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Original Research

Dietary patterns in men and women are simultaneously determinants of altered glucose metabolism and bone metabolism

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ABSTRACT

We hypothesized that diet would have direct effects on glucose metabolism with direct and indirect effects on bone metabolism in a cohort of Canadian adults. We assessed dietary patterns (Prudent [fruit, vegetables, whole grains, fish, and legumes] and Western [soft drinks, potato chips, French fries, meats, and desserts]) from a semiquantitative food frequency questionnaire. We used fasting blood samples to measure glucose, insulin, homeostatic model assessment insulin resistance (HOMA-IR), 25-hydroxyvitamin D (25OHD), parathyroid hormone, bone-specific alkaline phosphatase (a bone formation marker), and serum C-terminal telopeptide (CTX; a bone resorption marker). We used multivariate regression models adjusted for confounders and including/excluding body mass index. In a secondary analysis, we examined relationships through structural equations models. The Prudent diet was associated with favorable effects on glucose metabolism (lower insulin and HOMA-IR) and bone metabolism (lower CTX in women; higher 25OHD and lower parathyroid hormone in men). The Western diet was associated with deleterious effects on glucose metabolism (higher glucose, insulin, and HOMA-IR) and bone metabolism (higher bone-specific alkaline phosphatase and lower 25OHD in women; higher CTX in men). Body mass index adjustment moved point estimates toward the null, indicating partial mediation. The structural equation model confirmed the hypothesized

Abbreviations: 25OHD, 25-hydroxyvitamin D; BAP, bone-specific alkaline phosphatase; BMI, body mass index; BMD, bone mineral density; CaMos, Canadian Multicentre Osteoporosis Study; CTX, serum C-terminal telopeptide; HOMA-IR, homeostatic model assessment insulin resistance; PTH, parathyroid hormone; T2DM, type 2 diabetes mellitus.

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linkage with strong effects of Prudent and Western diet on metabolic risk, and both direct and indirect effects of a Prudent diet on bone turnover. In summary, a Prudent diet was associated with lower metabolic risk with both primary and mediated effects on bone turnover, suggesting that it is a potential target for reducing fracture risk.

1. Introduction

Higher body mass index (BMI) is linked to both higher blood glucose levels and higher bone mineral density (BMD). Therefore, individuals with type 2 diabetes mellitus (T2DM) who have elevated BMI might be expected to have lower fracture rates than individuals without diabetes [9,17]. Nevertheless, in a large Swedish study, diabetes was one of the most important risk factors for hip fracture [12]. Similarly, in a Canadian population, those with T2DM were at systematically higher risk for fracture than for calibrated fracture risk determined by the FRAX tool based on BMD [7]. Thus, paradoxically, although BMD is higher in people with T2DM, it does not appear to confer the expected fracture risk reduction.

In recent years, 2 dietary patterns have emerged as consistent predictors of health outcomes, namely, Prudent (a pattern characterized by vegetables, fruits, whole grains, and legumes) and Western (a pattern characterized by soft drinks, potato chips and French fries, processed meats, and desserts). These dietary patterns have been shown to be important risk factors for higher BMI [20], insulin resistance [5,19,27], and T2DM [6,11,21,25], and diet modification is a cornerstone of diabetes management. We have previously reported that a Prudent (or nutrient-dense) diet was associated with a lower risk of fracture independent of BMD [15]. This dietary pattern may play a dual role; that is, it may be associated with a reduced risk of diabetes and a reduced risk of fracture. Thus, the increased fracture risk among those with diabetes might be partially attributable to a common dietary risk factor. We have also shown that a Western (or energy-dense) diet was positively correlated with BMI but not similarly related to BMD [16]. In fact, when adjusted for BMI, the energy-dense diet was negatively associated with BMD. This observed decoupling of BMI and BMD could be related to increased bone fragility and would need to be confirmed by changes in markers of bone mineral metabolism. Such a linkage could be provided by pathways involving 25-hydroxyvitamin D (25OHD) and parathyroid hormone (PTH).

Accordingly, our aim was to determine the relationships of dietary patterns to bone and glucose metabolism in a cohort study. Our hypothesis was that the same dietary profile (high Western diet score, low Prudent diet score) that increases the risk of insulin resistance (direct effect) simultaneously increases bone turnover markers and, thus, increases fracture risk (through both direct effects and indirect effects through 25OHD and PTH).

2. Methods and materials

2.1. Participants

The Canadian Multicentre Osteoporosis Study (CaMos) is an ongoing cohort study that began in 1995. Households across Canada were randomly selected, and participants were chosen using a sex- and age-stratified sample frame of adults 25 years and older [14]. The study sample (see Fig. 1) for this analysis includes those participants in 3 centers who (1) completed the food frequency questionnaire (FFQ) at year 2 (1997-1999) with 10 or fewer missing responses in the food and drink section, (2) had fasting blood samples at year 5 (2000-2002), and (3) did not have a diagnosis of diabetes (type 1 or 2) at the time of the FFQ. An overview of the study appears on the study Web site www.camos.org. Two publications include more methodological details relevant to the present article [15,16]. Ethics approval was granted through McGill University and the appropriate research ethics board for each participating center. Signed informed consent was obtained from all participants in accordance with the Helsinki Declaration.

2.2. Data collection

The interviewer-administered questionnaire at baseline (1995-1997) queried demographic factors (age, sex, racial/ethnic background, and education), dietary sources of calcium and vitamin D, lifestyle factors (physical activity, smoking, and alcohol use), and a personal medical history. Medication and supplement use were assessed by a complete inventory of prescriptions and bottles brought to the interview. Baseline assessment included measured height and weight. An FFQ was mailed to all participants in the second year of the study (1997-1999). Follow-up visits were scheduled in the 5th and 10th years after enrollment.

2.3. Food frequency questionnaire

The FFQ used in CaMos is derived from items on the short-form Block questionnaire [4], with specified portion sizes and slight modifications excluding foods not common in the Canadian diet. We used the 69 food and beverage items from the main part of the questionnaire. The median of the study sample was used to impute missing FFQ responses, and sensitivity analysis showed that choice of imputation value (median vs zero) had little impact on the overall dietary pattern factor scores. Total energy intake was calculated using the frequency and specified portion size from the questionnaire together with caloric information from the Canadian Nutrient File (2007 version) [10].

2.4. Derivation of the dietary pattern factor scores

We briefly describe the derivation of the factor scores from the FFQ; more details are provided elsewhere [16]. The 69 food and beverage items were put into 34 groups of similar items. A 2-factor solution was chosen based on the scree-plot, robustness, interpretability, and previous studies. The analysis was robust to choice of food groups because very similar factor scores