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Association between Dietary Energy Density and Incident Type 2 Diabetes in the Women's Health Initiative

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ABSTRACT

Background Dietary energy density, or energy available in relation to gram intake, can inform disease risk.

Objective The objective of this study was to investigate the association between baseline dietary energy density and risk of incident type 2 diabetes in postmenopausal women.

Design Dietary energy density, weight status, and type 2 diabetes incidence were prospectively characterized in a large cohort of postmenopausal women participating in one or more clinical trials or an observational study.

Participants/setting The study involved 161,808 postmenopausal women recruited to the Women's Health Initiative observational study or clinical trials at 40 centers across the United States between 1993 and 1998.

Main outcome measures The primary outcome was incident type 2 diabetes.

Statistical analyses performed The association between dietary energy density quintiles and incident diabetes was tested using Cox proportional hazards regression.

Results A total of 143,204 participants without self-reported diabetes at enrollment completed baseline dietary assessment and were followed for 12.7±4.6 years. Risk of diabetes developing was 24% greater for women in the highest dietary energy density quintile compared with the lowest after adjusting for confounders (95% CI 1.17 to 1.32). Body mass index (calculated as kg/m^2) and waist circumference mediated the relationship between dietary energy density and diabetes. In waist circumference–stratified analysis, women in dietary energy density quintiles 2 to 5 with waist circumferences >88 cm were at 9% to 12% greater risk of diabetes developing compared with women with waist circumference ≤88 cm.

Conclusions In this prospective study, a higher baseline dietary energy density was associated with higher incidence of type 2 diabetes among postmenopausal women, both overall, and in women with elevated waist circumference.

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THE PREVALENCE OF DIABETES MELLITUS CONTINUES to increase, with tens of millions of new cases expected in the United States over the next 2 decades.[1] Adults aged 50 years and older comprise 65% of new diabetes cases in the United States, the majority of which are type 2.[2] Effective prevention strategies are needed to address this major public health challenge. While the management of obesity is considered to be the leading approach to reducing risk of type 2 diabetes,[3] not all overweight or obese adults desire to lose weight or are motivated to attempt weight loss. Many may attempt weight loss, but find long-term adherence to an energy-restricted diet challenging. In the absence of weight loss, following a healthy dietary pattern can reduce diabetes risk[4-7] and help manage existing disease.[8]

To support weight control, individuals must have an understanding of dietary quality as well as portion size. Dietary energy density, the ratio of energy (kcal) to food weight (g),[9] is an emerging approach to weight management in that it can provide a comprehensible and feasible approach to reduce energy intake. Specifically, foods can be defined as either low in energy density (eg, vegetables, whole grains, and beans) or high in energy density (eg, sugar-sweetened beverages, fried foods, and processed sweets). Several studies evaluating dietary energy density in relation to body weight in adults have shown that regular consumption of high dietary energy density foods predicts higher weight and waist circumference[10-13] and contributes to weight gain over time in normal weight and overweight adults.[11,14] Probable mechanisms include low satiation and greater palatability of high dietary energy density foods,[15] which are characterized by their high fat content and glycemic load and low fiber content, thereby contributing to passive overconsumption and higher total energy intake.[16,17]

While growing evidence suggests the effects of high dietary energy density diets on type 2 diabetes are largely mediated through body mass and body fat, it is possible that high dietary energy density diets also directly influence type 2 diabetes risk independently of weight and visceral adiposity. Limited epidemiological studies have assessed associations between dietary energy density of diets, type 2 diabetes, and other metabolic factors.[18,19] Biological plausibility for these relationships has been derived from experimental studies in which participants consuming high dietary energy density meals experienced negative metabolic effects, including decreased insulin sensitivity.[20] Two studies have prospectively investigated the relationship between dietary energy density and risk of type 2 diabetes within the same study population. A nested case–cohort study within the EPIC (European Prospective Investigation into Cancer) study of 340,234 older European adults did not find a significant association between dietary energy density and risk of type 2 diabetes,[21] while a region-specific study involving participants of the Norfolk EPIC cohort (n=21,919) showed 20% higher risk of diabetes per unit increase in dietary energy density (hazard ratio=1.2; 95% CI 1.05 to 1.37).[22]

The Women's Health Initiative Study (WHI)[23] affords an opportunity to assess the relationship between dietary energy density and incident type 2 diabetes in a large, ethnically and racially diverse population of postmenopausal women. Given the limited evidence of the relationship between dietary energy density and type 2 diabetes, investigating factors associated with incident diabetes in older women should provide a better understanding of whether dietary energy density can be considered as a preventive target. The objective of this study was to investigate the association between baseline dietary energy density and risk of incident type 2 diabetes in the WHI. Given previous literature suggesting that women with central adiposity may be at particularly high risk for incident diabetes,[24] the association between dietary energy density and incident type 2 diabetes among women with and without increased central adiposity as measured by waist circumference was also examined. The central hypothesis was that higher baseline dietary energy density would be associated with higher incidence of type 2 diabetes, both overall and in women with increased central adiposity.

METHODS

Study Design, Setting, and Participants

Healthy postmenopausal women age 50 to 79 years old were enrolled in the WHI at 1 of 40 clinical centers across the United States between 1993 and 1998. Recruitment methods have been described in detail elsewhere.[25] The study sample included 161,808 participants enrolled in the WHI Observational Study and in the three overlapping clinical trials (hormone therapy, dietary modification, and calcium plus vitamin D) prospectively followed for an average of 12 years or until earliest of treated type 2 diabetes, death, loss to follow-up, or end of study. Written informed consent was obtained from all study participants before study enrollment, and each of the trials was approved by the Institutional Review Boards of the 40 participating institutions.

Women excluded from the study included those with a history of diabetes at enrollment (n= 9,618), incident diabetes within the first year of follow-up (n= 589), or no follow-up data for the primary outcome of incident diabetes (n= 823). Additional exclusion criteria were implausible energy intake of <600 kcal or >5,000 kcal from the food frequency questionnaire (n=4,374), or body mass index (calculated as kg/m^2) <18.5 (n=1,298) or >50 (n=634), or missing (n=1,267). One individual was excluded for an extreme dietary energy density value. After these exclusions, the final study sample comprised 143,204 postmenopausal women.

Height, Weight, and Waist Circumference

Participants came to the study-designated clinical site at baseline to have weight, height, and waist circumferences measured by trained study personnel using standardized protocols and calibrated equipment.[26]

Type 2 Diabetes Outcomes Ascertainment

Type 2 diabetes was documented at baseline by self-report in which each woman was asked whether she had ever been told that she had "sugar diabetes" by her physician, with type 2 diabetes estimated by excluding participants who were diagnosed before 21 years of age. Incident diabetes during follow-up was documented by self-report at each semi-annual contact, when participants were asked, "Since the date given on the front of this form, has a doctor prescribed any of the following pills or treatments?" Choices included "pills for diabetes" and "insulin shots for diabetes." A WHI diabetes confirmation study has demonstrated consistency between these medical inventories and incident and prevalent diabetes.[27]

Dietary Assessment

Energy, nutrient, and food weight estimations were based on the dietary intake reported by participants, documented using the validated semi-quantitative WHI food frequency questionnaire (FFQ).[28] FFQs were collected during the baseline screening and reviewed by study staff for completeness before data processing. Data entry and nutrient analysis was conducted using the Nutrition Data Systems for Research software.[29] Food groups were determined using The MyPyramid Equivalents Database 2.0, which are food group measures based on the US Department of Agriculture's 2005 Food Guide Pyramid.[30]

Dietary Energy Density

The dietary energy density of a single food is defined as the ratio of its energy (kcal) content to its weight (g), and this ratio remains constant regardless of the amount consumed. There is no consensus on the optimal calculation of dietary energy density or what constitutes high or low dietary energy density. In general, foods with low or very low energy density—defined as those with energy density values between 0 and 1.5 kcal/g—are those naturally containing a higher volume of water (eg, vegetables, fruits, milk), while those of medium or high energy density—defined as those with energy density values >1.5 kcal/g—contain higher amounts of fats and sugar and less water by volume (eg, meat, cheese, grains, and nuts). Proposed methods of dietary energy density assessment primarily differ by the