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Social inequalities in osteoporosis and fracture among community dwelling older men and women: findings from the Hertfordshire Cohort Study

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Abstract

Introduction—Osteoporosis and osteoporotic fracture are major public health issues for society; the burden for the affected individual is also high. It is unclear whether osteoporosis and osteoporotic fracture are socially patterned.

Objective—To analyse social inequalities in osteoporosis and osteoporotic fracture among the 3,225 community dwelling men and women, aged 59–73 years, who participated in the Hertfordshire Cohort Study (HCS), UK.

Methods—A panel of markers of bone health (fracture since 45 years of age; DXA bone mineral density and loss rate at the total femur; pQCT strength strain indices for the radius and tibia; and incident fracture) were analysed in relation to the social circumstances of the HCS participants (characterised at the individual level by: age left full time education; current social class; housing tenure and car availability).

Results—We found little strong or consistent evidence among men, or women, for social inequalities in prevalent or incident fracture, DXA bone mineral density, bone loss rates, or pQCT bone strength, with or without adjustment for age, anthropometry, lifestyle and clinical characteristics. Reduced car availability at baseline was associated with lower pQCT radius and tibia strength strain indices at follow-up among men only ($p=0.02$ radius and $p<0.01$ tibia unadjusted; $p=0.05$ radius and $p=0.01$ tibia, adjusted for age, anthropometry, lifestyle and clinical characteristics).

Conclusions—Our results suggest that fracture and osteoporosis do not have a strong direct social gradient and that public health strategies for prevention and treatment of osteoporosis should continue to focus on the whole population.

Keywords

osteoporosis; osteoporotic fracture; socio-economic position; material deprivation; social inequalities

Introduction

Osteoporosis is a skeletal disorder characterised by low bone mass and microarchitectural deterioration of bone tissue which predisposes to fracture[1], typically of the hip, spine or wrist. The prevalence of osteoporosis increases rapidly with older age[2] and it has been estimated that the remaining lifetime risk of fracture at the hip, spine or wrist is 40% among white women and 13% among white men at age 50 years[3]. The annual cost to the NHS of managing osteoporotic fractures is £2.1 billion, with over 80% of this figure attributable to hip fracture[4]. Osteoporosis is a major public health issue for society, but the burden of osteoporosis for the affected individual is also high; fracture is typically associated with hospitalisation, increased risk of subsequent mortality, long term morbidity and loss of function[5]. Although treatments are available that have been shown to decrease the risk of fracture, problems arise in identifying individuals at high risk of fracture so that intervention can be effectively targeted[6].

Social inequalities in health have been recognized for centuries[7]. Even in generally wealthy Western countries, material deprivation and poverty are not uncommon[8] and, irrespective of absolute levels of standards of living, health inequalities exist across relative levels of deprivation[9]. However, little is known about social inequalities in osteoporosis and fracture. Brennan et al have recently conducted systematic reviews of the associations between socioeconomic status (income, education, occupation, and type of residence) and bone mineral density[10] and osteoporotic fracture[11] among population based adults. Brennan concluded that limited good quality evidence exists for social inequalities in bone mineral density and fracture and that further research, ideally from cohort studies rather than ecological or case-control studies, is required to elucidate the relationships between individual level markers of socioeconomic status and bone mineral density and fracture. Clarification of whether osteoporosis and fracture are socially patterned would inform planning for health and social care services and would enable public health strategies for prevention, intervention and treatment of osteoporosis and fracture to be effectively targeted[6].

The objective of the current study was to explore social inequalities in osteoporosis (bone mineral density, bone strength and bone loss rates) and osteoporotic fracture (prevalent and incident), among community dwelling older men and women who participated in the Hertfordshire Cohort Study (HCS), United Kingdom[12]. The social circumstances of the HCS men and women were characterised at the individual level by: age of leaving full time education; current social class; and housing tenure and car availability as markers of material deprivation[13;14].

METHODS

Study population

The Hertfordshire Cohort Study (HCS) has been described previously[12]. In brief, from 1911 to 1948, midwives recorded information on birth weight and weight at one year, on infants born in the county of Hertfordshire, United Kingdom. The records for people born 1911-1930 have been used in a series of studies linking early growth to health in later life. In 1998, a younger cohort was recruited to participate in studies examining the interactions between early life, diet, adult lifestyle and genetic factors as determinants of adult disease. 3822 men and 3284 women born between 1931-1939 in Hertfordshire and still living there were traced through the National Health Service central registry. Permission to contact 3126 (82%) men and 2973 (91%) women was obtained from their General Practitioners.

1684 (54%) men and 1541 (52%) women aged 59-73 years took part in a nurse administered home interview and 1579 (94%) men and 1418 (92%) women subsequently attended a clinic for investigations (herein referred to as the HCS baseline interview and clinic, Figure 1). Social history included: age left full time education; own current or most recent full time occupation; husband's current or most recent full time occupation for ever married women; housing tenure; number of cars and vans available to the household; and marital status. Medical history included: smoking habit; alcohol intake; physical activity[15]; fracture history; details of all currently prescribed and over-the-counter medications, coded to the British National Formulary; dietary calcium intake derived from an administered food frequency questionnaire; and menopausal status and HRT use among women. Clinical investigations included measurement of height (to the nearest 0.1cm using a Harpenden pocket stadiometer, Chasmors Ltd, London, UK) and weight (to the nearest 0.1kg on a SECA floor scale, Chasmors Ltd, London, UK[16]).

The HCS fieldwork was phased by region of the county for practical reasons; 737 of the men and 675 of the women who participated in the HCS baseline clinic were resident in East Hertfordshire. Bone mineral content (BMC), bone area and bone mineral density (BMD) were measured in a subgroup of 498(68%) of these men and 468(69%) of these women by dual energy X-ray absorptiometry at the proximal femur using a Hologic QDR 4500 instrument[17]; herein referred to as the HCS baseline DXA scan (Figure 1). Measurement precision error, expressed as coefficient of variation, was 1.45% for total femur and 1.83% for femoral neck BMD for the Hologic QDR 4500; these figures were obtained by twenty five volunteers who were not part of the study undergoing 2 scans on the same day, getting on and off the table between examinations. Short-term (2 month) precision error for the QDR 4500 was less than 1% (manufacturer's figures). Individuals taking drugs known to alter bone metabolism (such as bisphosphonates) were excluded from this part of the study, although women taking Hormone Replacement Therapy (HRT) were allowed to participate. There were no other exclusion criteria to this part of the study, and subjects were approached for consent as they attended the baseline HCS clinic.

In 2004-5, a follow-up study was performed in East Hertfordshire[18;19]; herein referred to as the East Hertfordshire follow-up study (Figure 1). In brief, of the original 498 men and 468 women who had undergone the HCS baseline DXA scan, 8 had died, 6 had moved away, we were unable to obtain GP permission to approach 4 people, 47 were no longer on family doctor lists, and 17 were unavailable. Hence, 437 men and 447 women were invited to take part in the follow-up study. Of these, 322 men (74%) and 320 women (72%) agreed to attend a follow-up clinic and DXA bone mineral measurements of the total femur were repeated, enabling calculation of annualised percentage change in bone mineral density at this site. Peripheral quantitative computed tomography (pQCT) was also performed of the radius and tibia (non-dominant side) using a Stratec 4500 instrument for 313 (97%) of the men, and 318 (99%) of the women[19]. Bone strength was estimated with respect to torsion (polar strength strain index) or bending with respect to the X or Y axis (fracture load X and fracture load Y). Measurements were made at two sites for the radius (4% and 66% slice) and three for the tibia (4%, 14% and 38% slice). Cadaveric studies have confirmed the high precision of pQCT and validated its use as a technique for assessing bone strength[20;21].

In 2007, a cohort-wide postal questionnaire was used to ascertain clinical outcomes, including fracture, since the baseline HCS clinic; herein referred to as the HCS clinical outcomes study (Figure 1). Of the original 2997 baseline clinic participants, 157 had died, 48 had moved away and 15 had withdrawn from the study (due to illness or at the participant's request). Hence, the questionnaire was posted to 2777 HCS participants of whom 2299 (83%) replied; 1093 of the men and 1049 of the women provided information on incident fractures since the HCS baseline clinic.

Intra- and inter-observer studies were carried out during the fieldwork. The study had ethical approval from the Hertfordshire and Bedfordshire Local Research Ethics Committee and all participants gave written informed consent.

Statistical methods

Registrar General's social class was coded from the 1990 OPCS Standard Occupational Classification (SOC90) unit group for occupation[22] using computer assisted standard occupational coding[23]. Current social class was coded from own current or most recent full-time occupation for men and never-married women, and from husband's occupation for ever-married women[13].

Height and weight were highly correlated ($r=0.45$, $P<0.001$ for men; $r=0.32$, $P<0.001$ for women); to avoid multi-collinearity problems a sex-specific standardised residual of weight-adjusted-for-height was calculated for inclusion with height in regression models.

Analysis of variance, chi-squared tests, and multiple linear and logistic regression were used to analyse the relationships between each of the markers of socio-economic position (SEP) and material deprivation as assessed at HCS baseline and: fracture since 45 years of age and DXA bone mineral density at HCS baseline; change in BMD from repeat DXA scans and bone strength indices from pQCT scans at the East Hertfordshire Follow-up study; and incident fracture between the HCS baseline and the HCS clinical outcomes study. Analyses were conducted with and without adjustment for HCS baseline age, anthropometry (height and weight-adjusted-for-height), smoking status, alcohol intake, marital status, physical activity, dietary calcium intake, HRT use and menopausal status (for women only), number of systems medicated as a marker of co-morbidity, bone medications (male sex hormones, oral steroids, tamoxifen, bisphosphonates and raloxifene) and fracture status and follow-up duration (the latter two for longitudinal analyses only). Categories of age left full-time education (14 versus 15 years) and number of cars available were used for presentational purposes but p-values for association were obtained from the continuously distributed variables. All analyses were conducted for men and women separately using Stata, release 10.0 (Stata Corporation 2007).

RESULTS

Descriptive statistics

Socio-economic position (SEP) and material deprivation among the HCS participants are described in Table 1. The average age of the HCS participants at baseline was 65.6 years for men and 66.6 years for women. 19.4% of men and 17.9% of women left full-time education aged 14 years or younger. 19.3% of men and 23.1% of women did not own or mortgage their home and 6.4% of men and 17.7% of women had no car available to their household.

Osteoporosis and fracture among the HCS participants are described in Table 1. At HCS baseline, 235 (14.0%) men and 333 (21.6%) women reported that they had sustained a fracture since 45 years of age (7.7% of men and 18.4% of women having sustained a minor trauma fracture). Women had lower baseline total femoral bone mineral density than men (0.90g/cm^2 vs 1.04g/cm^2 respectively). On average, between the HCS baseline and East Hertfordshire follow-up DXA scans, men and women had lost bone at the total femur ($-0.09\%/year$ and $-0.55\%/year$ respectively). Radius and tibia strength strain indices from the pQCT scans were higher among men than women. Between the HCS baseline study and the clinical outcomes follow-up questionnaire, 4.2% (46) of men and 10.8% (113) of women reported sustaining an incident fracture (33 and 62 of which were first fractures since 45 years of age for men and women respectively). The proportions of men and women taking bone medications (i.e. male sex hormones, oral steroids, tamoxifen, bisphosphonates or

raloxifene) increased during the HCS study from 1.8% among men and 5.3% among women at baseline, to 5.6% of men and 10.0% of women at the East Hertfordshire follow-up DXA and pQCT scans, to 5.1% of men and 16.0% of women at the clinical outcomes study.

Cross-sectional associations between socio-economic position, material deprivation and fracture and bone mineral density

Among men (table 2a), there were no significant cross-sectional associations ($p < 0.05$) between social class, age left full time education, home ownership or car availability and fracture since 45 years of age (all fractures or minor trauma) or total femoral BMD, with or without adjustment for age, anthropometry and lifestyle and clinical characteristics (Table 2a).

Among women (table 2b), there were few significant associations between social class, age left full time education, home ownership or car availability and fracture or bone mineral density. Reduced car availability was associated with an increased likelihood of having sustained a fracture since 45 years of age ($p = 0.02$ for trend for all fractures, $p = 0.04$ for minor trauma fractures) but adjustment for age, anthropometry and lifestyle and clinical characteristics attenuated these associations (adjusted $p = 0.07$ for trend for all fractures, $p = 0.20$ for minor trauma fractures). Average levels of total femoral BMD were actually lower among women of higher social class ($p = 0.01$ in unadjusted analyses) and this association was also attenuated by adjustment for age, anthropometry and lifestyle and clinical characteristics (adjusted $p = 0.22$ for total femoral BMD).

Longitudinal associations between socio-economic position, material deprivation and bone loss rates, bone strength and incident fracture

Among men (table 3a), there was little evidence for association between the panel of markers of socio-economic position and material deprivation and bone loss rates, bone strength, or incident fracture in unadjusted or adjusted analyses. The only significant associations identified were between reduced car availability at HCS baseline and lower pQCT radius ($p = 0.02$ unadjusted, $p = 0.05$ adjusted) and tibia ($p < 0.01$ unadjusted, $p = 0.01$ adjusted) strength strain indices at the East Hertfordshire Follow-up study.

Among women (table 3b), there was again little consistent evidence for association between socio-economic position and material deprivation and bone loss rates, bone strength, or incident fracture in unadjusted or adjusted analyses. Furthermore, even the associations which were statistically significant did not suggest a consistent social patterning of bone health; reduced car availability at HCS baseline was associated with lower radius strength strain index ($p = 0.02$ unadjusted; $p = 0.02$ adjusted) while not owning or mortgaging one's home at HCS baseline was associated with higher tibia strength strain index at the East Hertfordshire Follow-up ($p = 0.05$ unadjusted; $p = 0.03$ adjusted).

DISCUSSION

Using data from the Hertfordshire Cohort Study we have analysed the associations between a panel of individual-level markers of socio-economic position (social class and age left full time education) and material deprivation (home ownership and car availability) and fracture and osteoporosis among community dwelling young-old men and women. We found no strong or consistent evidence among men, or women, for social inequalities in prevalent or incident fracture, DXA total femoral bone mineral density, pQCT radius or tibia bone strength, or total femoral bone loss rate. Our results suggest that fracture and osteoporosis do not have a strong direct social gradient and that public health strategies for prevention,

intervention and treatment of osteoporosis and fracture should continue to focus on the whole population, rather than targeting specific subgroups of the population.

Limited good quality evidence exists for social inequalities in bone mineral density[10] and fracture[11] among older people and the limited number of UK studies which have previously addressed this issue have typically either employed an ecological study design[24;25] (which cannot adequately account for confounding factors and which may yield associations at the area level which are not replicated at the individual level) or have used a cross-sectional design but with an area based measure such as the Index of Multiple Deprivation[26-28] (IMD) or the Carstairs score[29] as an indicator of an individual's socio-economic position. Furthermore, the results from these previous UK studies are inconsistent; Quah[26], Court-Brown[29] and Dugue[28] concluded that higher levels of deprivation (IMD or Carstairs) were associated with higher rates of hip fracture or lower levels of BMD but, in parallel with our findings, Hamilton[27], West[24] and Jones[25] found no evidence for association between their area level markers of socio-economic status (IMD or Townsend) and hip fracture, hospital admissions for fracture or accident and emergency presentations for fracture. The COSHIBA (Cohort for Skeletal Health in Bristol and Avon) study of 3,200 women aged 65-84 years resident in south-west England is the only previous UK study to have collected cross-sectional individual-level data on history of fracture after 50 years of age and socio-economic status[30]; in parallel with our findings, no associations were identified between socio-economic status and fracture among the COSHIBA women.

The results from international cross-sectional, case-control or ecological study designs are similarly inconsistent. For example, Zingmond[31] (using an ecological study design) and Farahmand[32] (using a case-control study design) concluded that lower levels of income were associated with higher rates of hip fracture among American men and women and among Swedish women respectively. In contrast, Johnell[33] identified an association between lower levels of economic prosperity and lower rates of hip fracture using a country-level ecological study design. In further contrast, Hokby[34] conducted a cross-sectional study of Swedish men and women and found no association between home ownership and hip fracture rates and Vestergaard[35] found no association between income or education and any fracture in his case-control study of Danish men and women. Wang[36] and Varenna[37] conducted cross-sectional studies of women in the USA and Italy respectively; both concluded that lower levels of education or income were associated with lower levels of DXA bone mineral density.

No previous UK studies have analysed social-inequalities in incident fracture using a cohort study design; one international study has addressed this issue. Wilson[38] conducted a prospective cohort study of 5,630 community-dwelling elderly people 70 years or older who participated in the Asset and Health Dynamics Survey (USA). During a 2-year study period, 102 participants reported a new hip fracture; individuals with insufficient health insurance, those without a high-school diploma and those who lived in mobile homes were at more than a 2-fold risk of hip fracture. No previous studies in the literature have considered social inequalities in bone loss rates or pQCT bone strength.

The absence of convincing evidence for social inequalities in fracture and osteoporosis among our HCS participants is not surprising in the context of the limited and inconsistent literature on social inequalities in bone health. It is also possible that inequalities across social class groups in the HCS cohort may have been masked if the detrimental effects of lower socio-economic position on bone health were offset by a history of more manual work. The retirement status of the HCS cohort may also play a role; sixty-five percent of HCS men and 82% of women reported that they had stopped working and Benzeval[39] has questioned the appropriateness of social class for studies of health inequalities among older

people. In addition, physical activity is a major determinant of bone health; it is possible that we have not fully accounted for the potential confounding influence of physical activity (both currently, and across the lifecourse, in occupation and leisure) on social inequalities in fracture and osteoporosis. Finally, Clark[40] et al have studied the association between social position of the mother in pregnancy and bone mass of the child at age 10 years among 6,702 children who participated in the ALSPAC study and concluded that social position exerted opposing height- and weight-dependent effects on bone mineral content and area in childhood such that overall inequalities in bone health were masked; height and weight may have exerted similar divergent effects in our study. However, when we repeated our analyses with adjustment for height alone, with adjustment for weight alone, or with adjustment for height and weight-for-height but no other potential confounders, the results were little different from the fully adjusted results presented in tables 2a to 3b. Moreover, if the underlying social gradient in fracture and osteoporosis was strong among the HCS participants one would expect to have observed inequalities in spite of the possibilities advanced above; such associations were not evident and overall our results suggest that fracture and osteoporosis do not have a strong direct social gradient.

This study had some limitations. Firstly, we had no information on household income, receipt of benefits or highest educational qualification and data on material deprivation were limited to car availability and housing tenure. However, car availability and housing tenure are useful markers of social and material advantage[13;14] and reflect the amount and stability of household income[41]. We suggest that these markers will function well as markers of social and material advantage among this young-old cohort of men and women who are predominantly retired (as described above) and are settled in a county which is distinct from, though geographically close to, the London region. Secondly, Hertfordshire is in the relatively less deprived South Eastern area of England[42]. However, our analyses were internal; unless the association between e.g. deprivation and bone mineral density, is systematically different among sub-groups of the population with lower or higher levels of deprivation, no major bias should have been introduced. Moreover, there is a grading of deprivation levels in Hertfordshire[42], and HCS, and Wilkinson has discussed how relative levels of deprivation matter for health inequalities in addition to absolute levels[9]. Thirdly, the data on incident fracture between the HCS baseline and clinical outcomes study were ascertained by self-report. Such reports are subject to errors of recall and recall bias has the potential to create spurious statistical results. However, in a large study that assessed the validity of self-reported non-spine fracture using medical records, in men and women aged over 60 only 8% of self-reported fractures proved to be false-positives and an even smaller proportion turned out to be false-negatives[43]. As such, we suggest that the potential for recall bias to have affected our results is small. Fourthly, the HCS participants are a group of relatively young-old community dwelling men and women in whom incident fracture rates will still be relatively low in comparison with older men and women. It would be fascinating to replicate our study in suitable cohorts of older and frailer men and women. Finally, financial and practical constraints dictated that only a sub-group of HCS participants underwent DXA and pQCT scans and, additionally, participants were lost to follow-up. Unsurprisingly, a healthy participant effect was evident and men and women who participated in the East Hertfordshire follow-up study or who responded to the clinical outcomes postal questionnaire were on average younger, weighed less, were more active, had higher calcium intake, smoked and drank less, had fewer systems medicated and were more likely to be taking HRT at HCS baseline than their counterparts who only participated in the HCS baseline clinic (data not shown). However, as above, our analyses were internal; unless the associations between SEP and deprivation and our panel of markers of osteoporosis and fracture were systematically different among men and women who did or did not participate in various components of the HCS study then no major bias should have been introduced.

Our study also had many strengths. Firstly, we analysed a large dataset of individual rather than ecological level data which included directly ascertained individual level markers of socioeconomic status. Brennan et al specifically recommended this type of further research in their recent systematic reviews of social inequalities in bone mineral density and fracture[10;11]. Secondly, we have considered a range of markers of bone health including prevalent and incident fracture, bone mineral density ascertained by DXA scans, bone strength ascertained by pQCT scans, and bone loss rate assessed by repeat DXA scans. Thirdly, the data were rigorously collected according to strict protocols by trained research nurses and doctors[12]. Fourthly, we were able to adjust our analyses for lifestyle, medical history and co-morbidity. Finally, we are confident that our results are generalisable to the wider population of older people in England, because the cohort have been shown to be broadly comparable with participants in the nationally representative Health Survey for England[12].

In conclusion, our results suggest that fracture and osteoporosis do not have a strong direct social gradient and that public health strategies for prevention, intervention and treatment of osteoporosis and fracture should continue to focus on the whole population, rather than targeting specific subgroups of the population.

Mini-abstract It is unknown whether osteoporosis is socially patterned. Using data from the Hertfordshire Cohort Study we found no consistent evidence for social inequalities in prevalent or incident fracture, bone mineral density or loss rates, or bone strength. Public health strategies for prevention of osteoporosis should focus on the whole population.

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Figure 1.
Phases of data collection for the Hertfordshire Cohort Study (HCS)

Table 1
Socio-economic position, material deprivation and markers of bone health among Hertfordshire Cohort Study (HCS) participants

N(%)		Men	Women
<i>Socio-economic position at HCS baseline</i>		<i>N=1684</i>	<i>N=1541</i>
Age left full time education (years) *		15 (15, 16)	15 (15, 16)
Left full time education aged 14 years		327 (19.4)	276 (17.9)
Social class ^a	I Professional	107 (6.6)	84 (5.5)
	II Management and Technical	395 (24.2)	347 (22.5)
	IIINM Skilled non-manual	165 (10.1)	209 (13.6)
	IIIM Skilled manual	638 (39.1)	593 (38.5)
	IV Partly skilled	272 (16.7)	253 (16.4)
	V Unskilled	57 (3.5)	54 (3.5)
<i>Material deprivation at HCS baseline</i>			
Housing tenure	Owned/mortgaged	1357 (80.7)	1185 (76.9)
	Rented/other	325 (19.3)	356 (23.1)
Number of cars available	None	107 (6.4)	273 (17.7)
	1	898 (53.5)	893 (58.0)
	2	552 (32.9)	330 (21.4)
	3 or more	122 (7.3)	45 (2.9)
<i>Fracture and bone mineral density at HCS baseline</i>		<i>N=1684</i>	<i>N=1541</i>
Age (years) **		65.6 (2.9)	66.6 (2.7)
Any fracture since 45yrs of age		235 (14.0)	333 (21.6)
Minor trauma fracture since 45yrs of age		129 (7.7)	284 (18.4)
<i>HCS baseline DXA scan</i>		<i>N=498</i>	<i>N=468</i>
DXA Total femoral BMD (g/cm ²) **		1.04 (0.13)	0.90 (0.13)
<i>East Hertfordshire follow-up study</i>		<i>N=322</i>	<i>N=320</i>
Age (years) **		69.8 (2.5)	70.1 (2.6)
Follow-up time since HCS baseline (years) *		5.2 (4.8,5.6)	3.5 (3.0,4.0)
DXA total femoral change in BMD (%/yr) **, ^b		-0.09 (0.70)	-0.55 (1.20)
pQCT radius strength strain index (SSI) **		397 (82)	226 (51)
pQCT tibia strength strain index (SSI) **		2072 (328)	1400 (227)
<i>HCS clinical outcomes study fracture sample</i>		<i>N=1093</i>	<i>N=1049</i>
Age (years) **		71.7 (2.5)	71.6 (2.5)
Follow-up time since HCS baseline (years) *		5.8 (5.0,7.3)	4.9 (4.1,6.1)
Incident fracture since HCS baseline		46 (4.2)	113 (10.8)

* Median and interquartile range

** Mean and standard deviation

^aRegistrar General's social class was based on most recent full-time occupation, classified according to the 1990 edition of the standard occupational classification and was based on social class of the husband for ever married women. 21 women did not have a job code of their own

(having never worked or having provided insufficient information about their most recent full time occupation for successful social class coding) but were assigned a social class on the basis of their husband's job code. 1 woman had missing data for their own and their husband's job code class and no social class was therefore assigned. The woman's own job code was used in 110 cases because job code data for the husband were missing. For 333 women, their own and their husband's social class codes tallied. Use of the husband's social class resulted in 561 women being assigned a higher social class than had their own social class been used and 515 women were assigned a lower social class on this basis.

^b Change in BMD defined as BMD at the East Hertfordshire follow-up study minus BMD at the HCS baseline DXA scan, divided by BMD at the HCS baseline DXA scan and annualised per year of follow-up to yield a change variable with units of percentage change per year and with positive values indicating an increase in bone over time and negative values a decrease in bone over time.

Table 2a
Cross-sectional associations between socio-economic position and deprivation and baseline HCS fracture and DXA BMD for men

Any fracture since 45yrs of age			Minor trauma fracture since 45yrs of age			DXA Total femoral BMD		
OR	95%CI	P	OR	95%CI	P	beta	95%CI	P
Registrar General's current social class (vs IIIM)								
I	1.08	(0.59,1.99)	1.37	(0.65,2.92)		-0.01	(-0.07,0.04)	
II	1.11	(0.77,1.62)	1.27	(0.78,2.07)		0.01	(-0.02,0.04)	
IIINM	1.34	(0.83,2.17)	1.17	(0.60,2.29)		-0.03	(-0.07,0.01)	
IV	1.46	(0.98,2.17)	1.38	(0.81,2.35)		-0.01	(-0.05,0.02)	
V	0.84	(0.35,2.03)	0.83	(0.25,2.77)		-0.02	(-0.09,0.06)	
		<i>p for trend</i>		<i>p for trend</i>			<i>p for trend</i>	
		0.76		0.57				0.56
		0.51 ^a		0.87 ^a				0.64 ^a
Age left full time education								
14yrs vs 15yrs	1.26	(0.90,1.75)	0.92	(0.76,1.82)	0.14	-0.03	(-0.06,-0.01)	0.63
		0.46 ^a		0.41 ^a				0.85 ^a
Home ownership (vs owned/mortgaged)								
Rented/other	1.02	(0.72,1.44)	0.92	(0.89,2.07)	0.16	0.00	(-0.03,0.03)	0.89
		0.85 ^a		0.14 ^a				0.70 ^a
Car availability (vs 3 or more)								
None	1.10	(0.55,2.19)	1.41	(0.59,3.42)		-0.07	(-0.14,0.00)	
1	0.83	(0.50,1.39)	0.98	(0.49,1.95)		-0.01	(-0.06,0.04)	
2	0.73	(0.42,1.25)	0.74	(0.35,1.53)		0.00	(-0.05,0.05)	
		<i>p for trend</i>		<i>p for trend</i>			<i>p for trend</i>	
		0.55		0.18				0.07
		0.78 ^a		0.53 ^a				0.11 ^a

OR=odds ratio; CI=confidence interval; yrs=years; beta=regression coefficient in units of the bone variable concerned; I, II, IIIM, IIINM, IV and V represent social classes one, two, three non-manual, three manual, four and five; *p* = *p*-value; BMD=bone mineral density; DXA=dual x-ray absorptiometry.

Unless indicated otherwise, *p*-values are for unadjusted, univariate associations and are for trend across social classes and categories of car availability, and are for the underlying continuous variable for age left full time education.

^a Adjusted for age, height, weight-for-height, smoker status, weekly alcohol intake, marital status, physical activity, dietary calcium from foods, bone medication and number of systems medicated.

Table 2b
Cross-sectional associations between socio-economic position and deprivation and baseline HCS fracture and DXA BMD for women

	Any fracture since 45yrs of age			Minor trauma fracture since 45yrs of age			DXA Total femoral BMD		
	OR	95%CI	p	OR	95%CI	p	beta	95%CI	p
Registrar General's current social class (vs IIIM)									
I	0.99	(0.56,1.74)		1.03	(0.57,1.88)		-0.08	(-0.14,-0.02)	
II	1.24	(0.91,1.71)		1.26	(0.91,1.77)		-0.02	(-0.05,0.02)	
IIINM	1.01	(0.68,1.49)		0.92	(0.60,1.41)		-0.02	(-0.05,0.02)	
IV	1.03	(0.72,1.48)		1.03	(0.70,1.51)		0.02	(-0.01,0.06)	
V	1.36	(0.72,2.59)		1.51	(0.78,2.91)		-0.01	(-0.08,0.06)	
	<i>p for trend</i>			<i>p for trend</i>			<i>p for trend</i>		
			0.63			0.67			0.01
			0.78 ^a			0.85 ^a			0.22 ^a
Age left full time education									
14yrs vs 15yrs	1.33	(0.98,1.80)		1.52	(1.11,2.07)		-0.03	(-0.06,-0.00)	
			0.54			0.33			0.75
			0.62 ^a			0.51 ^a			0.59 ^a
Home ownership (vs owned/mortgaged)									
Rented/other	1.11	(0.84,1.48)		1.14	(0.84,1.53)		-0.01	(-0.04,0.03)	
			0.46			0.41			0.74
			0.93 ^a			0.96 ^a			0.26 ^a
Car availability (vs 3 or more)									
None	1.46	(0.62,3.45)		1.71	(0.64,4.55)		-0.03	(-0.11,0.05)	
1	1.76	(0.77,3.99)		2.14	(0.83,5.49)		-0.06	(-0.13,0.02)	
2	0.97	(0.41,2.29)		1.20	(0.45,3.20)		-0.03	(-0.10,0.05)	
	<i>p for trend</i>			<i>p for trend</i>			<i>p for trend</i>		
			0.02			0.04			0.28
			0.07 ^a			0.20 ^a			0.45 ^a

OR=odds ratio; CI=confidence interval; yrs=years; beta=regression coefficient in units of the bone variable concerned; I, II, IIIM, IIINM, IV and V represent social classes one, two, three non-manual, manual, four and five; *p* = *p*-value; BMD=bone mineral density; DXA=dual x-ray absorptiometry.

Unless indicated otherwise, *p*-values are for unadjusted, univariate associations and are for trend across social classes and categories of car availability, and are for the underlying continuous variable for age left full time education.

^a Adjusted for age, height, weight-for-height, smoker status, weekly alcohol intake, marital status, physical activity, dietary calcium from foods, bone medication, number of systems medicated and also HRT use and menopausal status.

Table 3a
Longitudinal associations between socio-economic position and deprivation and change in DXA bone mineral density, pQCT follow-up bone strength and incident fractures among men

Current social class (vs I/IIIM)	DXA total femoral Change (%/yr) ^b					pQCT radius SSI					pQCT tibia SSI					Fracture between HCS and COS ^d				
	beta	95%CI	p	beta	95%CI	p	beta	95%CI	p	beta	95%CI	p	beta	95%CI	p	OR	95%CI	p	OR	95%CI
Age left full time education	I	0.00	(-0.42,0.41)		-24.16	(-67.57,19.26)		-33.86	(-206.15,138.43)							1.50	(0.48,4.68)			
	II	0.00	(-0.22,0.23)		-5.79	(-30.18,18.61)		19.55	(-79.26,118.36)							1.35	(0.63,2.92)			
	IIINM	0.20	(-0.09,0.48)		-15.81	(-46.96,15.35)		98.7	(-27.85,225.24)							1.71	(0.67,4.34)			
	IV	0.02	(-0.23,0.27)		-8.14	(-36.42,20.14)		-40.61	(-153.94,72.72)							1.05	(0.40,2.79)			
	V	-0.06	(-0.64,0.53)		33.92	(-34.11,101.95)		22.34	(-247.33,292.01)							1.66	(0.36,7.61)			
			<i>p for trend</i>	0.87		<i>p for trend</i>	0.33		<i>p for trend</i>	0.50		<i>p for trend</i>	0.48		<i>p for trend</i>					
				0.97 ^c			0.18 ^c			0.61 ^c			0.40 ^c							
Home ownership (vs owned/mortgaged)	14yrs vs 15yrs	-0.06	(-0.28,0.16)	0.68	-0.75	(-24.31,22.82)	0.96	19.92	(-76.77,116.60)	0.83	0.95	(0.44,2.07)	0.03							
	Rented/other	0.07	(-0.18,0.33)	0.58	4.04	(-24.28,32.35)	0.78	-62.44	(-185.06,60.17)	0.32	1.36	(0.66,2.78)	0.41							
				0.25 ^c			0.82 ^c			0.19 ^c			0.53 ^c							
Car availability (vs 3 or more)	None	-0.22	(-0.75,0.31)		-21.77	(-80.07,36.53)		-105.4	(-351.77,140.98)							0.46	(0.09,2.37)			
	1	-0.04	(-0.36,0.27)		-6.59	(-42.06,28.89)		-56.55	(-195.01,81.90)							0.62	(0.25,1.55)			
	2	-0.09	(-0.42,0.23)		24.67	(-11.76,61.11)		106.21	(-35.80,248.22)							0.45	(0.16,1.22)			
			<i>p for trend</i>	0.87		<i>p for trend</i>	0.02		<i>p for trend</i>	0.00		<i>p for trend</i>	0.69		<i>p for trend</i>					
				0.59 ^c			0.05 ^c			0.01 ^c			0.42 ^c							

OR=odds ratio; CI=confidence interval; yrs=years; beta=regression coefficient in units of the bone variable concerned; I, II, IIINM, IV and V represent social classes one, two, three non-manual, three manual, four and five; *p* = *p*-value; BMD=bone mineral density; DXA=dual x-ray absorptiometry, pQCT=peripheral quantitative computed tomography; SSI=strength strain index.

Unless indicated otherwise, *p*-values are for unadjusted, univariate associations and are for trend across social classes and categories of car availability, and are for the underlying continuous variable for age left full time education.

^a All new fracture events arising between the baseline HCS study and the Clinical Outcomes Study (COS) follow-up postal questionnaire

^b Change in BMD defined as BMD at the East Hertfordshire follow-up study minus BMD at the HCS baseline DXA scan, divided by BMD at the HCS baseline DXA scan and annualised per year of follow-up to yield a change variable with units of percentage change per year and with positive values indicating an increase in bone over time and negative values a decrease in bone over time.

^c Adjusted for age, height, weight-for-height, smoker status, weekly alcohol intake, marital status, physical activity, dietary calcium from foods, bone medication, number of systems medicated, follow-up duration and HCS baseline fracture status.

Table 3b
Longitudinal associations between socio-economic position and deprivation and change in DXA bone mineral density, pQCT follow-up bone strength and incident fractures among women

	DXA total femoral				pQCT radius SSI				pQCT tibia SSI				Fracture between HCS and COS ^d			
	beta	95%CI	p		beta	95%CI	p		beta	95%CI	p		OR	95%CI	p	
Current social class (vs IIIM)																
I	0.26	(-0.31,0.83)			-31.1	(-54.57,-7.63)			-50.4	(-161.50,60.71)			0.63	(0.24,1.64)		
II	0.02	(-0.35,0.38)			-3.09	(-17.91,11.73)			-3.77	(-71.89,64.35)			0.78	(0.46,1.33)		
IIIM	-0.35	(-0.78,0.08)			7.48	(-9.80,24.75)			-17.05	(-96.45,62.34)			1.10	(0.61,2.00)		
IV	0.05	(-0.40,0.50)			-2.56	(-20.61,15.50)			0.35	(-85.23,85.93)			0.63	(0.33,1.19)		
V	-0.46	(-1.17,0.26)			-23.3	(-53.39,6.80)			21.24	(-114.95,157.43)			3.28	(1.42,7.59)		
		p for trend	0.45			p for trend	0.45			p for trend	0.46			p for trend	0.17	
			0.51				0.75				0.90				0.17	
Age left full time education																
14yrs vs 15yrs																
	-0.02	(-0.38,0.34)	0.71		-7.70	(-22.03,6.64)	0.76		-27.9	(-93.69,37.90)	0.26		0.99	(0.57,1.71)	0.68	
			0.89				0.64				0.09				0.84	
Home ownership (vs owned/mortgaged)																
Rented/other	0.14	(-0.23,0.51)	0.45		0.51	(-14.65,15.68)	0.95		71.82	(1.22,142.43)	0.05		0.75	(0.44,1.27)	0.28	
			0.35				0.65				0.03				0.34	
Car availability (vs 3 or more)																
None	-0.26	(-1.18,0.67)			-22.81	(-59.70,14.07)			2.07	(-172.06,176.19)			1.36	(0.30,6.26)		
1	-0.15	(-1.01,0.71)			-15.55	(-49.73,18.63)			-46.69	(-208.00,114.61)			2.21	(0.52,9.42)		
2	-0.22	(-1.10,0.67)			-3.28	(-38.61,32.04)			-2.41	(-169.08,164.26)			1.05	(0.23,4.80)		
		p for trend	0.83			p for trend	0.02			p for trend	0.65			p for trend	0.24	
			0.56				0.02				0.94				0.36	

OR=odds ratio; CI=confidence interval; yrs=years; beta=regression coefficient in units of the bone variable concerned; I, II, IIIM, IIINM, IV and V represent social classes one, two, three non-manual, three manual, four and five; p = p-value; BMD=bone mineral density; DXA=dual x-ray absorptiometry; pQCT=peripheral quantitative computed tomography; SSI=strength strain index.

Unless indicated otherwise, p-values are for unadjusted, univariate associations and are for trend across social classes and categories of car availability, and are for the underlying continuous variable for age left full time education.

^a All new fracture events arising between the baseline HCS study and the Clinical Outcomes Study (COS) follow-up postal questionnaire

^b Change in BMD defined as BMD at the East Hertfordshire follow-up study minus BMD at the HCS baseline DXA scan, divided by BMD at the HCS baseline DXA scan and annualised per year of follow-up to yield a change variable with units of percentage change per year and with positive values indicating an increase in bone over time and negative values a decrease in bone over time.

^c Adjusted for age, height, weight-for-height, smoker status, weekly alcohol intake, marital status, physical activity, dietary calcium from foods, bone medication, number of systems medicated, follow-up duration, HCS baseline fracture status and HRT use and menopausal status.