Chapter 2

ENERGY DENSITY, ENERGY COSTS, AND INCOME – HOW ARE THEY RELATED?

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Abstract

Objective: To examine the association between energy density and energy costs in single food items and composed diets, and to explore differences in energy density and energy cost between income levels.

Design: A cross-sectional study using data from two Dutch cohort studies and recent national food prices. Food prices were retrieved from two market leader supermarkets. Data on dietary intake were measured using a computerized face-to-face interview (cohort1) and 24h recalls (cohort2).

Setting: The Netherlands.

Subjects: A sample of 373 young adults from the Amsterdam Growth and Health Longitudinal Study (AGHLS, measured in 2000), and a sample of 200 community-dwelling elderly from the Longitudinal Aging Study Amsterdam (LASA, measured in 2007).

Results: We found significant inverse associations between energy density and energy costs in single food items (r= -0.436; p<0.01), and composed diets (AGHLS men r = -0.505, women r = -0.413, p<0.001; LASA men r= -0.559, women r= -0.562, p<0.001). Furthermore, we found that people stratified into higher energy density quartiles consumed significantly more energy per day; less fruits and vegetables; and had significant lower diet costs. Explorative analyses on income did not reveal significant differences regarding energy density, costs, or fruit and vegetable intake.

Conclusions: In the Netherlands also, energy density was inversely related with energy costs, implying that healthier diets cost more. However, we could not find differences in energy density or costs between income levels. Future research, using precise food expenditures, is of main importance in studying the economics of obesity and in the run of making the healthier choice easier.

Introduction

As in many industrialized countries, the Dutch population does not have an adequate food intake according to dietary guidelines. This is true especially for people with a lower social economical status (SES) [1-3]. Much research has focused on this topic and revealed several determinants that may explain this phenomenon. A relatively unexplored topic in this field is the economics of food choice. This is unfortunate, since price is a known important tool in marketing research [4, 5], and there are indications that food prices may be an important factor in food choice [6, 7], especially among low-income groups [8-10]. Studies in France and the USA have revealed that consuming a diet rich in energy-dense products, such as fast foods, is generally cheaper than a diet with less energy-dense products such as vegetables [11-13]. Also, a linear modelling study indicated that a cost constraint on food reduces dietary energy contributed to fruits and vegetables, and increases the share of energy-dense products, generally higher in fat and sugar [14]. These results suggest that food choice is not just a behavioural issue, but also an economic one [15]. However, the results described have only been reported in France and the USA, and it is unknown whether they also prevail in other Western countries. In order to gain more insight in this, we conducted the present study with a similar methodology to the French and American studies, but this time based on Dutch data. The aim of the study was to investigate whether the described associations are also prevalent in another West-European country with different dietary habits and cultural backgrounds compared with France. As it has been suggested that dietary habits in the northern regions of Europe differ from the more southern ones, the northwards located Netherlands is well suited for this purpose [16, 17].

As well as studying the association between energy density and energy costs, we also conducted a first exploration into the role of income on food purchases. Previous authors have suggested that financial barriers in purchasing healthy foods may be mainly prevalent among low-income consumers, simply because a healthy diet is too expensive for these groups [18]. However, it is not clear whether low-income consumers actually consume diets with a higher energy density and whether they spend less money on food, compared to higher-income groups [11]. Therefore, the second aim of our study was to gain insight in the role of income in dietary energy density and diet costs.

Methods

Study population

Cohort 1

Valuation of diet costs was based on dietary surveys conducted in two Dutch longitudinal cohort studies. The first cohort was part of the Amsterdam Growth and Health Longitudinal Study (AGHLS), consisting of a sample of Dutch adults who started in the study in 1977 at the age of 13 years. The original aim of this study was to investigate the natural development of health, fitness, and lifestyle of youngsters from the general Dutch population [19]. During this study several parameters were measured repeatedly, including dietary intake. In our study we used the most recent dietary data, measured in 2000, when the subjects' mean age was 36 years (n = 373). Details of this study, including examples of previously published articles, can be found in two edited books [20, 21].

Cohort 2.

Since AGHLS contains solitary data on a relatively healthy young adult population, analyses were also computed on an elderly population using data from the Longitudinal Aging Study Amsterdam (LASA). This on-going study was originally designed to study the changes in autonomy and well-being in the ageing population. The cohort was recruited in 1992-3 and consisted of community-dwelling elderly within the ages of 55-85 years. Sampling and data collection procedures of LASA can be found in detail elsewhere [22]. In 2007, a lifestyle study was conducted among 1421 persons meeting the following eligibility criteria: age <80 years, cognitively well-functioning (MMSE score > 23) and alive on January 1, 2007. Complete lifestyle data were obtained from 1058 persons (response rate 74.5%; n=326 no response, n=18 refused, n=8 not able due to physical problems, n=11 deceased). Of the 1058 persons, 516 indicated to be willing to participate in an additional nutrition sub study of which 210 were randomly selected to be interviewed. A complete interview was obtained from 200 persons (95.2%). The mean age of this sample was 69 years.

Dietary Assessment

Both studies used different methods to obtain dietary intake. Fruit and vegetable intake included fresh, canned and frozen items, but excluded juices.

Cohort 1

In AGHLS, dietary intake was assessed using a computer assisted version of the face-to-face interview method (FTF), using the preceding four weeks as a reference period. Subjects were asked about meal types, number of meals and times of meals consumption for both average school or work days, and weekends or holidays. This provided a global idea of the respondents' consumption patterns. Subsequently a cross-check was conducted which consisted of an additional verification on the reported frequency and amounts of the consumed products. Consumption amounts were recorded in household measures or grams for which models of glasses and spoons were used to illustrate portion sizes. The described method was validated and was found to be of similar quality as the original FTF method [19].

Cohort 2

In LASA, participants were send a booklet with coloured pictures of different food products (ranging from a buttered slice of bread to a plate with vegetables or pasta sauce) using different portion sizes. In this booklet persons were also instructed to measure the content of frequently used glasses, cups and serving spoons. The persons were telephoned unexpectedly by specifically trained dietetic students to recall their food intake of the previous 24 hours. The weight of the used food products was estimated using the portion size booklet, the measured content of commonly used kitchenware, and used recipes. Data on food intake were measured all days of the week, minimizing daily variation. For most respondents (81%) two recalls were used: one week day and one weekend day, for the remaining group only one recall was available.

Energy Density

Analyses on energy density (ED, defined as amount of energy per unit weight) of the consumed food items were based on energy and nutrient data of the Dutch Food Composition Database (NEVO) [23]. Individual dietary energy densities (DED), defined as amount of energy per unit weight, were calculated by summing both the edible weight (ΣW) and the energy content (ΣE) of all foods consumed during a day and dividing those outcomes ($DED = \Sigma E/\Sigma W$) [15]. Based on a report by Ledikwe *et al.*, beverages were excluded from the analyses. Generally beverages have a lower energy density than solid foods, and may therefore have a distorting effect on dietary energy density values [24].

Estimation of diet costs

Diet costs were estimated by linking food items from the dietary surveys with recent national food prices. National food prices (€) were based on supermarket prices of two Dutch market leader supermarkets, together accounting for a 44% market share. For one supermarket, price data were obtained by a price list containing the prices of all available items in the supermarket chain, which was provided to the research team by a supermarket manager. For the other supermarket, prices were collected by use of the supermarket website (which is also available for online shopping [25]) and in-store visits. Data were collected during February to April 2008, recording mean prices and portion sizes. Based on previous methods, measures were taken on regular prices, excluding discounts. For packaged foods, the medium package size was selected; portion or bundling discounts were excluded. When multiple items of the same product were available, mean prices were calculated, including branded, house-brand, and low-cost options. In a few cases consumed items were unavailable in the supermarket, such as pheasant, and had to be substituted by a comparable item, in this case turkey [26]. In the case of composed dishes, such as Chinese noodles, diet costs were calculated by summing the price of the single ingredients using standard recipes from a Dutch cookbook [27].

After the price assignment procedure, prices per 100 g edible portion (€/100g) and per kJ (€/kJ) were calculated for each single food item. These numbers were used to calculate individual diet costs based on the following steps: First, we calculated the costs for each consumed single food item corrected for consumed amount of energy by multiplying the energy intake for each single food item (consumed kJ per food item) by the energy price of this food item (€/kJ food item). Second, the consumed energy costs of all single food items were summed, resulting in diet costs for total energy intake (total €/ total kJ). Finally, these total costs were corrected for total energy intake, calculating diet costs per 8,368 kJ (2000 kcal) ((total €/ total kJ) x 8,368). The described calculation method is common in this type of research and a fair method to estimate diet costs [15, 26, 28, 29]

Income

In order to study the effect of income we classified subjects into subgroups based on the Dutch modal income levels (Table 2.1). In AGHLS, data were recorded on gross annual income, measured in five levels. For analyses these groups were reassigned in three groups (below modal, modal and somewhat above modal, more than two times

Table 2.1 Participant characteristics for the AGHLS and the LASA population.

AGHLS					LASA				
	Men (n = 157)		Women (176)			Men (n = 91)		Women (n = 80)	
	Mean	SD	Mean	SD		Mean	SD	Mean	SD
Age (y)	36.1	.80	36.2	.75		68.7	3.2	68.7	3.1
Fruit (gram/day)	152.4	103.8	140.3	97.2		142.9	103.1	107.5	93.1
Vegetables (gram/day)	189.2	76.8	190.7	72.1		136.7	79.9	142.9	87.4
	n	%	n	%		n	%	n	%
BMI (kg/m^2) [a]									
< 20	19	12.2	102	58.6		1	1.2	1	1.3
20 – 25	103	66.0	61	35.1		23	26.7	17	21.5
25 – 30	32	20.5	9	5.2		38	44.2	42	53.2
30 +	2	1.3	2	1.1		24	27.9	19	24.1
Income (€ gross/annual)					Income (€ net/month)				
0 – 25.000 (< modal) [b]	17	10.9 [c]	35	20.1	0 – 1,588 (≤ modal)	33	38.4	16	20.0
25.000 – 50.000 (≥ modal)	30	19.2	31	17.8	1,589 + (modal +)	53	61.6	64	80.0
50.000 + (modal ++)	109	69.9	108	62.1					
Education level									
Low	4	2.5	4	2.3		18	19.8	14	17.5
Medium	75	47.8	77	43.8		55	60.4	44	55.0
High	78	49.7	95	54.0		18	19.8	22	27.5

[a] In 2007 40.9% of men and 27.7% of women in the general Dutch population was overweight (BMI 25–30 kg/m^2), and 11.2% of men and 10.2% of women was obese (BMI>30 kg/m^2)[30]

[b] The modal gross annual income in the Netherlands (in 2007) was € 30,000 [44];

[c] National statistics reveal that (in 2007) 52.7% of the Dutch households had an income above modal [35]

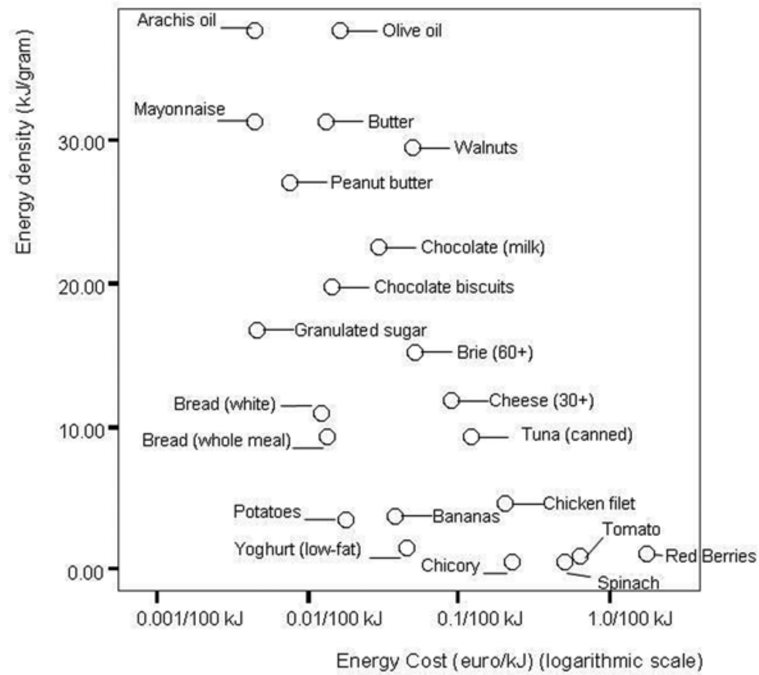
modal; using cut-off points before taxation). LASA used net monthly household income on the basis of eleven levels, with € 454 – 567 as minimum and > € 2270 as maximum level. Because the numbers in these groups were smaller, subjects were classified in two income groups (below modal, above modal; using cut-off points after taxation). Due to missing data, we were not able to correct for household size.

Statistical Analyses
Both datasets were corrected for outliers in which participants who were outside the range of mean ± 2SD on consumed grams of fruits and vegetables and costs per 8368 kJ (2000 kcal) were excluded from analyses. For LASA this included twenty-nine participants and for AGHLS forty participants. Then, we first analyzed the association between energy density and energy costs in single food items using simple Pearson's correlations. Following that, we analysed this association on diet level using both simple Pearson's correlations and linear regression methods. Subsequently, participants were stratified into quartiles of consumed energy density and differences between the four groups were analysed with respect to diet costs per day, kJ per day, and fruit and vegetable intake, using one way analysis of variance (ANOVA). Finally, initial analyses were done to study differences between income levels regarding dietary energy density, fruit and vegetable intake, and diet costs, using ANOVA and Student's *t* tests. Data for the AGHLS and LASA cohorts were analyzed separately, and due to different energy requirements, data for men and women as well. Analyses were conducted using SPSS statistical software package version 15.00 (SPSS Inc., Chicago, IL, USA).

Results

Table 2.1 shows participant characteristics for both the AGHLS and LASA populations. Both cohorts had a good dispersal of men and women, but differed on other parameters. Compared with the general Dutch population, we observed that overweight and obesity rates in the AGHLS population were lower (in AGHLS 20% of men were overweight and 1% obese, compared to 40.9% and 27.7% in the general population)[30]. In LASA overweight and obesity rates were higher, at 44% and 28% for men, respectively. Analyses on fruit and vegetable consumption revealed that intake in the AGHLS population was higher compared to the LASA subjects; these numbers can also be considered high compared with the general population[1].

Association between energy density and costs in single food items
First, we analysed the association between energy density and energy costs in single food items. Result s are shown in Figure 2.1. This figure displays, for twenty-two different food items, the energy density (y-axis) relative to the energy costs (x-axis). Because of the large range of values, data are plotted on a logarithmic scale. Results show that there exists a significant inverse relationship between energy costs and

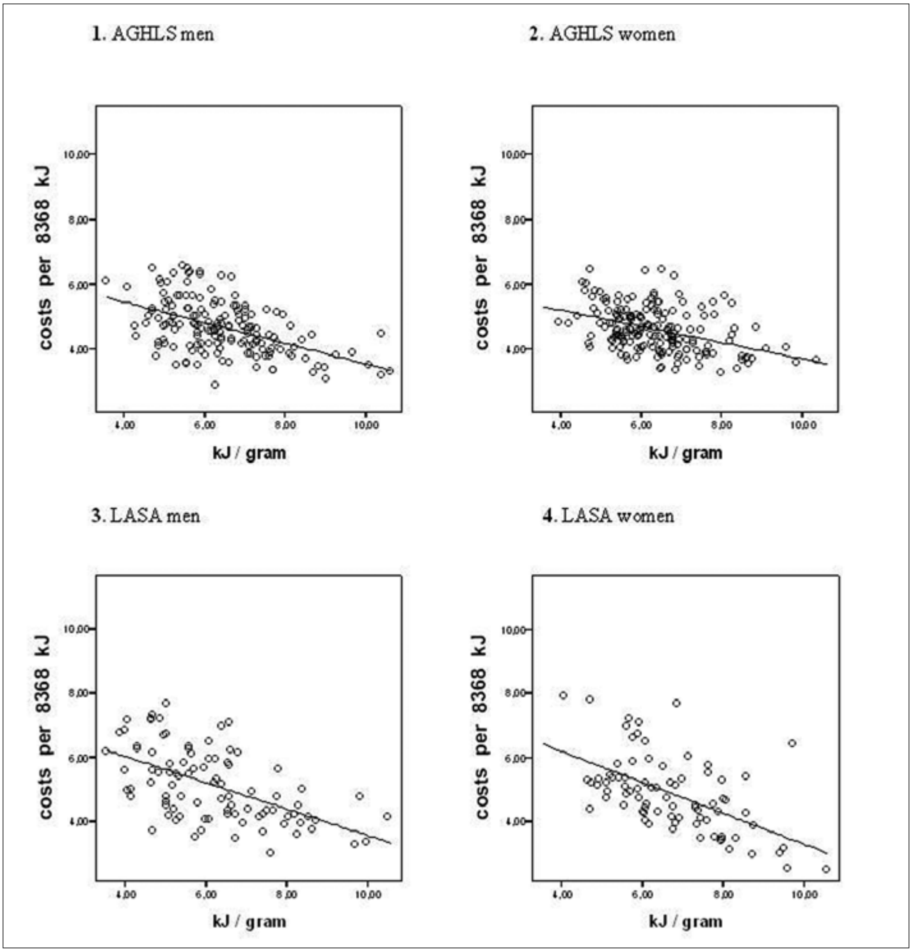


Figuur 2.1. Association between energy density (kJ/gram) and energy costs (€/kJ) in single food items (logarithmic scale) (r = -.436; p<.01)

energy density in single food items (*r* = -0.436; *P*<0.01). Food items with the highest energy density can be purchased for the lowest costs. For example, spinach costs € 5.25/418 kJ (100 kcal) while peanut butter costs € 0.035/418 kJ (100 kcal).

Dietary energy density, fruit and vegetable intake, and diet costs

Following the analyses on single food items we analysed the correlation between dietary energy density and diet costs, starting with Pearson's correlations. Results are shown in Figure 2.2. The plots show a significant negative correlation between the two parameters in both cohorts, for both men and women. People consuming diets with a higher energy density had significant lower diet costs (AGHLS men r = -0.505, p<0.001; LASA men r = -0.559, p<0.001). Second, we analyzed differences in energy intake per day, diet costs for 8368 kJ (2000 kcal), and fruit and vegetable intake by level of dietary energy density (Table 2.2). For this purpose participants



Figuur 2.2. Association between dietary energy density (kJ/gram) and diet costs (€/8368 kJ (2000 kcal)) separate for the LASA and AGHLS cohort and men and women. 1. AGHLS men (r = -.505; p<.001); 2. AGHLS women (r = -.413; p<.001); 3. LASA men (r = -.559; p<001); 4. LASA women (r = -.562; p< .001).

were stratified into quartiles of energy density (kJ/gram), and differences between the four groups were analysed using ANOVA. Results show that, except for vegetable intake in LASA women, there were significant differences between the energy density groups on all variables. As people were stratified in the higher energy density quartiles, total consumed energy per day increased, fruit and vegetable intake decreased, and diet costs per 8368 kJ (2000 kcal) decreased significantly.

Table 2.2 Consumed kJ per day, costs per 8368 kJ (2000 kcal), consumed fruit (g) and consumed vegetables (g) by quartiles of energy density [a]

LASA									
Men	**1** (0-5.05 kJ/g) (n = 25)		**2** (5.06-6.00 kJ/g) (n = 20)		**3** (6.01-7.17 kJ/g) (n = 23)		**4** (7.18+ kJ/g) (n = 23)		
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	p
kJ/day	4964.3	1470.3	5268.9	1578.2	6060.2	1355.2	6769.7	2137.2	.001**
€ / 8368 kJ (2000 kcal)	6.01	1.08	5.11	.87	5.18	1.03	4.19	.61	<.001***
Fruit (g/day)	210.7	88.5	156.9	116.6	118.6	91.8	81.4	69.4	<.001***
Vegetables (g/day)	169.3	74.8	155.9	92.7	120.3	66.7	100.8	70.4	.010*
Women	**1** (0-5.69 kJ/g) (n = 20)		**2** (5.70-6.59 kJ/g) (n = 20)		**3** (6.60-7.73 kJ/g) (n = 20)		**4** (7.74+ kJ/g) (n = 20)		
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
kJ/day	5740.0	1200.0	6534.6	1848.9	6941.7	2201.2	7907.8	2160.2	.006**
€ / 8368 kJ (2000 kcal)	5.61	1.04	5.23	.97	4.76	.99	3.93	1.03	<.001***
Fruit (g/day)	148.9	102.7	137.6	81.3	79.7	81.9	63.8	81.0	.005**
Vegetables (g/day)	160.1	89.6	160.1	84.3	146.5	86.2	104.8	83.7	.145
AGHLS									
Men	**1** (0-5.55 kJ/g) (n = 39)		**2** (5.56-6.34 kJ/g) (n = 40)		**3** (6.35-7.21 kJ/g) (n = 39)		**4** (7.22+ kJ/g) (n = 39)		
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
kJ/day	8327.4	1974.0	9843.7	2287.8	10,196.4	3179.0	11,247.8	2461.9	<.001***
€ / 8368 kJ (2000 kcal)	5.09	.80	4.86	.89	4.72	.62	4.01	.54	<.001***
Fruit (g/day)	201.6	100.0	148.3	116.5	144.3	99.7	115.4	80.3	.002**
Vegetables (g/day)	218.6	95.3	206.4	57.3	187.2	70.3	144.0	59.4	<.001***

[a] Energy density = amount of energy (kJ) per unit weight (g)
* Significant differences between the four groups on p <.05
** Significant differences between the four groups on p <.01
*** Significant differences between the four groups on p <.001

Table 2.3 Differences in dietary intake, food expenses, and education by income level.

AGHLS	Income group [a]								Income group						
	1 (n = 17)		2 (n = 30)		3 (n = 109)		P *Anova*		1 (n = 35)		2 (n = 31)		3 (n = 63)		P *Anova*
Men	Mean	SD	Mean	SD	Mean	SD		*Women*	Mean	SD	Mean	SD	Mean	SD	
kJ/day	9908.1	1930.9	9637.4	2770.2	9995.2	2801.6	.815		9432.4	2087.4	9439.5	2246.0	9520.7	2246.0	.952
Euro/day	5.89	1.26	5.13	1.17	5.38	1.30	.146		4.88	.96	5.16	1.22	5.21	1.04	.261
ED (kJ/g)	6.23	.92	6.49	1.46	6.52	1.34	.678		6.65	1.13	6.40	1.34	6.36	1.09	.410
€ / 8368 kJ (2000 kcal)	5.03	.89	4.60	.84	4.62	.79	.142		4.40	.59	4.65	.76	4.66	.67	.126
Fruit (gram)	176.5	98.4	153.2	125.9	147.7	98.6	.571		138.0	99.5	124.4	115.5	145.4	91.9	.571
Vegetables (gram)	234.2	69.4	196.2	79.0	178.5	73.1	.014*		183.8	80.4	204.0	84.4	186.4	62.6	.423
	n	%	n	%	n	%			n	%	n	%	n	%	
Education level: Low	-	-	1	3.3	3	2.8	.121		3	8.6	1	3.2	-	-	.046*
Medium	13	76.5	15	50.0	46	42.2			18	51.4	12	38.7	46	42.6	
High	4	23.5	14	46.7	60	55.0			14	40.0	18	58.1	62	57.4	

LASA	Income group [b]						Income group				
	1 (n = 33)		2 (n = 62)		P T-Test		1 (n = 16)		2 (n = 64)		P T-Test
Men	Mean	SD	Mean	SD		*Women*	Mean	SD	Mean	SD	
kJ/day	5857.6	1955.6	5717.0	1745.6	.730		6094.4	2640.5	6953.8	1816.7	.128
Euro/day	3.46	1.14	3.48	1.11	.948		3.61	1.64	3.97	1.22	.329
ED (kJ/g)	5.82	4.39	6.44	1.55	.069		6.78	1.76	6.74	1.26	.835
€ / 8368 kJ (2000 kcal)	5.03	1.05	5.20	1.19	.510		5.05	1.62	4.84	1.04	.626
Fruit (gram)	133.9	109.5	147.7	104.0	.560		98.2	107.2	109.8	90.0	.657
Vegetables (gram)	152.4	79.4	125.9	80.4	.139		135.4	110.0	144.7	81.4	.704
	n	%	n	%			n	%	n	%	
Education level: Low	10	30.3	9	16.1	.001**		8	50	6	9.4	<.001***
Medium	22	66.7	31	55.4			7	43.8	37	57.8	
High	1	3.0	16	28.5			1	6.2	21	32.8	

[a] Income groups in AGHLS were measured in gross annual income, and are defined as: 1. below modal; 2. around modal; 3. more than two times modal

[b] Income groups in LASA were measured in net monthly income, and are defined as: 1. below modal; 2. above modal

* Significant differences between the four groups on p <.05

** Significant differences between the four groups on p <.01

*** Significant differences between the four groups on p <.001

Diet composition and diet costs in relation with income

As well as examining the association between dietary energy density, fruit and vegetable intake, and diet costs we did some initial analyses on differences by income level regarding these variables. For this purpose, we compared values of the listed variables for different income groups based on modal income classifications. As described in the Methods section, AGHLS subjects were classified into three income groups and in LASA subjects into two. Results of the analyses are shown in Table 2.3. We could not find significant differences between the income groups regarding diet costs; dietary energy density, consumed energy, or fruit intake. Women in the highest compared to the lowest income group spent more on food per day (in AGHLS +7% and LASA +10%), but this was not significant. For vegetables we found that AGHLS men in the highest income group had a significant lower intake than those in the group with an income below modal (- 56 gram, p =0 .014).

Discussion

Results of our study are the first, outside France and the USA, confirming the suggested inverse associations between energy density and energy costs in single food items and composed diets. We found that also in the Netherlands it is cheaper to select energy-dense diets, instead of diets containing less energy. However, we could not find the expected differences in diet costs, dietary energy density, and fruit and vegetable intake by income level.

In the first part of our study we investigated the association between energy density and food costs in single food items; and the association between energy density, fruit and vegetable intake and costs in composed diets. In line with previous findings, our study revealed that energy costs for food items with a high energy density level were significantly lower compared to food items with a lower energy density [29]. When we further analysed the association on diet level, we found that diet costs and dietary energy density were inversely related as well. Again, these findings were in line with previous results [12, 28, 29]. The fact that we could confirm previous findings using Dutch data has some important implications. Up until now, findings were restricted to American and French studies; with our study it has been shown that similar associations are present in another West-European country with different cultural and dietary habits from the French [17]. With this finding, there are reasons to suggest that the association between energy density and energy costs also exists in other Western countries, which has important implications for obesity research. When healthier diets tend to cost more, economics may be of similar relevance in the onset of obesity as for example biological preferences for sugar and fat, growing portion sizes, caloric beverages, or the contribution of eating away from home [29]. This economic argument comes on top of the fact that, in the current market-driven economy, fruits and vegetables may be less promoted than more lucrative highly processed foods [31]. In general, foods indicated as less favourable for health, receive more marketing promotion than foods that are indicated to contribute to a healthy diet. Because of this skewed distribution of food prices and promotion, several authors argued that the introduction of pricing strategies may be a fair intervention to stimulate the selection of less fat- and sugar-rich food items [8, 13, 28, 32, 33]. Small-scale experiments on pricing strategies in controlled settings, such as schools and worksites, have revealed promising results regarding the effectiveness of such strategies [6, 34].

Because food pricing strategies may be particularly justifiable for low-income consumers, we conducted initial analyses to explore whether price is of additional importance in food selection for this subgroup. In this, we studied whether people with different income levels had different diet costs, dietary energy densities and fruit and vegetable intakes. Unlike the suggested associations, we did not find significant differences. We did find some differences in diet costs per day and costs per 8368 kJ (2,000 kcal) (e.g., AGHLS women in the highest income group spent 7% more on food per day than women with below-modal income, and in LASA this was even 10%); however none of these results were significant. We expect this finding may be partly due to a power problem, because numbers, in especially the groups with below-modal income, were small. Another point may be that we did not have data available on household composition. Numbers from Statistics Netherlands (CBS) reveal that household size is an important contributor to the disposable income, a factor we did not correct for [35]. Including disposable income, instead of annual income, may lead to the hypothesised differences by income level.

More importantly, we suggest that explanations can be found in the use of estimated diet costs in which sales, portion discounts, bundling discounts, or differences between expensive branded products and their low-cots equivalents, could not be taken into account. We made effort to correct for seasonal variability by collecting food prices of fruits and vegetables in a winter month (February) and a spring month (April) and including mean prices. Initial analyses on summer prices revealed that some products were cheaper (i.e. melon), but others were more expensive (i.e. apples), and mean prices were approximately the same. Still, we could not include the actual effect of seasonal variability on food choices, or how this differs among income groups. Low income consumers may cut down expenses mainly by purchasing discounted food items, low-cost, or seasonal foods [36]. We expect that the inclusion of discounts and other price differences between food products will reveal the expected differences in food expenditures between income groups. On top of this, food costs were exclusively based on solid foods, excluding beverages. Low income shoppers may consume more soft drinks and sugar sweetened beverages, which are important contributors to energy density, and therefore differentiate between high- and low-income consumers [37]. A final point is that we did not take other food expenditures into account, such as eating out of home, which has also found to be an important determinant in diet quality [38] Still, the chosen method is regularly used and a well-founded way to estimate diet costs [26]. Our estimation on food expenses of on average € 5 was similar to the mentioned French studies [12,26,29]. We suggest that the chosen method is well suited to study the relation between energy density and energy costs, which is supported by our clear results on this aspect. However, to reveal differences by income level and to get insight in the actual effect of food prices on the consumer, other methods (recording exact food expenditures) may be required.

Apart from the above-described restrictions, it is important to note some concerns regarding the cohorts used. AGHLS and LASA are two different cohorts with clearly different characteristics and different dietary intake measures. We deliberately included both cohorts in order to be confident that the results found were not restricted to a selective cohort or specific measurement methods. This makes that the results of both cohorts are not directly comparable. Still, this can be considered a merit of our study since the results of both AGHLS and LASA point in the same direction. Also, both cohorts used standardized methods for measuring dietary intake and contain detailed, recent information of a relatively large sample. A limit of both cohorts is that they included only a small number of subjects with a low income. Because of this, the cut-off point for the income groups was set on modal income which is still quite high (€ 30,000 gross annually). Different results may be found when separate analyses are conducted on groups with a minimum income or below.

Furthermore, AGHLS and LASA had some unique limitations. First, the AGHLS cohort was fairly highly educated: even in the lowest income group 24% of males and 40% of females were higher educated. Previous studies have shown that, next to income, education level is an important factor in food choice [39]. Moreover, AGHLS was a fairly healthy group. Both overweight and obesity numbers were low, and also the overall fruit and vegetable intake was high. Analyses on a lower educated, less healthy cohort may reveal other results. The LASA cohort was lower educated and less healthy, but may be biased because it includes exclusively an elderly population. Owing to changing taste and smell perceptions, and lower energy requirements, older subjects often have different eating patterns and a reduced energy intake compared to younger ones [40-42]. Because of these cohort limitations, the expected differences between income groups may have failed to appear. Also this may explain why our findings on fruit and vegetable intake were not evident. As differences in fruit and vegetable intake between SES groups are supported by a large body of evidence [2, 43], we expect that SES differences between our subjects were just too small to reveal such results.

Based on the outlined results we could conclude that also in the Netherlands it is cheaper to select a diet high in energy density and low in fruit and vegetables compared to a more nutrient rich and less energy dense diet. This complicates dietary advice aiming on the substitution of sugar- and fat-rich food items with fruits and vegetables, since it might result in higher diet costs. Still, we can not conclude that this skewed price dispersal especially forms a barrier for low-income consumers. Initial analyses on this topic did not reveal clear differences in food intake and expenses between income groups. This may imply that financial barriers are not particularly prevalent among low-income consumers; however we suggest that this finding may be more likely due to methodological limitations. Therefore, we suggest this topic should be more extensively studied in future research focussing on true food expenditures and including a good dispersal of SES groups. In this it is of importance to measure the exact type of food consumed (including brand), prices of these foods when purchased (including discounts), and also record foods that are consumed away from home. The availability of such data is of main importance to study the economics of obesity and healthy diets, and is needed in the run of making the healthier choice the easy and affordable choice.

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