European Journal of Clinical Nutrition (2011) 65, 800–807
 0954-3007/11
www.nature.com/ejcn

ORIGINAL ARTICLE

Dietary patterns, subclinical inflammation, incident coronary heart disease and mortality in middle-aged men from the MONICA/KORA Augsburg cohort study

J Meyer[1], A Döring[2], C Herder[3], M Roden[3,4], W Koenig[5] and B Thorand[1]

[1]*Institute of Epidemiology II, Department of Epidemiology, Helmholtz-Zentrum München, German Research Center for Environmental Health, Munich, Germany;* [2]*Institute of Epidemiology, Department of Epidemiology, Helmholtz-Zentrum München, German Research Center for Environmental Health, Munich, Germany;* [3]*Institute for Clinical Diabetology, German Diabetes Center, Leibniz Center for Diabetes Research at Heinrich Heine University Düsseldorf, Düsseldorf, Germany;* [4]*Department of Metabolic Diseases, Heinrich Heine University Düsseldorf, Düsseldorf, Germany and* [5]*Department of Internal Medicine II-Cardiology, University Hospital Ulm, Ulm Medical Center, Ulm, Germany*

Background/Objectives: We aimed to identify dietary patterns associated with inflammatory markers and to examine their impact on the incidence of coronary heart disease (CHD) and all-cause mortality, as subclinical inflammation is a risk factor for these outcomes.
Subjects/Methods: The study population comprised 981 middle-aged men participating in the first or third 'MONItoring of Trends and Determinants in CArdiovascular Diseases' (MONICA) Augsburg surveys who completed 7-day dietary records. Subjects were followed up until 2002 for CHD and until 2007 for mortality. Dietary patterns were derived using reduced rank regression (RRR) with C-reactive protein, interleukin (IL)-6 and IL-18 as responses. Alternatively, partial least squares and principal components regression were used.
Results: A high score of the RRR-derived pattern was characterised by high intakes of meat, soft drinks and beer and low intakes of vegetables, fresh fruit, chocolates, cake, pastries, wholemeal bread, cereals, muesli, curd, condensed milk, cream, butter, nuts, sweet bread spread and tea. This score was associated with a higher risk for CHD (hazard ratio = 1.33, 95% confidence interval: 1.06–1.67, $P = 0.013$) and mortality (hazard ratio = 1.34, 1.17–1.53, $P < 0.001$) after multivariable adjustment. However, for CHD and CHD mortality the significant association disappeared after further adjustment for smoking status; for all-cause mortality it was attenuated but remained significant (hazard ratio = 1.16, 1.00–1.33, $P = 0.046$). Patterns derived from the other methods resembled the RRR pattern showing similar results regarding disease outcomes.
Conclusions: Participants exhibiting higher dietary pattern scores had higher levels of inflammatory markers and higher risk for CHD and all-cause mortality, however, smoking was an important confounder, especially for CHD outcomes.
European Journal of Clinical Nutrition (2011) **65,** 800–807; doi:10.1038/ejcn.2011.37; published online 6 April 2011

Keywords: diet; dietary patterns; inflammation; coronary heart disease (CHD); mortality

Introduction

Increased levels of the acute phase protein C-reactive protein (CRP), and the proinflammatory cytokines interleukin (IL)-6 and IL-18 were found to be associated with the risk of coronary heart disease (CHD; Blankenberg *et al.*, 2003; Koenig *et al.*, 2006; Kaptoge *et al.*, 2010; Rodondi *et al.*, 2010), death from CHD (Heidema *et al.*, 2009) and all-cause mortality (Stork *et al.*, 2006; Tuomisto *et al.*, 2006; Jylha *et al.*, 2007). In addition, single food components have been found to be related to inflammatory markers; higher intakes of dietary fibre (Ma *et al.*, 2008; Herder *et al.*, 2009; Wannamethee *et al.*, 2009), whole-grain products (Qi *et al.*, 2006; Lutsey *et al.*, 2007), fruit and vegetables (Wannamethee *et al.*, 2006; Holt *et al.*, 2009), nuts (Salas-Salvado *et al.*, 2008;

Correspondence: Dr B Thorand, Institute of Epidemiology II, Helmholtz Zentrum München, German Research Center for Environmental Health, Ingolstädter Landstraße 1, 85764 Neuherberg, Germany.
E-mail: thorand@helmholtz-muenchen.de
Received 10 September 2010; revised 21 December 2010; accepted 17 February 2011; published online 6 April 2011

Casas-Agustench *et al*., 2010), and a moderate alcohol intake (Wang *et al*., 2008; Oliveira *et al*., 2010) were associated with lower concentrations of several immune mediators in the circulation.

An alternative to analysing associations between inflammatory markers and single dietary components is the examination of dietary patterns. This method takes correlations and structures between single food components into account and can identify dietary behaviours that are associated with inflammatory markers. One established method in nutritional epidemiology is reduced rank regression (RRR). RRR benefits from the possibility to bring in *a priori* knowledge in the form of response variables such as known risk factors for outcomes.

Several studies derived dietary patterns using RRR. McNaughton *et al*. (2009) found a dietary pattern associated with a higher CHD risk using blood lipids as response variables. Heroux *et al*. (2010) used eight response variables, such as triglycerides, total cholesterol and white blood cell count, to identify a pattern labelled the unhealthy eating index that was associated with a higher mortality. So far, only one study used inflammatory markers as response variables in RRR (Schulze *et al*., 2005). However, this study only assessed the association between the resulting dietary pattern and incident type 2 diabetes, and the study population consisted solely of women.

In our study, we were especially interested in inflammation as the link between diet and heart disease as well as mortality. Therefore, we aimed to identify dietary patterns in a representative sample of middle-aged men from Southern Germany, which are associated with the proinflammatory markes CRP, IL-6 and IL-18. CRP and IL-6 are well-established inflammation markers, which were found to be associated with heart disease and mortality by several previous studies. Results for IL-18 were not as consistent. However, there are several studies that point towards an association between IL-18 and CHD (Wang *et al*., 2006; Welsh *et al*., 2010). Furthermore, IL-18 was also found to be associated with a Mediterranean-like diet (Troseid *et al*., 2009). The dietary patterns were calculated through the use of RRR and another multivariate method namely partial least squares regression (PLS). For comparison, we also used principal components regression (PCR). Subsequently, the association between the identified patterns and the incidence of CHD, CHD mortality and all-cause mortality was analysed.

Materials and methods

Study population

In the years 1984–1995, three independent cross-sectional surveys were conducted at intervals of 5 years in Southern Germany as part of the multinational World Health Organisation MONItoring of Trends and Determinants in CArdiovascular Diseases (MONICA) project. Subjects were followed up until the end of 2002 for CHD and 2007 for mortality within the frame of the Cooperative Health Research in the Region of Augsburg (Kooperative Gesundheitsforschung in der Region Augsburg/KORA). Further details of the study design can be found elsewhere (Hense *et al*., 1998; Lowel *et al*., 2005). Our study population consisted of male participants aged 45–64 years from survey 1 (S1, $n=899$) and survey 3 (S3, $n=430$) conducted in 1984/1985 and 1994/1995, respectively, who completed a 7-day dietary record and for whom complete data for the inflammation markers and all covariates required for the Cox proportional hazards models were available (S1: $n=594$, S3: $n=387$). Of 981 participants, 101 experienced an acute coronary event within a median follow-up time of 16.7 and 7.9 years for S1 and S3, respectively. During a median follow-up time of 22.8 and 12.9 years for S1 and S3, respectively, 292 participants died, 88 of them from CHD.

Dietary assessment

The participants completed 7-day dietary records. The exact amount of food consumed was assessed through a combination of weighing with scales and household measures. Further details can be found elsewhere (Winkler *et al*., 2000). Subsequently, the records were coded according to the German national database BLS (Bundeslebensmittelschlüssel = German Federal Food Key) version II.2 and recipes were divided into single food items. Food items were classified into 38 food groups (see Supplementary Table 1).

Covariate assessment

All participants underwent standardised interviews conducted by trained medical staff to assess the information on sociodemographic variables, leisure time physical activity, smoking habits, history of diseases, such as diabetes, and alcohol consumption. Furthermore, standardised medical examinations, such as blood pressure measurements, weighing and drawing of non-fasting venous blood samples, were conducted. Details about examination methods were reported previously (Hense *et al*., 1998; Meisinger *et al*., 2002).

Inflammation marker measurement

CRP, IL-6 and IL-18 were measured in serum samples stored at $-80\,^{\circ}C$ using a high-sensitivity immunoradiometric assay (Dade Behring, Marburg, Germany), a sandwich enzyme-linked immunosorbent assay (CLB, Amsterdam, The Netherlands), and an in-house bead-based multiplex assay (Nagoya, Japan), respectively, as described previously (Thorand *et al*., 2005; Koenig *et al*., 2006).

Outcome ascertainment

Deaths were ascertained by regularly checking the vital status of all participants through the population registries. Death certificates were coded for the underlying cause of death by a single trained person using the 9th revision of the International Classification of Diseases. Myocardial

infarctions occurring before the age of 75 years were identified through the population-based MONICA/KORA Augsburg coronary event registry and follow-up questionnaires for participants who moved out of the study area. Self-reported cases of non-fatal incident myocardial infarctions were validated using hospital records or information provided by the treating physicians. The end points used in this study were incidence of fatal or non-fatal myocardial infarction, including sudden cardiac death, mortality from CHD (9th revision of the International Classification of Diseases: 410–414 and 798) and all-cause mortality.

Statistical analysis

Dietary patterns were derived using three established multivariate methods, that is, RRR, PLS and PCR. For each pattern factor scores were calculated for all subjects. These methods are described in detail elsewhere (Hoffmann *et al*., 2004). In brief, RRR derives patterns based on the covariance matrix of response variables. The resulting patterns are orthogonal and maximise the explained variation in the response variables. In contrast, PCR uses the covariance matrix of predictor variables to derive orthogonal patterns, which maximise the explained variation of the predictor variables. Finally, PLS uses the covariance matrix between predictor and response variables to gain orthogonal patterns, which maximise the explained covariance between predictor and response variables. In our analysis, we chose the proinflammatory markers IL-6, IL-18 and CRP as response variables and 38 food groups as predictor variables. The inflammatory markers were log transformed to better fit the normal distribution. Food group intakes were adjusted for survey using the residual method (Willett and Stampfer, 1986), because the eating habits changed somewhat between the two surveys. For all three methods, only the first pattern was biologically plausible. Hence, only the first pattern for each method was analysed further. Correlations between the identified factor scores and food groups as well as inflammatory markers were calculated using Spearman correlation coefficients, as the variables were not normally distributed. The standard normalised first factor score for each method was entered into Cox proportional hazards models to analyse their effect on the end points. Three multivariable adjusted models were calculated. The proportional hazards assumption was tested by computing the correlation between the Schoenfeld residuals for each variable in the model and the ranked survival time of the events. No relevant deviations from the proportional hazards assumption were found. All analyses were conducted using SAS statistical software, version 9.2 (SAS Institute Inc., Cary, NC, USA).

Results

At the time of assessment participants were on average 54.9 years old with a mean body mass index (BMI) of 27.6 kg/m^2. Further details about the study population stratified by survival status can be found in Table 1.

Factor loadings represent correlations of the factor score with food groups. The factor loadings of the identified patterns can be found in Table 2. Only food groups with absolute values of loadings $\geqslant 0.15$ were considered relevant and included in the table. Food groups with lower loadings are listed in the footnote of Table 2. The loadings of the patterns obtained by the three methods were similar with the same signs and similar food groups influencing the factor scores (see also the correlation between factor scores in Table 3). Low intakes of meat and beer and high intakes of fresh and cooked vegetables, fresh fruit, wholemeal bread, cereals and muesli, curd, nuts, sweet bread spread as well as tea were associated with an advantageous profile of inflammatory markers for the main patterns derived from all three methods.

In Table 3, the Spearman correlation coefficients between factor scores and food groups and between inflammatory markers and food groups as well as factor scores are listed. The correlations with food groups were highest for CRP and lowest for IL-18. The factor scores were significantly correlated with all inflammatory markers, but the correlation coefficients for IL-18 were low. CRP exhibited the highest correlation with the factor scores and was also best explained by them as can be seen from the proportions of explained variances in Table 4. Because of the different calculation methods, the RRR-derived factor explained most of the variance in inflammatory markers (5.01%) and the score resulting from PCR most of the variance in food groups (7.47%).

The results of the Cox proportional hazards regression for incident CHD, CHD mortality and all-cause mortality for the three factor scores can be found in Table 5. For every end-point, three different multivariable adjusted models were calculated: a model adjusted for survey and age (M1), a model further adjusted for BMI, education level, physical activity, actual hypertension, place of residence (urban/rural), self-reported diagnosis of diabetes, energy intake and ratio of total cholesterol to high-density lipoprotein-cholesterol (M2), and a fully adjusted model with further adjustment for smoking status (M3). As BMI is associated with mortality quadratically, for the end point all-cause mortality we additionally adjusted M2 and M3 for BMI^2.

The factor scores from all methods increased the risk of CHD in M1, and their effect was only slightly attenuated after further adjustment in M2. When smoking was added as an adjustment variable, the effects of the factor scores were not statistically significant anymore.

The factor scores from RRR and PLS also increased the risk for CHD mortality in M1 and M2, whereas the score from PCR was only borderline significant. On further adjustment for smoking, the significance was lost for all factor scores.

The risk for all-cause mortality was increased by the factor scores as well. Even after adjustment for all variables, including smoking, the effect of the RRR and PLS score

Table 1 Baseline characteristics of the study population stratified by survival status

	Survived	*Died*	
		From CHD	*From non-CHD causes*[a]
N	689	88	204
Person-years	12 496	1001	2622
Median follow-up time in years	22.7	10.1	12.2
BMI, kg/m^2[b]	27.5 (3.0)	28.7 (3.2)	27.7 (3.9)
Age, years[b]	53.8 (5.7)	57.9 (4.7)	57.3 (5.4)
Current smokers, %	26.1	44.3	39.7
Former smokers, %	43.3	40.9	37.8
Never smokers, %	30.6	14.8	22.6
Alcohol 0 g/day, %	14.7	13.6	16.7
Alcohol >0 and <40 g/day, %	50.4	50.0	44.6
Alcohol $\geqslant 40$ g/day, %	35.0	36.4	38.7
Physically active, %	45.7	35.2	27.9
Urban place of residence, %	73.6	60.2	59.8
Actual hypertension, %	45.7	69.3	59.8
Diabetes, %	3.3	17.1	9.8
CHD, %	3.6	27.6	11.3
High level of education, %	34.7	22.7	22.6
TC/HDL-C ratio[b]	5.19 (1.74)	6.29 (2.24)	5.26 (1.87)
Energy intake, kcal/day[b]	2529 (551)	2369 (528)	2380 (586)
C-reactive protein, mg/l[c]	1.22 (2.31)	2.44 (4.48)	2.57 (3.99)
Interleukin-6, pg/ml[c]	3.36 (1.66)	3.48 (2.53)	3.81 (2.36)
Interleukin-18, pg/ml[c]	213.0 (123.3)	195.9 (139.8)	215.4 (136.7)

Abbreviations: BMI, body mass index; CHD, coronary heart disease; TC/HDL-C, total cholesterol/high-density lipoprotein-cholesterol.
[a]In this category six participants are included, of whom the cause of death is unknown.
[b]Values are mean (s.d.).
[c]Values are median (inter-quartile range).

Table 2 Factor loadings of relevant food groups ($|\text{loading}| \geqslant 0.15$) for the three methods reduced rank regression (RRR), partial least squares (PLS) and principal component regression (PCR)

Food group	*Factor loadings*		
	RRR	*PLS*	*PCR*
Meat (except poultry)	0.24	0.20	0.16
Cooked sausage	—	0.17	0.20
Potatoes	—	—	−0.16
Rice	—	—	−0.15
Fresh vegetables	−0.23	−0.22	−0.24
Cooked vegetables	−0.17	−0.23	−0.26
Fresh fruit	−0.30	−0.32	−0.33
Chocolates	−0.19	—	—
Cake and pastries	−0.26	−0.16	—
Wholemeal bread	−0.26	−0.27	−0.30
Cereals and muesli	−0.20	−0.19	−0.18
Curd	−0.17	−0.20	−0.21
Cheese	—	−0.22	−0.26
Condensed milk and cream	−0.26	−0.19	—
Butter	−0.18	−0.18	—
Vegetable oil	—	—	−0.16
Nuts	−0.18	−0.16	−0.16
Sweet bread spread	−0.36	−0.33	−0.26
Fruit and vegetable juice	—	—	−0.15
Soft drinks	0.22	—	—
Tea	−0.18	−0.23	−0.22
Beer	0.27	0.31	0.30

Remaining food groups are poultry, fish, pasta, other confectionery, munchies/salty foods, white bread, egg, milk, margarine, miscellaneous fats, fruit products, water, coffee, spirits, wine and sugar.

remained significant and the effect of the PCR score was borderline significant.

Smoking status was an important confounder of the association between dietary patterns and disease risk as well as mortality, as it was strongly associated with both dietary habits and outcomes (data not shown). Besides the inflammation markers, CRP and IL-6 varied significantly by smoking status and IL-18 levels tended to be higher among current smokers as compared with ex- and never smokers (data not shown). As a consequence, associations between dietary patterns and CHD as well as CHD and all-cause mortality were considerably attenuated after adjustment for smoking status and they became nonsignificant for CHD and CHD mortality.

Discussion

In our study, we identified dietary patterns exhibiting similar loadings using RRR, PLS and PCR. They were characterised by higher intakes of meat and beer and lower intakes of fresh and cooked vegetables, fresh fruit, wholemeal bread, cereals and muesli, curd, nuts, sweet bread spread as well as tea. With an increasing pattern score, the risk of CHD and CHD mortality increased significantly, as long as the confounder smoking status was not included in the model. For all-cause mortality, the association with patterns derived from RRR

Table 3 Spearman correlation coefficients between food groups, scores and inflammation markers

	Correlation with factor score			*Correlation with inflammation marker*		
	RRR	*PLS*	*PCR*	*IL-6*	*IL-18*	*CRP*
Food group						
Meat (except poultry)	0.31***	0.32***	0.27***	0.03	−0.01	0.10*
Cooked sausage	0.11**	0.27***	0.33***	−0.04	−0.01	0.04
Potatoes	−0.11**	−0.20***	−0.26***	−0.04	−0.01	−0.06
Rice	−0.10*	−0.19***	−0.27***	−0.02	0.02	−0.07*
Fresh vegetables	−0.29***	−0.34***	−0.38***	−0.07*	−0.00	−0.17***
Cooked vegetables	−0.21***	−0.36***	−0.42***	−0.07*	−0.07*	−0.09*
Fresh fruit	−0.41***	−0.52***	−0.55***	−0.12**	−0.06	−0.14***
Chocolates	−0.27***	−0.24***	−0.16***	−0.07*	−0.01	−0.13***
Cake and pastries	−0.38***	−0.29***	−0.13***	−0.13***	−0.01	−0.12**
Wholemeal bread	−0.34***	−0.43***	−0.47***	−0.08*	−0.02	−0.16***
Cereals and muesli	−0.27***	−0.32***	−0.32***	−0.05	−0.03	−0.13***
Curd	−0.28***	−0.36***	−0.40***	−0.08*	−0.05	−0.12**
Cheese	−0.20***	−0.36***	−0.41***	−0.04	0.01	−0.11**
Condensed milk and cream	−0.31***	−0.30***	−0.23***	−0.06	−0.00	−0.10*
Butter	−0.27***	−0.29***	−0.19***	−0.07*	−0.06*	−0.09*
Vegetable oil	−0.11**	−0.15***	−0.21***	−0.03	0.03	−0.06
Nuts	−0.26***	−0.29***	−0.28***	−0.06*	0.02	−0.13***
Sweet bread spread	−0.49***	−0.50***	−0.40***	−0.10*	−0.04	−0.19***
Fruit and vegetable juice	−0.14***	−0.23***	−0.26***	−0.09*	−0.03	−0.10*
Soft drinks	0.18***	0.12**	0.09*	0.01	−0.01	0.05
Tea	−0.23***	−0.34***	−0.35***	−0.07*	−0.05	−0.08*
Beer	0.34***	0.49***	0.52***	0.08*	0.02	0.09*
Factor score						
RRR	1.00	0.87***	0.68***	0.27***	0.08*	0.33***
PLS	—	1.00	0.94***	0.23***	0.11**	0.29***
PCR	—	—	1.00	0.19***	0.11**	0.24***

Abbreviations: CRP, C-reactive protein; IL-6, interleukin-6; IL-18, interleukin-18; PCR, principal components regression; PLS, partial least squares regression; RRR, reduced rank regression.
*$P<0.05$, **$P<0.001$, ***$P<0.0001$.

Table 4 Percent variation accounted for by dietary pattern score (loadings shown in Table 2) for the three methods

Method	*Log IL-6*	*Log IL-18*	*Log CRP*	*Total biomarkers*	*Total food groups*
RRR	3.86	0.06	11.11	5.01	4.96
PLS	2.95	0.39	8.43	3.93	7.03
PCR	1.79	0.43	5.55	2.59	7.47

Abbreviations: CRP, C-reactive protein; IL-6, interleukin-6; IL-18, interleukin-18; PCR, principal components regression; PLS, partial least squares regression; RRR, reduced rank regression.

and PLS was weakened but was still statistically significant after adjustment for smoking status.

The association of dietary patterns with CHD was analysed in various studies. The prudent pattern (characterised by high intakes of fruits, vegetables, legumes, fish, poultry and whole grains) was found to be protective against CHD, whereas the western pattern (characterised by high intakes of red and processed meats, sweets, desserts, french fries and refined grains) was found to increase the risk for CHD in both women and men (Hu *et al*., 2000; Fung *et al*., 2001). These patterns were detected by factor analysis. RRR was applied in two studies (Weikert *et al*., 2005; McNaughton *et al*., 2009), but they did not use inflammation parameters as response variables.

The association of diet and CHD mortality was so far only analysed with regard to single food items. Fish was found to be protective against death from CHD (He *et al*., 2004; Zhang *et al*., 2009), high intakes of saturated fats were found to increase the risk in women, but not in men (Boniface and Tefft, 2002), and oils rich in α-linolenic acid were identified to lower CHD mortality (Zatonski *et al*., 2008), but results have not always been consistent.

Dietary patterns derived by RRR and their association with all-cause mortality were analysed recently by Heroux *et al*. (2010). Response variables were eight markers, such as uric acid, blood pressure, BMI and fasting glucose, whereas inflammation markers were not included. A pattern named the unhealthy eating index was significantly associated with all-cause mortality, but the association vanished after adjustment for self-reported physical activity and fitness. In their study, Hoffmann *et al*. (2005) found that dietary

Table 5 HRs with 95% CIs and corresponding *P*-values of the standardised dietary pattern score (loadings shown in Table 2) for different levels of adjustment for the incidence of coronary heart disease, CHD mortality and all-cause mortality

	RRR		*PLS*		*PCR*	
	HR (95% CI)	P	*HR (95% CI)*	P	*HR (95% CI)*	P
Incident coronary heart disease (101 cases)						
M1	1.40 (1.14, 1.73)	0.002	1.49 (1.19, 1.86)	0.001	1.46 (1.16, 1.83)	0.001
M2	1.33 (1.06, 1.67)	0.013	1.48 (1.16, 1.88)	0.002	1.49 (1.17, 1.92)	0.002
M3	1.15 (0.91, 1.45)	0.257	1.27 (0.98, 1.63)	0.070	1.29 (1.00, 1.67)	0.052
Coronary heart disease mortality (88 cases)						
M1	1.45 (1.15, 1.82)	0.002	1.40 (1.10, 1.77)	0.006	1.27 (1.00, 1.77)	0.050
M2	1.38 (1.07, 1.79)	0.013	1.40 (1.07, 1.84)	0.015	1.33 (1.02, 1.74)	0.039
M3	1.18 (0.90, 1.54)	0.225	1.18 (0.89, 1.56)	0.256	1.12 (0.85, 1.48)	0.420
All-cause mortality (292 cases)						
M1	1.41 (1.24, 1.59)	<0.0001	1.39 (1.22, 1.59)	<0.0001	1.32 (1.16, 1.50)	<0.0001
M2[a]	1.31 (1.15, 1.50)	<0.0001	1.35 (1.17, 1.56)	<0.0001	1.32 (1.15, 1.53)	0.0001
M3[a]	1.16 (1.00, 1.33)	0.046	1.18 (1.02, 1.37)	0.030	1.16 (1.00, 1.35)	0.054

Abbreviations: BMI, body mass index; CHD, coronary heart disease; CI, confidence interval; HR, hazards ratio; PCR, principal components regression; PLS, partial least squares regression; RRR, reduced rank regression.
[a]Additional adjustment for BMI^2.
M1: adjusted for age and survey (S1/S3).
M2: M1 with further adjustment for BMI, place of residence (urban/rural), actual hypertension (yes/no), education level (low/ high), self-reported diagnosis of diabetes, physical activity (active/not active), energy intake (kcal/day), ratio of total cholesterol and HDL cholesterol.
M3: M2 with further adjustment for smoking status (current/former/never smoker).

patterns derived from RRR using percentages of energy from different macronutrients as response variables predicted total mortality better than PCR derived patterns. A pattern derived from RRR characterised by high intakes of meat, butter, sauces and eggs and low intakes of bread and fruits was found to increase the risk of all-cause mortality. The Mediterranean diet characterised by high intakes of vegetables, legumes, fruits, nuts, whole grains, fish and low intakes of red meat was found to be protective against all-cause mortality by one study using a nine-point score (Mitrou *et al*., 2007), whereas this association was not present in two other analyses which used cluster analysis and PCR to detect the Mediterranean pattern (Waijers *et al*., 2006; Brunner *et al*., 2008). The prudent pattern detected by PCR was associated with lower all-cause mortality, whereas the PCR-derived western pattern yielded discrepant results (Osler *et al*., 2001; Heidemann *et al*., 2008). Bamia *et al*. (2007) found that a plant-based diet is not associated with mortality in Germany, but in several other countries such as Greece and Denmark.

This study has several strengths. First, for dietary assessment 7-day dietary records were used, so that the amount of every food consumed could be determined quite exactly for every day. This assessment method leads to more accurate ascertainment of food consumption in comparison with food frequency questionnaires. Second, through the use of RRR we were able to include *a priori* knowledge and therefore identify patterns that are associated with heart diseases and mortality. Third, we calculated patterns with the help of the multivariate methods RRR, PLS and PCR, and were able to compare the results. Fourth, we analysed the association between diet and the incidence of CHD, CHD mortality and all-cause mortality prospectively in a follow-up study. In contrast to cross-sectional studies, temporal sequences with implications for causality can be inferred.

Several limitations should also be noted. First, only men were analysed so that further studies are needed to analyse the transferability of the dietary patterns and their effect on the end points to women. Second, because the dietary assessment is extensive only 981 men could be included. Therefore, the number of events and consequently the power of the study were limited. Another reason for the limited number of events is that our population exhibits a relatively low risk for cardiovascular events, as we analysed men aged between 45 und 64 years at baseline from the general German population. Third, the follow-up times were quite long, especially for participants from survey S1. Dietary behaviour might have changed over time, which could attenuate the observed effects between dietary behaviour at baseline and outcomes.

In conclusion, our study found an association of a diet rich in meat and beer and low in fresh and cooked vegetables, fresh fruit, wholemeal bread, cereals and muesli, curd, nuts, sweet bread spread as well as tea with high circulating levels of inflammatory markers as well as with increased risk of incident CHD, CHD mortality and all-cause mortality in men. For CHD and CHD mortality, these associations were not independent of smoking status and for all-cause mortality they were attenuated after adjustment for smoking status.

Conflict of interest

The authors declare no conflict of interest.

Acknowledgements

We thank all members of the Institute of Epidemiology at the Helmholtz-Zentrum München and the field staff in Augsburg involved in the planning and conduct of the MONICA/KORA Augsburg studies. Furthermore, we thank Gerlinde Trischler (University of Ulm) and Gabi Gornitzka, Ulrike Poschen, and Karin Röhrig (all from the German Diabetes Center, Düsseldorf) for technical assistance and Andrea Schneider for excellent data management. Finally, we express our appreciation to all study participants. The MONICA/KORA Augsburg cohort study was funded by the Helmholtz Zentrum München and supported by grants from the Federal Ministry of Education and Research, Berlin. This study was supported by research grants from the German Research Foundation, Bonn, (TH-784/2-1 and TH-784/2-2) and by additional funds provided by the University of Ulm, the German Diabetes Center, Düsseldorf, the Federal Ministry of Health, the Ministry of Innovation, Science, Research and Technology of the state North Rhine Westphalia.

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Supplementary Information accompanies the paper on European Journal of Clinical Nutrition website (http://www.nature.com/ejcn)