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Diurnal eating rhythms: Association with long-term development of diabetes in the 1946 British birth cohort

S. Almoosawi [a,*], C.J. Prynne [a], R. Hardy [b], A.M. Stephen [a]

[a] MRC Human Nutrition Research, Elsie Widdowson Laboratory, 120 Fulbourn Road, Cambridge CB1 9NL, UK
[b] MRC Unit for Lifelong Health and Ageing, 33 Bedford Place, London WC1B 5JU, UK

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Abstract *Background and aims:* Few studies have described the association between time-of-day of macronutrient intake and diabetes. This study examined the prospective association between time-of-day and nutrient composition of eating occasions in relation to diabetes incidence in the 1946 British birth cohort.
Methods and results: The study included 1618 survey members who completed dietary assessment at age 43 (1989) and for whom data on glycosylated haemoglobin at age 53 years (1999) were available. Diet was assessed using 5d estimated diaries, divided into seven meal slots: breakfast, mid-morning, lunch, mid-afternoon, dinner, late evening and extras. Diabetes was defined by glycosylated haemoglobin (Hb_{A1c}) $\geq$ 6.5% or diabetes medication use. The association between time-of-day of macronutrient intake at age 43 years and diabetes at age 53 years was assessed using logistic multivariate nutrient density models after adjustment for potential confounders. There were 66 cases of diabetes at age 53 years. Survey members with diabetes obtained 50.4% of their energy from carbohydrate at breakfast compared to 55.9% in survey members without diabetes ($P = 0.001$). Increasing carbohydrate intake at breakfast at the expense of fat was related to lower odds ratio (OR) of diabetes (OR = 0.86; 95% CI = 0.79–0.93; $P < 0.001$). This relationship was attenuated after adjustment for body mass index and waist circumference.
Conclusion: Increasing energy intake from carbohydrate at the expense of fat at breakfast is inversely associated with 10-year diabetes incidence. However, further studies are required to elucidate whether the type or source of carbohydrates or fat influences the above association.

* Corresponding author. Tel.: +44 1223 437570.
E-mail address: suzana.almoosawi@mrc-hnr.cam.ac.uk (S. Almoosawi).

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Introduction

Diabetes affects more than 220 million worldwide and is one of the leading causes of mortality [1]. In the UK, diabetes affects over 2.8 million people with prevalence projected to rise to 4 million by 2025 [1]. The rapid increase in diabetes prevalence coincides with the epidemic rise in obesity. In fact, 90% of diabetes cases are due to type 2 diabetes, a condition largely associated with obesity, excess energy intake, high saturated fat intake, and a sedentary lifestyle [1].

To date, most epidemiological studies of dietary influences on diabetes risk have focused on the associations between individual foods, single nutrients or dietary patterns and glucose and insulin metabolism [2]. Only a few studies have assessed the effect of meal frequency [3–8], regularity [9], time-of-day of energy and nutrient intake on glycaemic control and insulin resistance [10]. In recent years, there has been growing evidence that when and how we eat is equally important to health as what we eat. Consistent with this, several studies have found a detrimental effect of night eating on a number of metabolic and cardiovascular parameters [11,12]. Similarly, breakfast consumption and its composition have been reported to influence daily energy intake and weight gain [13,14], factors that can contribute to the development of type 2 diabetes.

Both glucose and insulin homeostasis are modulated by circadian rhythms suggesting that the temporal distribution of energy and nutrients could be relevant to glycaemic control, hence type 2 diabetes prevention or treatment. Consumption of a standard mixed meal at night [15] or during simulated [16] or real night shift work [12] have been shown to induce greater glucose and insulin responses than consumption of the same meal during the day. These effects have been attributed to the progressive decline in glucose tolerance through the day [17]. Pancreatic β-cell responsivity to glucose [18] and sensitivity of peripheral tissues to insulin have also been found to be lower in the afternoon and dinner compared to morning [18,19].

We have previously reported that energy and macronutrient intake has shifted towards greater proportions of daily intake in the evening in the UK over the last decades [20] and that time-of-day of nutrient ingestion is related to long-term development of the metabolic syndrome [21]. The present study examined the prospective association between time-of-day and nutrient composition of eating occasions in relation to diabetes incidence in the 1946 British birth cohort.

Methods

Study population

The study population were members of the Medical Research Council (MRC) National Survey of Health and Development (NSHD), also known as the 1946 British Birth Cohort, a socially-stratified longitudinal cohort of 2815 men and 2547 women born in England, Scotland and Wales during one week of March 1946. Cohort members have been followed through the life course on twenty-two occasions until the most recent clinic visit. Medical, educational, social and lifestyle information were collected during home visits using various interview methods. Details of the cohort profile have been published previously [22]. The population interviewed at ages 43 and 53 years remains, in most respects, representative of the native-born population of similar age [23]. At age 43 years, 2280 survey members were interviewed. Of these, 511 had missing data on diabetes at age 53 years, 152 did not provide data on social occupation at age 43 years, 253 had missing data on smoking, 2 on region, 273 on BMI and 264 on waist circumference. 1650 had data for all covariates. Of the 1650 survey members, 17 cohort members were excluded because they reported having diabetes at age 43 years or younger and an additional 15 were removed because they completed less than 3 days of diet diaries. After these non-mutual exclusion, data from 1618 cohort members (830 men, 788 women) who completed at least 3 days of a diet diary at age 43 years (1989) and for whom data on glycosylated haemoglobin (Hb_{A1c}) or diabetes medication use was available at 53 years (1999) were included in the present analyses. Of these, 66 were classified as having diabetes based on the definition described below.

The present study was conducted according to the guidelines laid down in the Declaration of Helsinki. Ethical approval was obtained from the North Thames Multicentre Research Ethics Committee. NSHD data can be obtained from the NSHD Data Archive at http://www.nshd.mrc.ac.uk/data.aspx.

Diabetes

Diabetes was defined at age 53 years using the World Health Organisation Hb_{A1c} cut-off of 6.5% or on the basis of diabetes medication use or self-reported diabetes. Hb_{A1c} was measured in non-fasting venous blood by ion exchange chromatographic separation using high performance liquid chromatography Tosoh A1c-2.2 Analyser (Tosoh Bioscience, Tessenderlo, Belgium).

Dietary assessment

Details of the NSHD cohort and the dietary assessment methods have been published elsewhere [22]. All food and drink consumed both at home and away was recorded in 5-d estimated diaries. Portion sizes were estimated using household measures and photographs according to detailed guidance notes provided at the beginning of the diary. Diet diaries were divided into eight pre-defined meal slots: pre-breakfast, breakfast, mid-morning, lunch, mid-afternoon, dinner, late evening and extras. The "extras" time slot was developed to allow cohort members to record foods or drinks that may have been missed and not reported in other meal slots. For the purpose of the current analysis, the pre-breakfast and breakfast meal slots were combined because only 3% of the population reported eating >100 kcal during the pre-breakfast meal slot. Diet diaries at age 43 years were coded at the MRC Dunn Nutrition Unit using the in-house program Diet In Data Out (DIDO) and nutrient intake were estimated using a food composition database based on McCance and Widdowson's *The Composition of*