80 if FN_T, LS_T, or TOTHIP_T ≤ −1, (ii) women age 65–69 and men 70–79 if FN_T, LS_T, or TOTHIP_T ≤ −1.5, and (iii) men or women aged ≥50 who report a fragility fracture after age 50

[b] Sample sizes are unweighted while prevalences are weighted

history of spine fracture usually did not have one. The prevalence of vertebral fracture was threefold higher in individuals who met NOF screening criteria [10] based on age and BMD or on previous fracture; the findings correspond to approximately one fracture case out of every seven subjects meeting screening criteria. Identifying individuals with prevalent vertebral fractures as part of a comprehensive risk assessment may improve clinical decision making.

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Compliance with ethical standards

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