Food costs in vegetarian, vegan and omnivore diets of children and adolescents - Results of the cross-sectional VeChi Youth Study

Eva Hohoff
University of Bonn, DONALD Study Dortmund
Helena Zahn
University of Bonn, DONALD Study Dortmund
Stine Weder
Research Institute for Plant-Based Nutrition, Gießen
Morwenna Fischer
University of Applied Sciences (FHM)
Alfred Längler
University of Witten Herdecke
Andreas Michalsen
Charité-Universitätsmedizin
Markus Keller
Research Institute for Plant-Based Nutrition, Gießen
Ute Alexy (alexy@uni-bonn.de)
University of Bonn, DONALD Study Dortmund

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Abstract

Purpose: The aim was to analyse total food costs (€/day, €/1000kcal) and the impact of food groups to total food costs among vegetarian, vegan and omnivore children and adolescents in Germany.

Methods: Based on 390 three-day weighed dietary records of 6-18-year-old children and adolescents of the VeChi Youth Study, total daily food costs and food group costs (both €/day, €/1000kcal) of a vegetarian (n=145 study participants), vegan (n=110) and omnivore (n=135) diet were calculated. Minimum retail prices of 1,000 empirically selected foods reported in the dietary records were linked to individual food intakes. Group differences were analysed using ANCOVA. For food groups with a high number of non-consumers, Kruskal-Wallis tests were performed.

Results: Vegans had the highest energy adjusted total food costs at 2.98 €/1000kcal, vegetarians the lowest at 2.52 €/1000 kcal. Omnivores also had significantly higher costs than vegetarians with 2.83 €/1000 kcal (p=0.01) but total costs did not differ significantly between omnivores and vegans (€/d and €/1000 kcal). Compared to vegetarians vegans had significantly higher daily expenditures (€/day) on fruit (p=0.0003), vegetables (p=0.006), dairy alternatives (p=0.0003) and legumes/nuts (p=0.0003). Expenditure on starchy foods was significantly higher in vegetarian or vegan than in omnivore diets (p=0.0003). Omnivores spent a quarter of total food costs on animal source foods (25%), which is equivalent to the sum of food costs for legumes/nuts, dairy alternatives, meat alternatives in vegans and additionally dairy in vegetarians.

Conclusion: In the VeChi Youth Study a vegetarian diet pattern was the least expensive compared to an omnivore diet pattern, and food costs of a vegan pattern are comparable with an omnivore pattern.

Background

Food-based dietary guidelines in Europe mostly refer to health aspects, while sustainability often plays a minor role [1, 2]. Besides ecological aspects such as the emission of greenhouse gases or land use, sustainability also has an economic and social dimension. This includes that a healthy and ecologic sustainable diet must be affordable also for individuals of different socio-economic status [3], which is especially important for families with children.

To promote both health and environmental sustainability, plant-based diets are recommended, e.g. by the EAT-Lancet commission [4]. However, little is known about the respective food costs of plant-based diets compared to an omnivore diet. In a recent modelling study on global and regional costs of dietary pattern, the relative affordability was largest for vegetarian and vegan diets that focused on legumes and whole grains [3]. In contrast, another modelling study from New Zealand came to different results. Here, the vegan dietary pattern yielded highest food costs compared to the more inexpensive current diet [5]. In an older study the authors calculated food costs based on real-life data of a vegetarian and omnivore diet in German adult women [6, 7]. This resulted in lowest food costs in a dietary pattern with a high proportion of plant-based and unprocessed foods. However, a vegan diet excluding all animal source foods was not included. Furthermore, these results might be outdated and not comparable to other population groups such as children.

In Germany, the estimation of food costs of an omnivore diet for children and adolescents in 2009 showed daily costs of about 2 €/1000kcal, based on minimum food prices. In this analysis, meat (13% of total daily costs), milk and dairy products (12%) and beverages (13%) had the highest share [8]. Hence, the question is, whether plant-based diets that exclude one or two of these food groups, i.e., vegetarian and vegan dietary pattern, are cheaper or more expensive than omnivore diets. Furthermore, food prices change over time due to inflation, changes in production costs, increased global competition or changes in subsidies [9, 10]. For example, the prices of food and non-alcoholic beverages in Germany increased by about 10% between 2015 and 2020 [9]. The largest price increase related to the food groups fish (15%), meat (14%) and fruit (14%), followed by vegetables (11%) and dairy products (11%). The smallest price increase was observed for confectionery (2%) [9]. In addition, secular trends in dietary habits can affect daily food costs. For example, in recent years there has been a trend towards plant-based diets in Germany [11, 12], and meat and dairy intake is declining [13–15]. At the same time, plant-based dairy and meat alternatives are becoming increasingly popular [12, 16, 17]. However, in direct comparison prices of these alternative products are considerably more expensive than the original animal-derived foods [18]. As food prices are one key factor for food choices [19, 20], higher food costs are supposed to be a barrier for switching to a more plant-based diet, in particular for socially disadvantaged groups. This might explain the observed higher prevalence of a vegetarian or vegan diet among population subgroups with a high socio-economic status [21, 22].

Hence, the aim of this study was to calculate and compare food costs among children and adolescents consuming a vegetarian, vegan or omnivore diet based on real-life data. Hereto, data from the VeChi Youth Study, a cross-sectional study conducted in Germany from October 2017 to January 2019 [23, 24], were used and linked to retail food prices collected in 2021.

Methods

The VeChi Youth Study

The primary objective of the VeChi Youth Study was to collect and analyse dietary intake and anthropometric data, as well as to assess the nutrient status using blood and urine biomarkers from vegetarian (excluding meat and fish), vegan (excluding all animal foods) and omnivore children and adolescents aged 6–18 years. Details of the VeChi Youth Study have been described in detail elsewhere [24, 25].

Study sample

The VeChi Youth Study included 401 children and adolescents aged 6–18 years who were examined in three study centers in Germany. Of the participants, 390 (boys n = 169, girls n = 221) completed a three-day weighed food record. Accordingly, data from 110 vegans (28%), 145 vegetarians (37%) and 135 omnivores (35%) were evaluated for the present analysis.

Dietary assessment

Dietary intake was recorded using three-day weighed dietary records as described elsewhere [14]. In short, all foods and beverages consumed, as well as leftovers, were weighed and recorded over three days using electronic kitchen scales. If exact weighing was not possible (e.g., for out-of-home meals), semi-quantitative household recording (e.g., spoons, cups) was allowed. Missing data were obtained by the study staff by requesting the information from parents via email. For commercial food products, e.g., ready-to-eat meals and meat or dairy alternatives, the exact brand name was reported. Energy and nutrient composition of such food products were calculated by recipe simulation based on nutrient and ingredient declaration [26]. Hence, it was possible to collect not only staple food prices (e.g., apple, milk), but also brand-specific product prices (e.g., vegan meat alternatives or lemonades) in this project.

Food price collection

A total of 3,046 different foods and food products were reported in the dietary records of the VeChi Youth Study. After excluding condiments (e.g., salt, pepper) and dietary supplements, 2,866 foods and food products remained. To reduce the effort for price collection to a feasible level, a representative sample of 1,000 food items was selected, analogous to previous studies [8, 27]. In a first step, those 800 foods with the largest mean consumption amounts were selected (basic foods). From the remaining foods, a random sample of 200 foods was selected.

Food prices were collected in February and March 2021. Due to the covid pandemic restricting retail store visits, the prices were largely determined on the websites of two popular German supermarket chains (www.rewe.de and www.kaufland.de) and one discounter (www.aldi-onlineshop.de). If prices of specific branded products were not available on these shop websites, prices were collected in other online shops. If more than one kind of similar foods was offered, e.g., for staple food as apples or milk, the minimum price (€/100 g) at the respective point of sale was noted. To ensure comparability, special offer prices were excluded and prices of the same packaging sizes were collected. For food consumed out of home, the prices on the website of the respective restaurant chain or a comparable restaurant was collected. For out of season-varieties of fruit and vegetables, the price of frozen food was determined.

Calculation of food costs

First, average prices (€/100g) of different points of sale were calculated for each food item, if necessary, and all reported foods and food products were additionally assigned to one of 14 food groups (Table 1).

Table 1
Classification of food groups (modified according to Alexy et al. [23])

Food Group	Description
Vegetables	fresh, frozen and dried vegetables, mushrooms, fresh herbs, olives, vegetable juices, ready-made salads, vegetable products, preserves
Fruits	fresh, frozen and dried fruit, juices[a], smoothies, squash, preserves
Starchy foods	bread, rolls, flour, doughs, semolina, flakes, breakfast cereals, muesli mixes, rice, pseudo cereals, pasta, dumplings, potatoes, french fries, croquettes, potato dumplings, mashed (powdered) potatoes
Legumes/nuts	peas, beans, lentils, lupins, soybeans, also as flours, falafel, nuts (also nut butter, nut puree) and seeds (e.g. sesame, sesame puree), roasted almonds
Dairy	milk, cream, cheese, quark (products), fresh milk products, milk-based drinks, milk-based desserts
Meat/fish	meat, sausage, ham, meat products, fish, fish products, seafood
Eggs	hen's egg, scrambled egg, fried egg
Dairy alternatives	plant-based alternatives for milk, yoghurt, quark and cheese, silken tofu
Meat alternatives	meat and sausage imitates, roast meat, tofu, soy cutlets
Convenience Foods	frozen pizza, canned soups, ready-made sauces, food from snack bars, vegetable spreads based on pulses, vegetables, nuts or avocado
Oils/fats	oils, butter, margarine, lard
Sweet foods	sugar, syrups, sweet breads, jams, nut nougat cream, biscuits, nibbles, sweet foods, chocolate, ice cream, etc.
Beverages	water, coffee, tea, alcoholic drinks, soft drinks
Others	water for cooking, germ, vinegar, mustard

[a] Commercial spritzers were divided into juice and water and assigned to the respective groups

Since only prices of 1,000 selected food items were collected, the missing 1,866 prices had to be estimated afterwards. For this purpose, the missing prices were replaced by the respective average food group price.

The individual mean of total daily food costs (€/day) was now calculated by summing the product of food price (€/g) and individual mean food consumption (g/day). As energy requirements and intake differ by age and gender, the daily food costs were additionally standardised to the individual total energy intake (TEI) per day (€/1000 kcal TEI).

In addition, the food group costs were calculated, both as €/day and €/1000 kcal of energy intake from the respective food group (€/1000 kcal FG), as well as total daily food group cost shares (% of total daily food costs).

Assessment of covariables

In addition to sex (boys/girls), also age of participants (years), body mass index-standard deviation score (BMI-SDS), socio-economic status (SES, high/medium/low), and physical activity (MET-min = metabolic equivalent task-minutes) were considered as potential confounders.

The Winkler index [28] was used to determine SES, combining parental education, parental profession and total net household income (1–7 points, each) assessed by a questionnaire. In the case of different values of mother and father, the higher value was used. The index is categorised into low (Winkler Index 1–7 points), medium (Winkler Index 8–14 points) and high (Winkler Index 15–21 points) SES. Missing values of covariates (n = 11) were replaced by the respective median of the corresponding diet group.

BMI-SDS was calculated using the LMS method based on the German reference percentiles for children and adolescents [29] using measured values for body weight and height [23].

Physical activity was assessed by a questionnaire based on the validated Adolescent Physical Activity Recall Questionnaire [30] including questions on organised and non-organised sport activities.

Statistical analysis

All statistical analyses were carried out with SAS® 9.4.

Sample characteristics were described as median and quartiles (Q1; Q3) for continuous variables due to lack of normal distribution of most variables. The non-parametric Kruskal-Wallis test was used to examine differences of continuous characteristics.

Categorical variables were presented using absolute (n) and relative frequencies (%). Differences in categorical variables between diet groups were tested by Chi^2 test or Fisher’s exact test.

Analysis of covariance (ANCOVA) was performed to assess group differences of total daily food costs (€/day and €/1000 kcal TEI) between vegetarian, vegan and omnivore participants. All models were adjusted for sex (male/female), age of participants (years), BMI-SDS, SES (high/middle/low), and physical activity (MET minutes). In case of total daily food costs (€/day), models were additionally adjusted for TEI (kcal/d).

ANCOVA was also performed to assess group differences of food group costs among those food groups with a low number of non-consumers (vegetables, fruits, starchy foods, fats/oils, sweet foods as well as beverages, each calculated as €/day and €/1000 kcal FG). If necessary, some zero values were replaced by the smallest value > 0 (winsorised). For dairy intake, an ANCOVA was performed to assess group differences between vegetarians and omnivores, only.

Due to the high number of non-consumers of legumes/nuts, dairy alternatives and meat alternatives, convenience foods, and eggs, differences between vegetarian, vegan and omnivore participants were analysed using the non-parametric Kruskal-Wallis test, both for €/day and €/1000 kcal FG. Pairwise comparisons were performed using the non-parametric Wilcoxon-Mann-Whitney t-test. No statistical tests were performed for meat/fish.

Using the false discovery rate, the proportion of false positive dependencies (significant p-values) due to multiple testing was calculated and corrected with the Benjamini-Hochberg procedure [31]. The significance level was set at a p-value < 0.05.

Results

Sample characteristics

The present analysis includes all available complete dietary records of 390 study participants (boys n = 169; 43.3%) (Table 2). The age of study participants did not differ between groups. Most of the participants (n = 278, 71.3%) were from families with a high SES. The SES differed significantly between the diet groups (Fisher's Exact Test, $p = 0.0155$). Children and adolescents with a vegan diet came more often from families with medium SES and less often from families with high SES than children and adolescents with a vegetarian or omnivore diet. Both TEI and BMI-SDS was highest in the omnivore group and lowest in the vegan group ($p < 0.05$). With regard to physical activity, the diet groups did not differ.

Table 2
Sample characteristics of VeChi Youth Study participants (n = 390) stratified by diet group

charakteristics	Type of diet				
	total	vegetarian	vegan	omnivore	p-value[a]
participants	390	145 (37.2)	110 (28.2)	135 (34.6)	
girls	221 (56.7)	87 (60.0)	73 (66.4)	61 (45.2)	**0.0023**
age (in years)	12.5 (9.2; 16.3)	12.4 (9.2; 16.0)	12.8 (9.0; 16.9)	12.3 (9.5; 16.2)	0.8741
energy kcal/day	1671 (1384; 2021)	1708 (1367; 1975)	1634 (1358; 1903)	1737 (1432; 2150)	**0.0452**
BMI-SDS	-0.39 (-0.97; 0.20)	-0.35 (-0.93; 0.17)	-0.58 (-1.14; 0.12)	-0.24 (-0.93; 0.35)	**0.0277**
social status					**0.0058**
low	7 (1.8)	3 (2.1)	4 (3.6)	0 (0.0)	
middle	94 (24.1)	32 (22.1)	37 (33.6)	25 (18.5)	
high	278 (71.3)	105 (72.4)	67 (60.9)	106 (78.5)	
physical activity (MET-min)	2.9 (1.9; 4.1)	2.7 (1.8; 4.0)	2.9 (1.6; 4.3)	3.0 (2.0; 4.1)	0.7623

Values are n (%) or median (Q1; Q3)

[a] Kruskal-Wallis test, Fisher's Exact test or Chi²-test

differences statistically significant if $p < 0.05$

BMI-SDS = Standard-Deviation-Score of Body Mass Index

MET-min = metabolic equivalent task-minutes

Total daily food costs

The median total daily food costs were highest for vegan participants (€ 4.79/day), followed by omnivore (€ 4.75/day) and vegetarian participants (4.37 €/day). Total daily food costs differed significantly between diet groups (p = 0.036) (Table 3). Pairwise comparison showed no significant difference of total daily costs between vegan and omnivore participants. These results were confirmed when total daily food costs were standardised for TEI (€/1000 kcal).

Table 3: Total food costs and food group costs (€/day; €/1000kcal) among participants of the VeChi Youth Study (n=390), stratified by diet group

		vegetarian	**vegan**	**omnivore**		vegetarien vs vegan	vegetarien vs omnivore	vegan vs omnivore
		(n = 145) median (Q1; Q3)	(n = 110) median (Q1; Q3)	(n = 135) median (Q1; Q3)	**p-value^{x}**	p-value^{y}	p-value^{y}	p-value^{y}
total food costs[a]	€/day	4.37 (3.35; 5.45)	4.79 (3.99; 5.94)	4.75 (3.90; 6.42)	**0.0036**	**0.0030**	**0.0100**	0.6521
	€/1000kcal	2.52 (2.12; 3.16)	2.98 (2.51; 3.52)	2.83 (2.30; 3.24)	**0.0087**	**0.0036**	**0.0391**	0.4141
vegetables[a]	€/day	0.36 (0.24; 0.59)	0.47 (0.29; 0.72)	0.38 (0.19; 0.58)	**0.0003**	**0.0006**	0.7177	**0.0003**
	€/1000kcal	8.52 (6.20; 10.75)	8.23 (6.44; 10.15	8.63 (6.54; 11.44)	0.7835	0.9633	0.5795	0.5795
fruits[a]	€/day	0.56 (0.29; 0.83)	0.78 (0.51; 1.21)	0.45 (0.28; 0.84)	**0.0003**	**0.0003**	0.9674	**0.0003**
	€/1000kcal	3.53 (2.70; 4.89)	4.03 (3.16; 5.46)	3.53 (2.75; 4.85)	0.7994	0.5467	0.8135	0.7105
starchy foods[a]	€/day	0.72 (0.51; 0.97)	0.80 (0.52; 1.02)	0.60 (0.42; 0.91)	**0.0003**	0.1561	**0.0026**	**0.0003**
	€/1000kcal	1.19 (0.98; 1.53)	1.26 (0.96; 1.61)	1.13 (0.85; 1.52)	0.4548	0.6270	0.4548	**0.2239**
legumes/ nuts[b]	€/day	0.06 (0; 0.20)	0.18 (0.07; 0.46)	0.00 (0.00; 0.10)	**0.0003**	**0.0003**	**0.0003**	**0.0003**
	€/1000kcal	1.60 (0; 2.50)	1.92 (1.29; 2.41)	0.00 (0.00; 1.82)	**0.0003**	**0.0331**	**0.0003**	**0.0003**
dairy[a]	€/day	0.26 (0.02; 0.51)		0.42 (0.27; 0.66)			**0.0150**	
	€/1000kcal	1.62 (1.23; 2.03)		1.95 (1.55; 2.29)			**0.0011**	
meat/ fish	€/day			0.57 (0.26; 1.11)				
	€/1000kcal			3.82 (3.02;5.16)				
eggs[b]	€/day	0.00 (0.00; 0.06)		0.02 (0.00; 0.09)			**0.0184**	
	€/1000kcal	0.92 (0.0; 2.49)		2.49 (0.0; 2.49)			**0.0132**	
daity alternatives[b]	€/day	0.08 (0.00; 0.35)	0.45 (0.22; 0.69)	0.00 (0.00; 0.00)	**0.0003**	**0.0003**	**0.0003**	**0.0003**
	€/1000kcal	2.75 (0.00; 4.54)	4.61 (3.31; 5.75)	0.00 (0.00; 0.00)	**0.0003**	**0.0003**	**0.0003**	**0.0003**
meat alternatives[b]	€/day	0.17 (0.00; 0.61)	0.25 (0.07; 0.65)	0.00 (0.00; 0.00)	**0.0003**	0.1142	**0.0003**	**0.0003**
	€/1000kcal	5.18 (0.00; 7.80)	5.11 (3.57; 7.57)	0.00 (0.00; 0.00)	**0.0003**	0.5703	**0.0003**	**0.0003**
convenience foods[b]	€/day	0.05 (0; 0.34)	0.17 (0.02; 0.39)	0.05 (0; 0.4)	0.0865	0.1055	0.9693	0.1623
	€/1000kcal	2.97 (0.00; 5.12)	4.43 (1.47; 6.25)	1.88 (0.00; 4.44)	**0.0088**	**0.0391**	0.2911	**0.0036**
oils/ fats[a]	€/day	0.08 (0.03; 0.13)	0.06 (0.02; 0.13)	0.10 (0.04; 0.15)	0.6521	0.7324	0.5772	0.4056
	€/1000kcal	0.67 (0.49; 0.82)	0.61 (0.42; 0.87)	0.69 (0.53; 0.88)	0.1539	0.5330	0.2084	0.0650
sweet foods[a]	€/day	0.48 (0.27; 0.89)	0.42 (0.18; 0.77)	0.59 (0.32; 1.02)	0.0781	0.2766	0.2397	**0.0261**
	€/1000kcal	2.11 (1.68; 2.70)	2.41 (1.85; 3.28	2.41 (1.82; 2.89)	**0.0150**	**0.0042**	0.2852	0.0934
beverages[a]	€/day	0.08 (0.00; 0.87)	0.00 (0.00; 0.64)	0.57 (0.00; 1.51)	**0.0045**	0.4216	**0.0155**	**0.0022**
	€/1000kcal	0.00 (0.00; 7.86)	0.00 (0.00; 8.15)	2.72 (0.00; 23.67)	0.1460	0.9317	0.0934	0.1055
other[b]	€/day	0.01 (0.00; 0.02)	0.01 (0.01; 0.03)	0.01 (0.00; 0.01)	**0.0003**	**0.0011**	0.6518	**0.0003**
	€/1000kcal	2.45 (1.41; 4.46)	2.86 (1.74; 4.90)	2.16 (1.49; 3.98)	0.1309	0.2719	0.5028	**0.0404**

[ax; ay] Ancova

[bx] Kruskal-Wallis-test to verify differences between dietforms; [by] Wilcoxon-Mann-Whitney-test to verify differences between diets using pairwise comparisons

p-values corrected using false discovery rate (Benjamini-Hochberg method); differences statistically significant if $p < 0.05$ (significant p values are marked in bold)

Food group costs

Food group costs (€/day) differed significantly between diet groups ($p < 0.0045$), with exception of sweet foods, convenience foods, and oils/fats (Table 3).

When standardised for energy intake from the respective food group (€/1000 kcal FG), diet group differences were statistical significant for legumes/nuts, dairy alternatives and meat alternatives, as well as for sweet and convenience foods ($p < 0.015$) (Table 3).

Regardless of diet group, daily food cost shares were highest for starchy foods and fruits (Fig. 1 and Supplementary Table 1). Among omnivore participants, meat/fish had the fourth highest cost shares (14% of total daily food costs, 0.43 €/day).

Food group costs for vegetables accounted for around 9–12% of daily food costs, with highest shares among vegan participants and lowest shares among omnivore counterparts. Per day, vegetable food costs of vegans (0.57 €/day) were significantly higher than for vegetarians (0.36 €/day; $p = 0.0006$) and omnivores (0.38 €/day; $p = 0.0003$). When standardised for energy intake, these differences were no more significant. In all diet groups, vegetables was the food group with the highest cost per 1000 kcal (> 8 €/1000 kcal) followed by fruit (> 3.5 €/1000 kcal).

Omnivore participants spend significantly more money for dairy with 0.42 €/day than vegetarian participants with 0.26 €/day ($p = 0.015$). In contrast, vegan participants spend 0.45 €/day for dairy alternatives, vegetarian participants 0.08 €/day ($p = 0.0003$). Less than half of the omnivore group consumed dairy alternatives (zero median food costs). Food costs of meat alternatives were lower among vegetarians (0.17 €/day) and vegans (0.25 €/day) than food costs of meat for omnivores (0.57 €/day). Energy-related expenses for meat alternatives (> 5 €/1000 kcal) and dairy alternatives (2.75 €/1000 kcal among vegetarians and 4.61 €/1000 kcal among vegans) were higher than for the original animal-derived products.

Legumes/nuts contributed only little to the daily food costs, but they differed significantly (vegan 6%, vegetarian 3% and omnivore 1%).

Daily food costs for sweet foods differed not significantly between diet groups. But there was a statistically significance regarding €/1000 kcal between vegetarians and vegans ($p = 0.0042$), with higher expenditures for sweet foods by vegans. The median food costs for sweet foods ranged from 2.11 €/1000 kcal among vegan and 2.41 €/1000 kcal among vegetarian and omnivore participants.

Highest median beverage costs were found among omnivores (0.57 €/day), which were significantly higher than those among vegetarian (0 €/1000 kcal; $p = 0.0155$) and vegan participants (0 €/1000 kcal; $p = 0.0022$).

Food costs for convenience foods did not differ, but standardised for food group energy intake the difference between vegans (4.43 €/1000 kcal) and both other groups (vegetarian: 2.97 €/1000 kcal; $p = 0.0391$ and omnivore: 1.88 €/1000 kcal; $p = 0.0036$) was significant.

Discussion

Main results

To our knowledge, this is the first study comparing food costs of children and adolescents on a vegan, vegetarian and omnivore diet based on reports of self-selected diets and retail prices. Our data showed that the vegetarian diet was the most inexpensive dietary pattern, independent from TEI. In all diet groups, starchy foods, fruit, sweet foods, beverages, and vegetables contributed the most to daily costs. For omnivore participants, meat/fish also made a significant contribution. Protein foods, i.e., the sum of legumes/nuts, dairy alternatives, meat alternatives, dairy (vegetarian and omnivores only) and meat/fish (omnivores only), contributed a quarter of the total food costs, independent from diet group. The share for dairy alternatives of vegans in the total costs corresponded to the share of dairy products for omnivores.

Total daily food costs

According to our study, families had to spend 2.52 € – 2.98 €/1000 kcal a day on food for each child. The above mentioned evaluation using a similar approach with food prices from 2009 calculated food costs 1.84 € – 2.00 €/1000 kcal for omnivore children and adolescents [8]. Thus, the food costs calculated in this study were considerably higher, independent from the dietary pattern. Similar to our findings, a recent study in Germany investigating food costs of four week sample menus using minimum retail prices estimated food costs per day of 5.17 €/day (2.59 €/1000 kcal) and 5.69 €/day (2.85 €/1000 kcal) for 10–13 year old girls and boys on a vegetarian diet, respectively. There, food costs of a vegan diet were about 1 €/day higher (6.17 €/day for girls, 6.97 €/day for boys) [32]. The higher estimated total daily food costs in this study may be due to a higher assumed energy requirement (PAL 1.6, i.e., 2000 kcal/day for girls, 2200 kcal for boys). In the VeChi Youth Study, the TEI corresponded to the energy requirement with a PAL of 1.4 [33]. Energy requirements and thus the amount of food needed is the most important determinant of total food costs [8]. Therefore, daily food costs increase with age and are higher for boys than for girls [8, 32]. That is why the present evaluation considered food costs standardised to energy intake.

Both total daily food costs and standardised total food costs differed between the diet groups and showed a small but statistically significant benefit of vegetarian diets. Our results thus confirm the above mentioned German study from 2009, in which a vegetarian diet was associated with lower food costs in adult women than a diet that included the consumption of meat and fish [6]. Besides, in the aforementioned study on food costs of sample menus a vegetarian pattern (as well as an omnivore diet consisting of fresh food) was the most inexpensive pattern. A vegan diet was estimated to be more expensive [32]. However, total daily cost differences in our study were only small: The median total daily food costs of the omnivore and the vegan diet exceeded the daily food costs of a vegetarian diet by 0.31 €/day and 0.46 €/day, respectively. Per month, this results in a total difference of 9.30 € and 13.80 €. Nevertheless, for socially disadvantaged families or families with several children, these differences can be decisive for the choice of diet. However, it should be noted that the difference between the total daily food costs of vegan and omnivore diets was not statistically significant. Hence, a change from an omnivore diet to a more sustainable vegetarian diet could save money.

Furthermore, the wide interquartile ranges of energy standardised food costs in all diet groups are worth to mention (vegetarian participants: 1.04 €/1000 kcal, vegan participants: 1.01 €/1000 kcal and omnivore participants: 0.94 €/1000 kcal). Hence, food costs of the dietary patter overlap and there is a financial margin to make each diet pattern more inexpensive. Hence, a shift towards a vegan diet should not cause necessarily any additional costs.

Food group costs

The total daily food costs of a diet are partial determined by the amounts of food groups consumed. Because changes in the consumption of food groups, such as a shift from animal source to plant foods, also affect the consumption of other food groups, it is not possible to identify single food groups responsible for the observed differences in daily costs [6].

Starchy foods had the highest budgetary demand in our sample in the vegetarian and vegan group. This reflects the high contribution of this food group to TEI [24].

The high share of fruit and vegetables costs confirm the current state of the literature [3, 32], in particular when expressed as costs per calorie [20]. However, this calorie-based approach does not take into account that consumers do not only buy food to meet their energy needs, but also for other reasons, such as individual preferences in taste or health aspects.

Sweet foods were also relevant for the energy and food cost shares. Vegans had significantly lower cost shares for this food group (11%) than participants of the other two diets (14% each). This can be attributed to the lower consumption of sweets compared to omnivore and vegetarian participants [24]. In the aforementioned German modelling study [32], on the other hand, the cost shares of the food group snacks and sweet foods were 3% in a vegan diet, but only 1% in a vegetarian diet, which can be attributed to the fictive nature of the sample menus.

Dairy was consumed less by participants on a vegetarian diet than on an omnivore diet [24]. That is why vegetarians spent less money on this food group than omnivores. Instead, vegetarians also spent 5% of their daily food costs on dairy alternatives, vegans 8%. Both vegetarians and vegans spent less money on meat alternatives than omnivores for meat, although energy standardised costs of meat alternatives are higher than of meat.

Meat, fish and eggs as well as dairy account for substantial food cost shares in omnivore diets [3, 32, 34]. As these foods are important sources of nutrients, it is recommended for vegetarian and vegans to increase the consumption of soy, legumes, nuts and seeds to provide protein, iron and zinc sufficiently [35]. The nutrient profiles of meat alternatives and dairy alternatives are not comparable with the original animal-derived foods, and the nutrient content is variable depending on the ingredients used [36]. In a direct price comparison (€/100 g), they are often more expensive. Nevertheless, in the VeChi Youth Study, costs for meat were comparable to the sum of costs for, i.e., legumes/nuts and meat alternatives in vegans. Willits-Smith et al. [34] even predicted a food cost reduction of 10% when replacing meat by legumes, seeds, nuts and soy foods in a New Zealand modelling study.

Besides food group intake, also food choices within a group, for example the type of fruit or vegetable or the degree of processing, affect food costs. That is why it can be argued, that cost estimates based on real-life data are more valid than cost estimates based on sample menus or modelling studies. In the VeChi Youth Study, omnivores differed significantly from vegetarians and vegans in terms of daily beverage costs. This food group even accounted for the largest share of costs next to sweet foods in an omnivore diet. This can be explained by the fact that vegan but also vegetarian study participants consumed more inexpensive beverages such as tap water, while omnivores more often consumed expensive bottled water and soft drinks. Regarding the total costs for processed foods such as convenience foods, meat alternatives etc. vegans showed the highest values, which also contributed to the higher daily total costs.

Another important aspect of food selection is the distinction between conventional and organic produced foods. Organic food, as well as animal source food assuring special animal welfare, are more expensive than conventional food products [32]. About a quarter of the study participants in the VeChi Youth Study who followed a vegan or vegetarian diet reported buying more than 75% organic food, but only about 12% of those following an omnivore diet [23]. In our survey, we could not distinguish whether unprocessed foods, e.g., fruits, vegetables or starchy foods, were from organic or conventional production. However, price collection of special brands considered the production procedure. The associated price effects may contribute to the observed differences in food costs.

Strengths and limitations

The present analysis has some methodological strengths and limitations that need to be discussed. As mentioned before, a cost calculation based on real-life consumption data yields more plausible cost estimates than a calculation based on sample menus.

Another important strength is the detailed brand-specific dietary survey, which enabled a very accurate and diet group-oriented price survey.

Our price survey conducted in different supermarkets should provide a representation of food prices as comprehensive as possible. A limitation of our method is the short time span of the survey, which does not capture seasonal effects, e.g., for the price of vegetables and fruit. In addition, the survey of all 2,866 food items recorded in the food logs was not feasible within the framework of this project. However, the present approach is a proven method for calculating food costs [8, 27]. Moreover, due to the covid pandemic and the resulting lockdown measures, a price survey was only possible online. A price survey in stationary retail might have led to slightly different total daily food costs. However, this is a random error that affects all diet groups equally. The effect of food price differences on total costs was excluded in this evaluation, as minimum prices were used.

A further limitation is the lack of representativity of the study sample. The high SES of most participating VeChi Youth Study families are consistent with the known sociodemographic characteristics of vegetarians and vegans [37]. Although statistical models were adjusted for self-reported SES, some residual confounding cannot be excluded and the limited generalisability of the results must be kept in mind when interpreting them.

Last but not least, it should be mentioned, that we only assessed direct food costs, but did not consider further cost associated with nutrition, e.g. costs for purchase, storage or preparation.

Conclusions

Our data showed that a vegetarian diet pattern is the least expensive compared to an omnivore and vegan diet pattern. Overall, vegans had lower cost shares for sweet foods and beverages than vegetarians and omnivores. In contrast, vegans had higher cost shares of vegetables, legumes/nuts, fruits, dairy alternatives and meat alternatives than vegetarians and omnivores. These differences added up to the observed total daily food costs differences. Our results confirm previously published studies [3, 5, 6, 32, 34], although they do not correspond to them in all parts. Even though the food market is becoming increasingly global, there are differences in food prices between countries [32], e.g., due to subsidies or taxes. The comparability of international studies therefore is limited.

These political influences on food prices is why our data has some policy implications [3, 34]. For example, in Germany dairy and meat are taxed at a reduced value-added tax (VAT) rate of 7%, while dairy alternatives and meat alternatives are taxed at 19%. In 2017, German health professional societies have proposed a VAT reform whereby adipogenic foods would become more expensive and fruit and vegetables would become cheaper [38] to achieve significant reductions in obesity prevalence and health care costs [39]. However, such VAT reform should not only consider health effects of foods, but also promote environmentally sustainable diets.

Overall, our evaluation shows that a plant-based diet does not have to be more expensive than an omnivore diet. Financial restrictions do not impede a transition from an omnivore to a vegan and especially vegetarian diet.

Abbreviations

BMEL Bundesministerium für Ernährung und Landwirtschaft (Federal Ministry of Food and Agriculture)

BMI-SDS body mass index-standard deviation score

DGE Deutsche Gesellschaft für Ernährung (German Nutrition Society)

FG Food Group

Kcal Kilocalorie

MET-min metabolic equivalent task-minutes

SES socio-economic status

TEI Total Energy Intake

VAT value-added tax

Declarations

Ethics approval and consent to participate

The study was conducted in accordance to the Declaration of Helsinki. It has an ethics vote from the University of Witten-Herdecke (139/2017) and is registered with the German Register of Clinical Trials (DRKS00012835).

Consent for publication

Not applicable

Availability of data and materials

Summary results are available in figures, tables and additional files. Raw data can be obtained from the corresponding author upon a reasonable request.

Conflict of interest

The authors declare that they have no conflict of interest.

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Authors' contributions

U.A. formulated the research questions and designed the present analysis. U.A., M.K. and S.W. designed the underlying VeChi Youth study, M.F., S.W., A.M. and A.L. were involved in the implementation of the VeChi Youth study. H.Z. conducted the price collection and aggregation. E.H. analysed the data and drafted the manuscript. All authors contributed to the discussion and gave input on the writing of the manuscript. All authors have read and agreed to the published version of the manuscript.

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Figures

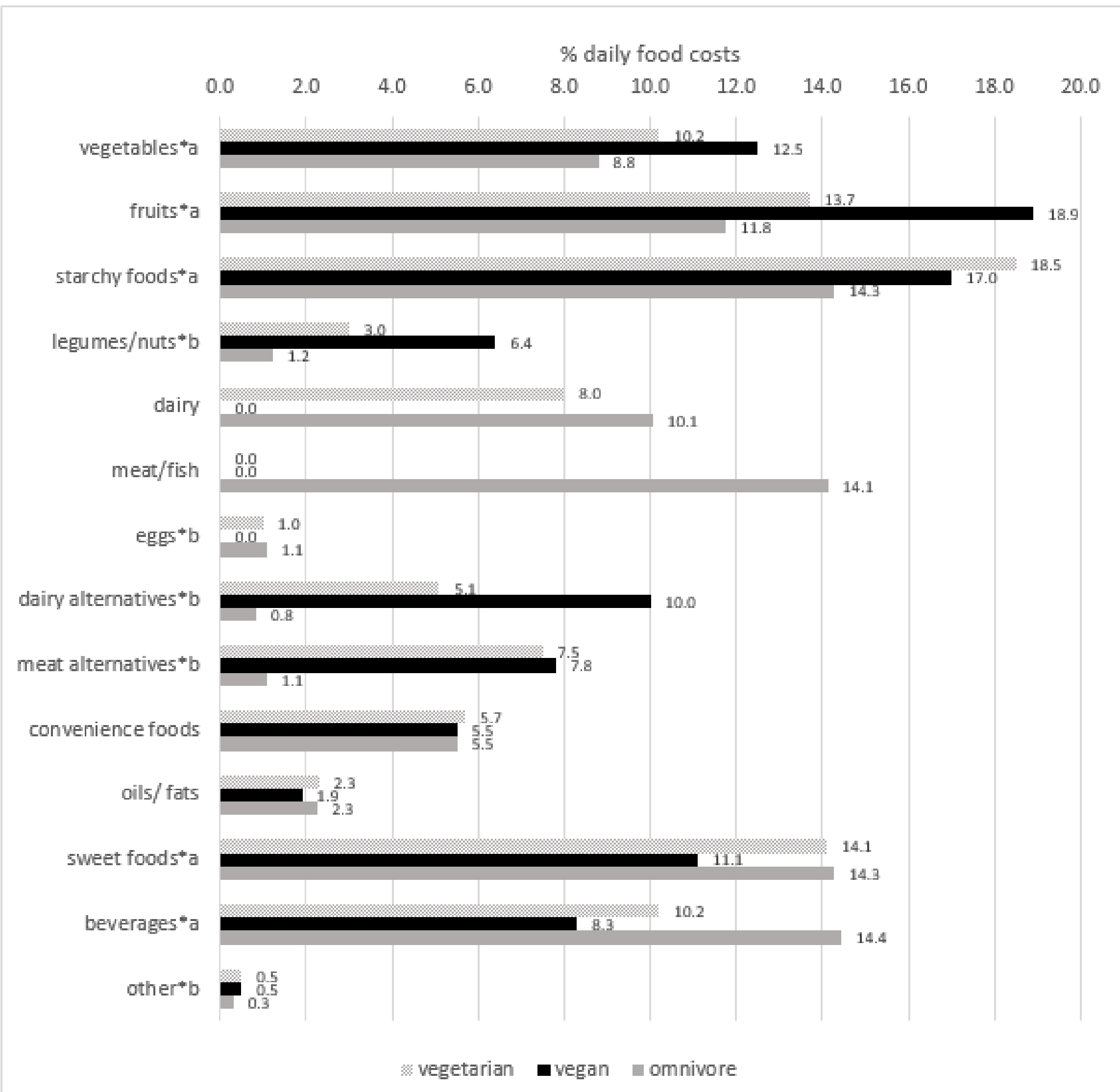

Figure 1

Daily food group costs as % of total daily food costs of participants of the VeChi Youth Study (n=390) stratified by diet group (* indicates significant differences between diet groups; performed using [a]Ancova and

[b]Kruskal-Wallis-test)

Supplementary Files

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