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ORIGINAL ARTICLE

Predictors of bone mineral density testing among older women on Medicare

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Abstract
Summary Although dual-energy X-ray absorptiometry (DXA) is recommended for all women ≥65 and is covered by Medicare, 40 % of women on Medicare report never having had a DXA. In a longitudinal cohort of 3492 women followed for two decades, we identified several risk factors that should be targeted to improve DXA testing rates.
Introduction DXA is used to measure bone mineral density, screen for osteoporosis, and assess fracture risk. DXA is recommended for all women ≥65 years old. Although Medicare covers DXA every 24 months for women, about 40 % report never having had a DXA test, and little is known from prospective cohort studies about which subgroups of women have low use rates and should be targeted for interventions. Our objective was to identify predictors of DXA use in a nationally representative cohort of women on Medicare.
Methods We used baseline and biennial follow-up survey data (1993–2012) for 3492 women ≥70 years old from the nationally representative closed cohort known as the Survey on Assets and Health Dynamics among the Oldest Old (AHEAD). The survey data for these women were then linked to their Medicare claims (1991–2012), yielding 17,345 person years of observation. DXA tests were identified from the Medicare claims, and Cox proportional hazard regression models were used with both fixed and time-dependent predictors from the survey interviews including demographic characteristics, socioeconomic factors, health status, health habits, and the living environment.
Results DXA use was positively associated with being Hispanic American, better cognition, higher income, having arthritis, using other preventative services, and living in Florida or other southern states. DXA use was negatively associated with age, being African-American, being overweight or obese, having mobility limitations, and smoking.
Conclusions Interventions to increase DXA use should target the characteristics that were observed here to be negatively associated with such screening.

Keywords Aging · DXA · Osteoporosis · Screening

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Introduction

Osteoporosis is a metabolic bone disorder characterized by low bone mineral density (BMD) and deterioration of bone matrix which increases fracture risk and is associated with significant and rising morbidity and mortality in the USA [1–3]. Epidemiologic data from the 2010 National Health and Nutrition Examination Study (NHANES) indicate prevalence rates among those ≥50 years old of 10.3 % for osteoporosis and 43.9 % for osteopenia (low BMD) [4].

With an aging population, the prevalence of osteoporosis and related fractures in the USA will increase dramatically.

Because osteoporosis is a silent disease until a fracture occurs, clinical practice guidelines recommend BMD screening of older adults using dual-energy X-ray absorptiometry (DXA) at the hip and spine in order to identify patients at high risk for fracture and in need of treatment [3, 5–8]. Since its introduction in 1987, DXA has revolutionized the way that osteoporosis is diagnosed and monitored [9]. Indeed, in 1994, the World Health Organization defined osteoporosis in postmenopausal White women as a DXA T-score at the spine, hip, or forearm of −2.5 or less [10]. In 1996 the US Preventive Services Task Force (USPSTF) recommended widespread screening for osteoporosis using DXA [11], and in 1999, the National Osteoporosis Foundation (NOF) issued guidelines for osteoporosis prevention and treatment based on DXA results [12]. Several large clinical trials have since demonstrated the effectiveness of bisphosphonates and other medications in the treatment of osteoporosis [13].

DXA screening is now the "gold standard" for identifying low BMD and improving the bone health of older adults, especially women, with most professional organizations recommending it for all women ≥65 years old and at earlier ages for higher-risk women [6, 12, 14, 15]. Starting on July 1, 1998, Medicare began covering one DXA test every 24 months at no cost to women if their provider accepted assignment and considered the DXA medically necessary [16]. Nonetheless, 40 % of women on Medicare (ranging from 33.0 % of non-Hispanic Whites to 62.0 % of African-Americans) report never having had a DXA test [17, 18], which is consistent with a recently published study that used data from one health care system [20], and found that DXA testing was underused among women at increased fracture risk.

Previous studies using prospective epidemiological cohorts have identified non-BMD risk factors for osteoporosis and fractures in women, including advancing age, poor health, previous fractures, chronic use of glucocorticoids, rheumatoid arthritis, metabolic disorders, prolonged immobilization, current cigarette smoking and excessive alcohol consumption, and low body weight [21–27]. In contrast, nationwide studies of DXA testing have generally relied solely on Medicare claims and have reported that annual DXA rates increased from 1999 to 2009 [28], with a slight decline after 2010 [29]. The ability of claim-based studies to identify predictors of DXA testing, however, is limited by the sparse data available on patient characteristics [28, 30, 31]. Moreover, most claim-based studies have focused on cross-sectional associations rather than the longitudinal analyses that are possible with prospective epidemiologic cohorts.

To identify characteristics of women who had DXA testing, we used the Survey on Assets and Health Dynamics among the Oldest Old (AHEAD), a nationally representative, prospective, closed epidemiologic cohort that is part of the larger Health and Retirement Study (HRS) to conduct Cox proportional hazard regressions of time to DXA testing. Documentation for the AHEAD is readily available online (http://hrsonline.isr.umich.edu/index.php?p=docs and http://hrsonline.isr.umich.edu/index.php?p=userg) and elsewhere [32]. AHEAD included men and women who were ≥70 years old at their baseline interviews in 1993 and who were re-interviewed biennially through 2012. At each interview, the comprehensive surveys asked about income, work, assets, pension plans, health insurance, disability, physical health and functioning, cognitive functioning, and health care use and expenditures. Most AHEAD participants consented to have their Medicare claims (1991–2012) linked to their survey reports. We use the AHEAD survey data for detailed information on demographic characteristics, socioeconomic factors, health status, health habits, and the living environment as five categories of predictors of DXA testing.

Methods and materials

Human subjects

The protocol for this study was fully approved by the University of Iowa IRB-01 (protocol number 2003–03008) in March 2003 and has maintained full IRB approval at each of its annual continuing reviews. Access to the restricted data for the AHEAD sample was approved by the HRS (protocol number 2003–06) in May 2003. Medicare claims were accessed under a data use agreement (DUA 14807) with the Centers for Medicare and Medicaid Services (CMS) that was fully approved in March 2005 and has been renewed every year since then.

Sample

Baseline AHEAD interviews were conducted with 7447 participants, of whom 61 % (4536) were women. Men were excluded because DXA testing is infrequent among men, treatment guidelines for them are unclear, and their risk of osteoporosis derives from different factors. We linked the baseline and biennial survey reports to Medicare claims (Denominator, Outpatient, and Physician Part B Standard Analytic Files) for 4046 women (90 %) from 1991 to 2012. We excluded 554 women who were not enrolled in Medicare fee-for-service plans with both Part A and B coverage at baseline or who had a DXA test between January 1, 1991, and their baseline interview. We censored the remaining women at the point when they no longer had continuous Medicare Part A and B coverage, had their first observed DXA test, were lost to follow-up, or died, whichever came first. This yielded an analytic sample of 3492 women (77 %) yielding 17,345 person years of observation.

Outcome

We identified the use of hip and spine DXA using Health Care Current Procedure Classification System (HCPCS) codes 76075 and 77080. Peripheral DXA was not included because it is seldom recommended for osteoporosis screening. Time to DXA testing was calibrated continuously from the baseline interview to the first observed DXA test date.

Predictors

The fixed (time-independent) predictors were taken from the baseline interview or Medicare claims, and the time-dependent predictors were taken from the interview immediately before DXA testing or censoring. We considered five categories of potential predictors drawn from both the survey reports and the Medicare claims: demographic characteristics, socioeconomic factors, health status, health habits, and the living environment. These factors vary across individuals and, according to the Health Belief Model (HBM) [33], should influence whether women undergo DXA testing.

According to the HBM [33], demographic and socioeconomic characteristics are modifying factors that may affect perceptions of screening (i.e., DXA) tests as well as access to them. Demographic factors included age (centered on its mean) and its quadratic term, indicators for Hispanic Americans and African-Americans (non-Hispanic Whites are the reference group), and an indicator for being married because the prevalence of osteoporosis increases with age and varies by race and ethnicity, and having a spouse present may reduce access barriers and increase health advocacy. Socioeconomic factors included indicators for elementary and college education (high school education is the reference group), the lowest and highest quintiles of total wealth and annual income (the three middle quintiles are the reference groups), and having other insurance (Medigap or other supplemental insurance) in addition to Medicare Part A and B because higher education is associated with better health lifestyles, and higher wealth and income and additional insurance coverage increase access to care.

Health status domains may serve as "perceived threats" or "cues to action" according to the HBM [33]. We included measures for rated health and memory (5 = excellent, …, 1 = poor) and objectively determined cognitive ability (using the six-item version of the Telephone Interview for Cognitive Status [TICS-6] that ranges from 0 [worst] to 10 [best] but was ascertained only for the self-respondents) [34] because these reflect general health perceptions and the ability to perceive health threats. Three functional limitation measures—counts of the number of difficulties performing or assistance provided for five activities of daily living (ADLs; e.g., bathing, dressing, toileting, range = 0–5), five instrumental ADLs (IADLs; e.g., medication management, using a telephone, shopping, range = 0–5), and four mobility limitations (e.g., walking up a flight of steps, stooping-kneeling-crouching, carrying a 10-lb bag of groceries, range = 0–4) [35]—were included because functional limitations create barriers for accessing health services and reflect higher comorbidity burdens. We included indicators for being underweight (BMI <18.5), overweight (BMI = 25–29.9) and obese (BMI ≥30) (normal weight [BMI = 18.5–24.9] is the reference group) because low body weight is associated with high risk of osteoporosis, and being overweight or obese may cause immobility or stigma that limits patients' access to DXA testing. Indicators for having had a prior hip fracture, rheumatoid arthritis, or other types of arthritis (from both the surveys and Medicare claims) were included because they may be a "cue to action" for patients or physicians about DXA screening.

Health habits may reflect both unhealthy lifestyles and predispositions for preventive (healthy) behaviors. We included indicators for being a former or current smoker (never having smoked is the reference group), excessive alcohol consumption (defined as drinking on ≥2 days per week), and using other preventative services (mammography or flu shots) annually in each of the past 2 years. Smoking and excessive drinking of alcohol are known risk factors for low BMD and can increase the perceived threat. Using other preventative services reflects an individual's assessment of perceived benefits of using health services, which may transfer to DXA testing.

Characteristics of the living environment, like urban-rural differences, the density of older adults, and climate, can create barriers to accessing DXA. We included an indicator to examine urban-rural differences because older adults in rural areas generally have lower access to health services, especially those involving specialists or technological procedures. Because Florida has the highest proportion (density) of older adults (17.6 % compared to 12.0 % overall and 9.6 % in other southern states) [36], we included an indicator for living in Florida because greater concentrations of older adults may lead to higher volumes of health service use and greater adherence to prevention and treatment policies targeting older adults, which may transfer to improved DXA testing rates perhaps due to increased media attention [33]. Because warmer temperatures and greater exposure to sunlight in Florida may also affect bone health and thus DXA use, we included an indicator for living in the other 15 southern states to isolate this potential confound.

Analysis

Cox proportional hazard regression models were used on time to DXA. We serially added the demographic characteristics, socioeconomic factors, health status, health habits, and the living environment measures into the models. This approach allowed for better assessment of the robustness of covariate

effects and the potential for under- or over-fitting of the models. Race and education were treated as fixed effects, whereas all other predictors were treated as time-dependent effects and were taken from the previous interview. In order to assess the influence of cognition on whether or not DXA testing was obtained, which was only ascertained for self-respondents, we conducted a secondary analysis on the 3252 self-respondents yielding 14,832 person years of observations with the same analytic approach.

A potential limitation of our analysis is not knowing if women had a DXA before 1991 (the earliest linked Medicare claims) and not knowing if women had BMD tests other than DXA. To evaluate this possibility, in secondary analyses, we re-estimated the Cox proportional hazard regression models excluding the 602 women who were diagnosed with osteoporosis or low BMD or who had a DXA test prior to their first re-interview (1995), as well as the 53 women who had other early measures of BMD including single-photon absorptiometry (SPA), dual-photon absorptiometry (DPA), and ultrasound.

Because other studies have shown increases in annual DXA rates after 2000 [29], in secondary analyses, we split the sample into two parts (1993–2000 and 2000–2012), re-estimated the proportional hazard regression models in the two samples separately, and then added the remaining waves of data going forward (i.e., 1993–2000, 1993–2002,…, 1993–2010) and backward (i.e., 2004–2012, 2002–2012,…, 1995–2012). All analyses were conducted using SAS version 9.4 (SAS, Cary, NC).

Results

Descriptive results

Among the 3492 AHEAD women in the analytic sample, 814 (23 %) had one or more post-baseline DXA tests. Among those who had DXA tests, 409 (50.3 %) had one, 196 (24.1 %) had two, and 209 (25.7 %) had three or more. The average time to the first post-baseline DXA was approximately 8 years (2640 days, SD = 6.5 years), and the average time between the first and second DXAs was 3 years (SD = 2.2 years).

Descriptive statistics for the predictors measured at baseline through 2012 are shown in Table 1. At baseline, the average age was 77.9 (SD = 6.0), 81.1 % were non-Hispanic Whites, 13.4 % were African-Americans, 4.6 % were Hispanic Americans, and 0.9 % were from other races. More than a third (36.2 %) were married and 54.8 % were widowed. Typical for this age cohort of women, one fourth reported only having elementary education, and one fourth reported having college education. Other health insurance coverage was widespread (68.3 %). Self-rated health was good (mean = 2.9, SD = 1.2) as was self-rated memory (mean = 3.1, SD = 1.0). On average, these women had few ADL (mean = 0.4, SD = 0.9) or IADL limitations (mean = 0.5, SD = 1.0), although mobility issues were observed more often (mean = 1.6, SD = 1.6). About 5 % were underweight, 32.0 % were overweight, and 15.9 % were obese. Nearly 6 % reported prior hip fractures, 1.4 % had rheumatoid arthritis, 27.3 % reported other types of arthritis, 28.9 % were former and 8.2 % were current smokers, 6.3 % were excessive drinkers (drank on ≥2 days per week), and 60.1 % had mammography or flu shots in each of the past 2 years. Finally, 75.1 % lived in urban areas, 11.5 % lived in Florida, and 30.0 % lived in other southern states.

Primary analyses

The hazard ratio estimates derived from the Cox proportional hazard regression models on time to DXA testing are shown in Table 2. Model 1 (the first column) contains only the demographic characteristics, while models 2–5 serially add socioeconomic factors, health status, health habits, and the living environment. Because the parameter estimates were robust across the models, we focus on the results from the fully adjusted model.

As shown in model 5, the hazards of having a post-baseline DXA decreased by 7.6 % with each 1-year increase in age, with a slight increase in that rate of decline at older ages (the quadratic term was significant and less than 1.0). Hispanic Americans were 1.6 times more likely to have a DXA test, while African-Americans were 0.34 times less likely to have a DXA test compared to non-Hispanic Whites. Higher annual income was associated with greater chances of having a DXA test. With every additional IADL limitation, the hazards of having a DXA test decreased by 21.7 %. Overweight and obese women had 21.2 and 28.7 % lower hazards of DXA testing compared to women of normal weight. Women who had rheumatoid arthritis or other types of arthritis were 2.7 times and 1.4 times more likely to have a DXA test compared to women who never had arthritis. Current smokers were 37.7 % less likely to have a DXA test compared to those who had never smoked. Women who had annual mammograms or flu vaccinations had 89 % higher hazards of having a DXA test. Those who lived in Florida had 53.0 % higher hazards of DXA testing than those who lived in other regions, while those who lived in southern states other than Florida had 18.8 % higher hazards of DXA testing compared to those living in non-southern states.

Secondary analyses

There were 774 (23.8 %) DXA tests during the study period among the 3253 self-respondents who had TICS-6 cognition scores. Cognition was positively associated with increases in the hazards of having a DXA test, and the effects of other

Table 1 Sample characteristics from the 1993–2010 Biennial AHEAD Survey Interviews

Predictors	AHEAD interview years								
	1993	1995	1998	2000	2002	2004	2006	2008	2010
Sample size	3492	3061	2646	2235	1815	1462	1156	891	587
Demographic characteristics									
Age[b,i]	77.9 (6.1)	79.7 (5.8)	81.5 (5.5)	82.9 (5.1)	84.6 (4.8)	85.9 (4.4)	87.5 (4.1)	89.1 (3.8)	90.8 (3.4)
Race[a,j]									
Non-Hispanic White	81.1								
Hispanic American	4.6								
African-American	13.4								
Other	0.9								
Married[b,j]	36.2	33.4	28.6	24.2	20.3	17.2	15.0	12.5	9.7
Education[a,j]									
Elementary education	26.8								
High school education	49.2								
College education	24.0								
Other insurance coverage[b,j]	68.3	63.4	56.5	54.9	63.2	62.2	56.9	51.9	44.9
Health status									
Self-rated health[b,c,i]	2.9 (1.2)	2.9 (1.2)	2.7 (1.2)	2.8 (1.1)	2.7 (1.1)	2.8 (1.1)	2.7 (1.1)	2.7 (1.1)	2.8 (1.1)
Self-rated memory[b,c,i]	3.1 (1.0)	3.0 (1.0)	2.9 (1.1)	2.8 (1.0)	2.8 (1.1)	2.7 (1.1)	2.7 (1.1)	2.7 (1.1)	2.8 (1.1)
ADLs[b,d,i]	0.4 (0.9)	0.7 (1.3)	0.8 (1.4)	0.9 (1.5)	1.0 (1.6)	1.1 (1.6)	1.2 (1.7)	1.3 (1.7)	1.6 (1.8)
IADLs[b,d,i]	0.5 (1.0)	0.7 (1.3)	0.9 (1.5)	0.9 (1.6)	1.1 (1.7)	1.2 (1.7)	1.4 (1.8)	1.5 (1.9)	1.8 (1.9)
Mobility limitations[b,e,i]	1.6 (1.6)	1.4 (1.4)	1.6 (1.5)	1.6 (1.5)	1.8 (1.5)	1.9 (1.5)	2.1 (1.5)	2.1 (1.5)	2.4 (1.5)
BMI[b,j]									
Underweight (BMI <18.5)	4.7	6.4	7.7	7.7	8.4	8.7	6.7	7.7	7.0
Normal (BMI = 18.5–24.9)	47.4	48.4	48.8	48.6	49.5	52.6	52.0	50.9	54.3
Overweight (BMI = 25.0–29.9)	31.9	30.6	29.5	31.0	28.7	27.3	28.5	29.1	26.9
Obese (BMI ≥30.0)	15.9	14.6	14.0	12.6	13.4	11.4	12.7	12.2	11.9
Hip fracture[b,j]	2.5	7.1	8.8	9.8	11.5	13.7	14.6	14.8	16.2
Rheumatoid arthritis	1.4	2.1	2.8	2.7	3.1	3.6	3.2	4.0	3.4
TICS-6 cognition score	8.8 (1.7)	8.8 (1.6)	8.9 (1.7)	9.0 (1.7)	8.6 (1.8)	8.6 (1.9)	8.4 (2.1)	8.1 (2.3)	8.9 (2.2)
Health habits									
Other arthritis	27.3	54.8	62.3	67.6	70.2	71.6	74.2	75.4	79.7
Smoking status[b,j]									
Non-smoker	62.9	63.4	63.3	63.6	64	63.8	65.8	66.2	68.4
Former smoker	28.9	29.4	30.8	31.3	32.1	32.1	31.3	31.3	29.6
Current smoker	8.2	7.2	5.9	5.1	3.9	4.1	2.9	2.5	2.0

Table 1 (continued)

Predictors	AHEAD interview years								
	1993	1995	1998	2000	2002	2004	2006	2008	2010
Excessive alcohol use[b,f,j]	6.3	11.6	9.6	8.7	10.0	9.5	10.4	9.3	8.7
Preventative service use[b,g,j,h]	60.1	68.4	67.7	65.5	66.2	68.7	64.4	62.7	56.6
Living environment									
Living in urban areas[b,j]	75.1	74.5	75.3	75.2	76.1	76.2	74.8	74.3	74.5
Geographic location[b,j]									
Living in Florida	11.5	11.5	11.5	11.1	10.5	9.8	9.1	8.9	8.5
Living in other southern states	30.0	30.4	29.9	29.6	28.8	28.5	30.1	29.3	29.9
Living in non-southern states	58.5	58.1	58.6	59.3	60.7	61.7	60.8	61.8	61.6

[a] These predictors were measured only at the baseline (1993) AHEAD interview (time-independent)

[b] These predictors were covariates measured at the immediately prior AHEAD interview from 1993 to 2010 (time-dependent)

[c] This is coded 5 = excellent, …, 1 = poor

[d] This is coded as the number of ADLs or IADLs performed with difficulty, ranging from 0 to 5

[e] This is coded as the number of mobility functions performed with difficulty, ranging from 0 to 4

[f] TICS-6 cognition score was only ascertained for self-respondents, ranging from 0 to 10

[g] Excessive alcohol use is defined as drinking on ≥2 days per week

[h] This measure reflects whether flu shots and mammography were done in the past 2 years

[i] These are means (standard deviations)

[j] These are percentages

Table 2 Cox proportional hazard regression models of time to post-baseline DXA with fixed and time-dependent predictors among AHEAD women

Predictors	Adjusted hazard ratio				
	Model 1	Model 2	Model 3	Model 4	Model 5
Demographic characteristics					
Age					
Centered age[b]	0.914***	0.921***	0.932***	0.932***	0.930***
Centered squared age[b]	0.996*	0.996*	0.997*	0.997	0.997
Race[a]					
Non-Hispanic White	Ref	Ref	Ref	Ref	Ref
Hispanic American	1.028	1.631**	1.555*	1.678**	1.571*
African-American	0.461***	0.587***	0.638**	0.685**	0.695*
Married[b]	1.094	0.934	0.949	0.921	0.919
Socioeconomic factors					
Education[a]					
Elementary education		0.727**	0.791*	0.816	0.829
High school education		Ref	Ref	Ref	Ref
College education		1.216*	1.200*	1.172	1.161
Total wealth[b]					
Lowest wealth quintile		0.700**	0.798	0.808	0.817
2nd, 3rd, and 4th wealth quintiles		Ref	Ref	Ref	Ref
Highest wealth quintile		1.043	0.999	1.007	1.014
Annual income[b]					
Lowest income quintile		0.990	0.994	1.004	0.981
2nd, 3rd, and 4th income quintiles		Ref	Ref	Ref	Ref
Highest income quintile		1.278*	1.301*	1.275*	1.273*
Other insurance coverage[b]		1.139	1.100	1.030	1.021
Health status					
Self-rated health[b,c]			1.027	1.037	1.037
Self-rated memory[b,c]			0.991	1.008	1.010
ADLs[b,d]			0.927	0.940	0.944
IADLs[b,d]			0.809***	0.814***	0.815***
Mobility limitations[b,e]			0.988	0.989	0.992
BMI[b]					
Underweight (BMI <18.5)			0.919	0.980	0.953
Normal (BMI = 18.5–24.9)			Ref	Ref	Ref
Overweight (BMI = 25.0–29.9)			0.817*	0.798**	0.788**
Obese (BMI ≥30.0)			0.743*	0.723**	0.713**
Hip fracture[b]			0.990	0.994	0.959
History of arthritis[b]					
Rheumatoid arthritis			2.591***	2.460***	2.495***
Other types of arthritis			1.386***	1.339***	1.336***
No history of arthritis			Ref	Ref	Ref
Health habits					
Smoking status[b]					
Non-smoker				Ref	Ref
Former smoker				1.081	1.038
Current smoker				0.682*	0.659*
Heavy drinker[b,f]				1.101	1.118
Preventative service use[b,g]				1.871***	1.887***

Table 2 (continued)

Predictors	Adjusted hazard ratio				
	Model 1	Model 2	Model 3	Model 4	Model 5
Living environment					
Living in urban areas[b]					1.031
Geographic location[b]					
Living in Florida					1.492***
Living in other southern states					1.188*
Living in non-southern states					Ref

*p value <0.05; **p value <0.01; ***p value <0.001

[a] These predictors were measured only at the baseline (1993) AHEAD interview (time-independent)

[b] These predictors were covariates measured at the immediately prior AHEAD interview from 1993 to 2010 (time-dependent)

[c] This is coded 5 = excellent,…, 1 = poor

[d] This is coded as the number of ADLs or IADLs performed with difficulty, ranging from 0 to 5

[e] This is coded as the number of mobility functions performed with difficulty, ranging from 0 to 4

[f] Heavy drinking is defined as drinking on ≥2 days per week

[g] This measure reflects whether flu shots and mammography were done in the past 2 years

predictors were relatively unchanged (see model 6 in Supplementary Table S1). Results from the sensitivity analyses evaluating the potential for unobserved DXA testing prior to 1991, early BMD measures, and secular trends in DXA testing rates were comparable to those shown here and therefore are not presented (but they are available on request).

Discussion

In a nationally representative prospective cohort of 3492 AHEAD women ≥70 years old who were continuously enrolled in Medicare fee-for-service plans with both Part A and B coverage and up to 19 years of follow-up, we identified several factors associated with DXA testing. DXA use was positively associated with being Hispanic American, better cognition, higher income, having rheumatoid or other forms of arthritis, using other preventative services, and living in Florida or other southern states. DXA use was negatively associated with age, being African-American, being overweight or obese, having mobility limitations, and smoking. These results confirm Amarnath et al.'s [20] recently published findings from a single health care system that DXA testing is underused among women who are older, African-Americans, smokers, overweight, or obese and who do not use other preventative health care services.

Our study is not without limitations. First, while we were able to identify the occurrence of DXA testing, we could not determine whether those DXA tests were for screening or diagnostic purposes or whether they were the first or just the most recent DXAs for these women. To fully identify DXA testing, a look-back window of at least 6 years would be needed (1993 minus 1987, when DXA was first introduced to clinical practice), rather than our look-back window of about 3 years. Second, these data were collected during 1993–2012, during which annual DXA rates changed somewhat [28, 29]. Therefore, our results may be time-bound and may not well characterize current DXA use. That said, our secondary analyses showed that the predictors of DXA testing were robust over the study period. Third, medications, which could potentially be important predictors of DXA testing, were not considered because Part D data for AHEAD participants during the observation period were not available. Finally, men were excluded, although only 114 DXA tests (5 %) were identified among the 2281 men with 9988 person years of observation during 1993–2012.

These limitations notwithstanding, several of our findings have implications for health care policy. First, women with known risk factors for osteoporosis (older age and current smoking) were less likely to undergo DXA, suggesting the need for interventions to stimulate DXA testing in these at-risk groups. That finding might partially be explained by potential unobserved DXAs during 1987–1991 and patients tested using other types of BMD measures. No support for that explanation, however, was observed in our secondary analyses, although the look-back window was limited to about 3 years. Second, African-American and socioeconomically disadvantaged women were less likely to undergo DXA testing, which confirms reports from *Healthy People 2020* and underscores the need for targeted campaigns to increase DXA testing in these hard-to-reach population subgroups [17, 18, 37]. The lower chance of African-American women having DXA testing reflects their lower risk of osteoporosis as well the access barriers generally associated with minority status and

socioeconomic disadvantage [3–6]. In contrast, we found that Hispanic Americans were more likely than non-Hispanic Whites to undergo DXA testing. While only marginally significant statistically, this finding may reflect the growing risk of hip fracture among Hispanic American women resulting from their greater lactose intolerance and reduced calcium intake, as well as their increased likelihood of diabetes, which may increase their risk for osteoporosis [38]. Third, women who were overweight or obese and those with poor mobility were less likely to have DXA testing. This suggests that transportation and other physical or stigma impediments for accessing DXA services need to be overcome, perhaps by targeting such individuals during their "Welcome to Medicare" visits during their first year of eligibility, although only 13 % of new beneficiaries use this one-time benefit [7, 8, 17, 18]. Fourth, because DXA testing is more likely among those who use other preventative services, incentives for bundling these preventative procedures should be considered. Finally, DXA testing was higher in Florida where the proportion of the population ≥65 years old is highest [36], suggesting that the standards of care there might be more compatible with practice guidelines for preventative care for older adults and/or greater media attention to older adults. This suggests that interventions to better inform providers and the media in other states about DXA guidelines may raise testing rates.

In conclusion, we identified age, race, income, weight, mobility, cognition, smoking status, use of other health preventative services, and the living environment as important predictors of DXA use among older women. These findings indicate that despite the well-established guidelines for targeting DXA testing, the actual use of DXA services was still low among some "higher risk" (older age and current smoker) population segments. We also found that African-Americans, those with poor mobility, and overweight and obese women were less likely to undergo DXA. These findings have implications for targeting interventions to improve DXA use among specific subgroups of older women who may be at high risk for osteoporosis and fracture.

Compliance with ethical standards

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Conflicts of interest None

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