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PAPER

A longitudinal study of food intake patterns and obesity in adult Danish men and women

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OBJECTIVE: The aim of this study was to test the hypothesis that specific food intake patterns or changes in food intake patterns were related to future changes in body mass index (BMI).
DESIGN: Longitudinal observational study, with clinical and questionnaire examinations at baseline and two follow-up surveys, after 5 and 11 years.
SUBJECTS: In all, 3785 men and women attended at baseline, of which 2436 aged 30–60 y attended all three examinations.
MEASUREMENTS: A 26-item food frequency questionnaire, standardised measurements of height and weight and a lifestyle questionnaire. Food intake patterns were identified by factor analysis. Regression models including: scores on each factor, BMI, smoking, leisure time physical activity, education, parity, age; and as outcomes: baseline BMI, BMI change between baseline, 5- and 11-y follow-up and obesity at 11-y follow-up, respectively.
RESULTS: For men, three factors labelled 'Green', 'Sweet' and 'Traditional', and for women, two factors labelled 'Green' and 'Sweet-Traditional' were identified. Scores on the 'Sweet' and 'Sweet-Traditional' factors were inversely associated with baseline BMI. For men, baseline 'Traditional' factor score and, for women, baseline 'Sweet-Traditional' factor score was inversely associated with subsequent 11- and 5-y BMI change, respectively. Using the three examinations, a more advanced longitudinal model, which included preceding changes in BMI and factor scores, was tested but no significant associations between factor scores, changes in factor scores and subsequent BMI changes or obesity were found.
CONCLUSION: In this longitudinal study of a Danish population, food intake factors could not consistently predict changes in BMI or obesity development.
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Introduction

In view of the need for preventive actions to meet the challenges of the obesity epidemic,[1] the identification of determinants for the development of obesity has great importance. Clinical studies clearly show that a reduced dietary fat intake is associated with weight loss, but prospective observational epidemiology does not support any significance of dietary fat independent of energy intake for subsequent change in weight.[2–4] On this background, it has been hypothesised that different food intake patterns, rather than the intake of nutrients such as fat *per se*, may influence weight development.[5] Conceivable, though speculative possibilities are that some food intake patterns could promote energy storage by the combined effect of the foods within the pattern on total energy density, transit time, uptake capacity, or possibly cause overeating due to 'craving' if the pattern does not supply sufficient minerals, vitamins, etc. This could be the case in a food intake pattern of poor diversity (junk food). Other patterns could induce a higher heat production, change the compartmentalisation of the stored energy or affect physical activity behaviour by inducing various degrees of satiety or fullness, which may be uncomfortable when engaging in physical activity.

The assessment of food intake patterns has become increasingly popular as an alternative or supplementary method in nutritional epidemiology.[6] The concept of food intake pattern analysis is to identify sets of 'indicator' foods, the intakes of which are correlated, and compute a score for

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each set, according to the frequency of intake of the foods. These score variables can then be used as replacement for the food variables. Kant *et al*[7] reviewed published indexes of overall diet quality and found that scores, based on either predefined indexes or factors found by factor analysis, were able to predict the various study outcomes more strongly than were individual nutrients. The pattern approach may take into account the interactions in the effects of nutrients correlated within the pattern.[8] Furthermore, in public health communication, foods and sets of foods may be easier for the consumer to identify than nutrient composition, the information about which is available on the food declaration labels, only, and its use must take into account the composition of the rest of the diet.

In our review, we concluded that, at the cross-sectional level, food intake patterns were generally not associated with relative weight measured as body mass index (BMI).[5] There was, however, some indication that a diet reflecting a traditional Western food intake pattern, high in meat and fat, and low in vegetables and cereals, was associated with a higher concurrent BMI, but results from prospective studies were not available at the time of submission of this paper. However, a new study, which used cluster analysis, revealed that subjects in a 'healthy' cluster (high fruit, vegetables, reduced fat dairy and whole grains) increased their BMI and waist circumference significantly less than subjects in a 'meat and potato' cluster and a 'white bread' cluster, respectively.[9]

In the present study, we therefore examined *prospective* associations between food intake factor scores and subsequent BMI changes, as well as *longitudinal* associations between changes in food intake patterns and subsequent changes in BMI.

Material and methods

Subjects

The data were collected as part of the MONICA study (Monitoring of Trends and Determinants in Cardiovascular Diseases).[10] In 1982–1983, 4807 Danish citizens, aged 30, 40, 50, or 60 y were invited for the baseline examination (M-82) at Copenhagen County Centre for Preventive Medicine (now named Research Centre for Prevention and Health) at Glostrup University Hospital. The group was a random sample of the Danish population, selected from the Central Person Register among citizens who all lived in the Western part of the Copenhagen County. Of the invited, 3785, 1845 women and 1940 men (79%) attended M-82. A subgroup of the remaining 21% who did not attend the examination agreed to participate in a short telephone interview. It showed that lower social classes were over-represented and the prevalence of overweight (self-reported) was lower among the telephone interviewed (ie nonparticipants in this study). This has been described elsewhere.[11]

This study population was re-examined in 1987–1988 (M-87) and again in 1993–1994 (M-93), where 2987 (79% of the 3785) and 2656 (70% of the 3785) subjects participated, respectively. In total, 2436 (1200 women (65%) and 1236 men (64%)) participated in all three surveys. The nonparticipants included 324 subjects who died in the follow-up period between 1982 and 1994 and 177 men and women, who were considered of non-Danish origin. The latter were not invited for the follow-up examinations, in order to enhance the genetic homogeneity of the study population. The number of subjects included in each analysis was smaller due to the lack of information in some covariates (exact numbers are given in the tables).

Each participant gave informed consent, and the study was approved by the Danish scientific ethical committee and carried out in concurrence with the Helsinki declaration.

Anthropometry

Height was measured to the nearest 0.5 cm with subjects standing without shoes, heels together, and head in horizontal Frankfurt plane. Body weight was measured to the nearest 0.1 kg using a SECA scale, and subjects wearing only light indoor clothes. BMI was calculated as weight/height^2 (kg/m^2) and obesity defined as BMI ≥ 30 kg/m^2. For analyses with BMI differences or obesity at M-93 as dependent variable, height at baseline was used for all BMI computations to overcome change in BMI due to age-related changes in height ($BMI_{82} = weight_{82}/height^2_{82}$; $BMI_{87} = weight_{87}/height^2_{82}$; $BMI_{93} = weight_{93}/height^2_{82}$). The difference in height would have a considerable influence on the change in BMI had a standardised baseline height not been used as the height in all BMI calculations shown above. For example, for the 11-y period between M-82 and M-93, from 12% of the 30-y-old to 53% of the 60-y-old women had a higher BMI 'change' due to height alone ($weight_{82}/height^2_{93} - weight_{82}/height^2_{82}$) rather than a similar change due to weight alone ($weight_{93}/height^2_{82} - weight_{82}/height^2_{82}$; data not shown).

Food intake assessment

The dietary information used in this study was obtained by a 26-item categorical food frequency questionnaire (FFQ). The subjects were asked to state how often they had consumed each type of food on average within the last year, and they were given eight options: 'never', 'once a month or less', 'twice a month', 'once a week', 'two–three times a week', 'once a day', 'two–three times a day' and 'four times a day or more'. Portion sizes were not given and only the most important food groups were included (originally the FFQ was designed to capture differences in intake of foods considered important for cardiovascular disease in an early-1980s Danish diet). Therefore, the food intake could not be quantified by weight or energy and instead the (relative) frequency of intake was used as an indicator for the factors.

Other covariates

Smoking practices were reported at all surveys: in M-82 and M-93 using the question: 'Do you smoke?' and the reply options: (1) 'yes, daily', (2) 'yes, occasionally' or (3) 'not smoking'; and, if not smoking, the question: 'Did you smoke previously?' and the reply options: (1) 'yes, daily', (2) 'yes, occasionally' or (3) 'never'. These questions were merged into one variable for the two surveys with the categories: (1) never smoker, (2) ex-smoker (including ex-occasional smokers) and (3) smoker (including occasional smokers). Subjects stating they were smokers in M-87 and ex-smokers in M-93 were categorised as recent ex-smokers in a separate variable. The level of *physical activity during leisure time* was classified as: (1) mostly sitting, (2) walking, gardening, etc, (3) low-level sports and (4) competitive sports. Categories (3) and (4) were merged due to few subjects in the latter category. *Educational level* was estimated by a question in eight categories of vocational education (additional to 7–10 y of primary school). The categories were: (1) no education, (2) semiskilled worker or acquired skills, (3) 1-y education (theoretical), (4) basic vocational courses or apprentice, (5) short (2–3 y) theoretical education, (6) medium length (3–4 y) theoretical education, (7) academic or longer education (5 + y) or student/ in training. The original category 'student or in training' had only 10 subjects and was merged with academic or longer education as stated. The women were asked to state the *number of children born* at M-82 and if they had given birth within the years between M-82 and M-87 and between M-87 and M-93 (y/n).

Statistical analyses

The statistical analyses were carried out in three steps: identification of food intake patterns by factor analyses separately for each gender, computation of factor scores and investigation of the associations between factor scores and BMI or obesity. A baseline analysis and four prospective and longitudinal analyses in which the temporal relationship between food intake pattern, change in food intake pattern and obesity development was addressed.

Identification of food intake patterns

Food intake patterns were identified by exploratory factor analysis on the FFQ data in a subsample of 1806 participants who also filled in a diet record at M-82. In all, 21 variables were entered in the analysis. Five items (bread of rye flower without grains, oatmeal, pasta, juice and diet margarine) were omitted because more than 50% stated their intake as 'once a month or less' or 'never', which made the distribution of these variables skewed and difficult to use in factor analyses. The number of factors was based on scree-plots[12] (the eigenvalues plotted as a function of the number of possible factors) and the ease of interpretation of the factors. Foods loading more than 0.3 on these factors in the exploratory analyses were used in the 'confirmatory' factor analyses for factor score computation. Two-factor solutions were chosen with three factors for men ('Green', 'Sweet' and 'Traditional') and two for women ('Green' and 'Sweet-Traditional'). Details of the initial exploratory factor analyses, comparisons with equivalent analyses on diet record data and some nutritional correlates of the factors were published in another recent paper, in which the factors were also tested on the participants who had FFQ information only, and shown to be very consistent (data not shown).[13]

Computation of factor scores

The computation of factor scores was carried out in two ways. For the baseline cross-sectional analysis and the prospective analyses (see below), factor scores were computed in a simple confirmatory factor analysis model, in which the factors were identified by the foods listed in Table 1 with the loadings on the respective factors (M-82). In the model, the factors were allowed to be intercorrelated resulting in moderately correlated factor scores. The complete baseline population was used to maximise power for the cross-sectional and prospective analyses. To include the diet information at 5-y follow-up in the longitudinal model, the computation of factor scores was carried out in a mean–structure factor analysis. In this analysis, loadings on the three factors and thresholds[1] of the categorical variables were kept equal at the two time points (loadings shown in Table 1: M-82–87). The factor scores were standardised and the group mean factor scores at baseline were set to zero, for each sex, while the factor score means were free to be estimated in M-87. In this manner, the changes in factor scores (factor score change = Δ factor = score M-87 − score M-82) best reflect actual differences in the intake frequency of foods identifying the factor (pattern) rather than change in the individuals' relative rank position compared to the group mean intake frequency. To accommodate the hypothesised continuous distribution of the underlying factor (pattern) variable when using categorical FFQ data as input, Mplus uses minimisation techniques to calculate the individual factor score (described on pp. 385–386 in the Mplus manual;[14] see also footnote[†]). However, the resulting factor score is closely correlated to a weighed sum score using factor loadings as weights (data not shown).

Factor characteristics

See Table 1 for a list of the loadings estimated in the entire baseline population (M-82) and the subgroup that provided complete follow-up data (M-82–87). The percentage of the total explained variance attributable to each factor was in the *exploratory* factor analysis on FFQ data: 'Green' 12%, 'Sweet' 10.2% and 'Traditional' 8.3% in men and 'Green' 12.9% and 'Sweet-Traditional' 10.9% in women, respectively. The 'Green' factor probably reflects a diet that is more in agreement with the current recommendations and similar to

[†]The factor analysis of categorical variables in Mplus involves 'interposed' continuous variables representing the propensity of a participant to tick a certain category in the FFQ for each food. Thresholds in the hypothetical continuous variables 'decide' what categorical answer is given by the participant.

Table 1 Factor loadings (standardised to variance 1) in confirmatory factor analysis on baseline (M-82) data[a] and in model incl. follow-up (M-82–87)[b]

'Green' foods factor	*M-82*	*M-82–87*	*'Sweet' foods factor*	*M-82*	*M-82–87*	*'Traditional' foods factor*	*M-82*	*M-82–87*
Men								
Wheat bread with whole grains or bran	0.70	0.69	Cake, biscuits or other baked goods	0.70	0.72	Meat	0.60	0.54
Rye bread with whole grains or bran	0.57	0.53	Candy or chocolate	0.66	0.64	Pâté and meat for bread	0.58	0.54
Raw vegetables	0.45	0.52	Soft drink or ice-cream	0.42	0.41	Potatoes	0.45	0.42
Fruit	0.43	0.44	Jam/marmalade or honey	0.48	0.44	White (wheat) bread	0.41	0.45
Boiled vegetables	0.40	0.37				Sausage	0.35	0.32
Rice	0.36	0.34				Butter, lard and hard margarine	0.35	0.42
Cheese	0.26	0.22				Eggs	0.13	0.19
Fish	0.23	0.25						
Milk products	0.19	0.10						
White (wheat) bread	−0.33	−0.31						
'Green' foods factor	*M-82*	*M-82–87*	*'Sweet-Traditional' foods factor*	*M-82*	*M-82–87*			
Women								
Wheat bread with whole grains or bran	0.58	0.58	Candy or chocolate	0.61	0.57			
Raw vegetables	0.55	0.60	Cake, biscuits or other baked goods	0.58	0.56			
Rye bread with whole grains or bran	0.49	0.49	Pâté and meat for bread	0.47	0.52			
Fruit	0.44	0.49	White (wheat) bread	0.42	0.39			
Boiled vegetables	0.44	0.40	Butter, lard and hard margarine	0.40	0.43			
Fish	0.35	0.36	Soft drink or ice-cream	0.41	0.37			
Cheese	0.28	0.32	Jam/marmalade or honey	0.37	0.36			
Rice	0.21	0.23	Potatoes	0.37	0.31			
Jam/marmalade or honey	0.21	0.19	Meat	0.36	0.37			
Milk products	0.21	0.12	Sausage	0.35	0.40			
White (wheat) bread	−0.40	−0.41						

[a]Factor loadings and scores were estimated separately using the full baseline data set. [b]Factor loadings and scores were estimated in a model that only included subjects who had information on both the M-82 and M-87 surveys.

the Mediterranean diet (high intake of fruit, vegetables and whole grain, fish and cheese), while the 'Sweet' and 'Traditional' factors contain more meat, foods of higher energy density and less vegetables (except for potatoes). Obviously, the 'Sweet-Traditional' factor for women is a combination of the two namesakes for men, but a three-factor solution produced high correlation between the two 'sub'factors ('Traditional' and 'Sweet'), and the scree-plot also suggested two rather than three factors for women. However, judging by the loadings and the association with covariates, the 'Sweet-Traditional' factor in women was more closely related to the 'Sweet' factor than the 'Traditional' in men. The Pearson between-factor score correlation coefficients were, for men, 'Green' with 'Sweet' 0.31, 'Green' with 'Traditional' −0.16 and 'Sweet' with 'Traditional' 0.30; for women, the correlation was −0.11 between the 'Green' and the 'Sweet-Traditional' factor. Owing to the design of the longitudinal food factor model with fixed loadings and factor–factor correlation over time, it was expected that the factor scores in M-82 were highly correlated with the same factor scores in M-87 (coefficients from 0.88–0.95). The model specified the mean factor scores to be zero at M-82, but allowed the changes over time in food intake frequency to be reflected in a corresponding factor score change. The 'Green' factor score mean increased to 0.30 for men and 0.24 for women, while the 'Traditional' for men and the 'Sweet-Traditional' for women decreased to −0.27 and −0.18, respectively, between M-82 and M-87. The 'Sweet' factor score was virtually unchanged between M-82 and M-87. The 'Green'-, and 'Sweet'- or 'Sweet-Traditional' factor scores were clearly lower in the older age groups, while for men, the 'Traditional' factor score was nearly the same in all age groups. Absolute changes over time were uniform over age groups for both sexes (data not shown).

Tests of the associations between food factor scores, BMI, BMI change and obesity

The associations between food factor scores and BMI, BMI-change or obesity, respectively, were tested in three different ways for each outcome: (1) unadjusted univariate analyses, entering one factor score at a time (and in addition, in the longitudinal analyses, one factor score *change* at a time); (2) multivariate analyses entering all factor scores simultaneously (plus, in the longitudinal analyses, all factor score changes) but without covariates; and (3) multivariate analyses entering all factor scores simultaneously (plus, in the longitudinal analyses, all factor score changes) with all covariates. However, only the univariate and the fully adjusted analyses were reported in the tables for simplicity.

Age, education, smoking, leisure time physical activity and parity at baseline were included as covariates in all analyses. In addition, updated physical activity, recent childbirths and smoking cessation were included in the prospective and longitudinal analyses as specified in the tables. The covariates were chosen among a range of possible confounders because they were both associated with BMI and with the food intake factors. Interaction terms were not used, as preliminary analyses did not find important examples of interaction and to avoid overadjustment and chance findings.

Initially, analyses were conducted using the baseline (M-82) data to study *cross-sectional* association between BMI and the factor scores as well as the covariates. The *prospective* analyses were carried out examining associations between factor scores at baseline (M-82) and change in BMI between M-82 and M-87 and between M-82 and M-93, before and after adjustment for baseline BMI, covariates and recent childbirths. *Longitudinal* analyses included associations between baseline factor scores and change in factor scores between M-82 and M-87 and subsequent change in BMI between M-87 and M-93. In the adjusted model, baseline BMI and covariates, physical activity in leisure time (M-87), change in BMI (from M-82 to M-87), recent smoking cessation, and for women, childbirths (after M-87) were included. Similar analyses were run using a logistic regression with obesity (BMI $\geq 30\,kg/m^2$, yes or no) in M-93 as outcome, and baseline BMI and covariates, physical activity in leisure time (M-87), recent smoking cessation, and for women, childbirths (after M-87) as covariates. See the notes in Tables 2–5 for detailed model specifications.

Data were analysed using SPSS statistical software package version 10.0 and 11.0 (SPSS Inc., Chicago, IL USA) and Mplus statistical software package version 2.01 (Muthen & Muthen, Los Angeles, CA, USA).

Results

Analyses of nonparticipation in follow-up (dropout)

Logistic regression analyses, conducted separately for men and women with participation status as dependent variable (participation in M-82 and nonparticipation in M-87 or M-93 = dropout *vs* complete participation at all examinations) showed higher odds of dropout associated with older age. Furthermore, after adjusting for age, the following baseline characteristics were associated with dropout: being a smoker, reporting low leisure time physical activity, having a low education or a parity of four or more children. Controlling for age and the other factor scores, scoring low on the 'Sweet' factor (men only), low on the 'Sweet-Traditional' factor (women only) and low on the 'Green' factor (both genders) was associated with higher odds of dropout (data not shown).

BMI and obesity

BMI at M-82 was on the average $25.2\,kg/m^2$ for men and $23.7\,kg/m^2$ for women. BMI were higher in the older age groups and increasing over time, considerably for the youngest age group and just slightly in the oldest age group, approximately 1 and $0.2\,kg/m^2$ for every 5 y among the

Table 2 Cross-sectional analyses of the association between food factor scores and BMI, before and after adjustment for other covariates at M-82 (baseline) by linear regression analyses

BMI at M-82 (baseline)	*Univariate models*[a] Beta 95% CI	*Adjusted multifactor models*[b] Beta 95% CI
Men (N = 1792)		
Food factor scores (M-82)		
'Green'	−0.29* (−0.58; 0)	0.20 (−0.11; 0.51)
'Sweet'	−0.79** (−1.07; −0.51)	−0.65** (−0.96; −0.33)
'Traditional'	−0.58* (−1.12; −0.05)	−0.10 (−0.67; 0.46)
Covariates (M-82)		
Age (y) (30 = 1;40 = 2;50 = 3;60 = 4)	0.71** (0.57; 0.86)	0.64** (0.50; 0.79)
Physical activity level (1–3)	−0.40** (−0.64; −0.17)	−0.35** (−0.58; −0.13)
Education (1–7)	−0.33** (−0.43; −0.22)	−0.28** (−0.39; −0.17)
Smoking (1–3)	−0.43** (−0.64; −0.21)	−0.67** (−0.89; −0.46)
R^2		0.09
Women (N = 1693)		
Food factor scores (M-82)		
'Green'	−0.19 (−0.60; 0.22)	0.15 (−0.27; 0.56)
'Sweet-Traditional'	−0.93** (−1.32; −0.54)	−0.85** (−1.22; −0.47)
Covariates (M-82)		
Age (y) (30 = 1,40 = 2,50 = 3,60 = 4)	1.10** (0.93; 1.26)	0.89** (0.72; 1.07)
Physical activity level (1–3)	−0.29 (−0.59; 0.01)	−0.40** (−0.69; −0.11)
Education (1–7)	−0.42** (−0.53; −0.30)	−0.22** (−0.34; −0.10)
Smoking (1–3)	−0.44** (−0.65; −0.23)	−0.51** (−0.71; −0.30)
Number of childbirths (1–5)	0.61** (0.43; 0.79)	0.35** (0.17; 0.52)
R^2		0.13

[a]Univariate models: BMI = β_0+β*variable+ε (one variable—factor score or covariate—in each model). [b]Adjusted multifactor model (men): BMI = β_0+β_1*green+β_2*sweet+β_3*traditional+β_4*covariate$_4$+···+β_n*covariate$_n$+ε (all factor scores and other covariates entered in one model). *$P<0.05$, **$P<0.01$. Beta coefficients (Beta) and 95% confidence interval (95%CI) are shown.

Table 3 Prospective analyses of the association between M-82 food factor scores and 5- and 11-y change in BMI[a] before and after adjustment for covariates by linear regression analyses

	Univariate models[b]	*Adjusted multifactor models*[c]
	Beta (95% CI)	*Beta (95% CI)*
Men		
5-y change in BMI, M-82 to M-87 (N = 1491)		
Food factor scores (M-82)		
'Green'	−0.04 (−0.17; 0.10)	−0.12 (−0.27; 0.03)
'Sweet'	0.02 (−0.12; 0.16)	−0.07 (−0.23; 0.08)
'Traditional'	−0.01 (−0.27; 0.24)	−0.06 (−0.33; 0.21)
R^2		0.06
11-y change in BMI, M-82 to M-93 (N = 1259)		
Food factor scores (M-82)		
'Green'	0.15 (−0.06; 0.35)	−0.04 (−0.26; 0.17)
'Sweet'	0.06 (−0.15; 0.27)	−0.11 (−0.34; 0.12)
'Traditional'	−0.37* (−0.73; −0.00)	−0.40* (−0.78; −0.01)
R^2		0.10
Women		
5-y change in BMI, M-82 to M-87 (N = 1413)		
Food factor scores (M-82)		
'Green'	0.10 (−0.11; 0.31)	−0.02 (−0.20; 0.24)
'Sweet-Traditional'	−0.24* (−0.44; −0.04)	−0.33** (−0.54; −0.13)
R^2		0.04
11-y change in BMI, M-82 to M-93 (N = 1227)		
Food factor scores (M-82)		
'Green'	0.06 (−0.25; 0.36)	−0.02 (−0.33; 0.30)
'Sweet-Traditional'	−0.09 (−0.38; 0.20)	−0.26 (−0.55; 0.03)
R^2		0.07

[a]ΔBMI: 5-y BMI change = $weight_{87}/height_{82}^2 - weight_{82}/height_{82}^2$; 11-y BMI change = $weight_{93}/height_{82}^2 - weight_{82}/height_{82}^2$ (only baseline height was used). [b]Univariate models: $\Delta BMI = \beta_0 + \beta^* factor_x + \varepsilon$ ($factor_x$: factor score at M-82—one model for each factor). [c]Adjusted multifactor model (men): $\Delta BMI = \beta_0 + \beta_1 {}^*green + \beta_2 {}^*sweet + \beta_3 {}^*traditional + \beta_4 {}^*covariate_4 + \cdots + \beta_n {}^*covariate_n + \varepsilon$. Covariates are: age, smoking, education, physical activity in leisure time, BMI (all M-82) and, for women, number of childbirths (M-82) and additional childbirths from M-82 to M-87 and M-87 to M-93 (y/n). *$P<0.05$; **$P<0.01$. Beta coefficients (Beta) and 95% confidence interval (95%CI) are shown

30- and 60-y olds at baseline, respectively (data not shown, but reported earlier by Heitmann and Garby[15]).

Cross-sectional associations between food factor scores and BMI

Baseline univariate analyses between each of the food factor scores and BMI showed that all factor scores for men and the 'Sweet-Traditional' score for women were inversely associated with BMI (Table 2, left). Owing to the correlation between the factors among men, the association with BMI weakened significantly for the 'Green' and 'Traditional' factor scores, when all factor scores were included simultaneously in the (multifactor) model, while the 'Sweet' factor score remained significantly inversely associated with BMI also when other covariates were entered. For women, there was little effect of adjustment on the inverse association between the 'Sweet-Traditional' factor score and concurrent BMI.

Associations between food factor scores and subsequent BMI change and obesity

Multivariate analyses of the association between food factor scores (M-82) and subsequent 5- and 11-y *change* of BMI (between M-82 and M-87 and M-93, respectively) revealed inconsistent and minor associations only (Table 3). For men, the 'Traditional' factor score in M-82 was inversely associated with subsequent 11-y change in BMI, while the 5-y difference was not significantly associated with any of the factor scores at baseline. On the contrary, for women 5-year change in BMI was inversely associated with the 'Sweet-Traditional' factor score at M-82, while the association was not significant for the 11-y change. Adjustment for the covariates listed in the notes of the table only changed the results a little.

The data structure with three examinations during the 11-y follow-up period made it possible to analyse the association between baseline food intake pattern (factor scores), subsequent change in factor scores and the—possibly resulting—subsequent change in BMI. However, the analyses did not reveal any associations that were resistant to adjustment for relevant covariates (Table 4). Despite this, as expected from the cross-sectional and prospective analyses, there was a tendency for a *change* in the 'Traditional' and 'Sweet-Traditional' factor scores to be inversely associated with subsequent change in BMI. The results of the analyses, in which *obesity* (BMI $\geq 30\,kg/m^2$) at M-93 was the outcome, are listed in Table 5 (note that in this table, coefficients are

Table 4 Longitudinal analyses of association between baseline food factor scores and changes in factor scores and subsequent change in BMI[a] by linear regression analyses before and after adjustment for covariates

Change in BMI from M-87 to M-93	Univariate models[b] Beta (95% CI)	Adjusted multifactor models[c] Beta (95% CI)
Men (N = 1159)		
Food factor scores M-82		
'Green'	0.09 (−0.06; 0.24)	−0.07 (−0.24; 0.10)
'Sweet'	0.07 (−0.08; 0.21)	0.04 (−0.13; 0.21)
'Traditional'	−0.17 (−0.42; 0.07)	−0.20 (−0.47; 0.06)
Change of score from M-82 to M-87		
Δ 'Green'	0.01 (−0.45; 0.47)	−0.13 (−0.64; 0.38)
Δ 'Sweet'	0.03 (−0.33; 0.39)	0.44 (−0.02; 0.90)
Δ 'Traditional'	−0.20 (−0.69; 0.30)	−0.56 (−1.20; 0.07)
R^2		0.10
Women (N = 1095)		
Food factor scores M-82		
'Green'	0.03 (−0.19; 0.26)	−0.02 (−0.29; 0.25)
'Sweet-Traditional'	0.17 (−0.05; 0.39)	0.02 (−0.23; 0.26)
Change of score from M-82 to M-87		
Δ 'Green'	0.08 (−0.59; 0.74)	−0.07 (−0.86; 0.71)
Δ 'Sweet-traditional'	−0.69** (−1.19; −0.19)	−0.42 (−0.96; 0.12)
R^2		0.06

[a]BMI change = ΔBMI = $weight_{93}/height^2_{82} - weight_{87}/height^2_{82}$ (only baseline height was used). [b]Univariate models: ΔBMI = $\beta_0+\beta_1$*factor(M-82)$_x$ or $\beta_0+\beta_2$*Δfactor(M-82–87)$_x+\varepsilon$. (factor$_x$: factor score—one model for each factor score or change in score). [c]Adjusted multifactor model (men): ΔBMI = $\beta_0+\beta_1$*green+β_2*sweet+β_3*traditional+β_4*Δgreen+β_5*Δsweet+β_6*Δtraditional+β_7*covariate$_1$+β_n*covariate$_n+\varepsilon$ (factor scores M-82, Δ-factor scores M-82–87). Covariates are: age, BMI, education, smoking and, for women, parity (all M-82), physical activity in leisure time (M-82 and M-87), change in BMI (M-82 to M-87), smoking cessation (after M-87) and, for women, childbirths from M-87 to M-93 (y/n). *$P<0.05$; **$P<0.01$.

Table 5 Odds ratios (OR) of being obese (BMI ≥30) in M-93 per one unit change in baseline food factor scores and changes in factor scores by logistic regression analyses before and after adjustment for covariates with 95% confidence intervals (95% CI)

Odds of BMI ≥30 at M-93	Univariate models[a] OR (95% CI)	Adjusted multifactor models[b] OR (95% CI)
Men (N = 1159, of which 174 obese at M93)		
Food factor scores M-82		
'Green'	0.69** (0.53; 0.91)	0.73 (0.45; 1.17)
'Sweet'	0.64** (0.50; 0.83)	1.22 (0.76; 1.96)
'Traditional'	0.70 (0.45; 1.09)	0.80 (0.38; 1.67)
Change of score from M-82 to M-87		
Δ 'green'	1.00 (0.43; 2.34)	0.90 (0.21; 3.89)
Δ 'sweet'	2.31* (1.19; 4.48)	3.80 (0.97; 14.94)
Δ 'traditional'	1.44 (0.58; 3.57)	0.66 (0.11; 3.93)
R-squared (Cox and Snell)		0.36
Women (N = 1095, of which 152 obese at M-93)		
Food factor scores M-82		
'Green'	0.97 (0.68; 1.38)	0.71 (0.38; 1.32)
'Sweet-Traditional'	0.54** (0.38; 0.77)	0.81 (0.47; 1.39)
Change of score from M-82 to M-87		
Δ 'green'	0.33* (0.12; 0.97)	0.22 (0.03; 1.46)
Δ 'sweet-traditional'	1.07 (0.49; 2.38)	1.63 (0.45; 5.87)
R-squared (Cox and Snell)		0.34

[a]Univariate models: logit(p(obese93)) = $\beta_0+\beta_1$*factor(M-82)$_x$ or $\beta_0+\beta_2$*Δfactor(M-82–87)$_x+\varepsilon$. (factor$_x$: factor score—one model for each factor or change in factor score). [b]Adjusted multifactor model (men): logit(p(obese93)) = $\beta_0+\beta_1$*green+β_2*sweet+β_3*traditional+β_4*Δgreen+β_5*Δsweet+β_6*Δtraditional+β_7*covariate$_1$ …+β_n*covariate$_n+\varepsilon$ (factor scores M-82, Δ-factor scores M-82–87). Covariates are: age, education, smoking, BMI and, for women, parity (all M-82), physical activity in leisure time (M-82 and M-87), smoking cessation (after M-87) and, for women, childbirths from M-87 to M-93 (y/n). *$P<0.05$, **$P<0.01$.

translated into odds ratios by one unit of factor score). In the univariate models, the 'Green' and 'Sweet' factor score for men and the 'Sweet-Traditional' score for women at M-82 was significantly inversely associated with the odds of being obese at follow-up. In the univariate models, male subjects who had an *increase* in the 'Sweet' score between M-82 and M-87 had *higher* odds of being obese at M-93, while women who had an increase in the 'Green' factor score had lower odds of obesity at follow-up. However, the baseline factor scores or the changes in factor scores between M-82 and M-87 were found *not* to be associated with obesity at follow-up in the fully adjusted model.

Discussion

In this study, food factor scores reflecting a diet with frequent intake of 'Green', 'Sweet' or 'Traditional' foods (or a combination of the latter two) were used to describe food intake pattern and the factor scores then used to predict concurrent BMI, and subsequent BMI change and obesity. Inverse cross-sectional associations were found for the 'Sweet' (men) and the 'Sweet-Traditional' (women) factor scores and BMI. Among men, the 'Traditional' factor score at baseline was inversely associated with a subsequent 11-y increase in BMI, but not with the odds of being obese at the second follow-up. Likewise, there was some indication among women that baseline score on the 'Sweet-Traditional' factor, and a *change* in score on the factor, was inversely associated with subsequent 5-y BMI increase, but not the odds of being obese. The associations could not be confirmed when the analyses included adjustment for other factor scores, prior BMI change and covariates (Table 4 and 5).

Other studies

The general picture emerging from this study was the lack of consistent associations between the factors and BMI, changes in BMI or obesity. These findings were in agreement with some previous cross-sectional studies, where associations between food intake factor scores and BMI were also not consistent or significant.[16–18]

The significant associations found in this study were in agreement with the findings from three other studies[19–21] in which factors *inversely* associated with BMI, labelled 'Low culinary complexity', 'Convenience' and 'High fat sugar-dairy', respectively, were found. These factors resembled the 'Sweet' and 'Sweet-Traditional' factors from the present study. On the contrary, Slattery *et al*[21] and other investigators[22–25] found *positive* associations between BMI and a 'Western' factor resembling the 'Sweet-Traditional' factor in this study; but interestingly, Sánchez-Villegas *et al*[25] found an inverse relation between a 'Western' diet factor and *history* of obesity. However, only the study by Maskarinec *et al*[22] had a primary focus on bodyweight while the other eight studies had other main objectives.

Dropout

The 65% participation rate at follow-up (about 50% of the invited) may have caused a selection bias since, at baseline; those who subsequently dropped out had a different food intake pattern from those remaining in the study (eg a lower 'Green' factor score among those who dropped out). On the other hand, the mean baseline BMI was similar among those who dropped out and those participating (data not shown). We also analysed the cross-sectional association between baseline factor scores and BMI stratified by participation status (complete *vs* incomplete participation in all three examinations M-82, M-87 and M-93). The stratified analyses adjusted for age, leisure time activity, education, smoking and parity showed no differences between groups for women. For men, the inverse associations between the 'Sweet' factor score and BMI was reduced, and the association between the 'Traditional' factor score and BMI was reversed, for those who dropped out compared with the others. In addition, a positive association between the 'Green' factor score and BMI was observed among those who dropped out only (data not shown). Indeed, dropout may explain, in part, some of the difference between the cross-sectional and the prospective and longitudinal analyses with regard to, for example, the lack of association between the 'Sweet' factor score and subsequent BMI change. Other covariates such as—physical activity, smoking or having a high education—showed the expected inverse association with BMI at baseline, indicating that the variation in BMI may well have been larger if those who dropped out *had* participated in the follow-up, and this could have increased the strength of the associations.

Strengths and limitations

Two major strengths of the study were first the longitudinal design and second the application of confirmatory factor analysis to compute factor scores over time.

The study included three examinations several years apart, which enabled us to include, as control variables, preceding changes in BMI and diet in the analyses of the association between factor scores and BMI change. We found that the change in BMI between M-82 and M-87 was *inversely* associated with the change from M-87 to M93 (data not shown). A similar inverse association was found between two subsequent 2-y weight changes in the 'Nurses Health Study'.[26] In a study on Finnish adults it was found that being on a diet was a major predictor of 15-y subsequent weight gain,[27] and a propensity to gain weight was likely to be recognised at an earlier age by the subjects who may frequently have changed diet, as well as their reporting on their diet, accordingly. However, additional fluctuations in both BMI and food intake between measurements, not picked up in our analysis, may have occurred during the long follow-up periods. On the other hand, a design with frequent measurements of food intake and weight might, in itself, influence food intake and weight, and hence may be difficult to isolate from the overall effect of the food intake.

By using the same FFQ at all examinations and one confirmatory factor analysis rather than separate exploratory factor analyses to compute the factor scores, the problem of the data dependency and lower exact reproducibility of factors in different data was reduced.

In addition, the approach followed in identifying the factors and computing the factor scores in this study supported by analyses on the EPIC data found that 'a simplified pattern variable based on the six highest loading food variables showed a correlation of >0.95 with the originally derived factor scores based on 46 food variables'.[28]

The most important limitation of this study may be the dietary assessment by a short FFQ and the subsequent data reduction involved in the factor analysis. In addition, the extent and consequences of under-reporting could not be estimated optimally.

To obtain comprehensive information on energy and macronutrient intake of the participants' diets, the natural choice of dietary assessment instrument would be the diet record or diet history interview method. However, for a number of reasons, the FFQ was preferred for this study. Firstly, the FFQ information was available for almost all the participants, and included repeated measurements at least at the first two examinations, whereas approximately half of the participants had completed a diet record most of whom completed this once at baseline only. Secondly, we assumed that the use of food intake patterns based on FFQ would capture information related to the development of obesity not captured by nutrient analysis. Foods eaten less than once a day may not be adequately picked up by the diet record method since 7 days of recording may not be sufficient to measure the average intake of some of the nutrients, due to the large within-person variation of intake over time.[29] Thirdly, the FFQ has been compared with the results from a diet history interview on the same subjects for a subsample of the population (from M-87), and has shown an acceptable association for food groups between the amount and frequency of intake.[30] In addition, we compared the mean intake of food groups recoded into the same food groups as on the FFQ on a group of subjects in this population (M-82) who filled in both the FFQ and a 7-day diet record (unpublished results). It showed significantly positive trends in the mean grams of intake of the diet-record food groups that were loading on the factor over quintiles of the same factors score.

Using the same FFQ at M-82 and M-87 may have resulted in an underestimation of the impact of the many new foods added to the possible daily menu during the study period such as 'Mediterranean' dishes, new milk products, pork cuts, fruits and ready-made frozen products or other fast food.[31] However, the additional foods were generally variations on the 'core' foods, used as indicators of the factors in this study, and the additional foods were unlikely to form new factors, since the 'Green' factor already reflects a more 'modern' food preference.

Two recent papers challenged the use of principal component analyses (an analysis closely related to factor analysis) to characterise dietary behaviour and suggested using simpler traditional methods like food groups.[32,33] The main argument was that principal component analysis involved a fair amount of data manipulation, the result of which was not superior to simpler food groupings, in discriminating diseased from not diseased (of endometrial cancer). The rationale of using factor analysis in this study was to describe the complex nature of food intake pattern by as few but powerful variables as possible, to avoid the problems of collinearity and multiple testing involved in the use of nutrients and individual food groups, respectively. Moreover, the 'traditional' pattern would not easily have been identified without the use of factor analysis, and the split sample design and use of confirmatory factor analyses in defining the factors, compared to only an exploratory factor analysis, increased the interpretability and internal validity of the factors found in the present study. Furthermore, the factor scores were associated with the covariates at baseline in the expected manner (eg the 'Green' factor was associated with a low-fat, high carbohydrate/protein intake, high education, physical activity and nonsmoking), which support the hypothesis that the food factor scores are linked to actual lifestyle patterns.

In studies of other diet–disease associations, it may be preferred to use a true *a priori* defined diet index instead of factor analysis, but in the particular case of obesity, it was difficult to make such an index, because of the inconsistent evidence of the relationship between specific diet components and obesity.

The issue of under-reporting was not directly addressed in the analyses in this study since we neither had access to complete information on total energy intake (the FFQ was without portion sizes and only half of the participants completed a diet record) nor exact measurements of energy expenditure. Instead, physical activity level based on a simple question that classified subjects into three groups was included as confounder in the analyses. This rough grouping most likely was not sufficient to describe the precise variation in total energy expenditure, and residual confounding is a possibility. The option of including a similar variable, classifying *occupational* physical activity, was considered, but not implemented in the analyses. The evidence of an association between BMI/obesity and occupational physical activity is limited, and in most studies the association was less significant or even the inverse of the association with leisure time physical activity.[34–38] Further, around 15% of the participants had no occupation and could not be categorised. In addition, under-reporting bias may have affected the associations between food pattern and BMI, since the obese tend to under-report their intake specifically.[39,40] On the other hand, the reported *frequency* of a specific type of food intake, relative to other types of food intake, may still be indicative of adherence to a specific pattern irrespective of a possible lower (reported) absolute intake. Finally, by the application of longitudinal analyses, in which change in intake before the subsequent changes in weight or development of obesity was included, under-reporting of diet intake occurring *because* of obesity or a history of weight gain was unlikely to influence the results.

In summary, this study examined associations between food intake patterns and subsequent development of obesity. For men, a diet with frequent intake of foods indicative of a 'Sweet' diet was inversely associated with a concurrent BMI, while the intake of foods indicative of a 'Traditional' diet tended to be associated with long-term BMI increase. For women, a high intake of 'Sweet and Traditional' foods was *inversely* associated with concurrent BMI as well as short-term BMI increase. These results could not be confirmed when analysed in a longitudinal model including changes in food intake pattern and history of BMI change as predictors of later BMI change or obesity. Rather, the findings were weak and not consistent for men and women, and need confirmation in other studies with similar longitudinal design and possibly a more broad assessment of food intake. Hence, this study does not substantially invalidate the current general dietary recommendations.

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