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ORIGINAL CONTRIBUTION

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Changes in time-trends of nutrient intake from fortified and non-fortified food in German children and adolescents – 15 year results of the DONALD Study

Summary *Background:* Although fortified products have played an increasing role in food marketing since the 1980 s in Germany, data as to the consumption of fortified food is sparse. *Aim of the study:* To assess long-term data on changes in fortified food supply or consumption patterns, nutrient intake, and time trends in the DONALD Study (Dortmund Nutritional and Anthropometric Longitudinally Designed Study). *Methods:* Between 1985 and 2000 consumption of nutrient intake (total and from fortified foods) was evaluated and time trends in energy and nutrient intake were assessed on the basis of 3-day weighed dietary records (n = 4193) of 2–14 year-old males (n = 383) and females (n = 404) enrolled in the DONALD Study. Nutrient intake was expressed as percentage of the current German recommendations. Food products were defined as fortified if enriched with at least one of the following nutrients: Vitamin A or provitamin A carotenoids (summarised as Vitamin A), Vitamins E, B1, B2, B6, C, niacin, folate, calcium or iron. Nutrient supplements and medicine were excluded from this evaluation. Time trends were analysed using linear and non-linear regression models (PROC MIXED, SAS® 6.12). *Results:* In percent of German references [3], non-fortified food contributed to folate intake by 20–30 %, to Vitamin E by about 40 %, to Vitamin B1 by 50–65 %, to Vitamin A, C, B2, calcium, iron by about 65–95 %, and to Vitamin B6 and niacin intake by 100 % and more. Fortified food alone provided no more than 5 % of calcium intake, about 10–20 % of iron, Vitamin A and folate intake, up to 40–50 % of Vitamin C, B 1, B2, E, niacin and up to 80 % of Vitamin B6 intake. During the 15 year period of the DONALD Study with total food, we only found a significant linear time trend for Vitamin C, whereas significant non-linear time trends were found for calcium, Vitamin E, B1, B2, B6, niacin and folate. In the latter there was a uniform increase until 1994 and a decrease thereafter. For iron and Vitamin A no significant time trend could be identified. Only iron and Vitamin A intake from fortified food showed a significant linear time trend. All other nutrients studied here gave significant non-linear time trends. Nutrient intake with fortified food reached maximum values between 1994 and 1996 followed by a decrease thereafter. *Conclusions:* Signs of changing food consumption patterns were found, pointing to an almost uniform decrease of nutrient intake since 1994/96 in our population of German children and adolescents. This could be an alarming indicator of a slight but unpreferable tendency to eat energydense, nutrient-poor foods.

Key words Adolescents – Children – Fortified food – Minerals – Time trends – Vitamins

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Introduction

The fortification of food on a wide scale started in Germany with multivitamin juices in the early 1980s. Fortified beverages are still the food group with the greatest variety of fortified products or brands. Fortified milk products were introduced as early as fortified beverages, but in diversity they remained comparatively small. Although fortified products have played an increasing role in food marketing since the 1980 s, data as to the consumption of fortified food is not available. Furthermore there are only a few newer studies dealing with the consumption of fortified food to be found and these are either focused an single groups of products, e. g. breakfast cereals, or on nutrient intake in adults. Long-term data on changes in fortified food supply or consumption patterns is not available for adults nor for children and adolescents.

In two previous evaluations of the DONALD Study (Dortmund Nutritional and Anthropometric Longitudinally Designed Study), we reported that fortified beverages and instant drinks were the most frequently consumed fortified products in children and young adolescents in Germany [1] and that vitamin and mineral intake from fortified food had increased over a 10 year period [2].

In the present paper we compare total energy and nutrient intake (total vs. fortified food) in 2-through 15-year-old participants from the DONALD Study according to the new German references [3]. We also study time-trends in nutrient intake over the past 15 years.

Subjects and methods

The DONALD Study is a cohort study collecting detailed data on diet, metabolism, growth and development from healthy subjects between infancy and adulthood (once a year for subjects older than 2 years). The study started in the middle of 1985 with children and adolescents of different ages participating in the until then exclusively anthropometric studies at our institute. Since then yearly cohorts of about 40–50 healthy infants have been enrolled. Mothers are recruited in maternity wards or are informed by other study participants. In the DONALD Study sample, upper social class families are over-represented. About 35 (45) % of the mothers (fathers) have a grammar school education and 21 (39) % hold a university degree or a professional qualification. Details have been described elsewhere [4, 5].

Parents of the children or the older subjects themselves kept 3-day weighed dietary records, weighed and recorded all foods and fluids consumed as well as leftovers using electronic food scales (± 1 g). Product information from wrappers, cartons, etc. were kept and evaluated with the dietary records by our dieticians. Semi-quantitative recording (e. g. numbers of scoops, spoons) was allowed if weighing was not possible. However, in 75 % of the completed records more than 90 % of the food items were weighed. In nearly 2 % of the records, less than 5 % of the items were weighed. Week days (68 %) and weekend days (32 %) were proportionally distributed in the sample. To validate dietary recording the ratio of reported energy intake (EI) and predicted basal metabolic rate (BMR) was calculated according to Goldberg et al. [6] and BMR was calculated according to Schofield et al. [7]. The mean EI:BMR-ratios of the sample (1.30 to 1.49; Table 1) are within the recommended range of plausible dietary information according to Torun et al. [8].

Nutrient contents of common foods were taken from standard nutrient tables [9–11]. Those of commercial food products were determined either by using the product labels or by simulating recipes from the ingre-

Table 1 Overall energy and nutrient intake in different age-groups of the DONALD Study 1986–2000

	2– < 4 y Boys. Girls n = 916		4– < 7 y Boys. Girls n = 1237		7– < 10 y Boys. Girls n = 1011		10– < 13 y Boys n = 364		Girls n = 364		13– < 15 y Boys n = 166		Girls n = 148	
	Mean	(SD)	Mean	(SD)	Mean	(SD)	Mean	(SD)	Mean	(SD)	Mean	(SD)	Mean	(SD)
Energy, kcal	1076	(208)	1358	(261)	1677	(317)	1999	(389)	1779	(350)	2289	(518)	1835	(372)
Energy/BMR	1.37	(0.22)	1.46	(0.23)	1.49	(0.26)	1.45	(0.27)	1.42	(0.26)	1.41	(0.29)	1.30	(0.28)
Calcium, mg	615	(211)	659	(216)	796	(275)	949	(325)	800	(287)	1055	(363)	846	(309)
Iron, mg	5.8	(1.6)	7.3	(1.9)	9.1	(2.2)	10.8	(2.8)	10.0	(2.6)	12.3	(3.1)	10.3	(2.9)
Vit. A, µg	538	(320)	588	(356)	697	(405)	745	(431)	739	(500)	883	(638)	816	(441)
Vit. E, mg	4.4	(2.6)	6.0	(3.5)	7.5	(4.3)	9.3	(5.2)	8.3	(5.0)	10.4	(5.2)	8.6	(4.7)
Vit. C, mg	70	(44)	76	(46)	94	(51)	105	(66)	105	(63)	110	(57)	117	(74)
Vit. B1, mg	0.6	(0.2)	0.7	(0.3)	0.9	(0.4)	1.1	(0.5)	1.0	(0.5)	1.2	(0.5)	0.9	(0.4)
Vit. B2, mg	0.9	(0.4)	1.1	(0.5)	1.4	(0.6)	1.5	(0.6)	1.4	(0.7)	1.8	(0.7)	1.3	(0.5)
Vit. B6, mg	0.8	(0.3)	1.0	(0.5)	1.2	(0.6)	1.5	(0.8)	1.3	(0. 7)	1.7	(0.7)	1.3	(0.5)
Niacin, mg	12	(4)	15	(5)	20	(6)	24	(9)	21	(8)	28	(9)	21	(7)
Folate, mg	90	(42)	114	(59)	142	(74)	164	(80)	158	(90)	183	(79)	152	(66)

BMR Basal Metabolic Rate (Schofield 1985); *n* number of records dients listed. For some fortified products we only knew the total nutrient content labelled (i.e. the sum of natural and fortified nutrient contents), e.g. vitamin C in fruit juices. Here food products were defined as fortified if enriched with at least one of the following nutrients: vitamin A or provitamin A carotenoids (summarised as vitamin A), vitamin E, B1, B2, B6, C, niacin, folate, calcium or iron. Nutrient supplements and medicine were excluded from this evaluation.

SAS® procedures (Version 6.12) were used for data analysis [12]. Energy and nutrient intakes were calculated as individual means of the 3 recorded days. Results are presented as mean values ± SD. To analyse the influence of effects (year, year*year, age, sex) on the outcome variables, mixed linear and non-linear models were used, in which the means of the data and the covariance structure (children of the family, repeated measurements) were modelled (PROC MIX) [13]. The model with the better fit was presented in the tables here and fixed effects were noted (see β1 and β2 in Table 2): increase (+), decrease (–).

The study is exclusively observational, non-intervening, and non-invasive as approved by the International Scientific Committee of the Research Institute for Child Nutrition.

Results

Between 1985 and 2000 a total of 4193 dietary records from 383 males and 404 females aged 2 to < 15 years were collected and evaluated. On average, five records per participant were available. Between 142 and 356 subjects participated per year. Mean age in the different years studied ranged from 6.1 to 8.2 years. Table 1 shows overall energy and nutrient intake data in the different agegroups of the study.

Contribution of non-fortified vs. fortified food to nutrient intake

Evaluated in percent of German references [3] non-fortified food contributed to folate intake by 20–30% (Fig. 1), to vitamin E intake by about 40% (Fig. 2), to vitamin B1 intake by 50–65% (Fig. 3), to vitamin A, C, B2, calcium and iron intakes by about 65–95% (Fig. 4–8), and to vitamin B6 (Fig. 9) and niacin intakes by 100% and more (Fig. 10). Fortified food alone provided no more than 5% to calcium intake, about 10–20% to iron, vitamin A and folate, up to 40–50% to vitamin C, B1, B2, E, niacin and up to 80% to vitamin B6 intake.

Total nutrient intake in percent of references

We identified three types of nutrient intake in our study population. 1): Mean intakes of vitamin B6 and niacin well above the reference values with 100% and more derived from non-fortified food alone. 2): Mean intakes of calcium, iron, vitamin C, B1 and B2 about 90–120% of reference values derived from both non-fortified and fortified food. 3): Mean intakes of vitamin A, E and folate below 90% of reference values derived from both non-fortified and fortified food.

Time trends in nutrient intake from total vs. fortified food

During the 15 year period of the DONALD Study with total food, we found a significant linear time trend for vitamin C only. However, significant non-linear time trends for calcium, vitamin E, B1, B2, B6, niacin and folate were also recorded (Table 2). In the latter there was a uniform increase until 1994 and a decrease thereafter. For iron and vitamin A no significant time trend could

Table 2 Linear and non-linear time trends (%/year) in mineral and vitamin intake from total and fortified food in 2–14 year-old participants of the DONALD Study 1985–2000

Nutrient	Total food						Fortified food					
	β1 (year)[1]	p-Value	β2 (year*year)[2]	p-Value	Sex p-Value	Age p-Value	β1 (year)[1]	p-Value	β2 (year*year)[2]	p-Value	Sex p-Value	Age p-Value
Iron	0.01	0.3938			0.0001	0.0003	**0.86**	0.0001			0.0032	0.0237
Calcium	**3.32**	0.0001	**–0.16**	0.0001	0.0001	0.0001	**0.84**	0.0001	**–0.03**	0.0001	0.5613	0.0001
Vit. A	–0.02	0.9465			0.0375	0.0162	**0.80**	0.0001			0.5739	0.5569
Vit. E	**5.65**	0.0001	**–0.32**	0.0001	0.2374	0.0085	**5.90**	0.0001	**–0.33**	0.0001	0.6147	0.0243
Vit. C	**1.37**	0.0001			0.2872	0.1557	**5.00**	0.0001	**–0.15**	0.0269	0.3689	0.0001
Folate	**1.31**	0.0013	**–0.08**	0.0004	0.0017	0.1324	**2.53**	0.0001	**–0.14**	0.0001	0.5994	0.7976
Vit. B1	**3.06**	0.0001	**–0.15**	0.0007	0.0059	0.1228	**5.33**	0.0001	**–0.24**	0.0001	0.3327	0.5266
Vit. B2	**5.10**	0.0001	**–0.30**	0.0001	0.0001	0.0001	**6.43**	0.0001	**–0.31**	0.0001	0.6894	0.3539
Vit. B6	**8.19**	0.0001	**–0.37**	0.0001	0.0001	0.0001	**11.03**	0.0001	**–0.45**	0.0001	0.1276	0.0001
Niacin	**4.25**	0.0001	**–0.16**	0.0058	0.0001	0.0342	**5.30**	0.0001	**–0.19**	0.0002	0.2699	0.1955

[1] linear time trend weighted least square estimates in %/year
[2] non-linear time trend weighted least square estimates in %/year

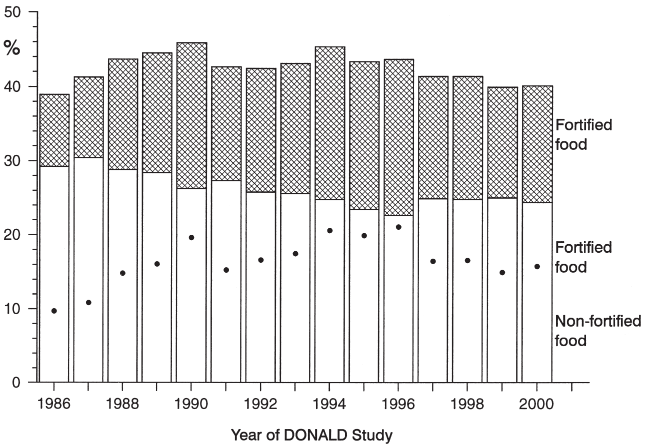

Fig. 1 Mean folate intake from fortified and non-fortified food in % of new references [3] in German children and adolescents of the DONALD Study.

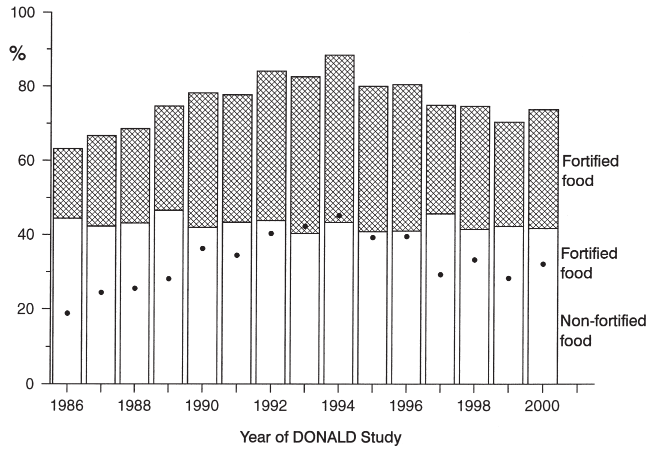

Fig. 2 Mean vitamin E intake from fortified and non-fortified food in % of new references [3] in German children and adolescents of the DONALD Study.

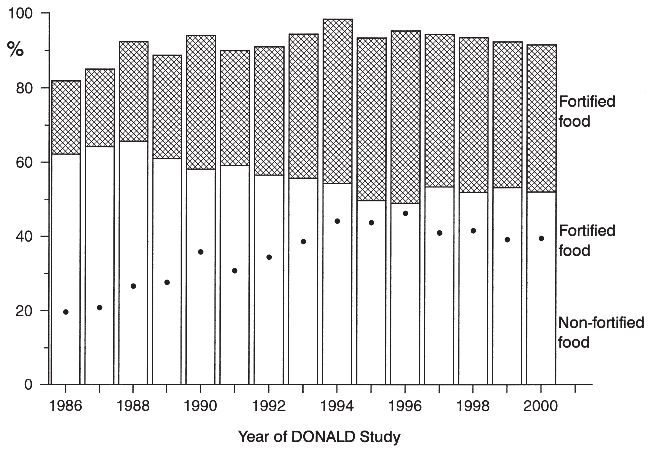

Fig. 3 Mean vitamin B1 intake from fortified and non-fortified food in % of new references [3] in German children and adolescents of the DONALD Study.

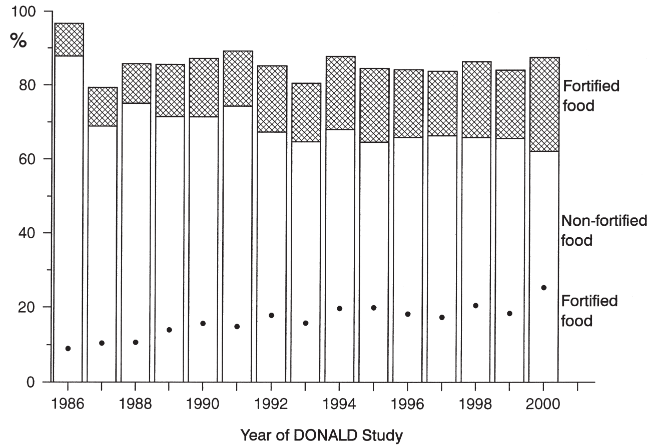

Fig. 4 Mean vitamin A intake from fortified and non-fortified food in % of new references [3] in German children and adolescents of the DONALD Study.

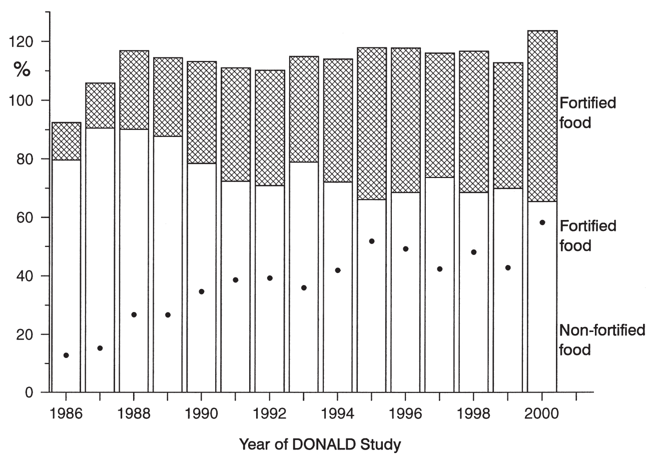

Fig. 5 Mean vitamin C intake from fortified and non-fortified food in % of new references [3] in German children and adolescents of the DONALD Study.

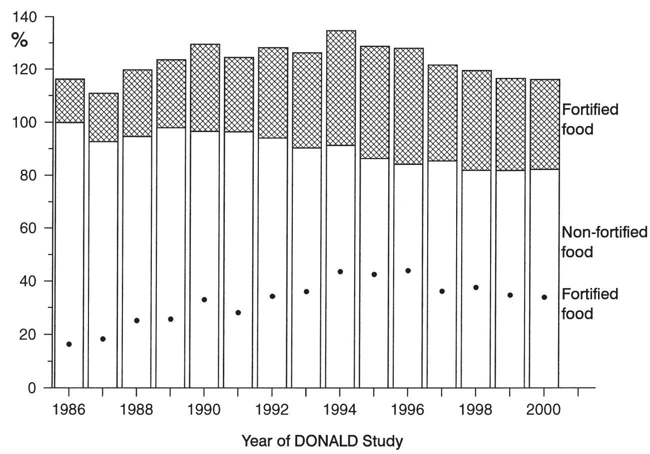

Fig. 6 Mean vitamin B2 intake from fortified and non-fortified food in % of new references [3] in German children and adolescents of the DONALD Study.

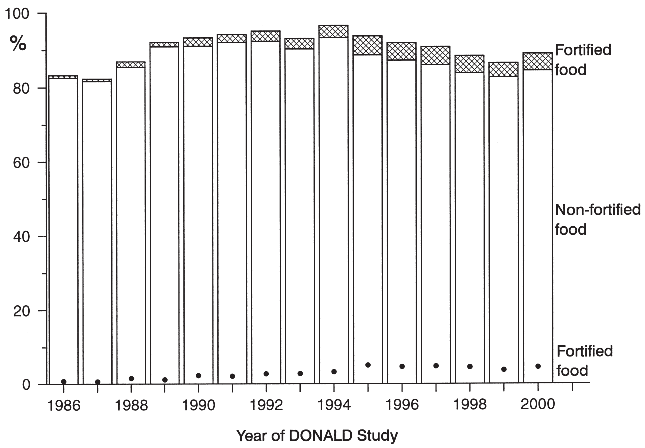

Fig. 7 Mean calcium intake from fortified and non-fortified food in % of new references [3] in German children and adolescents of the DONALD Study.

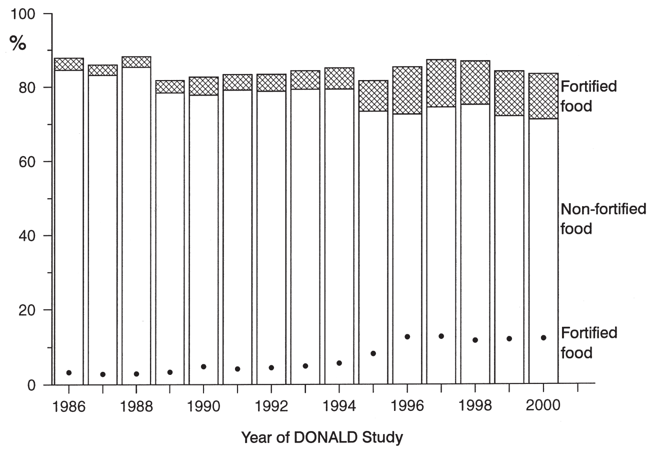

Fig. 8 Mean iron intake from fortified and non-fortified food in % of new references [3] in German children and adolescents of the DONALD Study.

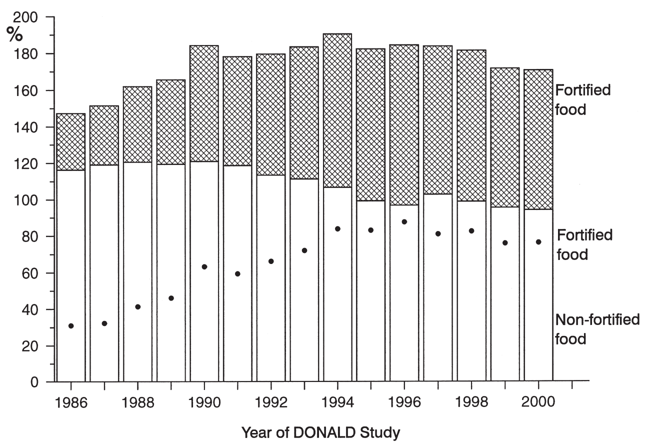

Fig. 9 Mean vitamin B6 intake from fortified and non-fortified food in % of new references [3] in German children and adolescents of the DONALD Study.

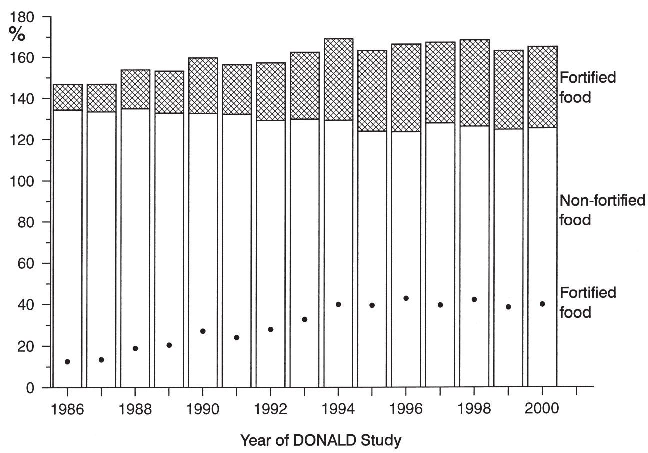

Fig. 10 Mean niacin intake from fortified and non-fortified food in % of new references [3] in German children and adolescents of the DONALD Study.

be identified. With the exception of vitamin C and E intake in percent of references was sex dependent and except vitamin C, B1 and folate age-dependent.

Only iron and vitamin A intake from fortified food showed a significant linear time trend. All other nutrients studied here gave significant non-linear time trends (Table 2). Nutrient intake with fortified food reached maximum values between 1994 and 1996 followed by a decrease thereafter. With the exception of iron no sex-dependent intakes with fortified nutrients were found and only iron, calcium, vitamin E, C and B6 were age dependent.

Discussion

The DONALD Study is a longitudinal, non-intervening study. Uniform methodology including the 3-day dietary record and the nutrient data base especially with fortified food items has been used from the start. This offers a differentiated insight into total nutrient intake, the contribution of fortified food to nutrient intake, and consumption patterns over time in German children and adolescents.

In the literature only a few studies are concerned with the intake of fortified food. Some are confined to single food groups. e. g. breakfast cereals [14–18], while others focus on nutrient intake from fortification in adults only [19–22]. Long-term data on fortified food consumption patterns is not available for adults nor for children and adolescents. General results of the DONALD Study considering fortification have been reported [1, 2] and showed an increase in the consumption of fortified food in children and young adolescents in Germany.

Total nutrient intake

Total nutrient intakes in the DONALD Study are in good accordance with results of representative cross-sectional European studies using dietary records, e. g. in the Netherlands [23], Greece [24], Spain [18], and England [25]. The only longitudinal study in children and adolescents of the same ages as the subjects of the DONALD Study originates from the Netherlands [23] where total intake of some nutrients (calcium, iron, vitamin A and C) was assessed in 1987/88, 1992 and 1997/98. These intake data are in good accordance with the results presented here. Although the parents of the DONALD Study have a high socio-economic status compared to the general German population, several evaluations showed no or only minor differences of dietary habits in our sample compared to the first nationwide German Dietary Survey (NVS) [4].

Total nutrient intake in percent of references

Compared to the new German references [3] nutrient intakes studied in our Population were sufficient with the exception of vitamin E and folate where fortification plays an important role.

Contribution of fortified food to nutrient intake

In our evaluation there could be a tendency to overestimate fortified nutrient intake due to food labelling practice. However, the overall concentration of most added nutrients in fortified products is higher than stated in order to compensate for nutrient destruction during shelf life. Our data show a great variety of contributions of fortified food to total nutrient intake. In general fortified minerals are less important than vitamins. Calcium and iron intakes from fortified food never exceeded 15% but for vitamins the situation differs considerably. Some vitamins (e. g. vitamin A, folate) show only minor contributions to nutrient intake while others (e. g. vitamin E, B1, B2, niacin) are more important and some contribute by as high as 50% (vitamin C) or by 80% (vitamin B_6). In some cases fortification was unnecessary (vitamin B6, niacin) or inefficient (calcium, iron), and in the case of vitamin E and folate (to some extent vitamin B1) fortification was necessary to improve nutrient supply.

Time trends

The most striking result of our study are signs of changing food consumption patterns pointing to an almost uniform decrease in intake of some nutrients since 1994/96, although there was no significant (linear nor non-linear) time effect in energy intake during the study period. With the exception of vit. C where we found an increase of +1.4%/year, and vitamin A and iron without any time trend at all, we found a significant reduction of total nutrient intake in calcium and 7 vitamins. Moreover, our evaluation of the contribution of fortification showed a significant decrease in 8/10 nutrients. However, with the exception of vitamin E there was a decrease of nutrient intake from non-fortified food alone. From a preventive point of view, this points to a slight but unpreferable tendency to eat energy-dense, nutrient-poor foods (EDNP) in our study population – as was although recently reported in an evaluation of NHANES III [26].

According to a Codex Alimentarius Commission statement, added essential nutrients should not lead to either excessive or insignificant intake and should not be used to mislead or deceive the consumer as to the nutritional merit of the food. In industrialised countries, food fortification is often justified by rapidly changing lifestyles and by increasing reliance on more highly processed foods. But there is no general consensus regarding the extent to which food fortification should be practised and fear of over-fortification is rising as manufacturers seek to use fortification as a marketing tool [27]. To meet special needs (iron, folate) in some target population groups the use of single nutrients or at least well-composed nutrient supplements might be considered instead of non-specific fortification of food. However, at present there is no agreement in the scientific community as to whether to fortify food or to educate people either to choose common food properly or to use supplements. But it is mostly agreed upon that priority should be given to a balanced food choice combined with nutrition education, especially in children and adolescents.

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