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Determinants of diet quality

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Abstract

Background: An unbalanced diet is a main risk factor for several chronic diseases. This paper identifies groups of individuals with an unbalanced diet based on the consumption of nutrients. A characterisation of the groups may help to focus efforts aimed at improving the dietary behaviour of the population.

Methods: Using nutritional data of 1763 men and 2267 women participating in the German Nutrition Survey of 1998, we constructed two indices for diet quality that each combines a large amount of nutrients into a single indicator. The impact of sociodemographic and lifestyle characteristics on the diet quality indices was analysed using multiple regression analyses.

Results: The results show a considerable variation of diet quality between different groups of individuals. High diet quality in terms of the consumption of vitamins, minerals and trace elements is positively associated with income, education level, age, energy intake, food diversity, sport activity and vegetarianism. On the other hand, a low diet quality as indicated by high intakes of e.g. fat, sugar, alcohol and sodium can be expected when energy intake is high, for individuals of middle age and for pregnant and breast-feeding women.

Conclusion: The results of this study help to identify groups of individuals with preferable and non-preferable diet quality. For developing public health strategies, in particular the impact of age on diet quality seems to be interesting. The rising diet quality with increasing age could reflect a changing health consciousness. It could thus be a challenge for health policy to promote a healthy way of living focused especially on young individuals.

Keywords
Diet quality index
Sociodemographic determinants

An unbalanced diet is a main risk factor for several chronic diseases, among which are obesity, stroke, cancer and type 2 diabetes mellitus. These diseases contribute to preliminary deaths, restrict life quality and lead to enormous costs for health systems. Thus, health policy is strongly motivated by the need to monitor the population's diet and, when necessary, to help improve dietary status by providing nutrition information and education. This population focus raises the question of whether groups of individuals can be identified whose consumption of certain nutrients is systematically too high or too low. If these groups can be characterised, efforts to improve the dietary behaviour of the population may be undertaken in a more focused and efficient manner.

The predominant approach undertaken in previous studies that attempted to identify such groups focused on the measurement of single dietary components for evaluating diet quality[1]. For example, dietary energy, fat and selected micronutrients have been used as indices of overall nutrient adequacy[2]. Since prevention and therapy of diet-related diseases may need a more holistic approach based on foods[3,4], some recent studies have concentrated on developing a composite index of dietary behaviour[1,4–11]. The general purpose of these indices is to combine a large amount of information about eating habits into a single indicator. The advantage of such an indicator is that dietary behaviour can be analysed as a single factor evaluating many compounds of our diet.

The nutrition literature contains a wide variety of diet quality indices. An overview of these indices has been given by Kant[2]. Composite indices differ in the number of dietary components included, which ranges from eight[1] to approximately 20[8]. They also vary in the composition of the components. Some authors combine foods and nutrients in one index[4,7,9], while others separate them[6]. Whereas some authors combine indicators of excess intake and of deficient intake in one single index[1,4,6,7,9], others make separate indices[8]. Finally, indices also differ in the construction of scores. In some studies, each index component was scaled into a few subgroups (e.g. dietary guidelines reached = 1, not reached = 0)[4,8,9]. In other studies, the individual score was determined more

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quantitatively, as a proportion of dietary recommendations[5]. Dubois *et al.* have compared different diet quality indicators[12].

All mentioned indices have specific advantages and disadvantages. In this analysis two new diet quality indices were constructed, which combine positive aspects of previous indices into single indicators. These new indices are used empirically to analyse several determinants of diet quality, to identify groups of individuals with a low or high diet quality.

Materials and methods

Data assessment

From October 1997 to March 1999 the representative German National Health Interview and Examination Survey was conducted, with a total of 7124 participants aged 18–79 years, by the Robert Koch Institute (RKI), Berlin. The participants were sampled from population registries, stratified by age, gender, community size and federal state. A sub-sample of 4030 persons (2267 women, 1763 men) participated in the affiliated German Nutrition Survey. The Nutrition Survey participants were interviewed comprehensively about their diet of the preceding four weeks by trained nutritionists using a validated computerised dietary history (DISHES 98 – Dietary Interview Software for Health Examination Studies)[13,14]. Also during the DISHES interview the participants were asked about their use of dietary supplements. The intake frequency during the past year, together with brand names of the following vitamin and mineral supplements, was assessed: vitamin B complex, vitamin C, vitamin E, folate, multivitamins and mineral supplements. From the quantitative information on both foods and supplements obtained, the average total nutrient intake per day was summarised for each individual using both the German Food Composition Table ('Bundeslebensmittelschlüssel') version II.3 and a supplement composition database developed by the GSF – National Research Centre for Environment and Health, Institute of Epidemiology, Neuherberg, and updated by the RKI[15].

Index construction

To analyse the diet quality comprehensively, a comparatively high number of 35 nutrients were included. According to Herrmann and Röder[8], components of excess and of deficient intake were separated into two indices for the following reasons. First, important information would be lost in an aggregate index. It is of great scientific interest to know whether a special diet quality is the result of over-consumption (e.g. of fat and cholesterol) or under-consumption (e.g. of vitamins, minerals and trace elements)[16,17]. Second, the general problem of weighting index components would become very obvious in an aggregate index. It is difficult to assess the health value of components of under-consumption like vitamin C, in comparison with components of over-consumption like saturated fats.

The score of the indices was determined by the ratio of nutrient intake relative to the respective reference intake. Ratio calculations of each nutrient available in the database were performed. Two examples are shown in Appendix A. Such nutrient ratios were first reported by Madden *et al.*[18,19]. As the empirical database refers to German individuals, the guidelines of the German Nutrition Society (DGE) were used as a reference for nutrient intake[20]. The reference values stated by the DGE include both Recommended Dietary Allowances, which are defined to meet nutritional needs, and so-called 'Richtwerte' that refer to desirable levels of intake, e.g. for carbohydrates, fibre, total fat and alcohol. It was taken into account that recommendations differ according to gender, age, pregnancy, breast-feeding and physical activity. Physical activity was taken into account only for the intake of fat, although the need for other nutrient components is also influenced by physical activity. This had to be neglected, since the DGE provides no physical activity-specific

Table 1 Components considered in the indices

Deficient index (index 1)
13 vitamins
Vitamin A (retinol equivalents)
Vitamin D
Vitamin E
Vitamin K
Vitamin B_1
Vitamin B_2
Niacin equivalents
Vitamin B_6
Folate equivalents
Pantothenic acid
Biotin
Vitamin B_{12}
Vitamin C
12 minerals and trace elements
Sodium
Chloride
Potassium
Calcium
Phosphorus
Magnesium
Iron
Iodine
Fluoride
Zinc
Copper
Manganese
Proteins
Carbohydrates
Two essential fatty acids
Linoleic acid (n–6)
Linolenic acid (n–3)
Dietary fibre
Excess index (index 2)
Fat
Cholesterol
Ratio of saturated to unsaturated fatty acids
Sugar
Alcohol
Sodium

information. If a person reached more than 100% of the recommendation (e.g. >100 mg vitamin C day^{-1}), no further credit was given, which means the maximum score of each nutrient is 100 and the minimum 0.

The indices were constructed by adding up scores of the nutrients. The first index (deficient index) includes 13 vitamins, 12 minerals and trace elements, proteins, carbohydrates, two essential fatty acids and dietary fibre. The second index (excess index) contains fat, cholesterol, the ratio of saturated to unsaturated fatty acids, sugar, alcohol and sodium. Whereas it is preferable from a health perspective to consume the components of the first index in amounts above 100% of recommendation, the components of the second index should be consumed in moderation. The components of the indices are shown in Table 1.

Since all scores of the single nutrients were summed up, the maximum of the deficient index, which included 30 components, was 3000. The excess index, on the other hand, consisted of six elements, and the maximum score was 600. Within the boundary of zero up to 3000 and 600, respectively, a higher score indicates a more favourable diet.

The diet quality indices developed were used to analyse several socio-economic determinants of health-related dietary behaviour among 4030 German adults participating in the German Nutrition Survey 1998.

Statistical analyses

Multiple linear regression models were used to explore the relationship between the constructed indices and a variety of explanatory variables. The regression models were performed for men and women, separately, with SPSS version 10.0 (SPSS Inc., Chicago, IL, USA). The separate analysis for men and women allows us to choose more flexible models. Preceding analysis, where a gender variable was included in one regression model, showed significant differences between men and women.

Results

The definition and descriptive statistics of all variables involved are reported in Appendix B. Results of the regression models for men and women are shown in Table 2.

Income shows a positive association with the deficient index and a negative association with the excess index among women. Among men, the first-degree term of income shows a significant positive association, the second-degree term a negative association with the excess index. This combination of both terms indicates that diet quality increases with rising income, reaches its maximum in a high-income group and then decreases moderately again. Total energy intake is positively associated with the deficient index and negatively associated with the excess

Table 2 Impact of different variables on diet quality (regression coefficients)

	Deficient index (index 1)		Excess index (index 2)	
Independent variable	Men Parameter (*t*-value)	Women Parameter (*t*-value)	Men Parameter (*t*-value)	Women Parameter (*t*-value)
Constant	2119 (76.842)**	1759 (47.720)**	692 (46.945)**	656 (61.878)**
Equivalence income	0.004 (1.533)	0.008 (2.730)**	0.013 (3.332)**	−0.004 (−4.231)**
Equivalence income^2/10 000			−0.018 (−3.216)**	
Energy intake per day	0.099 (27.894)**	0.169 (29.841)**	−0.072 (−40.603)**	−0.068 (−33.090)**
Food diversity	2.729 (16.148)**	2.420 (12.255)**	−0.101 (−1.919)	0.128 (1.762)
Age	5.091 (4.980)**		−2.951 (−5.779)**	−1.517 (−3.516)**
Age^2	−0.035 (−3.215)**		0.029 (5.440)**	0.015 (3.277)**
Logarithm of age		88.535 (9.575)**		
Education level				
Low	−12.483 (−2.020)*	6.471 (0.910)	4.010 (1.296)	0.876 (0.335)
High	2.758 (0.354)	22.175 (2.295)*	−0.385 (−0.099)	−1.931 (−0.548)
Region				
North	14.626 (1.484)	17.068 (1.510)	2.302 (0.468)	−4.652 (−1.131)
South	−15.196 (−2.181)*	−4.963 (−0.595)	−6.183 (−1.778)	−2.030 (−0.669)
East	−13.788 (−1.807)	4.580 (0.512)	−8.002 (−2.098)*	−3.217 (−0.988)
Quarter of the year				
First	−10.865 (−1.384)	−2.724 (−0.312)	−1.625 (−0.415)	4.111 (1.296)
Second	1.990 (0.258)	12.017 (1.351)	−4.640 (−1.207)	5.450 (1.684)
Fourth	−7.448 (−1.000)	1.506 (0.174)	−0.440 (−0.118)	−0.235 (−0.075)
Pregnancy		4.890 (0.191)		−36.284 (−3.903)**
Breast-feeding		−36.068 (−1.546)		−83.872 (−9.882)**
Sport activity	25.329 (4.782)**	29.181 (4.870)**	2.584 (0.975)	2.465 (1.131)
Vegetarian	96.437 (5.820)**	45.457 (4.155)**	15.869 (1.918)	−0.035 (−0.009)
Adjusted R^2	0.49	0.47	0.58	0.45
N	1763	2267	1763	2267

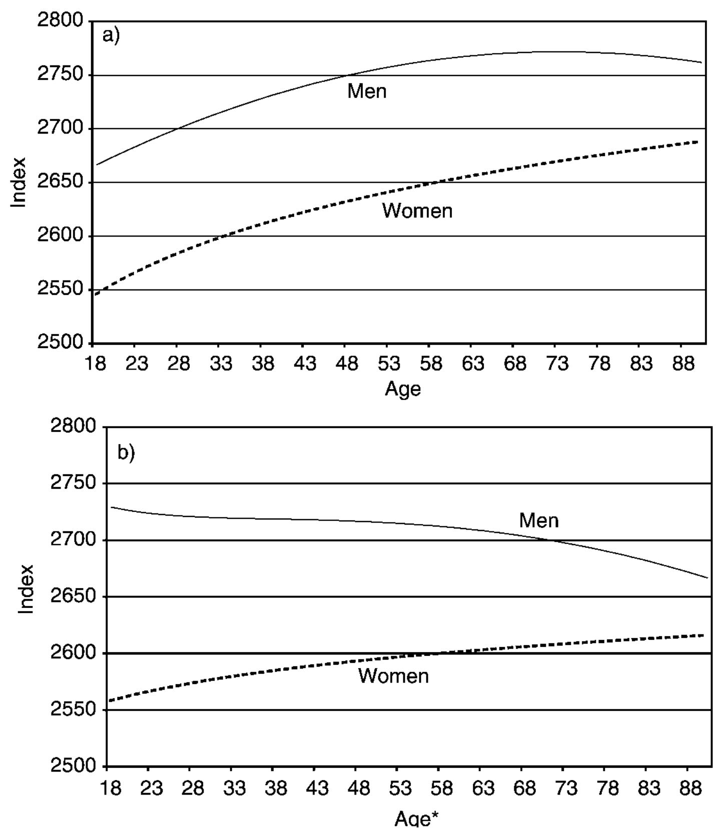
A positive sign indicates a better diet quality. This means, for the deficient index, a higher consumption of vitamins, minerals and trace elements and for the excess index, a lower consumption of fat, sugar, alcohol and sodium. The variables are described in Appendix B. Missing age and income coefficients mean that different models are used for the four estimated regression models.
*, $P < 0.05$; **, $P < 0.01$.

index for both men and women. Food diversity, expressed by the number of different foods consumed, is positively associated with the deficient index. Thus, with a larger variation in diet, its quality rises considering the intake of vitamins, minerals and trace elements.

Diet quality is strongly associated with age for both men and women. With respect to the deficient index, the significant contribution of a quadratic term for men and a logarithmic term for women indicates that diet quality increases with age but in a different way for men and women. For women it continues through old age, while for men it increases to the age of 73 years and then decreases moderately thereafter (see Fig. 1a). In our database 57 males are older than 73 years. These results refer to constant energy intake with increasing age. In fact, people consume less energy with increasing age. Considering this, the combined effect of age and energy intake on diet quality is presented in Fig. 1b. For men, the negative effect of a reduction of energy on diet quality is stronger than the positive effect with increasing age. Therefore diet quality declines with increasing age. For women, however, the diet quality index increases (see Fig. 1b). In general, men have a better diet quality regarding vitamins, minerals, etc. than do women.

The parameter estimate of the excess index for both genders indicates that the influence of age on diet quality decreases to the age of approximately 50 and then increases with age (see Fig. 2a). Similar to the deficient index, the influence of age interferes with that of energy intake. As seen in Fig. 2b, the reduction of energy associated with increasing age has a stronger positive effect on diet quality than the direct negative effect of age. In summary, diet quality increases with increasing age constantly for women and for men from age approximately 45 years upwards. In contrast to the deficient index, women have a higher excess index than do men.

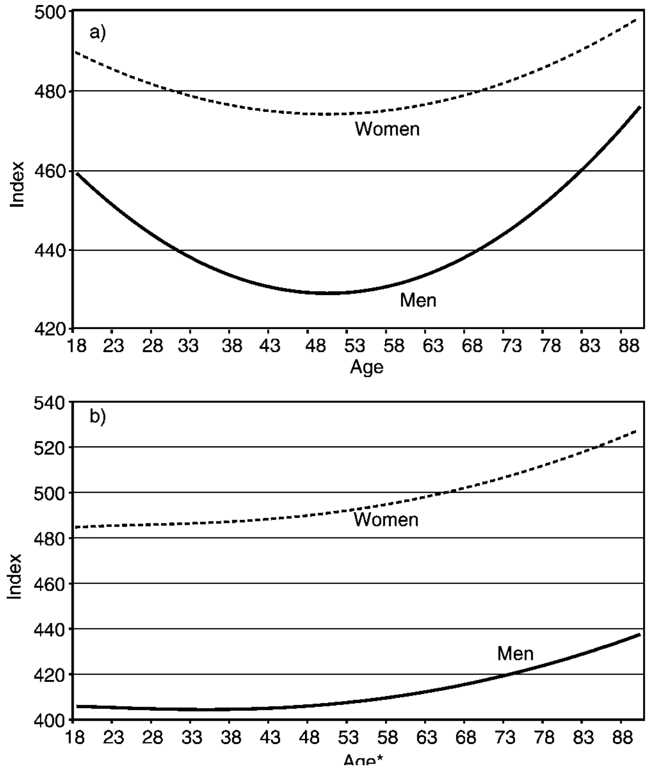
The relationship between education and diet quality is significant for the deficient index only. Men with a low education level have a lower index than men with an intermediate education level (the reference population), whereas women with a higher education level have a



* Assigned kcal (derived from separate estimations of age on kcal)
$kcal_{men} = 6303.332–987.477 \ln age$
$kcal_{women} = 3075.398– 311.934 \ln age$

Age	18	23	28	33	38	43	48	53	58	63	68	73	78	83	88
Men	3449	3207	3013	2851	2711	2589	2481	2383	2294	2212	2137	2067	2001	1940	1882
Women	2174	2097	2036	1985	1941	1902	1868	1837	1809	1783	1759	1737	1716	1697	1679

Fig. 1 Impact of age and energy intake on diet quality for the deficient index. (a) Pure age effect (constant energy intake with increasing age); (b) combined effect: age and energy intake (decreasing energy intake with increasing age)



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Women	2174	2097	2036	1985	1941	1902	1868	1837	1809	1783	1759	1737	1716	1697	1679

Fig. 2 Impact of age and energy intake on diet quality for the excess index. (a) Pure age effect (constant energy intake with increasing age); (b) combined effect: age and energy intake (decreasing energy intake with increasing age)

higher deficient index than do women with an intermediate education level. There is no pronounced relationship between region and diet quality. The parameter estimates of almost all indicator variables did not differ significantly from zero. Only men living in South and East Germany have a significantly lower quality of diet compared with the reference population of men living in central Germany. In addition, seasons do not have any effects on diet quality. Both pregnant and breast-feeding women have a significantly lower excess index. Obviously, these women consume higher amounts of e.g. fat and sugar than the reference female population. Concerning the intakes of vitamins, minerals and trace elements (represented by the deficient index), no better diet quality could be observed for pregnant or breast-feeding women compared with other women. Finally, sport activity and vegetarianism show a significant positive association with the deficient index. Persons participating in sports for more than 1 h per week and vegetarians tend to achieve an adequate and healthy diet more frequently than their counterparts. However, no differences exist with respect to the excess index.

Discussion

An excess intake of e.g. fat and a deficient intake of vitamins, minerals and trace elements are associated with the development of chronic diseases. To ensure that intakes meet recommended guidelines, public health organisations and dietitians need to develop practical educational strategies for making adequate food choices. The results of this study could help to identify groups of persons with a preferable and groups with a non-preferable diet quality.

Among women, the micronutrient composition of the diet becomes more favourable with increasing income, which we expected. On the other hand, the index reflecting intakes of fat, cholesterol, the ratio of saturated to unsaturated fatty acids, sugar, alcohol and sodium becomes less favourable as income increases. Both findings were observed previously[8]. Men with low income tend to consume too much fat, cholesterol, saturated fatty acids, sugar, alcohol and sodium. Up to a high-income group, diet quality increases with rising income. Nevertheless, the impact of income on diet quality is comparatively small. Figures 3 and 4 show, for the deficient and excess index respectively, that compared with a person of the middle income group (50% quartile), a change in income to the 25% or 75% quartile results in a change in diet quality by less than 1%.

The positive association between total energy intake and diet quality is as expected. If a person eats more, he has a higher ability to reach the recommended intakes of vitamins, minerals and trace elements. However, he may additionally tend to have excessive intakes of fat, cholesterol, saturated fatty acids, sugar, alcohol and sodium, which we also observed. Murphy *et al.* previously reported a strong inverse correlation between energy intake and the number of nutrient intakes below recommended guidelines[16]. The high relationship between energy intake and diet quality is shown in Figs 3 and 4. Regarding the deficient index, the deviation from the reference individual with a middle energy intake is approximately 2%; regarding the excess index, it is up to 9%.

As previously observed, we also found a positive association between food diversity and diet quality, which indicates that a well-balanced diet might be reached more easily by choosing a large variety of foods[21]. Figure 3 indicates that high and low food diversity, respectively, lead to a change in the diet quality index by approximately 1%.

The results show a considerable variation of diet quality between sociodemographic groups. High diet quality in terms of the consumption of vitamins, minerals and trace elements can be expected when income and education levels are high, when energy intake and food diversity are high, among persons of higher age, for physically active persons and among vegetarians. On the other hand, a low diet quality with high intakes of fat, cholesterol, saturated fatty acids, sugar, alcohol and sodium is correlated with higher income (for women) and energy intake. These two variables are found to be opposing in the two indices of diet quality (excess intake and deficient intake). In addition, an unfavourable dietary composition can be expected for persons of middle age (about 50 years). In particular, pregnant or breast-feeding women have an unfavourably high consumption of unhealthy nutrients.

For health policy, the impact of age in particular seems to be interesting. The results of the present paper suggest that diet quality rises with increasing age. Such behaviour might reflect a changing health consciousness with increasing age. It could thus be a challenge for health policy to promote a healthy way of living focused particularly on young individuals. In addition, the positive influence of high food diversity on diet quality could be interesting for public health strategies. To inform people about the importance of consuming a larger variety of foods could be a task for health politics. So far, we measured food variety by counting the number of food items actually consumed. This index has the disadvantage that it neither considers information on the distribution of food quantities consumed nor on the heterogeneity of the different foods. Studying the impact of food diversity on diet quality with a more appropriate measurement could be a promising area of future research.

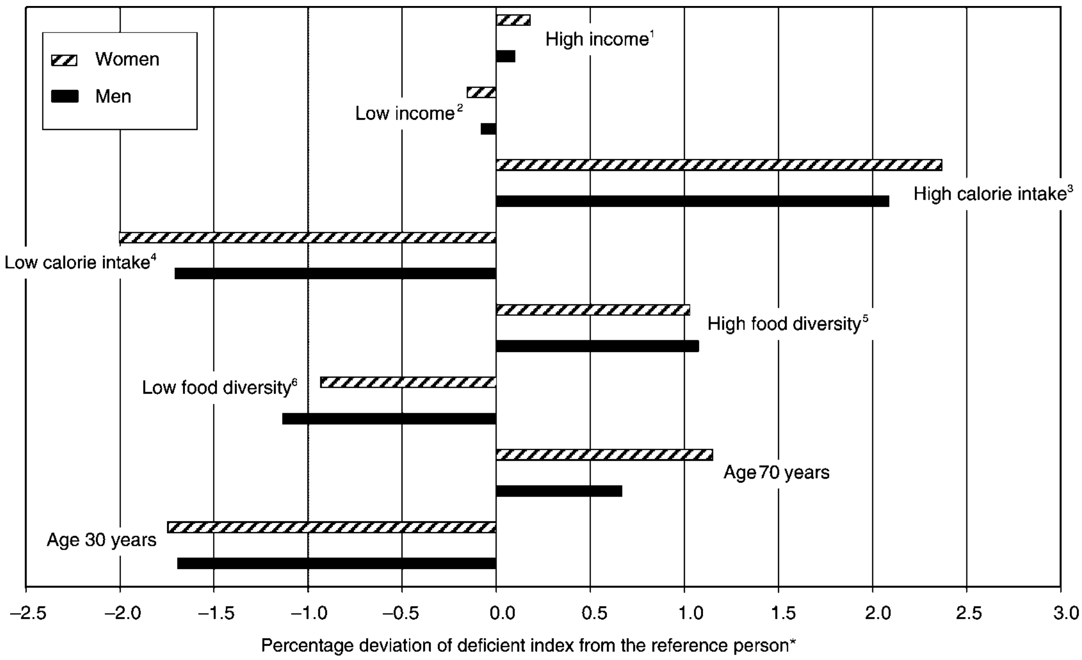

Fig. 3 Comparative impact of different determinants on the deficient index. *The reference person is defined as a man (woman) with a median equivalence income per month of 2167 (2024), a median energy intake per day of 2502 (1848) and a median food diversity of 65 (66). The person is 50 years of age. All dummy variables are set to zero (see Appendix B). [1]75% quartile: 2917 (2639), [2]25% quartile: 1568 (1500), [3]75% quartile: 3073 (2212), [4]25% quartile: 2035 (1540), [5]75% quartile: 76 (77), [6]25% quartile: 54 (56)

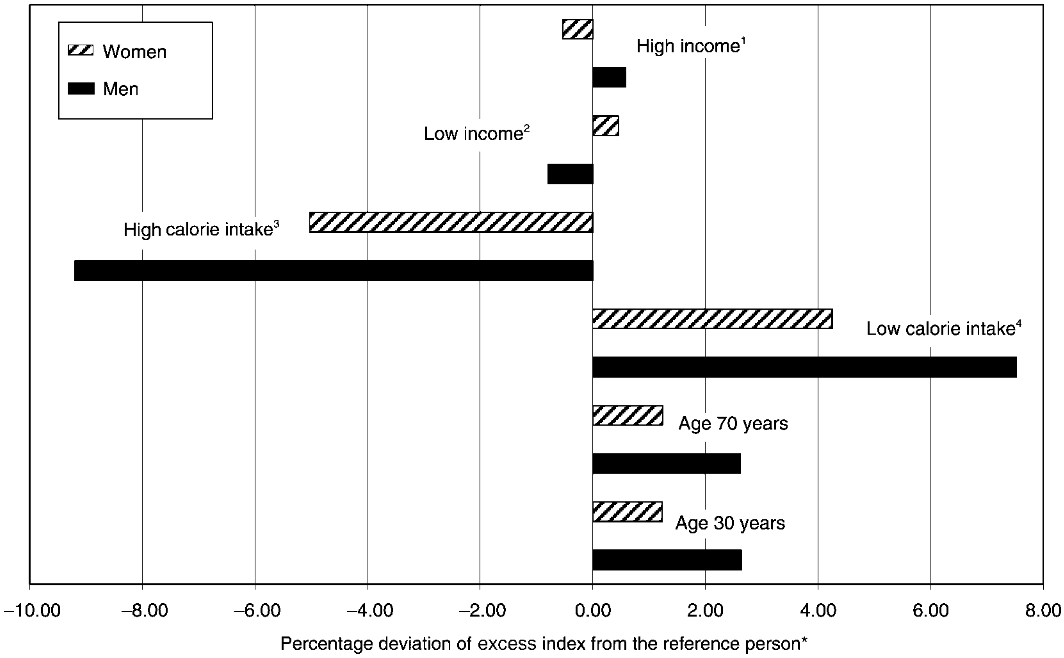

Fig. 4 Comparative impact of different determinants on the excess index. *The reference person is defined as a man (woman) with a median equivalence income per month of 2167 (2024), a median energy intake per day of 2502 (1848) and a median food diversity of 65 (66). The person is 50 years of age. All dummy variables are set to zero (see Appendix B). [1]75% quartile: 2917 (2639), [2]25% quartile: 1568 (1500), [3]75% quartile: 3073 (2212), [4]25% quartile: 2035 (1540), [5]75% quartile: 76 (77), [6]25% quartile: 54 (56)

The results of this study are based on a cross-sectional survey, giving a *status quo* that may change over the years since patterns of food choices may change over time. Nevertheless, they are also representative for the German adult population and therefore reflect general trends in Germany. These analyses may be a first step to determine population groups with excess and deficient intakes.

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Appendix A

Example 1: Calculation of the score of vitamin C (nutrient of the deficient index)	
Recommended dietary intake*	100 mg day^{-1}
Intake of a person	80 mg day^{-1}
Ratio	80/100 = 0.8
	⇒ 20% under reference
	⇒ score = (100 − 20) = 80
Score is bounded between 0 and 100	
Score 0:	0 mg day^{-1}
Score 100:	≥ 100 mg day^{-1}
Example 2: Calculation of the score of cholesterol (nutrient of the excess index)	
Recommended dietary intake*	max. 300 mg day^{-1}
Intake of a person	550 mg day^{-1}
Ratio	550/300 = 1.83
	⇒ 83.3% above reference
	⇒ score = (100 − 83.3) = 16.7
Score is bounded between 0 and 100	
Score 0:	≥ 600 mg day^{-1}
Score 100:	≤ 300 mg day^{-1}

* According to the DGE. Example for men aged 25–51 years.

Appendix B – Definition and descriptive statistics of variables used in the estimation models

	Men (n = 1763)				Women (n = 2267)			
	Mean	SD	Minimum	Maximum	Mean	SD	Minimum	Maximum
Deficient index (0 = lowest diet quality, 3000 = highest diet quality)	2708.795	138.910	1737.307	2960.131	2611.297	168.936	1425.245	2946.420
Excess index (0 = lowest diet quality, 600 = highest diet quality)	388.112	56.525	168.735	500.000	405.874	48.354	173.394	500.000
Equivalence income per month (DEM) of the household – net income reported in 13 income intervals. The mean of each interval was chosen as the income for the respective household. This income was divided by the equivalence value of the household*	2431.795	1188.008	296.296	8000.000	2208.563	1139.864	333.333	12000.000
Energy intake per day (kcal)	2621.440	826.479	669.985	7311.005	1916.464	554.950	218.180	4961.575
Food diversity expressed by the number of different consumed foods	65.302	15.505	12.000	132.000	66.501	15.834	14.000	125.000
Age in years	44.587	15.744	17.000	79.000	43.981	15.598	17.000	78.000
Education level low – dummy variable is set equal to 1 if the person has not finished a 9-year elementary school or has finished a 9-year elementary school but does not have additional professional training, and 0 otherwise	0.054				0.121			

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Appendix B *Continued*

	Men ($n = 1763$)				Women ($n = 2267$)			
	Mean	SD	Minimum	Maximum	Mean	SD	Minimum	Maximum
Education level high – dummy variable is set equal to 1 if the person has finished high school and has a university degree, and 0 otherwise	0.145				0.100			
Education level intermediate – dummy variable is set equal to 1 if the person has an education level that is not mentioned before, and 0 otherwise	0.801				0.779			
Region north – dummy variable for North Germany is set equal to 1 if the person is living in Schleswig-Holstein, Hamburg, Niedersachsen or Bremen, and 0 otherwise	0.121				0.130			
Region middle – dummy variable for Middle Germany is set equal to 1 if the person is living in Nordrhein-Westfalen, and 0 otherwise	0.243				0.209			
Region south – dummy variable for South Germany is set equal to 1 if the person is living in Rheinland-Pfalz, Baden-Württemberg, Bayern or Saarland, and 0 otherwise	0.289				0.285			
Region east – dummy variable for East Germany is set equal to 1 if the person is living in Brandenburg, Mecklenburg-Vorpommern, Sachsen, Sachsen-Anhalt or Thüringen, and 0 otherwise	0.347				0.375			
First quarter of the year – dummy variable is set equal to 1 if the person was interviewed within the first quarter of the year, and 0 otherwise	0.266				0.262			
Second quarter of the year – dummy variable is set equal to 1 if the person was interviewed within the second quarter of the year, and 0 otherwise	0.240				0.232			
Third quarter of the year – dummy variable is set equal to 1 if the person was interviewed within the third quarter of the year, and 0 otherwise	0.226				0.229			
Fourth quarter of the year – dummy variable is set equal to 1 if the person was interviewed within the fourth quarter of the year, and 0 otherwise	0.268				0.277			
Pregnancy – dummy variable is set equal to 1 if the woman is pregnant, and 0 otherwise	0.000				0.011			
Breast-feeding – dummy variable is set equal to 1 if the woman is breast-feeding a baby, and 0 otherwise	0.000				0.015			
Sporting activity – dummy variable is set equal to 1 if the person participates in sport for at least 1 h per week, and 0 otherwise	0.406				0.392			
Vegetarian – dummy variable is set equal to 1 if the person is a vegetarian, and 0 otherwise	0.026				0.076			

SD – standard deviation.
* Equivalence values take into account that, depending on size and composition, different households need different incomes to realise a particular living standard. The values used here are: 1 for the first person in the household (e.g. man), 0.5 for the second person (e.g. woman) and 0.3 for each further person (e.g. child). These values are summarised to a specific equivalence value for each household.