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Estimating Usual Intake in the 2nd Bavarian Food Consumption Survey: Comparison of the Results Derived by the National Cancer Institute Method and a Basic Individual Means Approach

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Abstract

Background: The valid estimation of the usual dietary intake remains a challenge till date. We applied the method suggested by the National Cancer Institute (NCI) to data from the 2nd Bavarian Food Consumption Survey (BVS II) and compared it to an individual means approach. ***Methods:*** Within the cross-sectional BVS II, 1,050 Bavarian residents aged 13–80 years participated in a personal interview and completed three 24-h dietary recalls by telephone interview. For the 13 main food groups and 23 subgroups the usual intake was calculated by (1) an individual means approach and (2) by the NCI method. ***Results:*** The distributions derived by the individual means approach are wider than those derived from the NCI approach. For a majority of food groups and subgroups, the proportion of participants who meet the dietary recommendations published by the German Nutrition Society is higher when the NCI approach is applied. The proportions of participants above or below recommended amounts differ greatly for "meat and meat products" and "cheese." ***Conclusion:*** The mean intake at the groups level can easily be derived from the individual means approach. Since only the NCI method accounts for intra-personal variation, this method provides more valid intake estimates at the individual level and should be applied when, for example, individual intakes are compared with dietary recommendations.

Introduction

Food consumption survey methods are generally designed to estimate the dietary intake of a defined population and its subgroups. If the dietary intake distribution of a population is estimated based on a single-day measurement, the intake distribution contains between-person information, while the within-person variation is not captured. This means that the variance of the usual group intake is inflated by day-to-day variation in individual intake. Repeated 24-h dietary recalls allow accounting for this intra-individual variability. However, it is hardly feasible to collect more than a small number of repeats. In this situation, simply calculating individual means as the subjects' usual intake estimates lead to biased results, since the intra-individual variation is not sufficiently accounted for (e.g., [1] or [2]). This is of special interest when the calculated food intake distribution is not correct. Especially with regard to the estimation of the prevalence of insufficient or excess food intake, the lower and upper ends of the distributions are relevant.

A variety of statistical methods exist that have been developed over the past decades to estimate usual intake distributions from repeated 24-h dietary recalls (e.g., [2–11]).

In the final report of the European Food consumption Validation project, the use of repeated 24-h recalls combined with a food propensity questionnaire was recommended to assess the habitual dietary intake of subjects [12]. Souverein et al. [13] compared 4 established statistical tools (Iowa State University Method, National Cancer Institute [NCI] method, Multiple Source Method [MSM], and Statistical Program for Age-adjusted Dietary Assessment) and concluded that all methods provide comparable estimates of the simulated nutrient intake, but differing intake distributions of the simulated food groups. All methods are prone to lead to biased estimates in case of small sample sizes, skewed distributions, or high within-person variability. The NCI method and MSM are 2 statistical tools that enable estimations of the population's habitual intake distribution from at least 2 independent short-term measurements per subject, while offering the possibility to take into account some information from a food frequency questionnaire [8, 10, 14, 15]. Since the current implementation available for the MSM method may have limitations due to technical problems when covariates are included (see https://msm.dife.de/), we focused on the NCI method. In previously published comparisons of these different methods (e.g., [13, 16]), the NCI method has not been found to be superior to the other methods, but it allows the inclusion of covariates when modeling intake amounts and probabilities. The sample size of the 2nd Bavarian Food Consumption Survey (BVS II) is sufficiently large to allow the application of the NCI approach [17]. We compare the NCI method and the individual means approach for describing the distribution of usual intake of food groups in the population. As the individual means approach underestimates low percentiles and overestimates high percentiles [18], we compare it to the more sophisticated NCI approach that overcomes the individual means approach's drawbacks. We examine implications when assessing the adequacy of food intake in the Bavarian population according to nutrition guidelines.

Methods

Study Design

The BVS II was designed as a cross-sectional study representative for the Bavarian population to investigate dietary and lifestyle habits. Between September 2002 and June 2003, 1,050 German-speaking subjects aged 13–80 years were recruited following a 3-stage random-sampling procedure. This recruitment procedure included the selection of 42 communities as so-called sampling points (stratified by county and community characteristics), a random walk (every third household) with a given start address, and a random selection of one household member who meets the selection criteria.

At baseline, data on lifestyle, socioeconomic and health status were collected using a computer-assisted personal interview. Within the following 2 weeks, both dietary intake and physical activity were assessed by 3 standardized computer-assisted telephone interviews on randomly selected days. All adult study subjects (≥18 years) who had completed at least one 24-h dietary and physical activity recall ($n = 879$) were invited to their nearest health office for blood sampling and standardized anthropometric measurements within 6 weeks after recruitment. The overall participation rate in the study was 71%.

All participants gave their written consent and the study protocol was approved by the local Ethics Committee.

Assessment Methods

The standardized computer-assisted personal interview was conducted by trained interviewers from the NFO Health, Munich (now named TNS Infratest) and checked for plausibility and completeness. The interview topics included dietary attitudes, dietary knowledge and skills, shopping habits, reaction to food scandals, control of body weight, health status, physical activity, sedentary behavior, smoking behavior, sleeping behavior, and sociodemographic information.

Within 14 days after the recruitment, 3 standardized 24-h dietary recalls were conducted (CATI) by trained interviewers using the EPIC-SOFT software from the International Agency for Research on Cancer. The structure of the interview is described in detail elsewhere [19, 20]. Briefly, the 24-h dietary recall is divided into 4 sections: general non-dietary information, a quick list of foods consumed the day before the interview (foods are recorded per meal), a detailed description and quantification of the consumed foods, and quality control questions. The portion sizes were estimated by means of a photo book, showing pictures of models of cups, glasses, spoons, and plates filled with different sizes of food portions and dishes. The completion of one 24-h dietary recall took between 15 and 30 min.

The anthropometric measurements of a subsample were used to adjust self-reported weights and heights by means of regression models. As for other dietary assessment methods, dietary data resulting from 24-h dietary recalls are also at risk for underreporting (e.g., [21] or [22]). Therefore, we excluded under-reporters for the present study. Underreporting was defined as reported energy intake amounting to less than 80% of the basal metabolic rate [23, 24]. After the exclusion of under-reporters, data from 800 subjects with at least two 24-h dietary recalls remained in the sample for the analysis. For 780 participants of these participants, 3 recalls were available.

Covariates

Variables included in the analysis were age, gender, weight, height, BMI, smoking, physical activity, and socio-economic status (SES).

The descriptive analysis was carried out with respect to all of the above-mentioned variables. Here, BMI was analyzed as a continuous variable or categorized as underweight (BMI ≤18.5 kg/m^2), normal weight (BMI 18.5–24.9 kg/m^2), pre-obese (BMI 25–29.9 kg/m^2), or obese (BMI ≥30 kg/m^2) [25]. The age of participants was examined as a continuous as well as a categorical variable ("younger than 18 years," "18 to <30 years," "30 to <50 years," "50 to <65 years," and "65 years and older"). For the descriptive analysis, physical activity was included as a categorical variable, representing an either active or nonactive participant in self-reported regular sports activities during the last 12 months. A nonactive participant reported no regular activity on a weekly basis. Smoking status was assessed as "smoker," "ex-smoker" and "non-smoker." SES was assessed by household net income, educational level of the one who is being interviewed, and the career position of the principal earner. It was categorized into low, low-medium, medium, medium-high, and high based on the sum score derived by the single variables.

When modeling the usual intake, age and BMI were included only as continuous variables. Gender, smoking, physical activity, and SES were included analogously to the descriptive analysis. Additionally, the information whether the recall was referring to a weekday or a weekend day of consumption was accounted for in the models.

Statistical Methods

The descriptive analysis of main characteristics of the study population was conducted separately for men and women. We report arithmetic means and SDs or relative frequency as appropriate. No weighting was applied to the data, as the distribution of age among men and women was similar to the Bavarian source population [26]. In our sample, only males aged 60–64 and females aged 35–44 were slightly overrepresented.

We applied 2 different methods to estimate the usual intake of food groups. The basic individual means approach used data from the up-to-three 24-h dietary recalls and weighted it for weekday or weekend day by the factors 5/7 and 2/7, respectively, to estimate the mean amount of usual intake per participant (g/day). No further adjustment was undertaken with respect to age, gender, BMI, and so on. These results were compared to those derived by the NCI method [10, 15]. The NCI method fits a 2-part model for the consumption probability and the amount on consumption days. The probability is modeled by a logistic regression model, whereas for the amount on consumption days, a usual regression model is fitted. The consumption-day amount is fitted on a transformed scale: the dietary intake values are transformed by Box-Cox transformation close to a normal distribution and thereby the validity of the model parameters is increased. After appropriate back-transformation, the usual intake estimate in g/day is then derived as the product of probability and amount of consumption. The NCI provides SAS macros to carry out the modeling (http://epi.grants.cancer.gov/diet/usualintakes/macros.html). We used version V2.1 of the MIXTRAN and DISTRIB macro, and included age, gender, BMI, smoking, weekend or weekday of consumption, physical activity, and SES as predictors in both models. Age and BMI were included as continuous variables and the others as categorical variables. Freese et al. [27] described gender, age, and smoking status as major determinants of consumption-day amounts. To apply the NCI method, in some rare cases, food items had to be merged, as a minimum of 10 participants with at least 2 consumption days were required. This referred to "chicken and turkey," "milk and milk beverages" and "yoghurt and cream desserts, puddings." Further, outliers were removed where necessary to assure the convergence of the macros (beef consumption of more than 405 g/day, that is, more than mean ±4SD). For "nonalcoholic drinks" and "all cereals/cereal products," only the amount model was fitted, as the probability of consumption is equal to 1 for all participants.

Estimates derived from both methods were then compared with nutrition recommendations published by the German Nutrition Society (Deutsche Gesellschaft für Ernährung, DGE, www.dge-ernaehrungskreis.de). A comparison of the intake amounts derived from the individual means approach and the NCI method with the current food-based recommendations of the German Nutrition Society was not possible for all given complex recommendations. This is due to the fact that no individual estimates were derived by the NCI method and thus it was impossible to determine multivariate distributions to assess the simultaneous consumption of, for example, cooked vegetables and raw vegetables/salad. Almost all recommendations include favored types of food within a food group to be consumed, for example, low-energy drinks or low-fat cheese. We compared these recommendations to the general food groups, that is, including all types of cheese and nonalcoholic beverages. For meats and eggs, the guidelines suggest weekly amounts that should not be exceeded. These were converted to amounts on a daily basis.

The statistical analysis was performed using SAS software, version 9.3 of the SAS System for Windows (Copyright© 2002–2010 SAS Institute Inc.).

Results

Description of Population

Results from the descriptive analysis are presented in Table 1. In the present study, 328 male (41%) and 472 female (59%) participants with a mean age of 47.5 and 45.8 years, respectively, were analyzed. The majority of men were found to be pre-obese or obese (44.2 and 15.9%, respectively), whereas this does not hold for the female participants (28.4 and 17.6%, respectively). Almost half of the women had normal weight (48.9%) compared to only 37.2% of the men participating in the study. For both genders, the majority of participants had a low-medium or medium SES (54.8% of men and 54.9% of women). A higher proportion of men had a high SES (15.7%) com-

Table 1. Main characteristics of the study population, reported as mean ± SD or relative frequency (%) for male and female participants

Covariate	Males (n = 328)	Females (n = 472)
Age, years	47.5±18.0	45.8±15.9
Age groups, years		
<18	7.0	2.4
18–<30	10.4	11.0
30–<50	36.0	47.7
50–<65	26.8	23.7
≥65	19.8	14.2
Body weight, kg	80.7±14.9	67.6±13.5
Body height, cm	174.8±7.0	163.5±6.4
BMI, kg/m^2	26.4±4.4	25.4±5.4
BMI groups, kg/m^2		
Underweight (<18.5)	2.7	5.1
Normal weight (18.5–<25)	37.2	48.9
Pre-obese (25–<30)	44.2	28.4
Obese (≥30)	15.9	17.6
Socioeconomic status		
Low	12.5	15.5
Low-medium	27.7	22.9
Medium	27.1	32.0
High-medium	17.1	22.5
High	15.6	7.2
Smoking		
Non-smoker	43.0	62.2
Ex-smoker	26.5	16.1
Current smoker	30.5	21.7
Sports activity		
Active	68.9	67.5
Not active	31.1	32.5

pared to women (7.2%). Smoking was more prevalent among men (30.5%) compared to women (21.7%). About 2/3 of the male and female participants were regularly performing exercise during the last 12 months.

Comparisons of Mean Usual Intake Estimates

Usual food and beverage intake is described using both the individual means approach and the NCI method. Tables 2 and 3 report the arithmetic means for men and women respectively. Overall, there was a good accordance of mean intake values across all food groups and subgroups. Among men, the NCI approach yields slightly smaller usual intake estimates for most food groups or subgroups, whereas among women, the NCI approach yields slightly higher estimates compared to those derived with the individual means approach. Irrespective of the method used, mean intake amounts of cereals and cereal products (in particular bread), meat and meat products (in particular red meat and processed meat), soft drinks and alcoholic beverages (in particular beer) were higher in men than in women. In contrast, women had higher mean intake amounts of fruits, milk and dairy product, coffee and tea and water.

Comparisons of the Distributions of the Usual Intake Estimates

Tables 2 and 3 also show the percentiles for men and women derived by the individual means approach and the NCI method for all food groups and subgroups. The 25th, 50th, and 75th percentile values for the male participants are presented in Figure 1 and for the female participants in Figure 2 for the main food groups. When comparing the median usual intake amounts, the NCI method yields slightly higher values for all food groups or subgroups. This holds good for both men and women. Only for women, the median amount of "water" intake was estimated to be lower by the NCI method. These differences represent different locations of the food group and subgroup distributions. Examining the 1st, 5th, 25th, 75th, 95th, and 99th percentiles gives insight into the shape of both distributions. In men and women, all 1st, 5th, and 25th percentiles derived by the NCI method are higher than those derived by the individual means approach. This holds good for all food groups and subgroups. Regarding the 75th, 95th, and 99th percentiles for all main food groups in men and even the vast majority of subgroups in men and women, lower values are derived by the NCI method. In women, for the main food groups "all fruits," "all nonalcoholic beverages" and "all alcoholic beverages" slightly higher 75th percentiles and for "alcoholic beverages" even 95th percentiles were derived by the NCI method. This phenomenon generally reflects the shrinkage of the usual intake values toward the mean by taking into account that up to 3 repeated observations per individual are recorded. Exceptions arise mainly in cases for food groups that are irregularly consumed only, and therefore the individual means approach estimates a large number of zero amounts. This applies for example to "nuts and seeds," "ice cream" or "beef."

The major difference of both methods becomes apparent when looking at the 1st, 5th, and 25th percentiles. For food groups or subgroups that are only occasionally consumed, the individual means approach yields percentiles and even medians that are equal to zero. In contrast to this observation, the NCI method does not predict usual intake values of zero for potential non-consumers but instead very small amounts greater than zero. This holds true for men as well as for women.

Table 2. Mean and percentiles of daily food intake: individual means approach and NCI method (g/day), males

	Individual means approach								NCI method							
	mean	P 1	P 5	P 25	P 50	P 75	P 95	P 99	mean	P 1	P 5	P 25	P 50	P 75	P 95	P 99
All vegetables	134.4	0.0	18.8	67.1	111.3	174.8	325.9	425.7	132.5	35.7	55.2	94.3	126.7	164.5	229.0	281.1
Leafy vegetables	14.5	0.0	0.0	0.0	4.8	21.7	55.6	108.9	14.5	1.6	3.0	7.0	11.9	19.3	35.1	50.0
Fruiting vegetables	61.7	0.0	0.0	8.8	45.0	89.3	201.9	296.5	60.2	8.9	16.1	34.9	54.1	79.3	124.6	161.8
Root vegetables	12.4	0.0	0.0	0.0	0.0	15.5	55.3	106.3	12.3	1.1	2.1	5.2	9.2	15.9	33.1	52.1
Cabbages	16.1	0.0	0.0	0.0	0.0	18.4	73.3	185.7	15.6	1.2	2.3	5.9	11.1	20.1	44.5	73.2
All fruits	118.9	0.0	0.0	0.0	58.4	184.7	412.1	559.8	115.0	0.9	4.2	28.4	80.9	169.9	339.8	476.7
Nuts, seeds	3.1	0.0	0.0	0.0	0.0	0.0	21.4	35.2	3.8	0.0	0.1	0.5	1.4	3.9	14.5	33.0
Potatoes	67.2	0.0	0.0	0.0	51.3	106.9	201.1	268.0	66.2	22.3	31.1	48.3	63.4	81.3	110.7	133.5
All cereals, cereal products	238.4	63.6	96.6	165.9	226.9	285.4	444.9	520.6	234.5	137.0	160.9	203.2	236.5	273.7	335.4	383.8
Pasta, rice	75.0	0.0	0.0	5.9	61.1	111.8	210.6	380.1	73.7	20.6	29.9	49.4	68.2	92.3	136.3	172.0
Bread	143.2	0.0	47.1	94.7	137.7	177.9	262.0	349.3	142.6	41.5	71.7	112.2	140.3	170.7	221.7	260.8
All sugar, confectionary	39.8	0.0	0.0	12.7	30.4	55.3	119.0	164.4	39.4	1.3	5.1	19.5	34.3	53.5	91.3	127.5
All cakes	59.8	0.0	0.0	0.0	35.7	89.5	191.4	292.0	60.1	5.2	11.2	30.4	53.7	83.4	131.2	166.8
All added fats	26.4	0.7	2.9	11.9	24.1	35.7	59.1	91.1	25.8	3.4	7.7	16.9	24.5	33.2	48.4	61.5
Vegetable oils	5.1	0.0	0.0	0.0	2.9	5.9	19.7	46.3	5.0	0.5	1.0	2.4	4.2	6.7	12.1	17.2
Butter	13.3	0.0	0.0	0.0	7.8	21.9	45.0	63.5	12.9	0.0	0.2	2.7	9.6	19.8	36.6	50.8
Margarines	5.5	0.0	0.0	0.0	0.0	5.8	28.4	55.7	5.5	0.0	0.0	0.2	1.3	6.4	25.7	45.3
All milk/dairyproducts	179.6	0.0	11.5	58.9	138.8	252.7	461.2	659.9	177.7	11.1	30.1	83.4	145.8	235.6	438.1	636.7
Milk and milk beverages	94.7	0.0	0.0	0.0	31.1	147.7	341.4	574.7	92.6	0.1	0.9	11.9	45.8	121.8	341.3	615.0
Cheese	33.1	0.0	0.0	10.7	28.6	48.9	93.5	123.6	32.0	5.8	10.2	20.8	30.6	41.7	58.8	72.1
All meat, meat products	166.2	0.0	19.5	100.0	157.4	216.4	326.1	452.2	161.5	34.9	67.3	120.4	158.7	199.3	264.4	314.2
Red meat	51.5	0.0	0.0	0.0	35.6	88.6	157.9	200.0	51.2	9.7	16.2	31.8	47.7	67.2	98.5	119.8
Beef	12.6	0.0	0.0	0.0	0.0	0.0	74.5	144.6	11.3	1.0	1.9	4.5	8.2	14.7	31.3	49.3
Pork	32.1	0.0	0.0	0.0	0.0	52.9	125.1	176.6	32.0	3.3	6.4	15.2	26.1	42.6	77.6	110.1
Poultry	17.2	0.0	0.0	0.0	0.0	26.3	92.9	112.7	18.6	2.5	4.3	9.1	14.9	24.0	45.3	65.8
Processed meat	93.8	0.0	0.0	45.1	79.1	123.5	217.9	314.3	91.7	17.0	31.6	61.6	86.9	116.4	167.8	210.0
All fish, fish poducts	19.9	0.0	0.0	0.0	0.0	25.5	97.7	175.9	18.6	7.7	9.8	13.8	17.8	22.6	30.1	35.5
Eggs, egg products	10.1	0.0	0.0	0.0	0.0	17.1	42.9	77.1	10.1	2.2	3.4	6.2	9.1	12.9	20.7	27.7
All non-alcoholic beverages	1,834.9	600.1	789.5	1,234.2	1,727.0	2,337.7	3,278.6	4,156.4	1,808.2	678.0	926.5	1,379.8	1,752.7	2,173.7	2,876.4	3,418.1
Fruit-, vegetable juices	217.1	0.0	0.0	0.0	96.4	321.4	821.4	1,342.9	214.0	0.2	1.8	26.7	122.0	325.8	712.5	1,039.8
Soft drinks	188.7	0.0	0.0	0.0	0.0	214.3	942.9	1,642.9	192.6	0.0	0.1	3.0	31.0	232.1	915.4	1,506.0
Coffee, tea, herbal teas	668.1	0.0	0.0	288.9	591.4	909.6	1,560.7	2,500.0	659.0	5.1	66.4	368.6	604.5	887.8	1,421.3	1,882.0
Water	738.4	0.0	0.0	208.2	544.9	1,035.7	2,250.0	3,071.4	729.1	3.8	30.9	275.9	613.2	1,047.0	1,835.9	2,534.5
All alcoholic beverages	423.6	0.0	0.0	0.0	321.4	668.2	1,285.7	1,607.1	412.4	2.3	14.0	123.6	343.0	621.0	1,072.9	1,434.2
Wine	68.1	0.0	0.0	0.0	0.0	89.3	338.5	507.1	65.4	0.1	0.6	5.6	24.2	86.4	269.0	424.5
Beer	345.4	0.0	0.0	0.0	178.9	553.0	1,142.9	1,463.9	342.3	0.8	4.6	56.5	242.0	560.2	978.7	1,288.7

Table 3. Mean and percentiles of daily food intake: individual means approach and NCI method (g/day), females

	Individual means approach								NCI-method							
	mean	P 1	P 5	P 25	P 50	P 75	P 95	P 99	mean	P 1	P 5	P 25	P 50	P 75	P 95	P 99
All vegetables	135.6	0.0	19.9	69.7	123.9	180.0	303.8	432.6	134.5	38.1	59.3	96.7	128.7	166.1	229.1	282.8
Leafy vegetables	13.4	0.0	0.0	0.0	5.1	20.5	53.6	90.4	13.1	1.5	2.8	6.4	10.7	17.3	31.4	45.1
Fruiting vegetables	62.2	0.0	0.0	14.0	45.3	90.4	182.8	293.6	60.9	9.6	17.6	36.6	55.6	79.8	122.1	158.8
Root vegetables	13.8	0.0	0.0	0.0	0.0	17.9	71.4	112.6	13.7	1.3	2.5	6.0	10.5	17.8	36.1	56.2
Cabbages	17.8	0.0	0.0	0.0	0.0	27.9	85.7	134.0	18.1	1.3	2.6	6.9	13.1	23.7	50.7	81.2
All fruits	142.1	0.0	0.0	34.3	112.3	203.7	405.5	582.5	144.4	2.0	9.0	50.9	117.1	210.2	373.1	510.1
Nuts, seeds	2.8	0.0	0.0	0.0	0.0	0.9	16.1	40.4	2.8	0.0	0.1	0.4	1.1	3.0	11.2	24.6
Potatoes	60.4	0.0	0.0	12.9	50.4	90.1	165.4	244.0	60.8	20.9	29.3	44.8	58.3	74.2	100.8	121.5
All cereals, cereal products	176.9	52.7	81.1	132.4	170.0	216.4	285.2	383.3	178.4	96.4	116.0	148.7	175.3	204.9	253.1	290.4
Pasta, rice	56.2	0.0	0.0	3.0	44.8	85.7	157.7	228.0	56.8	15.9	23.2	38.3	52.7	70.8	104.3	132.2
Bread	105.6	17.1	30.7	72.5	99.2	136.0	190.4	250.6	104.2	28.2	50.5	80.5	101.8	125.6	165.3	198.7
All sugar, confectionary	37.7	0.0	0.0	13.8	29.3	51.5	101.8	164.8	38.1	1.3	5.2	19.2	33.2	51.2	87.4	122.6
All cakes	56.9	0.0	0.0	11.4	46.1	85.7	159.7	241.5	57.7	5.7	12.6	32.1	53.1	78.6	117.8	148.3
All added fats	19.8	0.0	2.8	9.8	16.5	26.0	44.9	72.5	19.9	2.3	5.6	12.8	18.7	25.9	38.2	48.7
Vegetable oils	4.9	0.0	0.0	0.0	3.0	6.8	16.7	31.5	4.8	0.5	1.0	2.4	4.0	6.4	11.3	16.0
Butter	10.5	0.0	0.0	0.9	6.8	15.1	32.9	55.0	10.6	0.0	0.2	2.7	8.2	16.0	29.1	40.6
Margarines	3.3	0.0	0.0	0.0	0.0	3.2	16.3	32.6	3.3	0.0	0.0	0.1	0.8	3.9	15.0	25.7
All milk/dairy products	195.3	0.0	20.7	78.5	163.0	267.4	496.9	737.9	197.8	16.2	40.4	98.8	164.8	260.7	464.3	675.2
Milk and milk beverages	107.4	0.0	0.0	4.4	57.1	163.5	382.1	521.7	112.9	0.3	2.0	21.5	66.1	152.0	380.6	659.5
Cheese	28.2	0.0	0.0	10.0	22.5	39.0	74.6	123.1	27.4	5.0	9.0	18.0	26.3	35.7	49.5	60.1
All meat, meat products	95.7	0.0	7.8	48.8	89.6	131.8	204.2	286.3	99.3	11.0	27.2	65.4	95.7	129.3	182.7	228.5
Red meat	32.2	0.0	0.0	0.0	23.6	52.9	100.0	157.9	33.1	5.9	10.1	20.0	30.2	43.3	65.7	82.7
Beef	6.9	0.0	0.0	0.0	0.0	0.0	46.4	66.1	7.2	0.6	1.2	2.9	5.2	9.3	19.9	32.0
Pork	18.7	0.0	0.0	0.0	0.0	31.8	79.9	115.2	19.3	2.0	3.9	9.1	15.4	25.5	47.7	70.7
Poultry	14.1	0.0	0.0	0.0	0.0	19.1	76.1	114.3	15.1	2.1	3.6	7.6	12.3	19.7	36.1	51.6
Processed meat	46.9	0.0	0.0	12.1	36.6	65.6	135.5	209.9	47.7	4.9	10.7	26.8	43.0	63.6	100.1	134.0
All fish, fish poducts	15.3	0.0	0.0	0.0	0.0	18.4	81.6	161.6	14.4	6.3	8.0	11.0	13.8	17.1	23.3	28.2
Eggs, egg products	9.1	0.0	0.0	0.0	0.0	17.1	38.6	60.0	9.3	2.1	3.2	5.8	8.3	11.8	18.6	25.2
All non-alcoholic beverages	1,891.4	741.1	962.5	1,397.0	1,840.7	2,276.6	3,015.9	3,626.4	1,910.2	742.5	1,016.7	1,472.8	1,855.6	2,291.0	2,989.6	3,523.8
Fruit-, vegetable juices	187.0	0.0	0.0	0.0	109.8	284.8	685.7	1,000.0	188.7	0.2	2.0	29.8	118.9	283.9	603.7	886.0
Soft drinks	100.8	0.0	0.0	0.0	0.0	71.4	600.0	1,185.7	98.0	0.0	0.0	1.2	11.3	91.5	522.0	939.8
Coffee, tea, herbal teas	731.8	0.0	108.6	412.1	642.1	910.0	1,637.5	2,554.3	735.4	37.3	190.2	448.8	674.6	953.0	1,487.1	1,964.6
Water	866.0	0.0	0.0	378.6	805.6	1,249.3	1,964.3	2,500.0	870.1	15.1	94.1	428.8	767.5	1,193.4	1,995.5	2,719.3
All alcoholic beverages	110.4	0.0	0.0	0.0	42.9	160.7	428.6	821.4	118.6	0.2	1.1	13.0	56.7	171.0	433.7	675.5
Wine	47.7	0.0	0.0	0.0	0.0	71.4	230.8	410.7	48.6	0.1	0.5	4.6	19.0	64.2	197.1	321.2
Beer	52.1	0.0	0.0	0.0	0.0	0.0	323.2	537.1	53.9	0.0	0.1	1.7	9.8	52.6	280.4	493.6

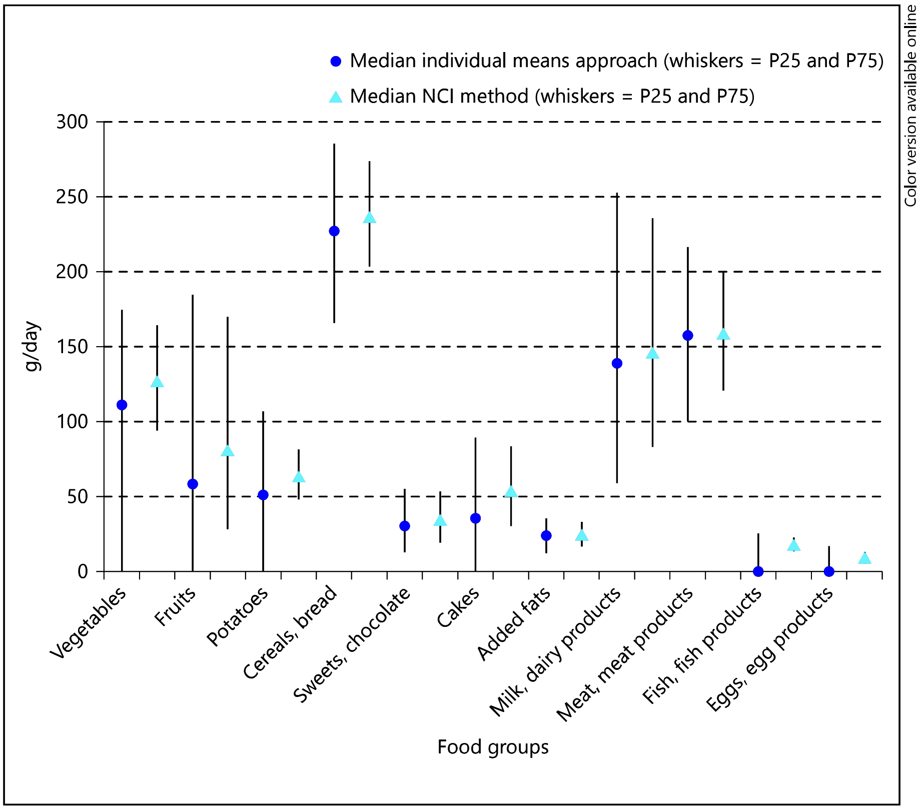

Fig. 1. Usual intake (g/day) by main food groups: comparison of medians derived by the individual means approach and NCI method for male participants.

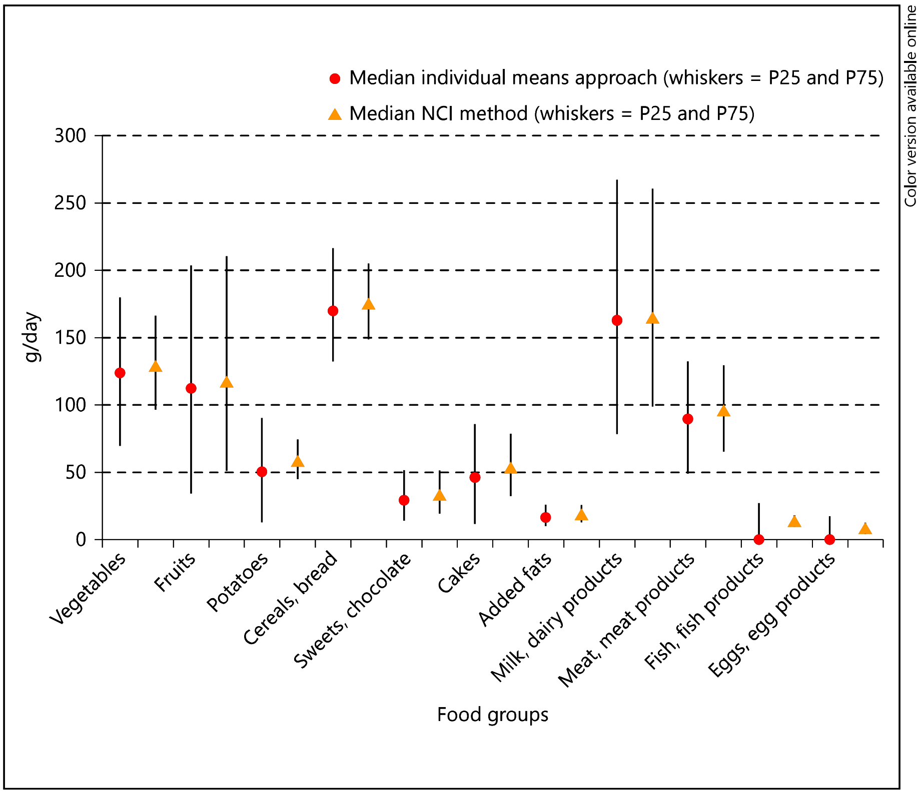

Fig. 2. Usual intake (g/day) by main food groups: comparison of medians derived by the individual means approach and NCI method for female participants.

Table 4. Proportion (%) of the study population who meet the recommendations published by the German Nutrition Society (DGE). In case of ranges recommended, the proportion of the study population with excess and insufficient consumptions is reported

Food group	Recommended daily intake	men				Women			
		% meet recommended amount	% do not meet recommended amount	% below min recommended amount	% above max recommended amount	% meet recommended amount	% do not meet recommended amount	% below min recommended amount	% above max recommended amount
NCI									
Vegetables	At least 400 g/day	0	100	–	–	0	100	–	–
Fruits	At least 250 g/day	13	87	–	–	18	82	–	–
Milk and all dairy products[1]	250–310 g/day	9	91	77	14	9	91	73	18
Cheese	50–60 g/day	8	92	87	5	3	97	95	2
Meat and meat products[2]	42–85 g/day	8	92	1	91	30	70	10	60
Fish[2]	21–30 g/day	27	73	67	6	9	91	90	1
Eggs[2]	Up to 21 g/day	95	5	–	–	97	3	–	–
Added fats	25–45 g/day	41	59	51	8	26	74	72	2
Non-alcoholic beverages	At least 1.5 L/day	68	32	–	–	74	26	–	–
Individual means approach									
Vegetables	At least 400 g/day	2	98	–	–	1	99	–	–
Fruits	At least 250 g/day	18	82	–	–	19	81	–	–
Milk and all dairy products[1]	250–310 g/day	9	91	74	17	8	92	71	21
Cheese	50–60 g/day	6	94	77	17	5	95	85	10
Meat and meat products[2]	42–85 g/day	11	89	9	79	27	73	20	53
Fish[2]	21–30 g/day	4	96	73	23	4	96	76	20
Eggs[2]	Up to 21 g/day	20	80	–	–	18	82	–	–
Added fats	25–45 g/day	33	67	53	14	23	77	72	5
Non-alcoholic beverages	At least 1.5 L/day	59	41	–	–	71	29	–	–

[1] Sum of recommendations for "milk and dairy products" and "cheese."
[2] Weekly recommendations converted to a daily basis.

Comparisons of Usual Intake Estimates with Dietary Guidelines of the German Nutrition Society (DGE)

Table 4 shows comparisons of the selected recommendations with the derived usual intake estimates. Details on the conversion and selection of recommendations are given in the Methods section.

Comparing both methods, we found good accordance for the proportions of the study population meeting the recommendations. An exception arises for the food groups "eggs," "added fats" and, among men, as well for "fish." Here, the NCI method suggests a far better achievement of the recommended amounts in contrast to the individual means approach.

Taking a closer look at those who did not meet the recommendations of meat and meat product consumption, we found that the NCI method identified 91% of men and 60% of women consuming too much. These fractions are remarkably higher than 79% of men and 53% of women as identified by the individual means approach. The upper limit of the recommended amount, that is 85 g/day, is lower than the median of both distributions. For the food group "fish" and the sub group "cheese," the individual means approach identified considerably higher fractions of over-consumers (23% of men and 20% of women in contrast to 6% of men and 1% of women for "fish" and 17% of men and 10% of women in contrast to 5% of men and 2% of women for "cheese") compared to the NCI method.

Discussion

We used 2 different methods to assess the usual food intake: an individual means approach and the NCI method. The individual means approach weighted the data by taking the frequency of weekdays and weekend days into account. Applying the NCI method, the amount models as well as the probability models were adjusted for age, gender, BMI, SES, physical activity, and smoking. Additionally, the weekday of consumption was included.

Summing up the results, we see a good accordance of mean estimates by both methods among men as well as among women. Further, the median usual intake amounts estimated by the NCI method are slightly higher for all food groups or subgroups in men as well as in women.

Although both methods yielded comparable arithmetic means (by definition of the method), they were differing slightly due to the included adjustment variables in the NCI method. In contrast to the mean values, there were considerable differences with regard to the percentile values of most food groups and subgroups. When we compared the individual means approach with the NCI method, the median intake amounts (50th percentile) as well as the overall distribution differed. Higher 1st, 5th, 25th, and 50th percentile values and a majority of lower 75th, 95th, and 99th percentile values were found when the NCI method was used, reflecting the adjustment for within-person variation. Furthermore, extreme values (e.g., zero consumption) were more frequent when using the weighted means approach, as the NCI approach does assume that there are no usual non-consumers. This affects the tails of the distributions derived. The individual means approach does not result in a unimodal distribution for food groups with a number of zero amounts consumed. It seems that the distribution derived by the NCI with very low amounts instead of zero amounts better represents the true distribution. There are food groups that are not consumed on a daily basis and are therefore at risk of being missed by the 24-h dietary recall. Only in rare cases this will happen because of the fact that a food group is not consumed at all.

The distribution difference also had an impact when food intake was compared with the current recommendations of the German Nutrition Society. Using the NCI method, a larger proportion of the study population was identified to reach the recommendations for 5 resp. 6 food groups and subgroups out of 9 for men and women, respectively. Distributions of the usual intake of "fish," "egg," and "added fats" showed the largest differences with respect to the proportions that meet the recommendations. Interestingly, the proportions below the minimum and above the maximum of the recommended amounts differed strongly for certain food groups. Especially for the consumption of meat and meat products, the NCI method identified an even higher proportion of subjects exceeding the recommendations than the individual means approach. For "cheese," a distinctly elevated proportion of those consuming too little was identified by the NCI approach, whereas for "milk and dairy products" both approaches yielded very similar results. Therefore, by comparison of the 2 methods, additional insight is gained about the extent of over- and under-consumption for the various food groups compared to their recommended intakes.

The individual means approach is very easy to handle, but this comes with major drawbacks. It accounts neither for reported days without consumption nor for positively skewed consumption-day amounts. The individual means approach cannot distinguish within-person from between-person variation. This means that the distribution of within-person means has a larger variance compared to the distribution of the true usual intake values. This leads to biased estimates of the fraction of the population with usual intake values above or below given reference values [17]. Lastly, the individual means approach does not allow for the correlation between the probability of consumption and the consumption-day amount. Therefore it is evident, that the NCI method provides adequate estimates of the usual intake in a population, as has been shown by simulation studies (e.g., [13] or [18]).

A feature of the NCI method is that it may incorporate food frequency information from an FFQ as a covariate. Since with the 24-h dietary recall only up to 3 days of consumption were recorded, there is a larger risk that foods were classified as not consumed just because they were randomly not consumed. However, this does not mean that these foods were generally not consumed. The usual intake of this food group or subgroup is estimated as a value greater than zero in any case. Including the FFQ can reasonably adjust the derived values [28]. This is another advantage of this method, although we do not have FFQ information available in the BVS II study. This is especially important when individual estimates are of interest, which is not the case in our analysis. Instead, our focus is the comparison to recommended reference values on the group level. The individual means approach cannot incorporate this information.

Our food intake data are in line with the 24-h dietary recall data of the National Food Consumption Survey II conducted between November 2005 and January 2007, which provides representative information on food intake in Germany [29]. We fitted the models for the main food groups on the aggregated food data and did not sum up all usual intakes derived for the sub food groups. This has to be kept in mind when comparing our findings to other studies, as we can therefore only compare main food groups. Overall, mean amounts of food intake differ only slightly between the 2 studies. Differences worth noting are found among Bavarian men, who usually consume more beer and meat or meat products and less milk or dairy products compared to the German population. Among Bavarian men and women, a lower usual intake of fruits and a higher usual intake of vegetables and cereals or cereal products compared to the overall German population were found [30]. However, regional differences in dietary behavior as well as differences concerning the food group definition may explain these results. Furthermore, data from the National Food Consumption Survey II showed that food intake differed considerably according to the dietary assessment method applied [31].

The BVS II is a well-designed population-based study, representative of the Bavarian population with comprehensive data on dietary behavior. This allowed us to apply different methods for estimating dietary intake. We did not apply sampling weights to the data set because its sex-specific age distribution has been reported to be similar to the Bavarian reference distribution [26]. Three highly standardized 24-h dietary recalls allow a valid estimation of food intake at the group level (e.g., [32]). However, since there was only one dietary assessment method conducted, it was not possible to combine data from different methods such as 24-h DR data with FFQ data. Usual intake estimates based on BVS II data have not been published before.

As we do not know the true usual intake amounts, the superiority of the NCI method over the individual means approach cannot be quantified, which is a drawback of the data reported. Nonetheless, the NCI overcomes the major disadvantages of the individual means approach.

Conclusion

Using the NCI method, this study provided reliable data on usual food intake among the Bavarian population. Although mean intake can easily also be derived from the individual means approach, only the NCI method gives valid information on the distribution accounting for intra-individual variation, which is important when food consumption or nutrient intake of a population above or below a given limit is evaluated.

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Disclosure Statement

The authors declare no conflicts of interest.

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