**Clustering of lifestyle risk factors and low bone density in older adults: the Hertfordshire Cohort Study**

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ABSTRACT

Purpose: Lifestyle factors are associated with bone mineral density, which in turn is strongly linked with risk of fragility fracture. Clustering of ‘adverse’ lifestyle factors may occur in some individuals. We examined the relationship between a number of lifestyle risk factors (low physical activity, poor diet, smoking, alcohol intake, grip strength, personal and family history of prior fracture) and low bone mineral density in a population of older community dwelling men and women.

Method: A cross-sectional study with 498 men and 498 women aged 59 to 72 years, who were participants in the Hertfordshire Cohort Study. Physical activity, diet quality, history of prior fracture, family history of fracture, cigarette and alcohol consumption were obtained through questionnaire. Information on co-morbidities: bronchitis, diabetes, ischaemic heart disease, hypertension and stroke were noted. Measurements of grip strength and bone mineral density of the lumbar spine and total femur were also taken.

Results: In women, a graded association between the number of risk factors and bone density at the lumbar spine and total femur was seen, with the strongest association seen in those with 3+ risk factors and their BMD (regression coefficient: 0.758, p-value <0.001, regression coefficient: 0.531, p=value: 0.005, total femur, lumbar spine respectively). Among women strong relationships were seen between the number of risk factors and incident fracture; women with three or more risk factors had the highest adjusted hazard ratio (HR) of incident fracture of 5.98 (1.67, 21.43; p=0.006) compared to women with no risk factors. Whilst women with two risk factors had an adjusted HR of 2.97 (1.14, 7.74; p=0.03) and those with one, 2.28 (0.90, 5.75; p=0.08).

Conclusion There is a clustering of lifestyle factors that is associated with increased risk of fracture and adverse bone health in women, with similar but non-significant trends echoed in men. Health education programmes may be important in reducing these risks.

KEY WORDS: clustering, lifestyle, BMD, smoking, alcohol

**Introduction**

Certain lifestyle factors are known to be associated with bone mineral density. In turn low bone mineral density is strongly linked with fragility fracture, which is associated with a significant personal and public health burden. In the UK, 1 in 2 women and 1 in 5 men over the age of 50 years will suffer a fracture in their remaining lifetime [1]. This results in serious consequences relating to loss of mobility, independence and self-esteem [1]. UK fragility fracture cost is currently estimated at 9 million per year, and across Europe 32 billion EUR per year [2]. With an aging population across the globe, the burden is set to rise.

Higher levels of physical activity both in youth and in late adulthood have been shown to be positively associated with bone mineral density [3] [4, 5]. Body mass index is another major determinant of bone mineral density (BMD) [6, 7].Smoking is another well explored and modifiable lifestyle choice with regards to its impact on bone. A negative influence of teenage smoking on adolescent bones has been observed [8, 9], and an independent and dose-dependent effect of cigarette smoking on bone loss has been documented in a meta-analysis [10]. Alcohol consumption has a varied effect on bone health; however heavy intake is well documented with deleterious changes on bone health [11-13]

Previous studies have shown that clustering of risk factors for adverse health outcomes occurs, with a recent study highlighting the association of such clustering with poor physical performance in late adulthood [14]. Similarly co-existence between certain lifestyle choices (low physical activity, poor diet and smoking and increase alcohol consumption (greater than the UK recommendation) has been shown to be associated with excess mortality [15]. In contrast a combination of healthy lifestyle behaviours i.e. not smoking, adopting a healthy diet and regular physical activity appear to reduce the risk of all-cause mortality [16]. Here, we explore whether clustering of lifestyle factors that are traditionally independently associated with poor bone health occurs, and the consequence of such clustering on bone health.

**Methods**

In the late 1990s, 3000 men and women aged 59-73 years were recruited to a study, which was designed to examine the relationship between growth in infancy and the subsequent risk of adult disease, including osteoporosis (the Hertfordshire Cohort Study [17]). The selection procedure for these individuals was as follows: in brief, with the help of the National Health Service Central Registry at Southport, and Hertfordshire Family Health Service Association, we traced men and women who were born during 1931-39 in Hertfordshire, and still lived there during the period 1998-2003. The birth weight and weight at one year of age of each individual had been recorded in a ledger by a team of midwives and health visitors who had attended each birth in Hertfordshire in the 1930s and visited the child’s home at intervals during the first year of life.

This analysis is based on the 498 men and 498 women who participated in baseline clinic visits held in 1999-2003, which included baseline assessment of bone health through DXA. Lifestyle risk factors were assessed at baseline by nurse-administered questionnaires, and included information on smoking habits (current or historical, allowing calculation of pack years) and alcohol consumption (number of units consumed per week). Physical activity was assessed from responses to questions about the frequency and duration of gardening, housework, climbing stairs and carrying loads in a typical week. A standardised activity score ranging from 0-100 was calculated, with a score of <50 classified as low activity. The questionnaire has been designed specifically to characterise the level of physical activity in the elderly community dwelling population in [18]. Data on history of prior fracture and participants’ co-morbidities was also recorded, which included bronchitis, diabetes, ischaemic heart disease (IHD), hypertension and stroke.

Diet was assessed using a food frequency questionnaire (FFQ). Foods were categorised into 51 groups based on their type and nutrient composition. Principal component analysis of the reported weekly frequencies of consumption of the food groups was used to describe the dietary patterns of the men and women. The diet pattern classified as a prudent dietary pattern follows the recommendations for a healthy diet which consists of high consumption of fruit, vegetables, whole-grain cereals and oily fish, with a low consumption of white bread, chips, sugar and full-fat dairy products. A prudent diet score was calculated using the co-efficient of each food group multiplied by the reported frequency of consumption of the food group, with the sum of these values providing a single score. Thus a high prudent diet score shows the participant’s diet has a high consumption of fruit, vegetables, whole-grain cereals and oily fish; and a low prudent diet score indicates a diet consist of high consumption of white bread, chips, sugar and full-fat dairy products. Poor diet was classified as a prudent diet score in the lower quarter of the distribution [19].

At the clinic, a Jamar hand held isokinetic dynamometer was used to measure the grip strength of each hand three times following a standardised protocol [20]. Low grip strength was defined as a maximum grip strength of <30kg for men and <20kg for women. Participants were also invited to attend for measurement of bone mineral density of the lumbar spine and total femur using a Hologic QDR 4500 dual energy x-ray absorptiometer. A subgroup of participants (322 men and 320 women) attended a follow up clinic in 2004-2005. In 2011 222 men and 221 women attended another follow-up clinic. At both these clinics data on fractures that had occurred since baseline were recorded.

The East and North Hertfordshire Ethical Committees granted ethical approval for the study and all participants gave written informed consent.

Statistical analysis

Variables were assessed for normal distribution. Risk factors were categorised to look at the effect of increasing number of lifestyle factors on bone health: low activity was defined as a physical activity score ≤50; poor diet was defined as a prudent diet score in the bottom quartile; current smoker; alcohol consumption greater than the recommended UK units per week (21 for men, 14 for women); low grip strength was defined as <30kg for men and <20kg for women; previous fracture after the age of 45 and a family history of fracture after the age of 45. The number of co-morbidities (bronchitis, diabetes, IHD, hypertension, and stroke) was collected from self-reported data and clinic data. IHD was defined as the presence of typical angina pectoris (Rose questionnaire), angioplasty, coronary artery bypass or presence of significant Q waves on electrocardiogram. The risk factors were assessed in a binary fashion to investigate the associations between lifestyle factors and bone health. Unadjusted and adjusted regression analyses were carried out looking at the clustering effect of the risk factors and its association with BMD expressed as negative Z scores. Data analysis was carried out using Stata version 13 **[21].**

**Results**

The characteristics of the participants are summarised in Table 1. The mean age for the 498 men that participated was 64.8 ± 2.5 SD, and the mean age for the 498 women that participated was 66.4 ±2.5 SD. The men overall had a higher BMD at baseline than women (1.04 ±0.13 g/, 1.08 ±0.16 g/ versus 0.90 ±0.13 g/, 0.96 ±0.17 g/) at the two measured sites, total femoral and lumbar spine. Men were marginally more active than women with a higher mean activity score of 64.0 (±14.8 SD) compared with a female mean of 61.2 (±15.0 SD). Women reported a higher mean prudent diet score than men (0.67 ±1.71, -0.78 ±2.06, respectively). Unsurprisingly, men had stronger grip strength at baseline with a mean of 44.1kg (±7.3 SD) in contrast to a mean female grip strength of 27.7kg (±5.1 SD). A greater proportion of women were categorised as never smokers (62.2%) compared with men (33.5%), but the percentage of current smokers were comparable in men and women (14.7%, 9.5% respectively). Men appeared to consume on average more alcohol than women (median: 9.3, IQR: 2.5-21.5; median: 1.5, IQR: 0.0-5.0). There was little difference in the proportion of men (12.7%) and women (16.5%) reporting having previously had a fracture at baseline, though women were more likely to report a family history of fracture (33.9% compared to 20.0%). Men and women reported similar numbers of comorbidities. More women than men reported incident fracture; 47 (14.8%) compared with 23 (7.3%). The proportion of men with two or more risk factors was greater compared with women (40.7%, 30.1% respectively). Table 2 shows the distributions of participants with regards to the number of risk factors.

In men alcohol consumption greater than the UK recommended units per week was associated with higher BMD at the total femur and the lumbar spine (-0.195 (95% CI -0.399, 0.010) negative z-score, p-value:0.062 at the total femur; -0.217 (95% CI -0.421, -0.014) negative z-score, p-value:0.036 at the lumbar spine). In women, having previously had a fracture after the age of 45 was associated with lower BMD at both the total femur and lumbar spine (0.513 (95% CI 0.280, 0.746) negative z-score, p-value <0.001 total femur; 0.452 (95% CI 0.218, 0.687) negative z-score, p-value<0.001 lumbar spine).

Clustering of adverse risk factors did occur, and was associated with adverse bone outcomes (Table 3). There was a graded association between the number of risk factors and bone density (negative z-score) at the lumbar spine and total femur in women (Table 3 and Figure 1), with lowest bone densities observed in women with three or more risk factors. Among men, no significant trend was observed. Among individuals in whom follow up data were available, we observed similar relationships with incident fracture among women. Those women with three or more risk factors had an adjusted hazard ratio (HR) of incident fracture of 5.98 (1.67, 21.43; p=0.006) compared with women without risk factors, whilst women with two risk factors had an adjusted HR of 2.97 (1.14, 7.74; p=0.026) and those with one, 2.28 (0.90, 5.75; p=0.081).

**Discussion**

We have shown that clustering of lifestyle factors occurs, and is related to poorer bone health in a cohort of elderly community dwelling adults. This negative relationship is seen with both BMD, and also with incident fracture, where women with three or more risk factors had an adjusted hazard ratio (HR) of incident fracture of 5.98 (1.67, 21.43; p=0.006) compared with women without risk factors. These data highlight the importance of relevant, effective interventions in such high risk populations.

There are some limitations to our study; our cohort is based on a group of men and women recruited because they were born in Hertfordshire and still lived there in adult life. However, we have previously shown this group to be representative of the UK population with regard to lifestyle characteristics such as BMI and smoking habits [17]. Furthermore, incident fracture data was collected by questionnaire. It is likely that some relevant fractures (vertebral fractures) may be underreported because of well-known failure to recognise such fractures clinically, and in addition there may be some recall bias when collecting data from questionnaire. The accuracy of lifestyle data will be liable to recall bias, but the similarity to national values is reassuring. Of note, we were unable to follow up all baseline study participants.

There is a large amount of literature focusing on the individual risk factors that we had examined in our study and their effects on the bone health. While the concept of co-existence of certain lifestyle choices has been explored in other studies, the effect on bone health has not, to our knowledge, been reported in this way previously. There have been previous studies looking at effects of diet, physical activity, smoking and alcohol intake on mortality [22, 23], and others looked at how lifestyle choices impacted on the risk of developing stroke [24, 25]. Individually many of the risk factors measured in our study have been linked to BMD negatively. The effect of smoking has been analysed to be independently linked to bone health, and a dose-dependent effect on bone loss has been made [10]. Several studies have shown the positive relationship between increased physical activity and bone health [26, 27]. BMI is another positive determinant of bone health [28, 29] and a low BMI is associated with an increased risk of fracture risk [30]. Excessive alcohol consumption is well known to cause deleterious effect on bone health. We have linked the risk factors known to have a role in the health of bones, and found that the clustering effect does occur and the more risk factors that are present in the cluster the greater the effect it has on BMD.

In summary, clustering of certain lifestyle factors adversely affects bone health with respect to reduced bone density and increased rates of fracture. Health education programmes may play an important role in educating the population about their lifestyle choices, and reduce these risks.

Table 1: Summary of characteristics of cohort.

|  |  |  |  |
| --- | --- | --- | --- |
| Characteristics | Men | Women | P-value³ |
| Age (yrs), n, mean ± SD | 498, 64.8 ± 2.5 | 498, 66.4 ± 2.5 | <0.001 |
| Total femoral BMD (g/cm²), n, mean ± SD | 495, 1.04 ± 0.13 | 497, 0.90 ± 0.13 | <0.001 |
| Lumbar spine BMD (g/cm²), n, mean ± SD | 497, 1.08 ± 0.16 | 498, 0.96 ± 0.17 | <0.001 |
| Activity score, n, mean ± SD | 498, 64.0 ± 14.8 | 498, 61.2 ± 15.0 | 0.004 |
| Prudent diet score, n, mean ± SD | 498, -0.78 ± 2.06 | 498, 0.67 ± 1.71 | <0.001 |
| Maximum grip (kg), n, mean ± SD | 498, 44.1 ± 7.3 | 498, 27.7 ± 5.1 | <0.001 |
| Alcohol consumption (units per week), n, median, IQR | 498, 9.3, 2.5-21.5 | 498, 1.5,0.0-5.0 | <0.001 |
| Smoker status, n (%)  Never, n (%)  Ex-smoker, n (%)  Current, n (%) | 498 (100)  167 (33.5)  258 (51.8)  73 (14.7) | 497 (100)  309 (62.2)  141 (28.4)  47 (9.5) | <0.001 |
| Previous fracture after age 45, total n, n (%) | 498, 63 (12.7%) | 498, 82 (16.5%) | 0.088 |
| Family history of fracture after age 451, total n, n (%) | 491, 98 (20.0%) | 496, 168 (33.9%) | <0.001 |
| No of comorbidities², n (%)  0, n (%)  1, n (%)  2, n (%)  3+, n (%) | 471  257 (54.6)  140 (29.7)  56 (11.9)  18 (3.8) | 477  254 (53.2)  156 (32.7)  60 (12.6)  7 (1.5) | 0.120 |
| Incident fracture (after baseline), total n, n (%) | 314, 23 (7.3) | 318, 47 (14.8) | 0.003 |
| ¹A fracture in a parent or sibling after the age of 45  ²Out of bronchitis, diabetes, IHD, hypertension and stroke  ³P-value for difference between men and women | | | |

Table 2: Distribution of participants with regards to number of risk factors

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Men (n = 491) | | Women (n = 495) | |  |
|  | **N** | **%** | **N** | **%** | **p-value** |
| Number of risk factors (out of 7)¹ |  |  |  |  | <0.001 |
| 0 | 96 | 19.6 | 150 | 30.3 |  |
| 1 | 195 | 39.7 | 196 | 39.6 |
| 2 | 144 | 29.3 | 115 | 23.2 |
| 3 | 44 | 9.0 | 29 | 5.9 |
| 4 | 12 | 2.4 | 5 | 1.0 |
| 1 Number of risk factors out of low activity, poor diet, current smoker, alcohol consumption greater than the recommended amount, low grip, previous fracture and family history of fracture | | | | | |

Table 3: A graded association between number of risk factors and BMD (negative Z score) in women

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Number of risk factors | Total femur  Adjusted¹ (n=473) | | | Lumbar Spine  Adjusted¹ (n=474) | | |
| Regression Coefficient | 95% CI | P- value | Regression Coefficient | 95% CI | P- value |
| 0 (reference) | 0 | (0.000, 0.000) | - | 0 | (0.000, 0.000) | - |
| 1 | 0.129 | (-0.078, 0.336) | 0.223 | 0.115 | (-0.096, 0.327) | 0.285 |
| 2 | 0.223 | (-0.014, 0.460) | 0.065 | 0.255 | (0.013, 0.497) | 0.039 |
| 3+ | 0.758 | (0.392, 1.124 | <0.001 | 0.531 | (0.157, 0.905) | 0.005 |
| Trend (per additional risk factor | 0.176 | (0.083, 0.269) | <0.001 | 0.153 | (0.058, 0.248) | 0.002 |
| ¹Adjusted for age and number of co-morbidities (bronchitis, diabetes, IHD, HTN, and stroke) | | | | | | |

Figure 1 Bone mineral density in women by number of risk factors, after adjustment for age and number of comorbidities



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