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Trends in Dietary Fat Intake and High-Fat Foods from 1991-2008 in the Framingham Heart Study participants

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Abstract

Few longitudinal studies among US adults have evaluated long-term dietary fat intakes and compared them to national recommendations during the 2-decade period when the prevalence of obesity and insulin resistance increased substantively. We examined trends in dietary fat intake and rich dietary sources of fats in the Framingham Heart Study Offspring Cohort over a 17-year period. The cohort was established in 1971-75 with follow-up examinations approximately every 4 years. Dietary data were collected using a semi-quantitative food frequency questionnaire beginning in 1991 (Exam 5). We included 2,732 adults ages ≥25y with complete dietary data in at least three exams from 1991-2008. Descriptive statistics were generated using SASv9.3 and a repeated measures model was used to examine trends in macronutrient and food intake using R. Over 17-years of follow-up, the %energy from total fat and protein increased (27.3-29.8% energy and 16.8-18.0% energy respectively) and %energy from carbohydrate decreased (51.0-46.8% energy;p-trend<0.001). Increases were seen in all fat subtypes except for trans-fats, which decreased over time (p-trend<0.001). Trends were similar between sexes, although women had a greater increase in %energy from saturated fats and less reduction in %energy from trans-fats (p-interaction<0.05). Trends of fat intakes were similar across BMI categories. Weekly servings of cheese, eggs, ice cream desserts, nuts, butter, and sausages/processed meats increased, whereas intake of milk, margarine, poultry, confectioneries, chips and breads decreased(p-trend<0.001). In

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this cohort of predominantly Caucasian older adults, %energy from dietary fat increased over time but remained within national recommendations of <35% of total energy, on average.

Keywords

dietary fat; trends; Framingham Heart Study; longitudinal

INTRODUCTION

The prevalence of obesity has increased dramatically in the recent past in the U.S. and remains a significant public health concern with nearly 35% of the adult population meeting the clinical criteria for obesity[1; 2]. At present, it is unclear whether the macronutrient composition of the diet contributes to body weight. However, it has been hypothesized that greater dietary fat consumption is related to energy imbalance because it is the most energy-dense macronutrient[3]. Additionally, some types of dietary fats have been implicated in the inflammatory processes that contribute to chronic disease burden[4]. Despite the known adverse consequences of excess dietary fat intake, it is unclear whether recommendations to reduce dietary fat influence its consumption. In response to consistent recommendations to reduce dietary fat intake and accompanying consumer demand, more than 3,400 low-fat and fat-free products were introduced into the marketplace in the 1990's[5]. Consequently, health claims and low-fat labeling[6] may increase energy intake perhaps by encouraging consumers to select larger portions of foods they perceive to be less energy dense[7]. This may adversely or favorably influence fat intake.

Few longitudinal studies in the U.S. have evaluated long-term dietary fat intakes in adults or among lean, overweight, and obese participants[3]. Longitudinal observations may provide insights into how changes in the dietary composition of a population parallel shifts in national dietary recommendations and concomitant changes in the food environment, such as the introduction of low-fat products into the market[8]. The objective of the present study was to examine trends in dietary fat intake and foods rich in fat among participants in the Framingham Heart Study (FHS) Offspring Cohort from 1991-2008, representing a 17-year period. The availability of serially collected dietary and anthropometric data in the Offspring cohort provides a unique opportunity to investigate changes in dietary patterns during middle through older adulthood, which represents a critical window of exposure to risk factors that influence chronic disease pathophysiology. The current study encompasses a period in the U.S. when dietary recommendations consistently emphasized reductions in dietary fat intake[9].

METHODS

Study Population

The FHS Offspring Cohort—The FHS is an ongoing study based in Framingham, Massachusetts, consisting of ~14,000 adults recruited from three familial generations initiated in 1948-1953[10]. The first generation of participants, referred to as the Original Cohort, consists of a primarily Caucasian sample of men and women aged 30-62 years

(n=5,209)[11]. The second generation of participants (the Offspring cohort) consisted of children of the original cohort and their spouses (n=5,124 adults), and began in 1971-1975. Clinic exams were conducted on average every four years for the Offspring cohort and the latest exam was performed in 2008[12]. The details of the FHS have been published[10; 11; 13]. All research activities adhered to the ethical standards of New York University's Institutional Review Board for the analysis of secondary data (IRB #10-0555). The Framingham Study is conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects were approved by the Institutional Review Board of Boston University Medical Center. Written informed consent was obtained from all Framingham Study participants.

Analyses Dataset—The present analyses included participants from the Offspring cohort who were at least 25 years of age by Exam 5 and who completed at least three of four dietary assessments from 1991-2008. Collection of dietary data using the food frequency questionnaire (FFQ) was first initiated in 1991 corresponding to Exam 5, at which point, 981 participants had been lost to follow-up. An additional 810 participants were excluded because they did not complete at least 3 dietary questionnaires or had 13 or more blanks on the FFQ. Participants who reported energy intakes <600 or >4,000 kcal/day were considered as having invalid dietary data and were further excluded (n=446). Our final analytical dataset consisted of 2,887 men and women with valid dietary data (70% of those who attended Exam 5).

Data Collection

Assessment of Dietary Intake: Diet was assessed a total of four times (Exams 5-8) since 1991 (***Figure 1***) using the validated 131-item Harvard semi-quantitative FFQ that queried the intake of foods with standard serving sizes[14]. The FFQs were mailed to participants and reviewed with them for accuracy by trained personnel at the study visit. The participants reported their food intake and frequency of consumption, ranging from never or <1 serving/month to ≥6 servings/day, for the past year. The FHS derived weekly servings by using these categorical responses. The United States Department of Agriculture Nutrient database[15] was used in conjunction with the FFQ and was updated continuously to reflect changes in the food supply over time. [16]

Other covariates: Fasting blood glucose was assessed at clinic examinations. Impaired fasting blood glucose was defined as concentrations ≥110 mg/dl[17] in these analyses. Height and weight were measured by trained personnel at each visit and were used to calculate BMI. Other variables including age, education, and smoking status were self-reported at each exam, with the exception of education, which was self-reported once at Exam 2.

Statistical analyses—First, baseline (exam 5) descriptive characteristics including means and standard deviations (SD) were computed using SAS v.9.3[18]. Next, trends in dietary fats and intakes of high-fat foods over time, among men and women were evaluated using the longitudinal nature of the data. These analyses were conducted using the statistical package R.[19] The dietary trends were evaluated using a repeated measures model with subject-specific random intercepts to account for serial correlation. All p-values for trends

and interactions were derived from such models. We made an *a priori* decision to stratify the analyses by sex and BMI because of its potential clinical significance. Therefore we re-examined trends stratified by the following BMI categories: normal:≥18.5-24.9 kg/m^2,overweight:≥25-29.9 kg/m^2,obese:≥30 kg/$m^{2(20)}$. Bonferroni corrections were applied to subgroup analyses in order to correct for multiple comparisons.

RESULTS

Participant Characteristics at Exam 5

Participant characteristics at Exam 5 of the Offspring cohort are expressed as either percentages for categorical variables or means with their corresponding SD for continuous variables **(*Table 1*)**. The mean age of men was 54.4 years and the mean age of women was 53.9 years at Exam 5. At Exam 8, the mean age of both sexes was 66.8 years. On average, the population was educated beyond high school. Mean BMI at Exam 5 was 28.2 kg/m^2 in men and 26.5 kg/m^2 in women; 23% of participants were obese and 13% had impaired fasting glucose. At Exam 5, fewer than 20% of participants reported smoking over the past year.

Trends in Dietary Fat and Macronutrient Intake in Men and Women

The percentage of energy from total fat increased in the overall population (27.3%-29.8%), and in men (27.5%-29.7%) and women (27.2%-29.9%)(***Table 2***). The percentage of energy from animal fat (16.1%-17.2%), vegetable fat (14.9%-15.8%), saturated fat (10.4%-11.1%), polyunsaturated fat (5.7%-6.3%), monounsaturated fat (11.1%-12.4%), and omega-3 fats (0.1% -0.2%)) also increased in both sexes and in the population from Exams 5 through 8 (p-trend<0.01). The only exception was for trans-fats, which decreased in both men (1.6%-1.2%) and women (1.5%-1.2%) (p-trend<0.01). The percentage of energy from carbohydrate intake decreased among both men (50.1%-46.0% of energy) and women (51.7%-47.4% of energy) while protein intake (16.1%-17.3% of energy and 17.5%-18.5% of energy, respectively) increased (p-trend<0.01). We also observed significant interactions by sex for saturated fat with women reporting a greater increase in saturated fat intake (% of energy) over time compared to men (β=0.32 vs. 0.22, p<0.01) and for trans-fat with men reporting a greater decrease in trans-fat intake (% of energy) over time compared to women (β= −0.13 vs. −0.09, p<0.01) (***Table 2***). There was no statistical evidence of differences between men and women for trends in intake of any other fats.

Trends in Dietary Fat and Macronutrient Intake in Normal Weight, Overweight, and Obese Participants

Trends in dietary fat intake were also stratified by BMI category (***Table 3***). As in the main analysis (Table 2), the percent of energy consumed as fat and protein increased over time in all BMI categories (p-trend<0.01), while the percent of energy from carbohydrate decreased (p-trend<0.01). The percentage of energy from all types of fat, with the exception of trans-fat, increased (p-trend<0.01), and there was no effect modification by BMI category. Trans-fat intake decreased over time across all BMI groups (p-trend<0.01). There was no significant difference by BMI category for any of the dietary fat trends, but we observed a significant interaction by BMI category for total energy intake with energy intake increasing

over time in normal weight individuals (β=13.2) and decreasing in overweight and obese individuals (β=−10.7 and -15.5, respectively). However, the trends in energy intake over time were not statistically significant within any of the BMI categories.

Trends in High Fat Food Intake among Men and Women

Food groups determined to be key contributors to dietary fat intake by the nationally-representative Continuing Survey of Food Intakes by Individuals (CSFII) were selected a priori for these analyses (***Table 4***)[21]. The food sources that contributed at least 1% of dietary fat intake in the CSFII, with the exception of total oils, were examined in the Framingham Offspring cohort; in descending order, these foods were: beef, salad dressing/mayonnaise, oils, cheese, cakes, cookies, quick breads, doughnuts, and candy (confectioneries), margarine, other fats (shortening and animal fats), milk, poultry, pizza, chips and popcorn (snack foods), yeast bread, sausages/processed meats, ice cream, sherbet, and frozen yogurt, eggs, butter, and nuts and seeds[21]. Between 1991-2008 in the Framingham Offspring, the number of weekly servings of cheese, eggs, ice cream, sherbet and frozen yogurt, and nuts/seeds significantly increased in men, women, and the overall population (p-trend<0.01). Weekly servings of cakes, cookies, quick breads, doughnuts, and candy, margarine, milk, pizza, chips, and popcorn decreased over time in men, women, and in the overall population. Poultry intake decreased in the population (p-trend<0.05), but not in men or women when the sexes were evaluated separately. Weekly servings of sausages/processed meats increased in the population (p-trend=0.006), but no change in women or men was observed separately. Servings of butter increased in the population and among women (p-trend<0.01), but not in men.

Trends in High Fat Food Intake among Normal Weight, Overweight, and Obese Participants

Intakes of food groups determined to be key contributors of dietary fat intake in the CSFII study population were examined by BMI category (normal weight, overweight, and obese) (***Table 5***)[21]. Between 1991-2008, the number of weekly servings of cheese, eggs, ice cream, sherbet, and frozen yogurt, and nuts/seeds increased among normal weight, overweight, and obese participants (p-trend<0.05). Weekly servings of butter significantly increased in overweight and obese groups (p-trend<0.05) but not in normal weight participants. Servings from margarine and yeast breads significantly decreased among all weight subgroups (p-trend<0.01). Servings from cakes, cookies, quick breads, doughnuts, and candy decreased in overweight and obese groups (p-trend<0.01) but not among normal weight participants. Similarly, the number of servings of pizza, chips, and popcorn (snack foods) decreased among obese individuals (p-trend<0.01), but not in normal weight or overweight participants. No significant changes in the intake of the other food groups were noted.

DISCUSSION

We investigated trends in dietary fat intake between 1991-2008 in the Framingham Offspring cohort, which consists of older, predominately white American adults. Data from the FHS provided a unique opportunity to observe a population's dietary patterns during a

period when the prevalence of obesity and insulin resistance increased dramatically in this population (+7.4% and +12.7%, respectively, from Exams 5-8) and nationwide[2; 22].

Based on these analyses, it appears that the intake of foods rich in animal fats increased over time; however, the percentage of energy consumed from animal fats did not markedly increase in men and women (16.3-17.4% in men and 15.8-17.1% in women, $p<0.01$), probably due to a reduction in the animal fat content of the food supply during this period. Vegetable fats increased substantively (13.8-15.5% in men and 14.1-16.0% in women, $p<0.01$), and appears to be driven by an increased intake of nuts and seeds in this population. However, we were unable to examine trends of total oil intake in this population, which may have also contributed to an increase in vegetable fats over time. The reduction in trans-fat intake seems to be driven by a decrease in margarine intake. Intake of sources of fat from grain products decreased over time, and may partly reflect the low-carbohydrate dietary messages that occurred during this period. Importantly, the observed increase in percent of energy from dietary fat may partly be due to a reduction in carbohydrate intake over time, which is consistent with enthusiasm for the low carbohydrate trend beginning in the early 2000's[5]. This is noteworthy because the greatest increase in the percentage of energy from dietary fat occurred during Exams 7 and 8 (1998-2008), suggesting a shifting consumer focus toward reducing dietary carbohydrate in lieu of reducing dietary fat.

Changes in macronutrient intakes observed in this study differ from those observed in the cross-sectional National Health and Nutrition Examination Survey (NHANES) analyses that have historically been used to evaluate secular trends in dietary intake nationwide. In NHANES, the percentage of energy from carbohydrate (44.0%-48.7%) increased, while the percentage of energy from fat (36.6%-33.7%) and protein (16.5%-15.7%) decreased between 1971-1975 and 2005-2006[9]. However, absolute fat intake in grams remained unchanged, indicating that the observed decrease in the percentage of energy from fat could be attributed to an increase in energy consumption[9].

Trends in macronutrient intake within NHANES 1999-2008 coinciding with the last decade of the Offspring cohort follow-up period are more congruent with the current FHS observations. During this period, energy intake remained stable in NHANES, and the percentage of energy from carbohydrate decreased while the percentage of energy from protein increased[23], as noted in Framingham. However unlike in Framingham, no significant trends in fat intake were observed among Caucasian NHANES participants[23].

The first numerical recommendation for dietary fat intake was established in the 1990 Dietary Guidelines for Americans, suggesting that adults limit their intake of total fat to ≤30% of energy and saturated fat to ≤10% of energy[24; 25]. The 2005 Dietary Guidelines liberalized the range for total dietary fat to 20%-35% of energy[26]. In the Offspring cohort, dietary fat intake increased over time, but always remained <30% of total energy. The Offspring cohort (1991-2008) exceeded the recommended saturated fat limits and consistently consumed >10% of total energy as saturated fat over time.

Discrepancies between NHANES and FHS findings may be related to inherent differences between the two study samples as well as methodological differences. The mean age in the

Offspring cohort (66.6y in 2005-2008) is notably older than in NHANES (40.5y in 2005-2006)[9]. Aging can be associated with reduced food and energy intake, which may clarify some of the observed differences in dietary composition between the samples[27]. The Offspring population is predominately Caucasian and middle- to older-aged, and therefore findings are not generalizable to the larger American population. It is also possible that the FHS is healthier than the majority of the U.S. population based on their voluntary participation in a longitudinal health study.

Methodological differences between the FHS and NHANES studies may also contribute to some of the observed dissimilarities. The FHS is a longitudinal study while NHANES is cross-sectional. Additionally, most NHANES analyses rely on one or two 24-hour recalls to assess diet while the FHS used a validated semi-quantitative FFQ[14]. Each method has its own strengths and limitations. Data from one or two 24-hour recalls may not capture usual long-term intake[28], while FFQs may be subject to recall bias, particularly in older populations[29]. Moreover, FFQs are limited in their ability to precisely measure population mean intakes[30], thus attenuating any observed differences in consumption over time. Consequently, estimates between NHANES and the FHS may not be directly comparable.

Some limitations of the present study should be noted. Aging populations often consume less over time[27], and since FFQs were unable to capture differences in portion size, over- or underestimation of macronutrient intake is possible. Importantly, while the nutrient database used to analyze the FFQ was updated over the study period to reflect changes in food composition and the marketplace, the FFQ does not capture absolute changes in macronutrient and high fat food intake, partly because it does not distinguish between low- and high-fat versions of foods. Further, self-reported data on FFQ are especially prone to underreporting [30]. Despite the limitations of the FFQ, our estimates of fat intake are relatively consistent with a previous analysis among the Offspring cohort that used 3-day food records to characterize dietary fat intake at Exam 5[31].

Our study provides an important contribution to the understanding of changes in dietary fat intake over the past two decades, among white-American FHS participants. Our knowledge of trends in dietary fat intake in the U.S. has been drawn from the NHANES study population that examines secular rather than longitudinal trends. The current prospective analyses uniquely provide insights on dietary fat intakes over time among aging individuals. Further, we confirm earlier Framingham observations[32] with updated data to show that men and women embrace notably different eating patterns. Taken together, these observations suggest that tailoring dietary guidance by sex may be more effective for influencing positive dietary change than current population-based dietary guidelines.

In conclusion, despite national dietary guidance to reduce fat intake[9], the proportion of energy from fat increased in the Framingham Offspring cohort during the 17-year study period. This observation paralleled a significant increase in the prevalence of obesity and insulin resistance in this population and nationwide[2; 22]. Some favorable trends were noted in these analyses, particularly an increase in vegetable as compared to animal fats and a decrease in transfat intake. Additionally, overall dietary fat intake remained below the recommended <35% of total energy per the U.S. Dietary Guidelines, although this may

reflect the concomitant decrease in carbohydrate intake[25; 26]. The increase in energy from saturated fat in excess of the recommended limit of <10% of total energy, particularly among women, warrants policy consideration given its associations with poor health outcomes[33]. FFQs are known to underestimate intake[30], suggesting that our analyses minimize the importance of these findings. Policies targeting the price and availability of foods in the marketplace have been shown to be more effective for influencing dietary changes as compared to interventions that increase nutrition knowledge alone[34]. Our research supports the growing body of evidence that current strategies to improve dietary intake are insufficient at the population level.

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Table 1

Characteristics of male and female Framingham Heart Study Offspring population in 1995 (Exam 5)[1]

Characteristic	Men N=1239	Women N=1493	Overall Sample N=2732
Age (yr) (std. dev)	54.4 (9.5)	53.9 (9.4)	54.1 (9.5)
Education (years; High School=12)[2]	14.6 (2.8)	13.8 (2.3)	14.2 (2.6)
Weight (kilograms) (std. dev)	86.5 (13.5)	69.5 (14.6)	77.2 (16.4)
BMI (kg/m^2)	28.2 (4.0)	26.5 (5.3)	27.3 (4.9)
Prevalence of obesity (BMI>30 kg/m^2)	26.0 %(43.9)	20.3 %(40.2)	22.9% (42.0)
Prevalence of Insulin Resistance (Fasting blood glucose>110 mg/dl)	16.0 %(36.7)	10.4% (30.6)	13.0% (33.6)
Smoking status (% Current smoker in the last year)	17.4% (38.0)	18.2% (38.6)	17.8% (38.3)

[1] Baseline (exam 5) descriptive characteristics including means and standard deviations (SD) are cross-sectional in nature and were computed using the SAS v.9.3.

[2] Recorded during Examination 2; for a very small portion (<2%) of this cohort, education may have been recorded at a pre-college age, so this figure understates completed education.

Table 2

Trends in macronutrient in take and dietary fats in men and women from 1991-2008[1]

Characteristic	Men				Women				Overall Sample			
	Exam 5	Exam 6	Exam 7	Exam 8	Exam 5	Exam 6	Exam 7	Exam 8	Exam 5	Exam 6	Exam 7	Exam 8
	N=1239	N=1251	N=1242	N=1087	N=1493	N=1476	N=1481	N=1341	N=2732	N=2727	N=2723	N=2428
Total fat	27.5	26.8	27.9	29.7	27.2	26.3	27.7	29.9	27.3	26.5	27.8	29.8
(% kcal)	(6.0)	(6.1)	(6.0)	(6.0)	(5.9)	(6.0)	(6.3)	(6.1)	(6.0)	(6.1)	(6.2)	(6.1)
p-trend	0.01				0.01				<0.001			
Animal fat	16.3	16.5	17.3	17.4	15.8	16.0	17.0	17.1	16.1	16.2	17.1	17.2
(% energy)	(5.5)	(5.3)	(5.4)	(5.5)	(5.2)	(5.2)	(5.6)	(5.6)	(5.4)	(5.3)	(5.5)	(5.6)
p-trend	0.01				<0.01				<0.001			
Vegetable fat	13.8	12.9	13.5	15.5	14.1	12.9	13.6	16.0	14.9	12.9	13.6	15.8
(% energy)	(4.4)	(4.1)	(4.4)	(5.1)	(4.4)	(4.3)	(4.6)	(5.3)	(4.4)	(4.2)	(4.5)	(5.2)
p-trend	0.01				<0.01				<0.001			
Saturated fat [2]	10.5	10.1	10.7	11.2	10.3	10.0	10.7	11.1	10.4	10.1	10.7	11.1
(% energy)	(2.9)	(2.8)	(2.8)	(2.7)	(2.8)	(2.8)	(2.9)	(2.8)	(2.8)	(2.8)	(2.9)	(2.7)
p-trend	<0.01				<0.01				<0.001			
Polyunsaturated fat	5.7	5.5	5.7	6.2	6.0	5.7	5.9	6.4	5.7	5.6	5.8	6.3
(% energy)	(1.7)	(1.5)	(1.6)	(1.7)	(1.7)	(1.6)	(1.8)	(1.9)	(1.7)	(1.6)	(1.7)	(1.8)
p-trend	<0.01				<0.01				<0.001			
Monounsaturated fat	11.3	11.1	11.5	12.5	10.9	10.6	11.0	12.3	11.1	10.8	11.3	12.4
(% energy)	(2.6)	(2.7)	(2.7)	(2.8)	(2.6)	(2.6)	(2.7)	(2.8)	(2.6)	(2.6)	(2.7)	(2.8)
p-trend	<.01				<.01				<.001			
Trans-fat[3,4]	1.6	---	1.3	1.2	1.5	---	1.2	1.2	1.5	---	1.3	1.2
(% energy)	(0.8)		(0.5)	(0.4)	(0.7)		(0.5)	(0.4)	(0.7)		(0.5)	(0.4)
p-trend	<0.01				<0.01				<0.001			
Omega-3 fat	0.12	0.13	0.14	0.17	0.13	0.14	0.16	0.17	0.13	0.13	0.15	0.17
(% energy)	(0.12)	(0.12)	(0.13)	(0.17)	(0.11)	(0.12)	(0.14)	(0.16)	(0.11)	(0.12)	(0.14)	(0.16)
p-trend	<0.01				<0.01				<0.001			
Carbohydrate	50.1	50.7	49.1	46.0	51.7	52.8	50.8	47.4	51.0	51.8	50.0	46.8
(% energy)	(8.5)	(8.5)	(8.6)	(8.5)	(8.3)	(8.5)	(9.0)	(8.6)	(8.4)	(8.6)	(8.9)	(8.6)

Characteristic	Men				Women				Overall Sample			
	Exam 5	Exam 6	Exam 7	Exam 8	Exam 5	Exam 6	Exam 7	Exam 8	Exam 5	Exam 6	Exam 7	Exam 8
	N=1239	N=1251	N=1242	N=1087	N=1493	N=1476	N=1481	N=1341	N=2732	N=2727	N=2723	N=2428
p-trend	<0.01				<0.01				<0.001			
Protein	16.1	16.5	16.7	17.3	17.5	17.6	17.9	18.5	16.8	17.1	17.4	18.0
(% energy)	(3.2)	(3.1)	(3.3)	(3.4)	(3.3)	(3.3)	(3.3)	(3.6)	(3.3)	(3.2)	(3.4)	(3.6)
p-trend	<0.01				<0.01				<0.001			
Total energy	1988.0	1961.8	1944.1	1969.0	1751.7	1749.4	1716.0	1787.2	1858.9	1846.8	1820.0	1868.6
(kcal)	(625.8)	(624.7)	(612.9)	(650.4)	(561.7)	(561.6)	(526.1)	(594.2)	(603.1)	(600.7)	(578.5)	(626.4)
p-trend	0.44				1.0				0.48			

[1]The p-values listed are for the overall trend, then for males & females, which were calculated using the statistical package R. The dietary trends were evaluated using a repeated measures model with subject-specific random intercepts to account for serial correlation. Bonferroni corrections were applied to subgroup analyses in order to correct for multiple comparisons

[2]The p-values for interaction by sex were calculated. There was a significant interaction by sex for saturated fat with women reporting a greater increase in saturated fat intake (%energy) over time compared to men (β=0.32 vs. 0.22, p<0.01)

[3]Trans-fats data were not available for exam 6

[4]The p-values for interaction by sex were calculated. There was a significant interaction by sex for trans-fat with men reporting a greater decrease in trans-fat intake (%energy) over time compared to women (β= −0.13 vs. −0.09, p<0.01)

Table 3

Trends in macronutrient intake and dietary fats in normal and overweight participants from 1991-2008[1]

Characteristic	Normal Weight (BMI<25)				Overweight (BMI 25-30)				Obese (BMI≥30)			
	Exam 5	Exam 6	Exam 7	Exam 8	Exam 5	Exam 6	Exam 7	Exam 8	Exam 5	Exam 6	Exam 7	Exam 8
	N=968	N=850	N=802	N=711	N=1139	N=1140	N=1138	N=982	N=625	N=737	N=783	N=735
BMI (kg/m^2)	22.7 (1.6)	22.8 (1.7)	22.7 (1.7)	22.6 (1.8)	27.3 (1.4)	27.4 (1.4)	27.4 (1.4)	27.5 (1.4)	34.1 (4.0)	34.3 (4.2)	34.5 (4.5)	34.4 (4.3)
Total fat	26.6	25.6	25.6	28.9	27.3	26.4	27.9	29.7	28.5	27.8	28.9	30.9
(% energy)	(6.0)	(6.2)	(6.1)	(6.3)	(5.9)	(5.9)	(6.3)	(6.0)	(5.8)	(5.9)	(5.9)	(5.7)
p-trend	<0.01				<0.01				<0.01			
Animal fat	15.3	15.1	16.0	16.0	16.1	16.2	17.2	17.2	17.1	17.5	18.2	18.5
(% energy)	(5.4)	(5.2)	(5.5)	(5.4)	(5.2)	(5.1)	(5.6)	(5.5)	(3.3)	(5.3)	(5.2)	(5.6)
p-trend	<0.01				<0.01				<0.01			
Vegetable fat	13.9	12.9	13.4	15.9	13.9	12.8	13.6	15.7	14.2	13.0	13.7	15.7
(% energy)	(4.4)	(4.3)	(4.5)	(5.5)	(4.5)	(4.1)	(4.7)	(5.2)	(4.3)	(4.2)	(4.3)	(5.0)
p-trend	<0.01				<0.01				<0.01			
Saturated fat	10.0	9.6	10.2	10.6	10.4	10.0	10.8	11.1	10.9	10.6	11.2	11.6
(% energy)	(2.9)	(2.9)	(2.9)	(2.8)	(2.8)	(2.7)	(2.9)	(2.7)	(2.8)	(2.8)	(2.7)	(2.6)
p-trend	<0.01				<0.01				<0.01			
Polyunsaturated fat	5.9	5.6	5.7	6.2	5.8	5.6	5.9	6.3	6.0	5.7	5.9	6.4
(% energy)	(1.7)	(1.7)	(1.6)	(1.9)	(1.7)	(1.6)	(1.8)	(1.8)	(1.7)	(1.6)	(1.6)	(1.7)
p-trend	<0.01				<0.01				<0.01			
Monounsaturated fat	10.7	10.3	10.7	12.0	11.1	10.8	11.3	12.4	11.6	11.4	11.8	12.8
(% energy)	(2.6)	(2.6)	(2.7)	(2.9)	(2.6)	(2.6)	(2.7)	(2.8)	(2.5)	(2.6)	(2.6)	(2.7)
p-trend	<0.01				<0.01				<0.01			
Trans-fat[2]	1.4	---	1.2	1.2	1.6	---	1.3	1.2	1.6	---	1.4	1.3
(% energy)	(0.7)		(0.4)	(0.5)	(0.8)		(0.5)	(0.4)	(0.7)		(0.5)	(0.4)
p-trend	<0.01				<0.01				<0.01			
Omega-3 fat	0.13	0.14	0.15	0.18	0.13	0.14	0.15	0.17	0.12	0.13	0.15	0.16
(% energy)	(0.10)	(0.11)	(0.14)	(0.16)	(0.12)	(0.12)	(0.14)	(0.17)	(0.10)	(0.12)	(0.14)	(0.15)
p-trend	<0.01				<0.01				<0.01			
Carbohydrate	52.1	53.3	51.6	48.3	50.8	51.8	49.9	46.7	49.5	50.2	48.6	45.4

Characteristic	Normal Weight (BMI<25)				Overweight (BMI 25-30)				Obese (BMI≥30)			
	Exam 5	Exam 6	Exam 7	Exam 8	Exam 5	Exam 6	Exam 7	Exam 8	Exam 5	Exam 6	Exam 7	Exam 8
	N=968	N=850	N=802	N=711	N=1139	N=1140	N=1138	N=982	N=625	N=737	N=783	N=735
(% energy)	(8.6)	(8.9)	(8.9)	(9.0)	(8.3)	(8.3)	(9.0)	(8.4)	(8.2)	(8.4)	(8.4)	(8.2)
p-trend	<0.01				<0.01				<0.01			
Protein	16.7	16.9	17.3	17.6	16.8	17.1	17.2	17.8	17.1	17.3	17.6	18.4
(% energy)	(3.3)	(3.3)	(3.4)	(3.6)	(3.4)	(3.2)	(3.3)	(3.5)	(3.3)	(3.2)	(3.4)	(3.6)
p-trend	<0.01				<0.01				<0.01			
Total energy[3]	1814.2	1798.5	1786.3	1876.0	1871.5	1852.4	1816.7	1850.5	1905.1	1893.9	1859.5	1885.7
(kcal)	(kcal)	(567.9)	(553.8)	(606.1)	(607.4)	(612.9)	(576.8)	(623.5)	(632.4)	(614.8)	(603.6)	(649.4)
p-trend	<0.01				<0.01				<0.01			

[1]The p-values listed are for the overall trend for normal weight, overweight, and obese individuals, disaggregated, which were calculated using the statistical package R. The dietary trends were evaluated using a repeated measures model with subject-specific random intercepts to account for serial correlation. Bonferroni corrections were applied to subgroup analyses in order to correct for multiple comparisons

[2]Trans-fats data were not available for exam 6

[3]The p-values for interaction by BMI category were calculated. There was a significant interaction by BMI category for total energy intake with energy intake increasing over time in normal weight individuals (β=13.2) and decreasing in overweight and obese individuals (β= −10.7 and −15.5, respectively). It is important to note that the FFQ is not sufficiently accurate to be able to detect changes in energy, so rather than discuss energy trends, all analyses have been adjusted for energy as a means of removing error.

Table 4

Trends in food sources of fats in men and women from 1991-2008 (mean (std. dev))[1,2]

Characteristic[3]	Men				Women				Overall Sample			
	Exam 5	Exam 6	Exam 7	Exam 8	Exam 5	Exam 6	Exam 7	Exam 8	Exam 5	Exam 6	Exam 7	Exam 8
	N=1239	N=1251	N=1242	N=1087	N=1493	N=1476	N=1481	N=1341	N=2732	N=2727	N=2723	N=2428
Beef[4]	3.5 (2.6)	3.4 (2.4)	3.4 (2.4)	3.4 (2.6)	2.9 (2.2)	2.8 (2.2)	2.8 (2.2)	2.9 (2.3)	3.2 (2.4)	3.1 (2.3)	3.1 (2.3)	3.2 (2.4)
p-trend	1.0				1.0				0.85			
Salad dressings /mayonnaise [5]	3.9 (3.9)	3.8 (3.6)	3.9 (4.1)	3.9 (3.6)	4.4 (4.2)	4.2 (3.9)	4.2 (4.3)	4.5 (4.4)	4.1 (4.1)	4.0 (3.8)	4.1 (4.2)	4.3 (4.0)
p-trend	1.0				1.0				0.33			
Cheese [6]	3.1 (3.5)	3.1 (3.4)	3.5 (4.0)	3.8 (3.9)	3.1 (3.2)	3.1 (3.3)	3.4 (3.6)	4.2 (4.6)	3.1 (3.3)	3.1 (3.4)	3.4 (3.8)	4.0 (4.3)
p-trend	<0.01				<0.01				<0.001			
Cakes/cookies/ quick breads/ doughnut/ candy[7]	11.5 (11.0)	10.6 (10.1)	10.2 (9.9)	9.7 (9.9)	9.5 (9.1)	9.3 (9.6)	8.9 (9.5)	8.4 (8.7)	10.4 (10.0)	9.9 (9.9)	9.5 (9.7)	8.9 (9.3)
p-trend	<0.01				<0.01				<0.001			
Margarine [8]	6.1 (7.4)	4.4 (6.3)	4.1 (5.9)	3.7 (6.0)	6.0 (7.2)	4.5 (6.1)	4.2 (6.3)	3.5 (5.6)	6.0 (7.3)	4.5 (6.2)	4.2 (6.1)	3.6 (5.8)
p-trend	<0.01				<0.01				<0.001			
Other fats *(shortening and animal fats)* [9]	3.1 (7.0)	2.8 (5.9)	2.6 (5.8)	2.8 (5.9)	2.4 (6.1)	2.3 (5.5)	2.3 (5.4)	2.8 (6.0)	2.7 (6.5)	2.5 (5.7)	2.4 (5.6)	2.8 (6.0)
Milk[10]	5.6 (6.4)	5.4 (6.6)	5.3 (6.1)	4.6 (5.7)	5.3 (5.8)	5.5 (5.9)	5.3 (6.1)	4.8 (5.4)	5.4 (6.0)	5.4 (6.2)	5.3 (6.1)	4.7 (5.5)
p-trend	<0.01				0.02				<0.001			
Poultry[11]	2.7 (1.8)	2.6 (1.9)	2.6 (1.8)	2.7 (2.0)	2.8 (2.2)	2.7 (1.9)	2.7 (1.8)	2.7(1.9)	2.8 (2.0)	2.7 (1.9)	2.6 (1.8)	2.7 (2.0)
p-trend	1.0				0.14				0.025			
Potato chips/corn chips/popcorn/pizza[12]	6.8 (7.8)	6.3 (7.8)	6.4 (7.9)	5.8 (6.9)	7.3 (9.1)	6.3 (8.4)	6.4 (8.0)	5.7 (7.3)	7.1 (8.5)	6.3 (8.1)	6.4 (8.0)	5.8 (7.1)
p-trend	<0.01				<0.01				<0.005			
Yeast bread[13]	12.4 (10.3)	12.1 (10.4)	11.1 (9.3)	9.0 (7.9)	11.2 (8.7)	11.0 (9.0)	9.5 (8.0)	7.5 (6.9)	11.7 (9.5)	11.5 (9.7)	10.2 (8.7)	8.2 (7.4)
p-trend			<0.01				<0.01				<0.001	
Sausages/processed meats[14]	2.7 (3.2)	2.5 (3.1)	2.5 (2.9)	2.8 (3.1)	1.3 (1.8)	1.3 (1.8)	1.4 (2.0)	1.5 (2.2)	2.0 (2.6)	1.9 (2.6)	1.9 (2.5)	2.1 (2.7)
p-trend	1.0				0.11				0.006			
Ice cream/sherbet/ frozen yogurt[15]	1.6 (2.3)	1.5 (2.6)	1.6 (2.5)	1.8 (2.6)	1.2 (2.0)	1.2 (2.2)	1.4 (2.4)	1.6 (2.1)	1.3 (2.1)	1.4 (2.4)	1.5 (2.4)	1.7 (2.3)
p-trend	<.01				<.01				<.001			
Eggs	1.6 (2.2)	1.6 (1.8)	1.8 (2.4)	2.2 (2.6)	1.1 (1.2)	1.2 (1.4)	1.5 (2.0)	1.8 (2.2)	1.3 (1.8)	1.3 (1.6)	1.6 (2.2)	2.0 (2.4)

Characteristic[3]	Men				Women				Overall Sample			
	Exam 5	Exam 6	Exam 7	Exam 8	Exam 5	Exam 6	Exam 7	Exam 8	Exam 5	Exam 6	Exam 7	Exam 8
	N=1239	N=1251	N=1242	N=1087	N=1493	N=1476	N=1481	N=1341	N=2732	N=2727	N=2723	N=2428
p-trend	<0.01				<0.01				<0.001			
Butter	2.0 (4.5)	2.4 (4.9)	2.3 (4.5)	2.0 (4.8)	2.0 (4.8)	2.3 (4.8)	2.6 (5.3)	2.7 (5.2)	2.0 (4.7)	2.3 (4.8)	2.5 (5.1)	2.5 (4.9)
p-trend	1.0				<0.01				<0.001			
Nuts/seeds[16,17]	2.6 (3.8)	2.4 (4.0)	2.9 (4.6)	4.0 (5.3)	1.8 (2.8)	1.6 (2.7)	2.0 (3.1)	4.0 (5.4)	2.1 (3.3)	2.0 (3.4)	2.4 (3.8)	4.0 (5.3)
p-trend	<0.01				<0.01				<0.001			

[1] The p-values listed are for the overall trend, then for males & females, which were calculated using the statistical package R. The dietary trends were evaluated using a repeated measures model with subject-specific random intercepts to account for serial correlation. Bonferroni corrections were applied to subgroup analyses in order to correct for multiple comparisons

[2] Framingham researchers derived continuous weekly servings of each food from categorical responses provided by participants on the FFQ

[3] Based on food sources of total fat among U.S. adults from 1989-1991 Continuing Survey of Food Intake by Individuals. Oils were also a primary source of total fat among U.S. adults, but this information was not available in the Offspring cohort.

[4] Includes: hamburger, beef, pork, lamb as sandwich or mixed dish, and beef, pork, lamb as main dish

[5] Includes: oil and vinegar dressing, mayonnaise/creamy dressing

[6] Includes cottage/ricotta cheese, cream cheese, other cheese

[7] Includes muffins/biscuits, pancakes/waffles, homemade cookies, readymade cookies, brownies, doughnuts, homemade cake, readymade cake, homemade sweet rolls, readymade sweet rolls, homemade pie, readymade pie, chocolate, candy bars, and candy without chocolate

[8] Includes margarine added to food

[9] Includes cream, sour cream

[10] Includes skim or lowfat milk and whole milk

[11] Includes chicken/turkey with skin and chicken/turkey without skin

[12] Includes potato/corn chips, crackers, triskets, wheat thins, popcorn, pizza, and French fried potatoes

[13] Includes dark bread, white bread, english muffin/bagels

[14] Includes hot dogs, processed meats , bacon

[15] Includes sherbet/ice milk, ice cream

[16] Includes nuts, peanut butter

[17] The p-values for interaction by sex were calculated. There was a significant interaction by sex for nut intake with women reporting a greater increase in nut/seed intake over time compared to men (β= 0.69 vs. 0.46, p<0.01)

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Table 5

Trends in food sources of fats in normal and overweight participants from 1991-2008 (mean (std. dev)[1,2]

Characteristic[3]	Normal Weight (BMI<25)				Overweight (25-30)				Obese (>30)			
	Exam 5	Exam 6	Exam 7	Exam 8	Exam 5	Exam 6	Exam 7	Exam 8	Exam 5	Exam 6	Exam 7	Exam 8
	N=968	N=850	N=802	N=711	N=1139	N=1140	N=1138	N=982	N=625	N=737	N=783	N=735
Beef[4]	2.81 (2.17)	2.63 (2.13)	2.75 (2.25)	2.90 (2.40)	3.27 (2.50)	3.07 (2.29)	3.08 (2.19)	3.10 (2.29)	3.60 (2.44)	3.63 (2.51)	3.53 (2.54)	3.50 (2.60)
p-trend	1.0				1.0				1.0			
Salad dressings /mayonnaise[5]	4.19 (4.08)	4.12 (3.86)	3.94 (3.76)	4.41 (4.11)	4.06 (4.06)	3.99 (3.78)	4.14 (4.51)	4.26 (4.29)	4.23 (4.15)	3.86 (3.72)	4.13 (4.23)	4.11 (3.64)
p-trend	1.0				1.0				1.0			
Cheese[6]	2.85 (2.82)	3.06 (3.54)	3.22 (3.47)	3.84 (4.58)	3.07 (3.24)	3.00 (3.06)	3.42 (4.00)	3.85 (3.84)	3.61 (4.09)	3.44 (3.57)	3.65 (3.71)	4.43 (4.63)
p-trend	<0.01				<0.01				<0.01			
Cakes/cookies/ quick breads /doughnuts/candy[7,8]	9.88 (8.98)	9.82 (9.38)	9.50 (10.48)	9.50 (10.23)	10.66 (10.45)	9.84 (10.04)	9.41 (9.37)	8.71 (8.80)	10.68 (10.81)	10.16 (10.17)	9.75 (9.34)	8.70 (8.91)
p-trend	1.0				<0.01				<0.01			
Margarine[9]	5.51 (7.00)	4.18 (5.95)	3.98 (6.16)	3.37 (5.94)	6.16 (7.40)	4.51 (6.27)	4.12 (6.07)	3.35 (5.41)	6.63 (7.40)	4.78 (6.37)	4.42 (6.11)	4.01 (6.02)
p-trend	0.01				<0.01				<0.01			
Other fats *(shortening and animal fats)*[10]	3.15 (7.56)	2.57 (6.03)	2.52 (5.77)	2.78 (6.19)	2.58 (6.10)	2.56 (5.52)	2.34 (5.34)	2.86 (6.17)	2.23 (5.37)	2.41 (5.58)	2.42 (5.63)	2.73 (5.43)
p-trend	1.0				1.0				1.0			
Milk[11]	5.28 (6.00)	5.19 (5.78)	5.42 (6.26)	4.88 (5.91)	5.64 (6.11)	5.63 (6.60)	5.45 (6.28)	4.75 (5.46)	5.28 (6.00)	5.34 (6.04)	5.01 (5.68)	4.43 (5.25)
p-trend	0.30				0.08				0.08			
Poultry[12]	2.80 (2.33)	2.63 (1.93)	2.60 (1.76)	2.69 (2.03)	2.66 (1.75)	2.65 (1.94)	2.52 (1.76)	2.55 (1.71)	2.87 (1.96)	2.75 (1.82)	2.83 (1.87)	2.91 (2.18)
p-trend	1.0				0.14				1.0			
Potato chips/corn chips/popcorn/pizza[13]	7.20 (9.00)	6.65 (9.32)	2.60 (1.76)	5.98 (7.92)	6.67 (7.83)	6.15 (7.65)	6.43 (7.98)	5.50 (6.65)	7.64 (9.05)	6.21 (7.40)	6.17 (7.23)	5.88 (6.88)
p-trend	0.08				0.08				<0.01			
Yeast bread[14]	11.38 (8.81)	11.28 (8.93)	10.10 (8.37)	8.32(7.64)	11.92 (9.68)	11.00 (9.11)	9.78 (8.19)	7.87 (6.83)	12.02 (10.10)	12.58 (11.10)	11.03 (9.51)	8.44 (7.88)

Characteristic[3]	Normal Weight (BMI<25)				Overweight (25-30)				Obese (>30)			
	Exam 5	Exam 6	Exam 7	Exam 8	Exam 5	Exam 6	Exam 7	Exam 8	Exam 5	Exam 6	Exam 7	Exam 8
	N=968	N=850	N=802	N=711	N=1139	N=1140	N=1138	N=982	N=625	N=737	N=783	N=735
p-trend	<0.01				<0.01				<0.01			
Sausages/processed meats[15]	1.54 (2.27)	1.40 (2.36)	1.36 (2.16)	1.53 (2.29)	2.08 (2.54)	1.92 (2.72)	1.97 (2.70)	2.13 (2.45)	2.46 (3.19)	2.26 (2.59)	2.29 (2.54)	2.67 (3.15)
p-trend	1.0				1.0				0.15			
Ice cream/sherbet/ frozen yogurt[16]	1.17 (2.00)	1.23 (2.45)	1.35 (2.26)	1.60 (2.22)	1.40 (2.10)	1.44 (2.48)	1.50 (2.47)	1.68 (2.44)	1.55 (2.41)	1.42 (2.09)	1.70 (2.57)	1.75 (2.26)
p-trend	<0.01				0.02				0.03			
Eggs	1.17 (1.64)	1.16 (1.59)	1.35 (1.96)	1.81 (2.64)	1.37 (1.77)	1.38 (1.60)	1.66 (2.16)	2.01 (2.30)	1.46 (1.98)	1.51 (1.62)	1.90 (2.46)	2.14 (2.21)
p-trend	<0.01				<0.01				<0.01			
Butter	2.14 (4.85)	2.22 (4.62)	2.44 (5.19)	2.28 (4.27)	1.78 (4.12)	2.23 (4.57)	2.39 (4.80)	2.51 (4.63)	2.24 (5.37)	2.64 (5.39)	2.76 (5.49)	2.81 (5.80)
p-trend	1.0				<0.01				0.03			
Nuts/seeds[17]	1.98 (2.89)	1.93 (3.37)	2.45 (3.82)	4.23 (5.54)	2.24 (3.60)	1.91 (3.18)	2.47 (4.17)	4.04 (5.35)	2.19 (3.37)	2.05 (3.76)	2.26 (3.34)	3.77 (5.05)
p-trend	<0.01				<0.01				<0.01			

[1]The p-values listed are for the overall trend for normal weight, overweight, and obese indiv package R. The dietary trends were evaluated using a repeated measures model with subject- Bonferroni corrections were applied to subgroup analyses in order to correct for multiple com

[2]Framingham researchers derived continuous weekly servings of each food from categorical

[3]Based on food sources of total fat among U.S. adults from 1989-1991 Continuing Survey of fat among U.S. adults, but this information was not available in the Offspring cohort.

[4]Includes: hamburger, beef, pork, lamb as sandwich or mixed dish, and beef, pork, lamb as main as dish

[5]Includes: oil and vinegar dressing, mayonnaise/creamy dressing

[6]Includes cottage/ricotta cheese, cream cheese, other cheese

[7]Includes muffins/biscuits, pancakes/waffles, homemade cookies, readymade cookies, brownies, doughnuts, homemade cake, readymade cake, homemade sweet rolls, readymade sweet rolls, homemade pie, readymade pie, chocolate, candy bars, and candy without chocolate

[8]The p-values for interaction by BMI category were calculated. There was a significant interaction by BMI category for intake of confectioneries (i.e. cakes/cookies/quick breads/doughnuts/candy) with normal weight individuals reporting less of a decrease in confectionery intake over time compared to overweight and obese individuals (β= −0.13 vs. -0.62 p<0.01)

[9]Includes margarine added to food

[10]Includes cream, sour cream

[11]Includes skim or low-fat milk and whole milk

[12]Includes chicken/turkey with skin and chicken/turkey without skin

[13]Includes potato/corn chips, crackers, triskets, wheat thins, popcorn, pizza, and French fried potatoes

[14]Includes dark bread, white bread, english muffin/bagels

[15]Includes hot dogs, processed meats and bacon

[16]Includes sherbet/ice milk, ice cream

[17]Includes nuts, peanut butter