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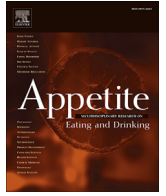Part of the Dietetics and Clinical Nutrition Commons, and the Health Psychology Commons

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

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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.

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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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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.
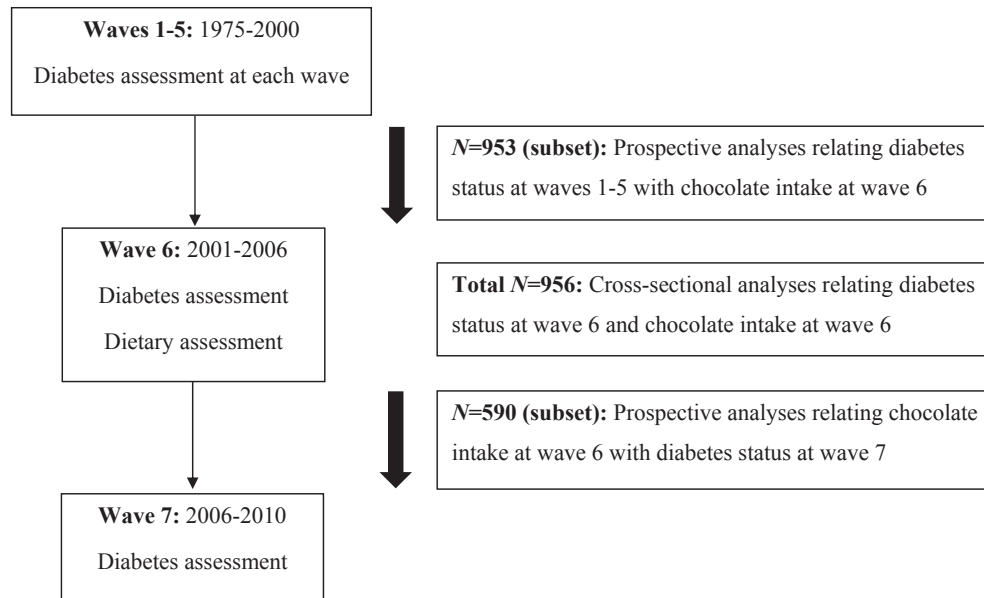
2.2.2. Diabetes assessment

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

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┌─────────────────────────────────┐
│ Waves 1-5: 1975-2000            │
│                                 │
│ Diabetes assessment at each wave│
└─────────────────────────────────┘
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N=953 (subset): Prospective analyses relating diabetes status at waves 1-5 with chocolate intake at wave 6

```
┌─────────────────────────────────┐
│ Wave 6: 2001-2006               │
│                                 │
│ Diabetes assessment             │
│                                 │
│ Dietary assessment              │
└─────────────────────────────────┘
```

Total N=956: Cross-sectional analyses relating diabetes status at wave 6 and chocolate intake at wave 6

N=590 (subset): Prospective analyses relating chocolate intake at wave 6 with diabetes status at wave 7

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┌─────────────────────────────────┐
│ Wave 7: 2006-2010               │
│                                 │
│ Diabetes assessment             │
└─────────────────────────────────┘
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Fig. 1. Flow diagram of the MSLS study design. Sample sizes at waves 1–5 and 7 are subsets of the total sample at these waves and represent the number of participants with available data at wave 6 also.

100DPC-120XEN, GE Healthcare) were taken in the right arm five times each in recumbent, standing and sitting position after a supine rest for 15 min, and the 15 values were averaged for systolic and diastolic BP. Hypertension was defined as BP of $\geq$140/90 mmHg, or on medication.

2.3. Statistical analyses

Participant demographics, health and dietary variables at wave 6 were compared according to diabetes status (Y/N) at waves 1 to 5 (Table 1) and diabetic status at wave 6. Independent samples t-tests were used for continuous variables and Chi-square for categorical variables for the comparative analyses of demographic, health and dietary variables. Normality of distribution for all health and dietary variables was ascertained by visual inspection of the histograms describing the distribution of scores.

For the cross-sectional and prospective analyses, logistic regression (categorical regression analyses) was used to relate chocolate intakes with the likelihood of having diabetes mellitus. Diabetes status was compared across three chocolate intake categories: <1 serve per week, 1 serve per week, and >1 serve per week. The highest chocolate intake group served as the reference group. Three covariate models were used to adjust for confounding; these variables were selected based upon correlational analyses (related significantly to chocolate intake and diabetes) or theoretical justification. Other polyphenol-rich foods and beverages (such as tea, coffee, red wine, fruit) were included in the final model if they correlated with either the predictor (chocolate intake) or outcome (diabetes status at wave 6). The following models were employed for all analyses:

Model 1: Basic: age (years) + gender + education (years) + ethnicity;

Extended 1: Basic + total cholesterol (mg/dL), obesity (Y/N), hypertension (Y/N), C-reactive protein (CRP; mg/L);

Extended 2: adjusted for Basic, Extended 1 + physical activity (MET-hours/day), total grains (serves/day), coffee (cups/day), red wine (glasses/week).

In our final step, we used general linear modelling to assess whether pre-existing diabetes (at waves 1–5) predicted chocolate intake between 5 and 30 years later (wave 6).

Except for sensitivity analyses the same covariates were taken from the examination in which chocolate consumption was assessed, wave 6. All statistical analyses were performed with PASW for Windows® version 21.0 software (formerly SPSS Statistics Inc. Chicago, IL, USA); $P < 0.05$ was considered statistically significant.

3. Results

3.1. Participant characteristics and chocolate consumption

Table 1 shows the demographic, health-related variables, and dietary intakes for MSLS participants ($N = 953$) at wave 6, according to diabetes status at waves 1 to 5 (Y/N). Those with diabetes had significantly higher BMI, glucose levels, systolic blood pressure and CRP, but lower total cholesterol than those without diabetes. A significantly higher proportion of diabetics were obese, had CVD and hypertension, compared with non-diabetics. Diabetics consumed more grains and diet soft drinks, but less chocolate, sweets and alcohol than non-diabetics. A comparison of diabetics and non-diabetics at wave 6 showed the same differences in terms of health characteristics and dietary habits.

3.2. Chocolate consumption and diabetes in the MSLS: cross-sectional and prospective

Chocolate intake was inversely associated with type 2 diabetes (Table 2). Cross-sectionally, the prevalence of type 2 diabetes was over twice as high in those who consumed chocolate less than once per week compared to those who ate chocolate more than once per week (OR: 2.15, 95% CI: 1.27, 3.67, $p = 0.005$; extended 2 model), with full adjustment for cardiovascular risk factors, obesity, physical activity and other dietary factors, including red wine and coffee.

Prospectively, individuals who consumed chocolate never or rarely had nearly double the risk of having type 2 diabetes approximately 5 years later (OR: 1.91, 95% CI: 1.03, 3.55, $p = 0.040$), compared to those who ate chocolate more than once per week (with full statistical adjustment).

Table 1
Demographic, health and nutritional factors at wave 6, according to diabetes status at waves 1—5, in the MSLS sample (N = 953).

Variable (at wave 6)	Diabetes[a] status (at waves 1—5)				
	No (n = 908, 95.3%)		Yes (n = 45, 4.6%)		p-value[*]
	Mean	SD	Mean	SD	
Age, years	62.1	12.7	66.0	10.7	0.042
Education, years	14.8	2.7	13.3	2.3	<0.001
Smoking, cigarettes/day	1.3	5.3	0.3	2.2	0.2
Body mass index, kg/m^2	29.1	5.6	32.8	9.2	<0.001
Physical activity, MET-hrs/week	21.0	28.0	13.0	18.8	0.06
Total cholesterol, mg/dL	203	39.6	179	32.4	<0.001
HDL cholesterol, mg/dL	53.9	15.5	46.6	11.8	0.002
LDL cholesterol, mg/dL	122	33.3	103	29.5	<0.001
Systolic blood pressure, mm Hg	130	21.5	140	23.8	0.004
Diastolic blood pressure, mm Hg	70.4	10.1	69.8	9.1	0.7
Fasting blood glucose, mg/dL	96.6	23.5	147	59.0	<0.001
Triglycerides, mg/dL	143 (median 115)	114	148 (median 127)	76.9	0.8
C-reactive protein, mg/L	0.41 (median 0.25)	0.47	0.61 (median 0.34)	0.62	0.006
Dietary variables					
Chocolate intake, times/week	2.0	1.8	1.2	1.5	0.009
Total grains, serves/day	3.7	2.0	4.4	2.4	0.036
Total meats, serves/day	2.0	0.9	2.3	0.9	0.1
Total fruit, serves/day	1.6	1.0	1.7	1.0	0.5
Total vegetables, serves/day	2.8	1.1	2.5	1.0	0.1
Total dairy foods, serves/day	2.0	1.1	2.1	1.1	0.5
Total sweets, serves/day	2.5	2.2	1.6	1.4	0.004
Regular soft drinks, glasses/day	0.4	1.1	0.3	0.5	0.5
Diet soft drinks, glasses/day	0.5	1.2	1.2	1.9	<0.001
Alcohol, g/week	37.8	71.3	11.8	29.7	0.015
Total intake, total serves/day all food groups	14.8	4.6	14.6	4.5	0.8
	n	%	n	%	p-values[*]
Gender					0.2
Males	367	40.4	23	51.1	
Females	541	59.6	22	48.9	
Ethnicity					0.037
African American	52	5.7	6	13.3	
Other	856	94.3	39	86.7	
Obesity[c] at wave 6	322	37.2	25	56.8	0.009
CVD[b] at wave 6	123	13.5	15	33.3	<0.001
Hypertension[d]	550	60.6	39	86.7	<0.001

Abbreviations: CVD, cardiovascular disease; HDL, high-density lipoprotein; LDL, low-density lipoprotein; MET, metabolic equivalent.
[*]P-values were obtained by analysis of variance for continuous variables or the chi-square test for categorical variables.
[a] Diabetes mellitus defined as fasting glucose level of ≥126 mg/dL, or being treated with anti-diabetic medication.
[b] CVD based upon self-reported history of coronary artery disease, myocardial infarction, congestive heart failure, transient ischemic attack, or angina pectoris, confirmed by medical records.
[c] Obesity defined as BMI ≥30 kg/m^2.
[d] Hypertension defined as BP ≥ 140/90 mmHg or being treated with anti-hypertensive medication.

3.3. Chocolate consumption and incident diabetes

The odds ratios associated with incident diabetes (new cases at wave 7 compared to wave 6) were not significantly different as a function of level of chocolate consumption (all p values > 0.05). Mean chocolate intakes were slightly lower amongst those who did develop diabetes (n = 30; mean chocolate intake = 1.7 ± 1.9 serves/week) compared to those who did not develop diabetes (n = 498; mean chocolate intake = 2.0 ± 1.8 serves/week) in this 5-year time period (p = 0.4). Of those individuals who did develop diabetes between waves 6 and 7, 30% consumed chocolate more than once per week; whilst 41% of individuals who did not go on to develop diabetes consumed chocolate more than once per week.

3.4. Pre-existing diabetes and chocolate consumption: prospective

Nearly 5% of participants at waves 1 to 5 had type 2 diabetes. As shown in Table 3, those with diabetes at these earlier waves ate significantly less chocolate at wave 6 than those without diabetes.

Statistically adjusting for demographic, health and dietary factors, including physical activity and intakes of coffee and red wine, those without diabetes ate chocolate approximately twice per week; compared to a mean intake of 1.2 serves per week by diabetics (fully extended model, p = 0.009). The same significant difference in mean wave 6 chocolate intakes were observed when we eliminated diabetics at waves 1 to 4, and performed the analyses comparing non-diabetics with persons who were diagnosed as diabetic at wave 5 (approximately 5 years between waves, data not shown).

3.5. Test of interactions and sensitivity analyses

Tests for interactions (multiplicative effects) with age, sex, and BMI were done. In each case the main effect of the risk factor was included in the model with the interaction term and the basic model was employed. Interaction tests were not statistically significant (p > 0.05). Replacing obesity (Y/N) with BMI (kg/m^2) and waist circumference in all models did not alter the results, and neither did replacing total cholesterol with HDL- and LDL-

Table 2
Odds of having diabetes at waves 6 (cross-sectional) and 7 (prospective), according to chocolate intake at wave 6 in the MSLS.

Model[a]	Chocolate intake group	Diabetes[b] wave 6 (N = 956)			Diabetes[b] wave 7 (N = 560)		
		OR	95% CI	p	OR	95% CI	p
Basic	<1 serve/week	1.92	1.15, 3.20	0.012	2.08	1.20, 3.61	0.010
	1 serve/week	1.39	0.80, 2.44	0.2	1.18	0.63, 2.22	0.6
	>1 serve/week	1.00			1.00		
Extended 1	<1 serve/week	2.01	1.17, 3.47	0.012	1.98	1.10, 3.57	0.023
	1 serve/week	1.25	0.68, 2.33	0.5	1.16	0.60, 2.27	0.7
	>1 serve/week	1.00			1.00		
Extended 2	<1 serve/week	2.15	1.27, 3.67	0.005	1.91	1.03, 3.55	0.040
	1 serve/week	1.23	0.67, 2.29	0.5	1.27	0.64, 2.52	0.5
	>1 serve/week	1.00			1.00		

Abbreviations: CI, confidence interval; OR, odds ratio.

[a] Basic: adjusted for age, education, sex, ethnicity; Extended 1: adjusted for Basic + total cholesterol (mg/dL), obesity (Y/N), hypertension (Y/N), CRP (mg/L); Extended 2: adjusted for Basic, Extended 1 + physical activity (MET-hours/day), total grains (serves/day), coffee (cups/day), red wine (glasses/week).

[b] Diabetes: ≥126 mg/dL or on anti-diabetic medication.

cholesterol. Replacing hypertension with systolic and diastolic BP (mmHg) in the statistical models did not alter the results. The main cross-sectional and prospective results remained unchanged when participants with CVD at wave 6 were excluded.

4. Discussion

The present study suggests an inverse association between chocolate consumption and diabetes. The findings indicate that those who consume moderate amounts of chocolate are at lower risk for diabetes mellitus. This was seen in the cross-sectional analysis conducted at wave 6, and prospectively between waves 6 and 7, following full adjustment for other polyphenol-rich beverages including coffee and red wine.

Two large epidemiological studies support the notion that consuming a moderate amount of chocolate may reduce the risk of diabetes (Greenberg, 2015; Oba et al., 2010). Data from 7802 ARIC participants showed that compared to individuals who ate 1 oz. (28 g) of chocolate less than once per month, those who ate it at least monthly had significantly reduced risk of being diagnosed with diabetes over 10 years (Greenberg, 2015). The greatest risk reduction of 34% was observed for those who consumed chocolate 2 to 6 times per week. Consuming chocolate more than once per day did not lower the risk further. This is consistent with the viewpoint that the added fat and calories in chocolate beyond a moderate intake may override the positive effects of the cocoa flavanols in chocolate. As for our study, the type of chocolate consumed (dark/milk/white) was not specified.

In a large Japanese study, Oba et al (Oba et al., 2010). examined the risk of diabetes in relation to the consumption of a number of

Table 3
Multivariate-adjusted mean and standard error for chocolate intake (times per week) at wave 6, according to diabetes status (N = 953) at waves 1-5.

Diabetes status, waves 1-5					
Model	No (n = 908, 95.3%)		Yes (n = 45, 4.6%)		p[a]
	Mean	95% CI	Mean	95% CI	
Basic[b]	2.00	1.85, 2.07	1.34	0.80, 1.87	0.029
Extended 1	1.97	1.85, 2.10	1.42	0.86, 1.97	0.05
Extended 2	1.98	1.84, 2.11	1.15	0.55, 1.75	0.009

Values are mean and 95% confidence interval (CI) for chocolate intake (times per week).

[a] p for difference between means.

[b] Basic: adjusted for age, education, sex, ethnicity; Extended 1: adjusted for Basic + total cholesterol (mg/dL), obesity (Y/N), hypertension (Y/N), CRP (mg/L); Extended 2: adjusted for Basic, Extended 1 + physical activity (MET-hours/day), total grains (serves/day), coffee (cups/day), red wine (glasses/week).

high-caffeine foods and beverages, including coffee, tea and chocolate. A 35% reduced risk for diabetes was observed in men who consumed chocolate at least once per week, compared to those who ate chocolate never or almost never. Similar associations were implied in women. These two studies, suggest that the greatest risk reduction may be observed amongst moderate chocolate consumers (at least once per week).

Supporting these studies, two thorough, recent reviews of the literature (Grassi et al., 2015; Hooper et al., 2012) suggest that cocoa and chocolate may offer cardiometabolic protection. The positive effects of chocolate are attributed to the cocoa flavanols. Epidemiological and clinical studies have repeatedly shown that high-flavonoid foods can improve endothelial function, as assessed by flow mediated dilatation, by elevating NO bioavailability and bioactivity (Grassi et al., 2009, 2010, 2013). Conditions of insulin resistance, such as diabetic states, are usually linked to endothelial dysfunction and decreased NO bioavailability. Our findings remained with the addition of coffee and red wine, which both contain polyphenols (Carluccio et al., 2003; Hecimovic, Belscak-Cvitanovic, Horzic, & Komes, 2011).

Larger, longer-term clinical trials to confirm the possible cardiovascular benefits derived from cocoa and chocolate consumption have been recommended (Grassi et al., 2015; Hooper et al., 2012). For example, it is unknown whether the high energy, sugar, and fat content of chocolate may weaken or nullify the benefits of cocoa. More attention needs to be paid to the flavanol concentration, sugar and calorie content of cocoa-based foods such as chocolate (Grassi et al., 2015).

Our findings when we related wave 1–5 diabetes status to chocolate consumption at wave 6 do raise the possibility that relationships between chocolate and diabetes may, in part, reflect a practice in which diabetics choose to eat less chocolate for health reasons. Those who were diabetic at waves 1 to 5 consumed less chocolate at wave 6. The chocolate-diabetes relation may be bidirectional. This may be likened to inactivity foreshadowing obesity but obesity being associated with poorer lifestyle habits such as lower levels of physical activity, smoking and drinking more alcohol (Crichton et al., 2014; Goday et al., 2016). At wave 6, the diabetic individuals consumed fewer sweets, less alcohol and more diet soft drinks and grains than non-diabetics; these practices are consistent with limiting chocolate consumption. These practices are also consistent with nutritional recommendations made for diabetics during this period of time (1975–2000). Until only recently, sugar was 'forbidden' for diabetics, with recommendations based on tradition rather than evidence (Wheeler, 2000). Diabetes nutrition recommendations have cycled between greater and lesser amounts of different foods, food groups, and

macronutrients throughout the history of diabetes nutrition therapy, ranging from starvation treatment in 1915 to evidence-based recommendations made in 2002 (Franz, 2004; Franz et al., 2002, 2003). The most commonly held food belief was that diabetics should avoid added sugars and sweets, and restrict naturally occurring sugars, based on the assumption that sucrose and other sugars would aggravate hyperglycaemia as they are more rapidly digested and absorbed, and cause a greater increase in blood sugar levels than starches (Franz et al., 2003). During the period of time in which waves 1 to 5 were conducted, this was the prevalent belief. Clinical trials have subsequently demonstrated that it is the total amount of carbohydrate consumed that is more important than the source or type, (Franz et al., 2002). Nutrition goals for diabetes are therefore similar to those all individuals should strive for to achieve a balanced and healthy diet, with consideration given to total caloric intake in relation to energy needs (American Diabetes Association, 2008). Our investigation of the literature indicates a number of studies that have not taken this dietary modification possibility into consideration, and in our view, it cannot be ruled out in the absence of clinical trials.

Several limitations of the present study must be acknowledged. Dietary data were only obtained at wave 6, so we are unable to examine any change in chocolate intakes over time in relation to diabetes status at waves 1—5. Chocolate intake was self-reported, and therefore subject to inherent reporting error. The dietary questionnaire used did not require the respondent to differentiate between dark, milk or white chocolate. Most clinical trials have used dark chocolate as the source of cocoa flavanols. In 2012, the distribution share of chocolate in the United States by favourite chocolate type was 57% milk chocolate, 35% dark chocolate, and 8% white chocolate (Statista). We can therefore make the assumption that the majority of chocolate consumed in this sample was dark or milk, both containing cocoa flavanols to varying degrees. It is certainly plausible that the findings are driven by those consuming milk or dark chocolate only. We are unable to calculate the actual quantities of chocolate and cocoa associated with diabetes status, due to the nature of the questionnaire. Finally, covariates were used from wave 6, as not all health variables, such as CVD, were collected at earlier waves, and oral glucose tolerance testing was not performed at any waves of the MSLS.

We were able to statistically control for a number of cardiovascular, lifestyle and dietary variables that may confound the association between habitual chocolate consumption and health outcomes such as diabetes. We were able to examine cross-sectional and prospective relations between diet and health. Importantly, we were able to consider whether persons with diabetes consumed less chocolate 4—30 years later. Moreover there is evidence that they modified aspects of their diet in a way consistent with reduction of intake of sweets as one would expect of diabetic individuals during the time period represented at waves 1—5 (1975—2000).

5. Conclusions

Clinical trials are necessary to further explore relations between diabetes and chocolate, with consideration given to type, nutritional content and quantity. Relations may reflect both self-selection away from chocolate and the adverse influence of low chocolate levels on prevalent diabetes. A moderate chocolate intake of several times per week may be related to the reduction of the incidence (new cases) of diabetes mellitus, but it is also possible that those diagnosed with diabetes limit or avoid chocolate. Further studies are necessary to examine the influence of chocolate consumption on diabetes mellitus and behavior around food choices.

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