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Original article

Association between nutrient patterns and bone mineral density among ageing adults

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SUMMARY

Background and aim: There is limited evidence on the link between the overall nutrients intake from diet and bone mineral density (BMD). We assessed the association between nutrient patterns and BMD among an ageing Australian population.

Methods: Participants (n = 1135; males, 45.8%; median age, 62.0 years) with dietary and BMD data in the North West Adelaide Health Study (NWAHS) were included. Dietary intake was assessed using a food frequency questionnaire. BMD was measured using dual-energy X-ray absorptiometry. Nutrient patterns were identified by factor analysis. Linear regression analyses were conducted to assess the association between nutrient patterns and BMD (mg/cm^2). Multiple imputation and sensitivity analyses were conducted to investigate the effect of missing data on the estimates.

Results: Three nutrient patterns (mixed-source [potassium, calcium, fibre, retinol and Vitamin B_{12}], animal-sourced [cholesterol, protein, Vitamin B_{12} and fat] and plant-sourced [fibre, carotene, vitamin C and Lutein]) were identified. After adjusting for socio-demographic, lifestyle and behavioural characteristics, chronic conditions and energy intake, animal ($\beta = -4.07$; 95% confidence interval (CI): −11.89, 3.76) and plant-sourced ($\beta = -0.99$; 95% CI: −7.43, 5.45) patterns were not associated with BMD. However, we found that the mixed-source pattern was positively associated with BMD ($\beta = 10.86$; 95% CI: 1.91, 19.80). We did not find interactions between the pattern, other covariates and BMD. The multiple imputation and sensitivity analyses including missing data identified similar patterns of association between nutrient patterns and BMD.

Conclusions: Whereas animal- and plant-sourced nutrient patterns are not associated with BMD, mixed-source pattern may have benefit in prevention of reduced BMD.

1. Introduction

Studies have focused on individual food items and nutrients to investigate their impact on bone mass and fracture risks [1–4]. However, in recent years, interest has grown to determine the combined effect of the whole diet and nutrients that are consumed on bone mass [5,6] and risk of fractures [7]. In this regard, evidence suggests that particular dietary patterns have effect on bone mass [8,9] and fracture risks [7]. For instance, there is a growing evidence that shows a dietary pattern characterized by high intake of vegetables, fruits, whole grains and dairy products benefits the maintenance of bone mass in adults [6,8,10]. Identifying dietary patterns that consider the overall eating habits, rather than focussing on individual foods, better reflects the complexity of dietary intakes and helps to understand the combined effect of diet components.

Previous studies have also focused on assessing the impact of individual nutrients on bone mass [11,12] and fracture risks [13,14]. The Framingham Study demonstrated the importance and role of polyunsaturated fatty acids (PUFA) in maintaining bone mass [15]. Other studies have also demonstrated the association between particular nutrients, such as protein [12], phosphorous [16], magnesium [17] and potassium [18], and bone mass and fracture risks. These studies however assessed the link between a single nutrient

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or few nutrients and bone mass/fracture risks without considering other nutrients that could have had a potential role.

People do not consume individual nutrients, rather a mixture of multiple nutrients. In addition, investigating a single nutrient does not consider the antagonist, additive and synergistic effects of nutrients. Therefore, assessing the combined effect of nutrients, taking into account the whole intake pattern, is important in order to address these effects. Some previous studies have determined the combined impact of nutrients (nutrient patterns) on chronic inflammation [19], cancer [20,21] and obesity [22]. These studies demonstrated the importance of identifying nutrient patterns and their associations with disease outcomes.

Assessment of associations between nutrient patterns and bone mass, in particular, is important because bone metabolism and structure depends on a diverse range of nutrients. Furthermore, identifying nutrient patterns that are associated with bone mass will allow mapping of particular nutrient combinations that could have a substantial influence. Previous studies have assessed the association of nutrient patterns with bone mass in post-menopausal women [5] and self-reported fracture risk [23], but the limitations of these studies do not allow for firm conclusions. Therefore, this study aimed to identify nutrient patterns and investigate their associations with bone mineral density (BMD) in an ageing population.

2. Methods

2.1. Study design and population

We used data from the North West Adelaide Health Study (NWAHS), which is a community-based follow-up investigation with the purpose of providing social, behavioural, clinical and biomedical data. Details of the study are published elsewhere [6,24]. In brief, three stages of data collections were undertaken—each occurred approximately five years apart (1999–2003, 2004–2006 and 2008–2010). Initially, households from the northern and western part of Adelaide city (South Australia) which were connected to a landline telephone were randomly selected using Electronic White Pages. Individuals residing in the selected household and aged 18 years were candidates for study participation. With the exception of health literacy and nutrient data (assessed at Stage 3), all other measurements used in this study were collected at Stage 2. At this stage, all study participants aged 50 years and above were invited to undergo an assessment of BMD by dual-energy x-ray absorptiometry (DXA); 1588 undertook the measurement. At Stage 3, 2500 study participants had dietary assessment, of which 2364 had complete nutrient data. Both dietary and BMD data were available for 1135 study participants aged 50 years and over (Fig. 1). Ethics approval was provided by Ethics of Human Research Committee of The Queen Elizabeth Hospital, Adelaide, South Australia. Participants provided a written informed consent.

2.2. Dietary and nutrient intake assessments

At Stage 3, dietary intake was assessed using a paper-based validated food frequency questionnaire (FFQ), Cancer Council Victoria Diet Questionnaire for Epidemiological Studies (DQES-V3.1) [25]. The questionnaire assesses intake of 167 foods and beverages with 10 frequency categories over the previous 12 months. Portion sizes were illustrated using photographs of six foods. Nutrient intakes were calculated from the dietary data using NUTTAB95 database (Food Standards Australia New Zealand, Canberra, 1995). Intake of nutrients from supplements (vitamin D) was not considered as part of the factor analysis because limited information was collected (i.e. only categorical response (yes/no) without dose).

2.3. Other measurements

Details of social, behavioural, clinical and biochemical assessment methods are described elsewhere [6,24,26]. In summary, a self-report questionnaire, clinic visits, as well as a computer assisted telephone interviews (CATI) were used to collect the data. At Stage 2, participants' sociodemographic (sex, age, income, and marital status) and behavioural characteristics (physical activity level (PAL), alcohol risk, smoking and sun light exposure), biomedical (family history of osteoporosis, diabetes, weight, height and BMD) data were collected. Income was categorized as $20,000, $20,001–$40,000, $40,001–$60,000 and more than $60,000. Marital status was classified as married/living with partner and single/separated/widowed/divorced. Leisure PAL was determined using Australian National Health Survey questions [27]. Detailed methods of PAL are published elsewhere [28]. Job-related PAL was determined and coded based on the type of occupation of participants by two occupational physicians. Both PALs were categorized sedentary/low and moderate/high for each study participant. Diabetes cases were either doctor-diagnosed self-reported or diagnosed during the clinic visit (fasting plasma glucose $\geq$7.0 mmol/l). The total number of medications prescribed in the past 6 months was obtained from the pharmaceutical benefits scheme. Menopausal status was defined as not having menstruation for 12 months or more preceding the data collection.

BMD was assessed using Prodigy and DPX + DXA (GE Lunar) as part of the clinic visit at Stage 2. BMD was measured in g/cm^2, however, we converted to mg/cm^2 (i.e. 1 g/cm^2 = 1000 mg/cm^2) in the current analysis. Osteopenia and osteoporosis were based on *T-scores*, t-score ≤ -1 and >-2.5 and ≤-2.5, respectively [29].

Data on dietary supplementation (vitamin D) and health literacy were collected at Stage 3. Data on health literacy were collected using Newest Vital Sign test tool [30] and categorized into limited and adequate.

2.4. Statistical analyses

2.4.1. Identification of nutrient patterns

Factor analysis was used to identify nutrient patterns using 33 nutrients that were collated from all measured nutrients. The analysis was performed for 2364 study participants to reflect the nutrient patterns of the whole study population at large. Orthogonal (varimax) rotation was used to reduce the correlation between the factors, attain optimal structure and increase interpretability. Eigenvalue >1, scree plot and interpretability were used to determine the number of factors. Factor loadings of the nutrients in each factors were calculated. For each participant and factor, we computed factor scores by summing the products of factor loading coefficients and standardizing it by the daily intake of each nutrient. Tertiles of each dietary pattern were constructed based on the factor scores of study participants. Names were given to each of the nutrient patterns based on the highest nutrient groups loading.

2.4.2. Data analyses

Data were summarized using means and standard deviations (for continuous normally distributed variables), medians and interquartile ranges (for continuous non-normally distributed variables) and proportions (for categorical variables). The chi-square test and ANOVA were used to compare differences between groups for categorical and continuous variables, respectively. The Kruskal–Wallis test was used for variables which were continuous but not normally distributed.