Appetite 108 (2017) 263–269

Contents lists available at ScienceDirect

Appetite

journal homepage: www.elsevier.com/locate/appet

Habitual chocolate intake and type 2 diabetes mellitus in the Maine-Syracuse Longitudinal Study: (1975–2010): Prospective observations

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ARTICLE INFO

Article history:
Received 29 July 2016
Received in revised form
4 October 2016
Accepted 5 October 2016
Available online 8 October 2016

Keywords:
Chocolate
Cocoa
Type 2 diabetes

ABSTRACT

Compounds in cocoa and chocolate have established cardiovascular benefits, including beneficial effects on insulin resistance, a risk factor for type 2 diabetes mellitus. The aims of this study was to investigate relations between habitual chocolate intakes and diabetes mellitus. Cross-sectional and prospective analyses were undertaken on 953 community-dwelling participants (mean age 62 years, 59% women) from the Maine-Syracuse Longitudinal Study (MSLS). Habitual chocolate intakes, measured using a food frequency questionnaire, were related to prevalence of diabetes mellitus (cross-sectionally) and with risk of diabetes measured approximately five years later (prospectively). We also examined the relation between diabetes (the predictor) and chocolate consumption (the outcome) up to 30 years later. Chocolate intake was inversely associated with type 2 diabetes. Compared to participants who consumed chocolate more than once per week, those who never or rarely ate chocolate exhibited a significantly higher odds of having type 2 diabetes 5 years later (OR: 1.91, 95% CI: 1.03, 3.55, $p = 0.04$), after adjustment for cardiovascular, lifestyle and dietary factors including other polyphenol-rich beverages. However, individuals diagnosed with diabetes prior to the nutritional assessment consumed lower amounts of chocolate at the time of the dietary assessment. Our findings suggest that relations between chocolate and type 2 diabetes may be bi-directional.

1. Introduction

Chocolate is a widely consumed food throughout the world, with particularly high intakes in the United States (Statista). With a rich natural complexity, it is commonly associated with pleasure and enjoyment, as well as having a wide-ranging number of medicinal benefits (Macht & Mueller, 2007; Wilson, 2010). More recent scientific interest has been directed at the cardiovascular benefits derived from chocolate and cocoa consumption (Grassi, Desideri, & Ferri, 2010; Heiss, Keen, & Kelm, 2010; Hooper et al., 2012). Flavonoids, naturally occurring polyphenolic compounds present in plant-based foods, represent up to 20% of the compounds present in cocoa beans (Sokolov, Pavlova, Klosterhalfen, & Enck, 2013), and may be responsible for the benefits to cardiovascular function (Grassi et al., 2010).

Interest in the biological and clinical effects of cocoa flavanols and cocoa-based products such as chocolate is increasing (Grassi et al., 2015; Hooper et al., 2012). To date, there here have been two large epidemiological analyses of the association between long-term chocolate intake and diabetes (Greenberg, 2015; Oba et al., 2010). In the United States, Greenberg (Greenberg, 2015) found an inverse association between frequency of chocolate consumption and diabetes risk over a 13-year follow-up in the prospective Atherosclerosis Risk in Communities Cohort (ARIC). A large analysis of over 13,000 Japanese individuals (Oba et al., 2010) showed a significant inverse association between the consumption of chocolate snacks and risk of diabetes among men, over a 10-year period. This research is supported by a number of short-term trials demonstrating that ingestion of dark chocolate (Grassi, Lippi, Necozione, Desideri, & Ferri, 2008, 2005) and cocoa flavanols (Davison, Coates, Buckley, & Howe, 2008) can improve insulin sensitivity, while a longer term trial has demonstrated that consumption of flavonoid rich chocolate for one year can reduce peripheral insulin resistance in women with type 2 diabetes (Curtis

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http://dx.doi.org/10.1016/j.appet.2016.10.008
0195-6663/

et al., 2012).

It may be hypothesised that diabetics however, avoid or limit their intake of high-sugar foods and sugar-sweetened beverages as a result of their diagnosis. Few, if any studies have asked if the association between chocolate intake and diabetes occurs because knowledgeable and treated diabetics limit their chocolate intake. Longitudinal prospective data are necessary to answer this question.

Using data collected from participants in the Maine-Syracuse Longitudinal Study (MSLS), residents of Central New York, USA, the aim of the present study was to determine 1) whether habitual chocolate intakes were associated with diabetes mellitus, with control for cardiovascular, lifestyle and dietary factors; and 2) whether pre-existing diabetes was related to chocolate intake assessed up to 30 years later.

2. Materials and methods

2.1. Participants

The MSLS was a study of cardiovascular risk factors and cognitive functioning in community living adults (Elias et al., 2009; Robbins, Elias, Elias, & Budge, 2005). The MSLS consists of five cohorts defined by time of entry into the study (1975–2000). The MSLS employs a time-lagged-longitudinal-cohort design with new subjects featuring an initial wave of data collection and then new subjects recruited into the study every five years with the same recruitment procedures as employed for every wave.

At initial recruitment, participants were living independently in Syracuse, New York or in the adjacent Central New York area. The only exclusions at recruitment were diagnosis of or treatment for psychiatric illness, alcoholism and inability to comprehend English.

The present study utilized data from participants at waves 1 to 5 (1975–2000), 6 (2001–2006) and 7 (2006–2010). Dietary data were collected for the first time at wave 6. At wave 6, participants were excluded for the following reasons: missing data on nutritional or health variables ($n = 58$), history of acute stroke ($n = 28$), probable dementia ($n = 8$), undertaking renal dialysis treatment ($n = 5$), inability to read English ($n = 1$), prior alcohol abuse ($n = 1$), and not participating in the diabetes outcome study ($n = 16$), leaving a sample of 956 study participants. Of these 956 participants with dietary data at wave 6, 953 individuals also had diabetes data at waves 1 to 5. This allowed for a prospective design in which diabetes status at waves 1 to 5 was used to predict chocolate intake at wave 6, as well as a cross-sectional examination of the relation between chocolate consumption and diabetes status at wave 6. Of those who participated at wave 6, the mean time period of participation leading up to wave 6 was 11.3 ± 7.7 years.

Eight-hundred twenty-two subjects who provided cross-sectional data on chocolate and diabetes (outcome) at wave 6 were invited back to the laboratory for testing at wave 7. Six-hundred nine participants completed data collection. Nineteen participants had incomplete data at wave 7 and were excluded leaving a sample of 590. This allowed for prospective analyses in which chocolate intakes at wave 6 were used to predict diabetes at wave 7. Mean time between waves 6 and 7 was 4.7 ± 0.6 years. The MSLS study design is shown in Fig. 1.

Stroke, defined as a focal neurological deficit of acute onset persisting more than 24 h, was based on self-report and was confirmed by a record review indicating a diagnosis of acute stroke. Clinical diagnoses of dementia were determined from cognitive data and medical records using the National Institute of Neurological and Communicative Diseases and Stroke/Alzheimer's Disease and Related Disorders Association (NINCDS-ADRDA) criteria (McKhann et al., 1984) and confirmed using the ICD-10 Guidelines (World Health Organization, 1992).

This study was conducted according to the guidelines established by the Declaration of Helsinki and all procedures were approved by the University of Maine Institutional Review Board. Written informed consent was obtained from all subjects.

2.2. Procedure and assessment

2.2.1. Dietary intake

Dietary intake was assessed using the Nutrition and Health Questionnaire, (Kaaks & Riboli, 1997; Riboli & Kaaks, 1997), in which participants were required to stipulate how frequently they consume foods including meat, fish, eggs, breads, cereals, rice and pasta, fruit, vegetables, dairy foods, chocolate, nuts, other snack-type foods, and beverages including alcohol. Participants were required to stipulate how frequently they currently consume each food, from six response options: never, seldom, once/week, 2–4 times/week, 5–6 times/week, and once or more per day. The dietary data was therefore a reflection of nutritional habits at the time of data collection (i.e. at wave 6).

The median score within each response option was used to estimate total intakes per week of the major food groups and total energy; for example, 2–4 times per week was estimated at 3. The mean number of times each food was consumed on a daily basis was calculated for all foods in the questionnaire. As portion sizes were not stipulated to participants, these totals are an estimate of the number of *times* each food was consumed. Foods were categorised into one of five major food groups - grains, fruits, vegetables, protein foods, and dairy foods - based on the USDA Food Guide Pyramid (United States Department of Agriculture, 2011). Chocolate intake was categorised into three intake groups: <1 serve per week, 1 serve per week, and >1 serve per week. Chocolate was not differentiated according to type, i.e. dark, milk, or white chocolate.

2.2.2. Diabetes assessment

Standard assay methods were employed (Elias et al., 2006) to obtain fasting plasma glucose (mg/dL), in addition to total cholesterol (TC, mg/dL), low-density lipoprotein cholesterol (LDL, mg/dL), high-density lipoprotein cholesterol (HDL, mg/dL), triglycerides (mg/dL) and C-reactive protein (CRP, mg/L), following an overnight fast. Diabetes mellitus was defined as fasting glucose level of ≥126 mg/dL, being treated with anti-diabetic medication following a medical diagnosis of diabetes.

2.2.3. Demographics and physical health assessment

Demographic, socioeconomic and lifestyle characteristics were obtained from the Nutrition and Health Questionnaire (Kaaks & Riboli, 1997; Riboli & Kaaks, 1997). Data obtained included smoking history, marital status and medical history. Physical activity was measured with the Nurses' Health Study Activity Questionnaire, a validated measure of time spent engaging in various physical activities (Wolf et al., 1994). Education level was obtained through self-report and ranged from 4 to 20 years.

Body weight was measured with participants wearing light clothing to the nearest 0.1 kg, and height was measured with a vertical ruler to the nearest 0.1 cm. Body mass index (BMI) was calculated as weight in kilograms divided by height in metres squared. Waist circumference (in centimetres) was taken over light clothing, using a non-extendable measuring tape, at the level of the iliac crest. Obesity was defined as BMI ≥30 kg/m^2, and cardiovascular disease (CVD) was based upon self-reported history of coronary artery disease, myocardial infarction, congestive heart failure, transient ischemic attack, or angina pectoris, confirmed by medical records. Automated blood pressure (BP) measures (GE DINAMAP