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Food and drinking patterns as predictors of 6-year BMI-adjusted changes in waist circumference

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Few studies have investigated the prospective associations between diet or drinking patterns and abdominal obesity; we therefore investigated whether food and beverage groups or patterns predicted 6-year changes in waist circumference (WC) and whether these associations were independent of concurrent changes in BMI as a measure of general obesity. The subjects were 2300 middle-aged men and women with repeated measurements of dietary intake, BMI and WC from 1982 to 1993. Intakes from ten food groups and from coffee, tea, wine, beer and spirits were assessed; gender-specific food factors were identified by factor analyses. Multiple linear regression analyses were done before and after adjustment for concurrent changes in BMI. A high intake of potatoes seemed to prevent gain in WC for men, while a high intake of refined bread was associated with gain in WC for women. The association persisted for refined bread, but not for potatoes, after adjustment for concurrent BMI changes. Among women, but not men, high intakes of beer and spirits were associated with gain in WC in both models. A high intake of coffee for women and moderate to high intake of tea for men were associated with gain in WC, but the associations were weakened, especially for women, after adjustment for BMI changes. None of the food factors was associated with WC changes. Based on the present study, we conclude that very few food items and no food patterns seem to predict changes in WC, whereas high intakes of beer and spirits among women, and moderate to high tea intake among men, may promote gain in WC.

Abdominal obesity: Food patterns: Prospective study: Waist circumference

Several studies have shown that abdominal obesity, independent of general obesity, is associated with a high risk of developing non-insulin-dependent diabetes, CHD and stroke (Walker *et al.* 1996; Rexrode *et al.* 1998, 2001; Lakka *et al.* 2002) and of mortality (Bigaard *et al.* 2003). Although some part of the variation in abdominal obesity is due to genetic factors (Carey *et al.* 1996; Lemieux, 1997; Nelson *et al.* 1999), it is of great interest to investigate how modifiable factors, such as diet and alcohol intake patterns, are related to the development or prevalence of abdominal obesity, and whether these associations are independent of changes in the degree of general obesity.

Until now, most studies that have investigated the associations between diet, for instance, energy intake, macronutrient or alcohol intake, and abdominal obesity, have had cross-sectional designs (Lapidus *et al.* 1989; George *et al.* 1990; Kaye *et al.* 1990; Laws *et al.* 1990; Troisi *et al.* 1991; Slattery *et al.* 1992; Duncan *et al.* 1995; Larson *et al.* 1996; Sakurai *et al.* 1997; Dallongeville *et al.* 1998; Han *et al.* 1998; Delvaux *et al.* 1999; Toeller *et al.* 2001; Trichopoulou *et al.* 2001; Koh-Banerjee *et al.* 2003; Vadstrup *et al.* 2003), whereas fewer studies have examined associations prospectively (Eck *et al.* 1995; Grinker *et al.* 1995; Kahn *et al.* 1997; van Lenthe *et al.* 1998; Ludwig *et al.* 1999; Lissner *et al.* 2000; Stookey *et al.* 2001). The design and methodology used in these prospective studies differ, and opposing or inconsistent results have been found. For fat intake, for instance, one study found a negative association with changes in waist circumference (WC) (Eck *et al.* 1995), while another found that an increase in fat intake was associated with a subsequent increase in waist:hip ratio (WHR) (Lissner *et al.* 2000). Other studies were unable to demonstrate associations between fat intake and changes in WC or WHR (van Lenthe *et al.* 1998; Ludwig *et al.* 1999). For other macronutrients or for total energy intake, prospective studies are sparse, diverse and barely comparable.

Studies examining the intake of food groups or food patterns, rather than macronutrients, may provide new insight on the possible determinants of abdominal adiposity. A few

Abbreviations: FFQ, food-frequency questionnaire; WC, waist circumference; WHR, waist:hip ratio.
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cross-sectional studies have addressed associations between abdominal obesity and food patterns (Greenwood *et al.* 2000; Williams *et al.* 2000; Haveman-Nies *et al.* 2001; Wirfalt *et al.* 2001) or single food items, such as wholegrain and refined grain products (Jacobs *et al.* 1998; Meyer *et al.* 2000; McKeown *et al.* 2002), where WHR or WC were negatively related to healthy patterns or intakes of wholegrain products, while positive associations were seen for 'meat/fat' patterns and, to some extent, for refined grains. There are few prospective studies in this area (Kahn *et al.* 1997; Newby *et al.* 2003). One study found that a high intake of vegetables and a low intake of meat were related to a lower odds ratio of 10-year 'weight-gain-at-the-waist' (Kahn *et al.* 1997). Another study found a significantly higher annual increase in WC among the subjects in the 'refined bread' cluster compared with subjects in a 'healthy' cluster (Newby *et al.* 2003).

The objectives of the present study were to investigate the association between changes in WC, with and without adjustment for concurrent change in general obesity, and the preceding intake of different food and beverage groups, and scores derived from a factor analysis of food patterns. This was carried out in a population-based, longitudinal setting taking into account the general tendency towards opposite changes in subsequent time periods (Colditz *et al.* 1990).

Materials and methods

Subjects and study design

Data were collected as part of the MONICA1 study (MONItoring of trends and determinants in CArdiovascular diseases). In 1982–83, 4807 Danish citizens, aged 30, 40, 50 or 60 years were invited for the first examination (M-82) at the Research Centre for Prevention and Health at Glostrup University Hospital, Denmark. The sample was randomly selected from the Danish Central Persons Register for citizens who lived in the western part of Copenhagen County. From those contacted, 79 % attended M-82 (1845 women and 1940 men). Follow-up studies were carried out in 1987–88 (M-87, *n* 2987) and in 1993–94 (M-93, *n* 2556). There were 2436 subjects (1200 women and 1236 men) who participated in all three studies. Those who dropped out included 324 subjects who died, and 177 men and women of non-Danish origin who were not invited to follow-up.

The survey was longitudinal with three point measurements, with BMI measured at all three occasions and WC measured at the second and third (Fig. 1). This gave us the opportunity to study the importance of diet at baseline, defined as the second measurement, as determinants for subsequent changes in WC. The design further allowed adjustments for previous changes in diet, for baseline BMI and for previous and concurrent changes in BMI (Colditz *et al.* 1990).

Anthropometrical measurements

A trained technician performed all the anthropometrical measurements. Height was measured to the nearest 5 mm with subjects standing without shoes. Weight in light indoor clothes was measured to the nearest 0·1 kg using a SECA scale (Seca scale, Vogel and Halke GmbH and Co. KG, Hamburg, Germany). BMI was calculated as weight/height^2 (kg/m^2). WC was measured midway between the lower rib margin and the iliac crest in the horizontal plane. Hip circumference was measured at the point yielding the maximum circumference over the buttocks. Both WC and hip circumference were measured to the nearest 5 mm.

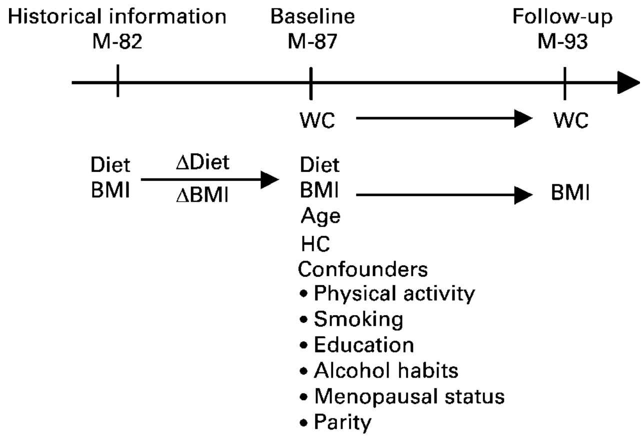

Fig. 1. Study design. WC, waist circumference; HC, hip circumference. Information on changes in BMI from M-87 to M-93 are included only in model B.

Although most studies have used WHR as a measurement of abdominal obesity, we have chosen to use WC and adjust for hip circumference in the model. Most studies have found WC to be a better surrogate of intra-abdominal fat content and to be correlated more strongly with the variables of the 'metabolic syndrome' and to CVD than WHR (Lean *et al.* 1995; Dobbelsteyn *et al.* 2001; Chan *et al.* 2003). Furthermore, new studies have revealed that there are independent and opposing effects of abdominal and gluteo-femoral fat tissues on diabetes and heart disease (for example Lissner *et al.* 2001; Van Pelt *et al.* 2002).

Another issue is that a ratio is more sensitive to measurement errors than a single measurement; thus, a change in WHR may be induced by an increase in one factor or a decrease in another factor. Finally, similar WHR values may occur for both lean and obese persons despite great variation in total fat mass and abdominal fat mass.

Food intake

Information on diet was assessed from a twenty-six-item food-frequency questionnaire (FFQ) for all three surveys. Data from the two first examinations were used in the analyses. The subjects were asked to state how often, on average, they ate each type of food, with the previous year as the reference period. Eight answering categories from 'never' to 'four or more times per d' were possible. The FFQ has been validated on a subset against a diet history questionnaire, showing that daily intake (g/d) increased by increasing frequency category, indicating that this short FFQ can approximate total food intake and detect changes in intake over time (Osler & Heitmann, 1996).

The diet information was used in two ways for the subsequent analyses; as absolute frequencies per week; as factor scores derived from a factor score analyses of the set of foods included. From the frequency categories, absolute frequencies per week were estimated (times per week): never, 0·00; once per month or less, 0·25; twice per month, 0·50; once per week, 1·00; two to three times per week, 2·50; once per d, 7·00; two to three times per d, 17·00; up to four times or more per d, 28·00; thereafter, twenty-four of twenty-six food items were merged into ten groups, each consisting of related food items (Appendix 1).

Factor analyses were conducted using twenty-one of twenty-six food items. Three food factors ('traditional', 'green' and 'sweet') were identified for men, and two factors ('traditional/sweet' and 'green') were identified for women (Appendix 2). The identification of the factors was carried out on the population examined in M-82, and the resulting factor solution applied on M-87 data by confirmatory analyses. This was a continuation of previous work (Togo *et al.* 2003, 2004), which contains more details on the identification and validation of the factors. This approach was in agreement with preliminary test analyses derived for each of the three surveys (M-82, M-87 and M-93); this showed very few differences over time in regard to which food patterns were identified at the three time points. Furthermore, it was intended that a score on a given factor means the same over time in a longitudinal study.

Intake of alcohol, tea and coffee

Information about consumption of alcohol types, coffee and tea was obtained from a lifestyle questionnaire. Alcohol intake was assessed separately for beer, wine and spirits and thereafter merged into one variable describing 'drinks' per week (Appendix 1). When alcohol intake was included as a confounder in the investigation of the food groups and factor scores, the number of drinks per week was categorised according to the Danish recommendations on drinking (Danish National Board on Health, www.sst.dk) into four and five groups for women and men respectively: non-drinkers (men/women); one to seven drinks per week (men/women); eight to fourteen drinks per week (men/women); more than fourteen drinks per week (women); fifteen to twenty-one drinks per week (men); more than twenty-one drinks per week (men).

Daily intake of coffee and tea was assessed as the number of cups per d, and divided into quartiles in the analyses (Appendix 1).

Other covariates

Information on leisure time physical activity was classified into four groups: (1) mostly sitting; (2) walking, gardening; (3) low level sport; (4) competitive sports. As there were very few subjects in the fourth category, this group was included in category 3. Smoking was classified as: (1) non-smokers; (2) current smokers (including occasional smokers); (3) ex-smokers. Educational level was assessed as years in school: (1) 0–7 years; (2) 8–11 years; (3) ≥12 years. For women, menopausal status (pre- or post-) and parity were assessed. Parity was classified in four groups: (1) no children; (2) one child; (3) two children; (4) three or more children. If parity status increased between surveys the women were excluded due to possible changes in body weight and status in connection with pregnancy.

Statistical analyses

The descriptive characteristics are presented as median values with 5th and 95th percentiles or percentages. For the analyses multiple linear regression was used. Subjects included in the analyses were those with complete information on the anthropometrical measurements, covariates and confounders (1169 men and 1131 women). The exact number in each analysis varied based on the decision that by one or more missing values on the food items included in a food group, the person was excluded from that particular analysis, but could still participate in the analyses investigating other food groups. The weekly dietary intake from each food group was divided into quintiles based on the total population (Appendix 1). No departure from linearity was found (tested by log likelihood ratio test); thereafter, all food groups were included as continuous variables, assuming the values from one to five.

Changes in diet were estimated as the difference in intake between M-87 and M-82, in which a negative number indicated a decline in intake; this was then divided into five groups: major decline; minor decline; unchanged intake; minor increase; major increase. 'Potatoes' and 'rice/pasta' were divided into three groups only, because of small variation in change. 'Butter' was divided into six groups (three groups with decline in intake, one group with unchanged intake and two groups with increased intake) because of a very skewed distribution in the changes from M-82 to M-87.

Alcohol types were included in the model in three groups for women and four groups for men: (1) non-drinkers of the specific type; (2) one to three drinks per week; (3) four or more drinks per week (women), four to nine drinks per week (men); (4) ten or more drinks per week (men) (Appendix 3). Inclusion of total alcohol as a continuous variable among drinkers was possible when an indicator variable separating non-drinkers from drinkers (drinking one or more drinks per week) was included in the model, thereby adjusting for the j-shaped curve (Jonansen *et al.* 2003). To adjust for teetotallers, who might deviate from non-drinkers of one specific beverage type, the alcohol indicator variable was included in the alcohol type analyses as well. Tea and coffee were included in quartiles in the analyses. Factor scores were included as continuous variables in which one unit corresponds to 1 SD.

Change in WC was included as the dependent variable; WC at baseline was included as a covariate in all models. Data from M-82 were used for additional historical information on changes in diet and BMI in the time period up to baseline M-87 (Fig. 1). As we wanted to study the relationships between diet and changes in WC before and after adjustment for concurrent changes in total obesity, two models were analysed. These were model A (including BMI M-87, but without inclusion of BMI (M-93) and model B (with inclusion of baseline (M-87) and follow-up (M-93) BMI). We were therefore able to analyse the BMI-adjusted changes in WC. Basic analyses of model A were carried out with regard to the associations between each food or beverage group, or the food factor scores at baseline (M-87), and the changes in WC adjusting for baseline WC and age. No estimates from the basic model B are presented. Advanced analyses of model A were carried out, further including the information on: baseline BMI (M-87), changes in diet/beverage intake (M-82 to M-87), BMI (M-82), hip circumference (M-87) and confounders; educational level, smoking status, alcohol habits (except in the alcohol analyses) and physical activity (M-87). In model B, the adjusted model A was further adjusted for BMI (M-93). For each of the ten food groups and for tea, coffee and total alcohol intakes, separate multiple regression analyses were employed, while analyses regarding type of alcohol were analysed in one model using the partition method (Willett, 1998; Johansen *et al.* 2003).

Regression analyses on the food factor scores were computed using a three-factor model for men and a two-factor model for women, where the scores were included simultaneously in the regression model. Analyses testing for interaction between BMI, physical activity or smoking and diet/beverages groups were performed, but no interactions were found. Sub-analyses for women with additional adjustments for parity and menopausal status did not change any of the associations between the food and beverages groups, or the factor scores and subsequent changes in WC for women. Therefore, all results are presented without these adjustments.

All analyses were carried out separately for men and women. Factor scores were computed using Mplus statistical software package (version 2.01; Muthen & Muthen, Los Angeles, CA, USA) and all the statistical analyses were conducted using SAS software (version 8.2; SAS Institute Inc., Cary, NC, USA).

Results

Descriptive characteristics

The characteristics of the study population are presented in Table 1. The median WC in M-87 were 90 and 76·5 cm for men and women respectively. WC was greater in older than in the younger age groups. Significant increases ($P < 0{\cdot}0001$) from M-87 to M-93 were seen for both genders. BMI increased significantly for both men and women from M-82 to M-87 and from M-87 to M-93.

Linear regression analyses

Food groups. Few and inconsistent associations between food intake in M-87 and subsequent changes in WC were found (Table 2). For men, a high intake of potatoes was associated with a subsequent decrease in WC; a high intake of refined bread (white wheat bread and rye bread without whole grain) tended to be associated with a subsequent decrease in WC in a model adjusted for age and M-87 WC (basic model A). The associations persisted in the advanced model A after adjustments for previous changes in diet and BMI, and for M-87 covariates (BMI, hip circumference) and likely confounders (education, physical activity, smoking status and alcohol habits); no associations were found after adjusting for concurrent changes (M-87 to M-93) in BMI (model B). For women, a high intake of refined bread was associated with a subsequent gain in WC, and the association became stronger after adjustment for covariates and confounders (advance model A). Further, a high intake of 'butter/margarine' tended to decrease subsequent change in WC in the basic model A; a high intake of wholegrain bread was associated with decreases in WC in the advanced model A. The positive association for refined bread and tendency towards a negative association for wholegrain bread persisted in model B after adjustment for concurrent changes in BMI; this was not the case for 'butter/margarine'.

Alcohol intake. For women, a high alcohol intake was associated with subsequent waist gain in model A after adjustment for covariates and confounders (Table 2). This association was mainly due to a significant positive association between intakes of spirits and beer, and subsequent changes in WC (Fig. 2). The significant results persisted in model B after adjustment for concurrent changes in BMI. For men, no association between M-87 intake of total alcohol and the subsequent changes in WC were found in model A; this was due to opposing associations for beer and wine. Drinking one to three servings of beers per week compared with not drinking beer was associated with a borderline significant increase ($P = 0{\cdot}10$) in WC; a moderate intake of wine compared with no intake was associated with a decrease in WC (Fig. 3). These associations were weakened considerably after adjustment for concurrent changes in BMI (model B).

Coffee and tea consumption. Women in the highest quartile for coffee consumption (more than eight cups per d) had a significantly greater ($P = 0{\cdot}03$) increase in WC, compared with those drinking four to five cups of coffee per d (second quartile), in the advanced model A (Fig. 4), but no significant linear trend was present. After adjustment for concurrent changes in BMI, this association was weakened considerably (model B). For men, coffee consumption was not associated with changes in WC in all models. For male tea drinkers, greater increases in WC were seen in the two highest quartiles (two to three cups per d, more than three cups per d) compared with those drinking one cup per d (second quartile) in the advanced model A (Fig. 5). Further adjustments for concurrent changes in BMI weakened the results (model B). Tea intake was not associated with changes in WC in women.

Factor scores. Irrespective of gender, the food factor scores were generally unassociated with changes in WC in all models (Table 3). For men, though, there was a tendency towards a negative association between the 'traditional' food score and subsequent changes in WC in model A, which changed direction when adjusting for changes in BMI in model B.

Discussion

In the present study we examined whether diet, expressed as food factor scores and as weekly or daily intakes of twelve food and beverage groups, or alcohol intake, predicted subsequent 6-year changes in WC, and whether these associations were independent of concurrent changes in overall obesity. None of the associations between the

Table 1. Anthropometric measurements and the confounders included in the models for participants with complete data at all examinations*
(Median values, and 5th and 95th percentiles or percentages)

	Men (*n* 1169)						Women (*n* 1131)					
	M-82		M-87 (baseline)		M-93		M-82		M-87 (baseline)		M-93	
	Median	5th, 95th percentile	Median	5th, 95th percentile	Median	5th, 95th percentile	Median	5th, 95th percentile	Median	5th, 95th percentile	Median	5th, 95th percentile
BMI (kg/m^2)	24·7	20·4, 31·1	25·2	20·8, 32·0	26·0	21·1, 32·8	22·8	18·9, 30·9	23·5	19·2, 32·3	24·4	19·7, 34·0
ΔBMI (kg/m^2)	–		0·5	−0·6, 2·9	0·7	−1·7, 3·1	–		0·7	−2·0, 3·5	0·9	−1·6, 3·8
WC (cm)	–		90·0	77·0, 109·5	93·0	78·0, 112·0	–		76·5	65·5, 98·0	79·0	67·0, 103·0
ΔWC (cm)	–		–		2·0	−6·0, 10·5	–		–		2·5	−6·5, 13·0
HC (cm)	–		98·0	89·5, 109·5	99·0	89·0, 111·0	–		97·0	87·0, 111·3	98·0	87·0, 116·0
Physical activity, leisure time (subjects doing sport regularly, %)	–		25		–		–		13		–	
Smoking (current smoker, %)	–		52		–		–		45		–	
≥12 years of school (%)	–		12		–		–		10		–	
Parity	–		–		–		–		2	0, 4	–	
Menopausal status (subjects postmenopause, %)	–		–		–		–		48		–	

WC, waist circumference; HC, hip circumference.
* For details of subjects and procedures, see pp. 736–737.

Table 2. Association between M-87 food (per quintile increase) and alcohol (per one drink) intake, and the subsequent change in waist circumference (cm) from M-87 to M-93 analysed by multiple linear regression with and without adjustments for concurrent changes in BMI†

(Regression coefficients and 95 % confidence intervals)

		Model A (without adjustments for changes in BMI)				Model B (with adjustments for concurrent changes in BMI)‡	
		Basic model§		Advanced model‖		Advanced model‖	
	n¶	β	95 % CI	β	95 % CI	β	95 % CI
Men							
Butter and margarine	1149	−0·07	−0·29, 0·14	0·18	−0·07, 0·44	0·04	−0·12, 0·19
Milk and cheese	1166	−0·11	−0·31, 0·09	−0·10	−0·34, 0,13	−0·03	−0·18, 0·11
Meat products	1166	−0·14	−0·37, 0·08	−0·10	−0·38, 0·17	0·11	−0·06, 0·28
Fish	1164	−0·15	−0·47, 0·16	−0·08	−0·45, 0·29	−0·07	−0·29, 0·16
Potatoes	1167	−0·51	−1·00, −0·03*	−0·51	−1·04, 0·02	−0·04	−0·37, 0·28
Rice and pasta	1166	−0·01	−0·23, 0·20	−0·10	−0·34, 0·15	−0·07	−0·22, 0·08
Wholegrain bread	1135	0·04	−0·16, 0·24	−0·07	−0·30, 0·17	0·004	−0·14, 0·15
Refined bread	1127	−0·21	−0·44, 0·02	−0·24	−0·50, 0·01	−0·06	−0·22, 0·09
Fruits and vegetables	1152	0·004	−0·21, 0·21	0·002	−0·26, 0·26	−0·01	−0·17, 0·15
Cakes and chocolate	1156	0·01	−0·20, 0·21	0·01	−0·22, 0·25	0·04	−0·10, 0·19
Total alcohol††	1169	0·005	−0·02, 0·03	0·01	−0·02, 0·04	0·01	−0·001, 0·03
Women							
Butter and margarine	1115	−0·30	−0·57, −0·02*	−0·13	−0·44, 0·18	−0·05	−0·27, 0·17
Milk and cheese	1123	−0·006	−0·27, 0·25	−0·11	−0·40, 0·18	0·08	−0·13, 0·29
Meat products	1120	0·12	−0·18, 0·42	0·21	−0·13, 0·55	0·20	−0·05, 0·44
Fish	1128	−0·04	−0·42, 0·35	−0·07	−0·50, 0·35	−0·19	−0·49, 0·12
Potatoes	1129	−0·22	−0·79, 0·35	0·16	−0·44, 0·76	0·20	−0·23, 0·63
Rice and pasta	1122	−0·08	−0·35, 0·19	−0·03	−0·32, 0·27	−0·09	−0·31, 0·12
Wholegrain bread	1092	−0·12	−0·39, 0·14	−0·20	−0·49, 0·09	−0·18	−0·39, 0·03
Refined bread	1073	0·30	0·02, 0·58*	0·42	0·11, 0·73*	0·29	0·07, 0·51*
Fruits and vegetables	1115	0·06	−0·21, 0·33	−0·03	−0·35, 0·28	−0·03	−0·25, 0·20
Cakes and chocolate	1119	−0·02	−0·27, 0·24	−0·05	−0·35, 0·24	−0·08	−0·30, 0·13
Total alcohol††	1131	0·05	−0·004, 0·11	0·10	0·03, 0·17*	0·08	0·03, 0·12*

* $P < 0.05$.
† For details of subjects and procedures, see Table 1 and pp. 736–737.
‡ Model B was further adjusted for BMI (M-87) and BMI (M-93) in both basic and advanced analyses.
§ Basic models included age M-87, WC M-87 and each food group or total alcohol separate.
‖ Advanced models included further: BMI M-87 (model A), BMI (M-82), HC (M-87), Δdiet (M-82 to M-87), educational level (three levels), physical activity (three levels), smoking status (three levels), and alcohol habits from M-87 (food group analyses only).
¶ Number of participants in the models in the analyses differed due to missing values on specific food items at either M-82 or M-87. Maximum number of participants was 1169 men and 1131 women.
†† In the analyses for total alcohol intake a variable indicating non-drinkers from drinkers drinking one or more drinks per week was included, thereby allowing the intake among drinkers to be included continuously (number of drinks per week) in the model.

food factor scores and changes in WC was significant, and only a few weak associations were seen for the food groups. For beverages more associations were found. For women, but not for men, a high intake of spirits and beer was associated with a subsequent increase in WC, also independent of the concurrent changes in BMI. High intakes of coffee among women and tea among men were also associated with gain in WC, but the associations were considerably weakened after adjustment for concurrent changes in BMI.

In contrast to the many cross-sectional studies and studies investigating concurrent changes in diet and WC, where an indication of a temporal direction between diet and WC cannot be inferred, the clear strength in the present study is the prospective design. The prospective study design eliminates many of the biases seen in cross-sectional studies, because participants are unaware of their possible future changes in WC at the time where they report their diet intake and lifestyle habits. The historical information on diet and BMI further allowed the possibility of adjusting for previous changes in BMI and food intake, as it is possible that a previous increase or decrease in food intake or weight may confound the association between the attained dietary intake level in M-87 and subsequent changes in WC. Most studies have only one measure, so this correction for previous changes is potentially a great strength of the present study. In addition, the measured rather than self-reported anthropometry is a strength and improves validity.

However, a limitation of the longitudinal study design is the potential for subjects to drop out. In the present study, about 65 % of the sample participated in all three surveys. Minor selection bias due to dropout might be present, since those who dropped out from M-87 to M-93 differed from those who attended all surveys in regard to some covariates (older age, low physical activity, low education level, current smoker, large WC at M-87, high BMI at M-87 (men)) and M-87 food patterns (high alcohol intake (men), non-drinkers (women), high intake of refined bread, high meat intake, low wholegrain bread intake, low potato intake, low intake of fruits and vegetables (women), low sweet score (men), high traditional score (men) and low

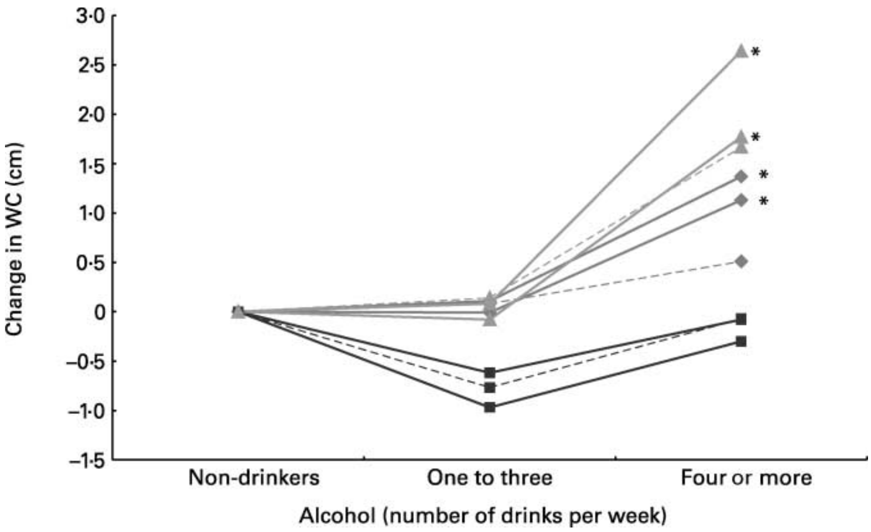

Fig. 2. Associations between intakes of wine, beer and spirits (M-87) in a mutually adjusted model and 6-year changes in waist circumference (WC) before and after adjustment for covariates and confounders (model A), and with adjustment for concurrent changes in BMI (model B) by linear regression analyses for women. ---◆---, Beer, basic model A; –◆–, beer, advanced model A; ▬◆▬, beer, model B adjusted for BMI changes. ---■---, wine, basic model A; –■– wine, advanced model A; ▬■▬, wine, model B adjusted for BMI changes; ---▲---, spirits, basic model A; –▲–, spirits, advanced model A; ▬▲▬, spirits, model B adjusted for BMI changes. For details of subjects and procedures, see Table 1 and pp. 736–737. By *WC changes were significantly ($P<0·05$) different from non-drinkers (reference group).

green score (women)). Similar results were seen studying the odds ratios for dropout in M-87 and/or M-93 compared with complete participation (Togo *et al.* 2004). These differences may generally have decreased the variation of WC and of food intake in these groups and attenuated the associations seen between changes in diet and WC. For example, the higher dropout rate among low fruits and vegetable and wholegrain bread consumers and for low 'green' score may explain why we did not see any protective effect from these food sources on changes in WC among women. However, there has to be a major difference between those subjects dropping out and those completing for both baseline diet and changes in WC before the associations found would change dramatically, which is not likely.

The self-reported food-frequency intake in the present study may also have been under-reported (Heitmann & Lissner, 1995; Heitmann *et al.* 2000). The general under-reporting of, for example, high-fat food items does result in lower absolute values of intake, but such a random bias does not necessarily disturb the ranking of subjects according to intake. However, if on the other hand under-reporting is higher in selective groups, such as in the obese, the results may be obscured without any clear

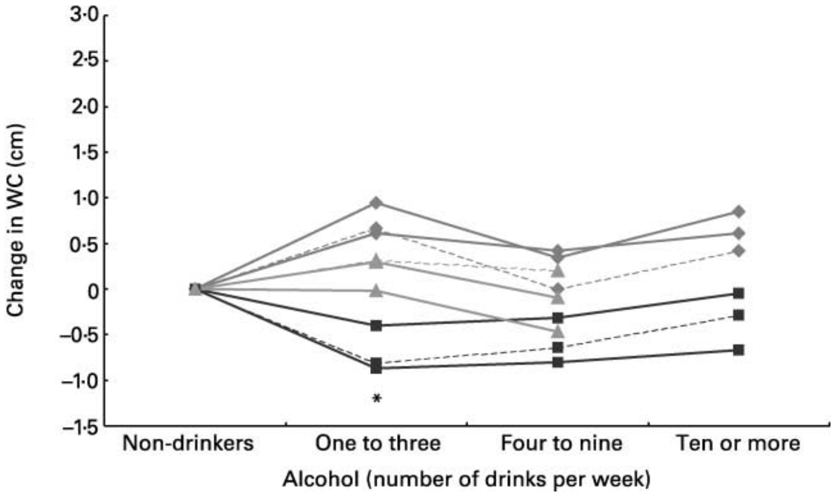

Fig. 3. Associations between intakes of wine, beer and spirits (M-87) in a mutually adjusted model and 6-year changes in waist circumference (WC) before and after adjustment for covariates and confounders (model A), and with adjustment for concurrent changes in BMI (model B) by linear regression analyses for men. ---◆---, Beer, basic model A; –◆–, beer, advanced model A; ▬◆▬, beer, model B adjusted for BMI changes. ---■---, wine, basic model A; –■– wine, advanced model A; ▬■▬, wine, model B adjusted for BMI changes; ---▲---, spirits, basic model A; –▲–, spirits, advanced model A; ▬▲▬, spirits, model B adjusted for BMI changes. For details of subjects and procedures, see Table 1 and pp. 736–737. Intakes of spirits were divided into three groups, while intakes of wine and beer were divided into four groups. By *WC changes were significantly ($P<0·05$) different from non-drinkers (reference group).

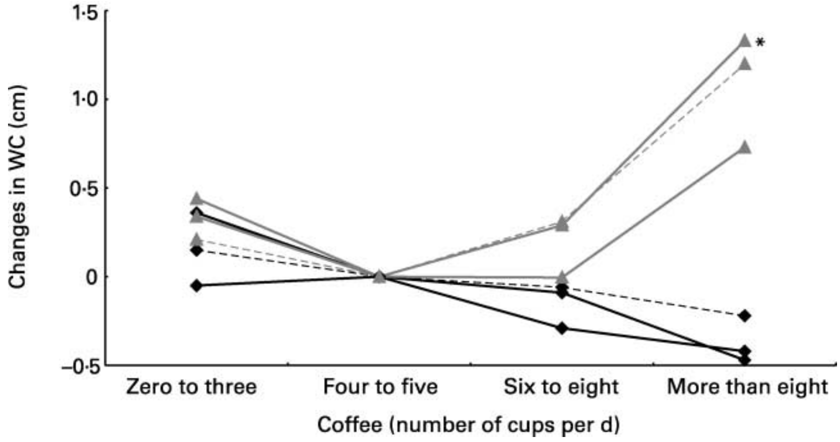

Fig. 4. Associations between intakes of coffee (M-87) and 6-year changes in waist circumference (WC) before and after adjustment for covariates and confounders (model A), and with adjustment for concurrent changes in BMI (model B) by linear regression analyses for men and women. ---◆---, men, basic model A; –◆–, men, advanced model A; ▬◆▬, men, model B adjusted for BMI changes; ---▲---, women, basic model A; –▲–, women, advanced model A; ▬▲▬, women, model B adjusted for BMI changes. For details of subjects and procedures, see Table 1 and pp. 736–737. By *WC changes were significantly ($P<0·05$) different from those drinking four to five cups per d (reference group)

interpretation of direction. In addition, reporting of a low intake of, for instance, butter by obese participants in M-87, may also be a consequence of reverse causality, namely that people who are already obese try to cut down on the high-fat food products in an attempt to lose weight. However, in the present study both general and specific under-reporting may attenuate the true association. The FFQ used in the present study did not describe the total daily energy intake, so that it was impossible to identify and characterise the under-reporters at baseline as, for instance, in a study by Rosell *et al.* (2003). Here, 'under-reporters', compared with non-under-reporters, had a higher WC, reported a lower % energy from fat and food items considered as unhealthy, while their % energy from protein and intake of bread, potatoes, meat, poultry and fish were higher (Rosell *et al.* 2003). However, it is unlikely that these reporting problems affect the relationship to the currently unknown future changes in WC in our present study.

The dietary assessment instrument used in the present study was a simple twenty-six-item qualitative FFQ, with eight predefined answering categories and no information on portion sizes. The conversion of these eight categories into an absolute intake per week followed by merging of different food items into larger groups does introduce some approximations, as the eight categories cannot be fully collapsed into a true numeric variable. However, in a previous validation study carried out on a subgroup of the present study population, the FFQ was found to be capable of ranking people correctly compared with a diet history interview (Osler & Heitmann, 1996). For nearly 60 % of the food groups a correlation coefficient of ≥0·5 was found between the food groups in the short FFQ and the quantities reported by diet history interview (Osler & Heitmann, 1996).

Because of the many food groups investigated, the number of tests of hypotheses performed in the present study was high. Hence, it cannot be excluded that the associations found between diet and changes in WC may

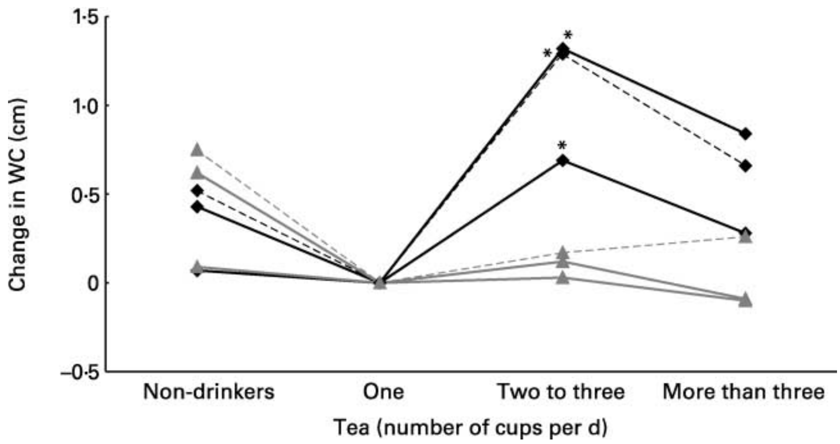

Fig. 5. Associations between intakes of tea (M-87) and 6-year changes in waist circumference (WC) before and after adjustment for covariates and confounders (model A), and with adjustment for concurrent changes in BMI (model B) by linear regression analyses for men and women. ---◆---, men, basic model A; –◆–, men, advanced model A; ▬◆▬, men, model B adjusted for BMI changes; –▲–, women, basic model A; –▲–, women, advanced model A; ▬▲▬, women, model B adjusted for BMI changes. For details of subjects and procedures, see Table 1 and pp. 736–737. By *WC changes were significantly ($P<0·05$) different from those drinking one cup per d (reference group).

Table 3. Estimates for the association between mutually adjusted factor scores (M-87) and the subsequent change in waist circumference (cm) from M-87 to M-93 analysed by multiple linear regression with and without adjustments for concurrent changes in BMI*

	Model A (without adjustment for changes in BMI)				Model B (with adjustments for concurrent changes in BMI)†	
	Basic‡		Advanced§		Advanced§	
	β	95 % CI	β	95 % CI	β	95 % CI
Men (*n* 1106)						
Traditional M-87	−0·66	−1·56, 0·24	−0·63	−1·57, 0·30	0·17	−0·41, 0·75
Green M-87	−0·02	−0·58, 0·53	−0·08	−0·65, 0·48	−0·03	−0·38, 0·32
Sweet M-87	0·24	−0·33, 0·81	0·24	−0·35, 0·83	0·18	−0·18, 0·55
Women (*n* 1049)						
Traditional/sweet M-87	−0·19	−1·01, 0·62	−0·009	−0·82, 0·80	−0·12	−0·70, 0·46
Green M-87	−0·05	−0·92, 0·83	−0·46	−1·35, 0·42	−0·24	−0·87, 0·39

* For details of subjects and procedures, see Table 1 and pp. 736–737.
† Model B was further adjusted for BMI (M-87) and BMI (M-93) in both basic and advanced models.
‡ Basic analyses were adjusted for waist circumference and age (M-87).
§ Advanced models further included: BMI (M-87) (model A), hip circumference (M-87); BMI (M-82); Δscore (M-82 to M-87); educational level (three levels); alcohol habits (four and five groups for women and men respectively); physical activity (three levels); smoking status (three levels) M-87.

be a consequence of mass significance. Even though more significant results were found than would have been expected due to chance alone in the analyses investigating the associations between food intake and WC changes, more studies are needed to confirm or explore the few significant findings in the actual cohort. Based on the relatively small sample size compared with the number of food groups and covariates, we chose not to include all the food groups in a simultaneously adjusted model in the analyses. Analyses with mutual adjustment could be a possibility, but on the other hand relatively high correlation between the many food items would be present and must be considered.

When investigating associations between diet and changes in body size, the separate estimates may seem rather small and unimportant, but even minor reductions in WC may substantially reduce the risk of diabetes and other obesity-related diseases (Chan *et al.* 1994). Assuming a true association between the intake of refined bread and changes in WC, a woman in the highest quintile will gain about $4 \times 0{\cdot}42 = 1{\cdot}68$ cm in WC compared with a person in the lowest quintile, and if the same woman also has a high intake of spirits and a low physical activity level, the total change may be considerably bigger. In addition, if we could adjust for measurement error, which attenuates the observed results, we may have seen effects of considerably bigger magnitude, as also suggested by Koh-Banerjee *et al.* (2003).

We adjusted for concurrent changes in BMI to isolate the potential effects of diet and beverage intake on abdominal fat accumulation from the effects of general body size. Eck *et al.* (1995), Lissner *et al.* (2000) and Koh-Banerjee *et al.* (2003) have also used this approach. It makes sense to investigate the associations between diet and changes in WC with and without adjustments of concurrent BMI, as WC and BMI may be independent risk factors for several chronic diseases. A recent study showed that the combination of BMI and WC seemed to be very important with regard to mortality, where WC for given BMI were found to be directly associated to mortality, while BMI for given WC were inversely associated with mortality (Bigaard *et al.* 2003).

Comparison with other studies

Food intake. Few studies have investigated the associations between food intake or patterns and abdominal obesity. These studies (seven cross-sectional (Jacobs *et al.* 1998; Greenwood *et al.* 2000; Meyer *et al.* 2000; Williams *et al.* 2000; Haveman-Nies *et al.* 2001; Wirfalt *et al.* 2001; McKeown *et al.* 2002) and two prospective (Kahn *et al.* 1997; Newby *et al.* 2003)) have found negative associations between a ‘healthy’ diet characterised by a high intake of food items such as ‘fruit and vegetables’ or ‘fibre/wholegrain bread’ and abdominal obesity, and positive associations between diets high in meat and fried food or refined grain items and abdominal obesity (except for Greenwood *et al.* 2000). These associations are also in good agreement with results from an intervention study, where guidance and education to promote a diet reduced in fat and high in fruits and vegetables, together with more physical activity, produced a decrease in WHR in the intervention group compared with a control group, who only got guidance about eating a diet with moderate fat intake (Singh *et al.* 1996). We did not find negative associations with WC changes for the ‘green’/‘healthy’ factor or the combined fruits and vegetables intake in our analyses. We found weak and insignificant positive associations for meat products for women, while for men the ‘traditional factor’, loading high in, for instance, meat, was negatively related to WC changes. For women, we did find a positive association between refined bread and changes in WC, as seen in other studies for a single food group (Jacobs *et al.* 1998) or for a ‘refined bread’ cluster (Newby *et al.* 2003). On the other hand, we did not find negative associations between changes in WC and intake of wholegrain bread, as one would have expected based on findings from several, but primarily cross-sectional, studies (Jacobs *et al.* 1998; Ludwig *et al.* 1999; Meyer *et al.* 2000; Wirfalt *et al.* 2001; McKeown *et al.* 2002). The observed positive association between refined bread intake and WC changes for women could indicate that a food pattern with a high glycaemic index may promote the development of both general and abdominal obesity, as suggested by others (Morris & Zemel, 1999; Ludwig, 2000; Ebbeling & Ludwig, 2001; Brand-Miller *et al.* 2002). For another high-glycaemic food item, potatoes, the association was negative, but this association may have been a chance finding, as the *P* value was not strong ($P=0{\cdot}04$) and the association disappeared in a model adjusted for concurrent changes in general obesity.

The use of factor scores or other estimates describing a food pattern may reduce the possibility of exact comparison with results from other studies, because the factor analyses are based on different types and numbers of food groups depending on type of dietary assessment method used in each study. However, many studies do identify an approximately comparable 'healthy'/'green' factor (covering food items such as fruits and vegetables, wholegrain products and fish), a 'traditional/western' food pattern (including meat and fried food items), a 'white bread' pattern and an 'alcohol' pattern (Tucker *et al.* 1992; Wirfalt & Jeffery, 1997; Greenwood *et al.* 2000; Hu *et al.* 2000; Williams *et al.* 2000; Fung *et al.* 2001; Haveman-Nies *et al.* 2001; Osler *et al.* 2001; Osler *et al.* 2002; Newby *et al.* 2003; Togo *et al.* 2004). One advantage of using food patterns is that the complexity of the many dietary variables is reduced and thereby the risk of collinearity and 'chance finding'. Food patterns may also give a more realistic description of peoples' dietary habits and whether one habit is 'better' than another with regard to risk of developing obesity or disease. The fact that we found no clear association between the food scores and WC or BMI changes (Togo *et al.* 2004) does not preclude the existence of different food patterns that may be associated with obesity. The identification of such patterns could prove to be a good tool in setting up dietary guidelines in the future.

Beverage intake. As in a prospective study by Kahn *et al.* (1997), we found a positive association between intake of alcohol and subsequent changes in WC for women, even after adjustments for concurrent changes in BMI. As in the study by Kahn *et al.* (1997), the association was due to a clear positive association for spirits and partly for beer, while wine intake was not associated with changes in WC. The same associations were also seen among women, but not men, in another Danish study investigating the associations between present WC and previous intakes of alcohol and beverage type (Vadstrup *et al.* 2003), and in other cross-sectional studies (Slattery *et al.* 1992; Duncan *et al.* 1995). However, one study in France, where wine is the preferable alcohol type, found that wine was also positively associated with WHR for women (Dallongeville *et al.* 1998). We could not identify the same clear associations for men. Here the tendencies towards positive association for beer, and towards minor preventive effects of wine on WC changes, did not persist when controlling for concurrent changes in BMI. Taken together, our present study and previous studies suggest that alcohol, especially spirits and beer for women, seems to be associated with the development of abdominal obesity in a different way than that seen for general obesity, where inverse associations are often seen for women, while the results for men are more mixed (Williamson *et al.* 1987; Lapidus *et al.* 1989; Tavani *et al.* 1994; Wannamethee & Shaper, 2003). Other sources of 'liquid' energy, such as from soft drinks, may also play a significant role in the obesity epidemic (Liebman *et al.* 2003). In our present study, due to low intake, soft drink consumption was not analysed separately but as part of the food group 'cake/sweets' (Table 2). However, even when analysed separately, no associations were found, suggesting that soft drinks are probably not a major participant to the changes in WC in the present study of middle-aged adults.

Based on evidence from short-term studies examining the effects of caffeine on energy expenditure and thermogenesis (Dulloo *et al.* 1989; Bracco *et al.* 1995; Yoshioka *et al.* 2001), one might expect negative associations between intakes of coffee or tea and changes in BMI. Two cross-sectional studies did find negative correlations between coffee intake and skinfold thicknesses or BMI (Kromhout *et al.* 1988; Merkus *et al.* 1995). Our present study found positive associations between coffee and tea intake and changes in WC before adjusting for BMI changes; this was also seen in some cross-sectional studies for BMI (Baecke *et al.* 1983; Jacobsen & Thelle, 1987; Kamycheva *et al.* 2003). There is no good explanation for the apparent gender differences for tea and coffee; they could be a result of chance finding, as the significance was not very strong. The associations almost disappeared after adjustment for BMI changes, which implies that high tea and coffee intake do not alter the abdominal fat accumulation independently of overall changes in obesity. The literature seems inconsistent and several studies do not find any correlation between coffee and WHR or BMI (Lapidus *et al.* 1989; Troisi *et al.* 1991; Tavani *et al.* 1994). One possible explanation for the positive association between coffee or tea and WC seen in our present study may be that caffeine induces high levels of cortisol, which may promote the abdominal fat accumulation (Bjorntorp, 1996). However, most of the association between coffee and tea and changes in WC could be explained by increases in overall obesity. Adjustment for adding sugar into coffee or tea or for intake of cakes and sweets in the present study, which might contribute to an extra intake of energy, did not change the association (results not shown). On the other hand, a lower intake of cakes and sweets seemed to be present in the group with the highest coffee intake.

In summary, few and weak independent associations between diet, expressed in food groups or in factor scores, and the subsequent changes in WC were present. It is possible that insufficient dietary information caused the unclear and inconsistent picture for similar food groups (e.g. refined bread and potatoes) and for men and women. However, it is also possible that diet does not have a specific independent influence on abdominal fat accumulation. Intakes of beer and spirits were clear predictors of increases in WC among women, but not men. Moderate to high intake of coffee and tea seemed to promote gain in WC, but part of the association seemed be explained by concurrent changes in BMI. Prospective studies with more detailed information on diet and drinking habits are needed to confirm these associations.

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Appendix 1.

Food items included in the food groups based on the twenty-six-item food-frequency questionnaire, and median intake (times per week) within quintiles for men and women

Food categories*	Food items from the food-frequency questionnaire	Median weekly intake within quintiles†				
		1st	2nd	3rd	4th	5th
Fruits and vegetables	Fresh fruit, fruit juice, boiled vegetables, raw vegetables	4·0	8·0	12·0	16·8	24·5
Wholegrain bread	Wholegrain rye bread, wholegrain wheat bread, oatmeal	2·8	8·0	14·0	17·3	24·3
Refined bread	Refined wheat bread, refined rye bread	0·0	0·5	7·0	9·5	24·0
Potatoes‡	Potatoes	1·0	2·5	7·0	–	–
Rice and pasta	Rice, pasta	0·5	0·8	1·0	1·5	3·0
Meat	Meat for dinner, sausages, pâté and meat on bread	3·8	8·3	10·0	14·5	15·0
Fish‡	Fish	0·3	0·5	1·0	2·5	–
Cake and sweets	Cakes and biscuits, sweets and chocolate, jam and honey, soft drinks and ice cream	1·5	3·8	6·5	10·0	16·0
Dairy products	Milk or yoghurt, cheese	3·5	9·5	14·0	18·0	24·0
Butter and margarine	Butter, lard, vegetable margarine	2·8	14·0	17·0	24·0	34·0
Coffee (number of cups per d)§	Coffee	2	4	7	10	–
Tea (number of cups per d)§	Tea	0	1	2	5	–
Alcohol (number of drinks per week)§‖	Wine, beer, spirits	0	4	8	20	–

* Twenty-four of the twenty-six food items were included in the ten food groups. Diet margarine and egg were not included in any food group.
† As the quintile distribution was made for the total population, the median intake within each quintile is presented for the total group. Few gender differences were seen.
‡ Because of a small variation in the intake of potatoes and fish, potatoes were divided into three groups, and fish into quartiles.
§ Intake of total alcohol, tea and coffee was divided into quartiles.
‖ Gender differences in total alcohol intake were present mainly due to a higher intake of beer among men.

Appendix 2.

Food items included in the factor scores based on the twenty-six item food-frequency questionnaire for men and women

Factor scores *	Food items from the food-frequency questionnaire
Traditional factor (men)	Meat, meat for sandwich, potatoes, refined wheat bread, sausages, butter and margarine, eggs
Green factor (men)	Wholegrain bread, raw vegetables, cooked vegetables, fruit, rice, cheese, fish, milk products, refined wheat bread†
Sweet factor (men)	Cakes and biscuits, sweets and chocolate, soft drinks and ice cream, jam and honey
Traditional/sweet factor (women)	Sweets and chocolate, cakes and biscuits, meat for sandwich, refined wheat bread, butter and margarine, soft drinks and ice cream, jam and honey, potatoes, meat, sausages
Green factor (women)	Wholegrain bread, raw vegetables, fruits, cooked vegetables, fish, cheese, rice, jam and honey, milk products, refined wheat bread†

* Because of a low frequency of intake ($\geq$50 % of subjects stated an intake less than once per month), five items (oatmeal, diet margarine, juice, refined rye bread and pasta) were not included in the factor analysis (and hence not in the factors). Vegetable margarine was not correlated with any of the factors. Foods are sorted by their loading on correlation with the factor (highest positive loading first).
† Refined wheat bread loaded negative on the green factor for both men and women.

Appendix 3.
*Percentage and median intake per week (men/women) within each category for intake of wine, beer and spirits**

	Non-drinker of specific type	One to three drinks per week	Four to nine drinks per week (m) or more than four drinks per week (w)	More than ten drinks per week (m)
Wine				
% Subjects	28/34	38/37	24/29	10/-
Median intake	0/0	2/2	5/6	14/-
Beer				
% Subjects	16/56	34/33	22/11	28/-
Median intake	0/0	2/1	5/6	15/-
Spirits				
% Subjects	51/71	36/23	13/6	-/-
Median intake	0/0	1/1·5	6/5	-/-

m, men; w, women.
* Intakes of beer and wine were divided into four groups for men and three groups for women, while intakes of spirits were divided into three groups for both men and women.