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Research report

High tax on high energy dense foods and its effects on the purchase of calories in a supermarket. An experiment☆

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ABSTRACT

The present study examined whether a high tax on high calorie dense foods effectively reduces the purchased calories of high energy dense foods in a web based supermarket, and whether this effect is moderated by budget and weight status. 306 participants purchased groceries in a web based supermarket, with an individualized budget based on what they normally spend. Results showed that relative to the no tax condition, the participants in the tax condition bought less calories. The main reduction was found in high energy dense products and in calories from carbohydrates, but not in calories from fat. BMI and budget did not influence the effectiveness of the tax. The reduction in calories occurred regardless of budget or BMI implying that a food tax may be a beneficial tool, along with other measures, in promoting a diet with fewer calories.

Introduction

The rapid increase in the prevalence of obesity is mainly due to the present environment, in which high caloric palatable foods are omnipresent and aggressively advertised. Fast foods, sweets, sweetened soft drinks and large portion sizes have all been linked to greater obesity risk (Drewnowski & Darmon, 2005). In addition, high caloric foods are relatively cheap: they provide an enormous amount of calories for their price, whereas in this sense fruits and vegetables are much more costly (Drewnowski, 2004). Prices are however adjustable and this imbalance in prices could be reduced. The law of demand states that consumers buy less of a good when its price increases. Increasing the price of energy dense foods should therefore reduce the demand for these products, also referred to as own-price elasticity. In addition, low energy dense food can be subsidized. These adjustments are one way to promote healthier diets. But are they effective?

Although there is a large body of research evidencing this economic principle, the effect is not equal for every type of product or for every single individual. Products that are necessary for survival are inelastic, meaning that its demand is relatively unaffected with any price change. Conversely, the demand for products that can easily be substituted is influenced much more with a price change. Obviously everyone needs food; one needs food for its energy which is necessary for one's survival. However, one does not necessarily need to obtain this energy solely from high energy dense food, like snack food. Indeed, considering that obesity is the direct result of energy intake outweighing energy expenditure, it is clear that people should not be eating high energy dense foods within and between every single meal. Perhaps a tax on these high energy dense foods might dissuade people from overly consuming these products. At the same time though, it is conceivable that such a pricing measure may not be as effective in every individual. Given the recent findings and suggestions that high energy dense foods in a very real sense can be highly addictive (Johnson & Kenny, 2010), the demand for snack food may be fairly inelastic in those individuals who already regularly overconsume these foods. The question thus is whether people are truly willing to substitute high energy dense (HED) food for low energy dense (LED) food when prices for HED change.

Three types of research at the effectiveness of pricing on food purchases can be distinguished. First, correlations between existing variations in price and purchases can be investigated in real life. In a systematic review of 166 studies, correlations between variations in price and purchases in real life were studied (Andreyeva, Long, & Brownell, 2010). Own price elasticity for food appeared on average 0.6, meaning that if the price of a specific food item increases with 1%, the demand for that item decreases with 0.6%. It appeared that food away from home and soft drinks were most elastic (0.81 and 0.79, respectively), whereas eggs and sugar were least elastic (0.27 and 0.34, respectively): even when prices increase steeply, people continue to buy eggs and sugar. However,

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people might replace the higher priced high caloric food with a cheaper alternative. Indeed, research showed that taxation of soda leads to decreased consumption, but this effect is completely offset by increased consumption of alternative high caloric drinks, like whole milk (Fletcher, Frisvold, & Tefft, 2010). This suggests that one should not apply a product-specific tax, but a calorie tax targeting all HED products. Such a broad tax for HED products is not applied yet and thus its effect on demand for HED food is unclear. The effect of income on price elasticity is scarcely researched: only 9 out of the 166 studies reviewed by Andreyeva et al. (2010) studied low income groups. However, income and low SES are very relevant to obesity (Drewnowski & Specter, 2004; Monteiro, Maura, Conde, & Popkin, 2004). Results of these studies are mixed, showing either no differences between income groups, or low income groups being affected more by price changes. In addition, the effect of weight status on effectiveness of a tax is not studied.

Although the real life studies have high external validity, they cannot study the impact of price elasticity in isolation. This means that price changes might be accompanied by other changes, economical and socially, which can have confounded the relation between price and purchase. More control can be executed in a second type of studies, which comprises experimental field studies on the influence of pricing. These studies showed that subsidizing healthy foods in vending machines (French et al., 2001; French, Jeffery, Story, Hannan, & Snyder, 1997), restaurants (Horgen & Brownell, 2002) and cafeterias (Cinciripini, 1984; Jeffery, French, Raether, & Baxter, 1994) led to increased purchase of these foods, compared to no subsidy conditions. However, people bought as much or even more unhealthy foods, indicating an unwanted effect of people using the money they saved on healthy products to buy more unhealthy products (French et al., 2001). The effect of taxing unhealthy foods has not been studied in field experiments, probably because making unhealthy food more expensive would decrease the competitive position of the selling point. In addition, the effect of income or weight status has not been studied: no information on individual participants was collected.

In a third type of research, the effect of pricing is studied experimentally with hypothetical purchases. The contribution of a tax can be analyzed in isolation, or in interaction with income, budget and weight status. Research showed that increasing the price of HED foods lead to a decrease in purchased calories (Epstein, Dearing, Paluch, Roemmich, & Cho, 2007; Epstein, Dearing, Roba, & Finkelstein, 2010; Epstein et al., 2006; Giesen, Payne, Havermans, & Jansen, 2011).

There are some indications that a HED food tax is less effective for obese people (Epstein et al., 2007). Because obese people find snack foods more reinforcing than non obese people (Giesen, Havermans, Douven, Tekelenburg, & Jansen, 2010; Saelens & Epstein, 1996) and snack foods can be addictive (Johnson & Kenny, 2010), obese people might be willing to pay a higher price for HED foods. In addition, it has been found that the effect of a tax is smaller when income or daily budget is higher (Epstein et al., 2006), because a high budget leaves more margins than a low budget. However, Giesen et al. (2011) found no effect of experimentally manipulated budget.

In sum, a large bulk of studies showed price elasticity in real life. However, these findings can be confounded by economical, social and environmental variables. In addition, most price changes were administered to only a few products, whereas a general tax for a broad range of energy dense products is most probably more effective. Only a few controlled experiments in the lab were performed, some of which suggest that a price tax might be less effective for people with higher budget (Epstein et al., 2006) or higher BMI (Epstein et al., 2007). Although these studies showed high internal validity, the small sample sizes and limited amount of products in the purchase tasks might have limited external validity.

In the present study, the effect of a large HED tax on purchases is studied in an internet supermarket with a wide variety (more than 700) of products, providing participants with the budget they usually spend on groceries. The tax is based on energy density, which is new and straightforward: people cannot evade the tax by buying other energy dense products which often happens in real life (Fletcher et al., 2010). The purchases and budget are hypothetical, but a real shopping event is modeled as good as possible. The internet enabled testing a large sample that varied in daily budget, income, education, gender and BMI. This way, external validity is kept high, while we still were able to exercise experimental control. We hypothesize that the HED tax is effective in reducing the calories people buy. More specifically, we look at calories from high and low energy dense products and calories from different macronutrients (carbohydrates, protein and fat). This allows us to look at the specific effects of the HED tax on the composition of the purchases. Because HED products contain relatively more carbohydrates and fat than LED products, we expect larger reduces from these macronutrients. Possible moderation of BMI and daily budget will be tested.

Method

Participants

Participants were recruited by advertisements on the internet, using GoogleAds. The advertisements were placed on Dutch websites, using Dutch language. When clicking on this advertisement, an informed consent was shown. It was explained that participants could win an I-pod in a lottery if they finished the task and entered their e-mail address. Finally, the inclusion criterion (being 18 years or older) was explained. Participants could give their informed consent by selecting the agreement button, which directed them to the first task. A total of 349 participants completed the tasks. After close inspection, 43 participants were excluded because it was suspected they did not participate seriously.[1] Demographics of the remaining 306 participants are revealed in Table 1.

We certify that all applicable institutional and governmental regulations concerning the ethical use of human volunteers were followed during this research. Approval of the Maastricht University Ethical Committee was obtained.

Measures

First, demographics were measured in a questionnaire, including age, length and weight, net family income, education level, number of people in their household (family size), money that is on average spend on groceries for their household for one whole day (daily budget) and momentary hunger, ranging from 0 (not hungry at all) to 10 (very hungry).

Next, a web based *internet supermarket task* was used to measure food purchasing behavior (Nederkoorn, Guerrieri, Havermans, Roefs, & Jansen, 2009). Participants received the following instructions on screen (translated from Dutch): "Imagine that you have to buy all the food for your entire family for one whole day. You have no food at home and must buy anything your family wants to eat. To this end, you now receive an imaginary budget of €xx that you may spend in the web shop. You do not have to spend your entire budget." The participants received an idiosyncratic budget to spend in the supermarket; that is the budget they

[1] The analyses were rerun including all 349 participants, which did not change the pattern of results.

Table 1
Demographics of the participants in the tax and no tax condition.

	Total	No tax	Tax
Total number	306	166	140
% Female	76%	76%	76%
Age	41.2	40.9	41.6
Family size	2.7	2.7	2.6
BMI	25.9 (5.6)	25.6 (5.3)	26.0 (5.9)
Hunger	2.6 92.6)	2.8 (2.7)	2.4 (2.4)
Highest education			
Lower education	17.3%	16.3%	18.6%
Secondary education	29.1%	26.5%	32.1%
Vocational training	22.2%	28.3%	15.0%
Higher education	31.4%	28.9%	34.3%
Daily budget			
<10 euro	27.1%	27.7%	26.4%
10–20 euro	52.9%	55.4%	50%
>20 euro	20%	16.9%	23.6%
Net family income (per month)			
<1000	15.7%	13.9%	17.9%
1000–2000	33.7%	33.1%	34.3%
2000–3000 (modal)	29.7%	27.1%	32.9%
3000–4000	14.7%	18.1%	10.7%
4000–5000	6.2%	7.8%	4.3%

Note: The participants in the no tax and tax condition did not differ from each other on any of the variables.

reported to spend on a daily base in the demographic questionnaire.

The web shop contained 25 main food categories (e.g., vegetables, fruits, candy, dairy products, etc.). When selecting a main category, 2–6 subcategories were shown (e.g., fresh vegetables, washed and sliced vegetables, canned vegetables, and frozen vegetables), each represented by the category name and a picture of a typical food item. When selecting a subcategory, all available food products of that category were shown in a list, including weight and price of the product. When selecting a food product, a picture and description was shown (no caloric information was provided). The participant could add products to a virtual shopping basket or delete products from the basket. Products in the shopping basket and their summed price were shown on the right side of the screen. In total, 708 products were available from the supermarket, consisting of only foods and drinks. When participants finished shopping (no time restraints were implemented), they selected the cash register icon. They were asked if they were sure they had all they needed for their family for one whole day and if confirmed, the shopping task was ended.

The amount of money 204 participants spent during this task (all in a control condition) were compared to the average amount of money spent in households in the Netherlands in 2009, according to Statistics Netherlands (2011) on the following food categories: bread, pastries and groceries, potatoes, vegetables and fruits, products containing sugar and beverages, oils and fats, meat

Table 2
The mean purchase of calories (+SD) per condition (no tax vs. tax).

	No tax	Tax
Total calories per household	9201.8 (4146.1)	8426.8 (4056.7)
LED calories	4378.2 (1702.5)	4368.8 (1871.4)
HED calories	4823.6 (3298.9)	4057.6 (3024.5)
%HED calories[a]	47.8 (18.3)	43.4 (19.6)
Total calories per person[a]	3992.5 (2263.8)	3573.5 (2132.2)
Total amount (€)	16.5 (6.1)	17.7 (7.8)
LED amount (€)	12.1 (4.5)	12.7 (5.6)
HED amount (€)	4.4 (2.7)	4.9 (3.7)
LED calories per euro[a]	384.3 (157.1)	367 (137.8)
HED calories per euro[a]	1199 (692)	992.4 (618.3)

[a] First the amount per person is calculated, then the average per condition.

products and fish, and dairy products. Results reveal a high correlation ($r = .85$, $p < .05$), confirming the validity of the task.

The experiment has a between-subject design and participants were randomly assigned to a condition. In the control condition, normal prices were used, based on prices from the nationally major supermarkets. In the energy density tax condition, all products with a caloric value of more than 300 kcal/100 g were indexed by 50%. This limit was chosen, so that all notoriously fattening foods such as crisps, cookies, chocolate, cheeses, sweets, margarine and butter were indexed, while staple foods (bread, rice, pasta), fruit and vegetables, and most meats and fish were priced normally. In total, 235 products were taxed, 33% of all available products. The participants were not informed about adjustments of prices and the instructions in the two conditions were completely the same.

Statistical analyses

The effect of the energy density tax was analyzed by seven hierarchical regression models, with total calories, calories from high energy dense products, calories from low energy dense products, percentage calories from HED products, calories from carbohydrates, fat and protein as dependent variables.

In the first step, control variables that correlated significantly with the dependent measure were entered. In the second step, condition (tax or no tax) was entered. In the third step, interactions between daily budget and tax and BMI and tax were added (the single variables were always entered in the model if the interaction-term is added). The interactions were only presented if they significantly improve the fit of the model. All variables were centered around their respective mean before entering in the model.

Results

Purchase behavior and correlations between the demographics and purchase behavior are displayed in Tables 2 and 3. Income, daily budget, age, and family size were all significantly correlated to at least one of the aforementioned dependent variables and

Table 3
Pearson bivariate correlations between calorie purchase behavior and demographic variables.

	Total kcal	kcal from HED products	kcal from LED products	% kcal from HED products	kcal from carbohydrates	kcal from fat	kcal from protein
Gender (Spearman's rho)	.05	.06	–.01	.05	.05	.02	–.02
Age	.08	.05	.13*	.06	.05	.16**	.07
Family size	.45**	.30**	.50**	.09	.48**	.35**	.52**
BMI	–.01	–.04	.07	–.02	–.06	0	.02
Hunger	–.05	–.02	–.08	.04	–.01	–.06	–.05
Education	.09	.10	.01	.09	.06	.08	.11
Daily budget	.53**	.44**	.44**	.24**	.48**	.53**	.59**
Net family income	.21**	.19**	.15**	.14*	.17**	.20**	.33**

* $p < .05$.
** $p < .01$.

Table 4
Hierarchical regression models predicting total purchased calories, calories from HED and LED products and percentage of HED products.

	Total kcal			kcal from HED products			kcal from LED products			% HED products		
	B	S.E.	*β*	*B*	S.E.	*β*	*B*	S.E.	*β*	*B*	S.E.	*β*
Step 1												
Age	4.7	13.0	.017	−2.7	11.2	−.012	7.4	5.8	.06	.00	.001	.013
Family size	907.9	149.3	.30***	380.3	128.5	.164***	527.7	65.9	.41***	−.001	.008	−.01
Income	127.0	181.1	.034	193.6	155.9	.07	−66.7	80.0	−.041	.016	.01	.094
Daily budget	1904.5	221.5	.42***	1297.3	190.6	.37***	607.2	97.8	.31***	.046	.012	.221***
Step 2												
Age	5.8	12.9	.02	−1.7	11.1	−.005	7.5	5.8	.06	.00	.001	.016
Family size	925.3	147.3	.31***	394.9	126.8	.17***	530.4	65.9	.41***	−.001	.008	−.005
Income	50.1	180.2	.013	128.7	155.2	.045	−78.6	80.7	−.05	.013	.01	.075
Daily budget	1972.2	219.4	.44***	1354.5	188.9	.39***	617.8	98.2	.32***	.049	.012	.234***
HED tax	−1181.3	377.4	−.14***	−997.0	325.0	−.16***	−184.3	169.0	−.052	−.048	.021	−.127*

* $p < .05$.
*** $p < .005$.

therefore entered in the first step of the hierarchical regression analyses.

The hierarchical linear regression models on total calories and calories from HED and LED products are presented in Table 4. Daily budget significantly predicted the purchase of total calories, HED calories, LED calories and percentage calories from HED products. In addition, family size significantly predicted total calories, HED and LED calories, but not percentage calories from HED products. This indicates that when a family is larger they need more calories, but the ratio HED/LED products is not qualitatively different from smaller families. The other variables (age and net family income) did not predict purchase of calories when controlling for family size and daily budget.

As hypothesized, HED tax predicted the purchase of calories significantly. Specifically, the tax diminished the purchase of total calories ($\Delta R^2 = .021$, $p < .01$), HED calories ($\Delta R^2 = .026$, $p < .01$) and the percentage calories from HED products ($\Delta R^2 = .018$, $p < .01$) and had no effect on LED products. To put it differently, the same price elasticity was significant and appeared to be 0.32 (a tax of 50% on HED products caused a 16% decrease of purchase of these products; 1% increase in price would lead to 0.32% decrease of purchase).

The influence of the HED tax was not significantly moderated by daily budget or BMI, the interaction terms were therefore removed from the hierarchical regression model. Thus, the HED tax had an equal effect on participants (see Fig. 1).

Presented in Table 5 are the hierarchical linear regression models in which the purchased macronutrients are predicted. Daily budget and family size significantly predicted purchased calories from carbohydrates, fat and protein. Income only predicted calories from protein: people with higher income purchased more calories from protein. HED tax only influenced the calories purchased from carbohydrates: the tax diminished the calories purchased from carbohydrates ($R^2 = .018$, $p < .005$). The effect of the tax on calories from fat and protein was not significant (see Fig. 2). Again, the influence of the HED tax was not significantly moderated by daily budget or BMI, the interaction terms were therefore removed from the hierarchical regression model.

When looking at the calories people buy per euro, calories from HED products are much cheaper than calories from LED products (see Table 2). The tax logically decreased the HED calories people can buy per euro, because the same products cost 50% more. Without a tax, people bought 1199 HED kcal per euro. When people would buy the exact same products with tax, they would have bought 800 HED calories per euro (1199 per euro/1.5 = 800 per euro). In fact they bought 992 calories per euro, indicating that people partly compensated for the tax and bought cheaper HED products than in the no tax condition, or products with a higher energy density within the category of HED products.

There was no difference between the two conditions in the amount of money people had left after their purchases

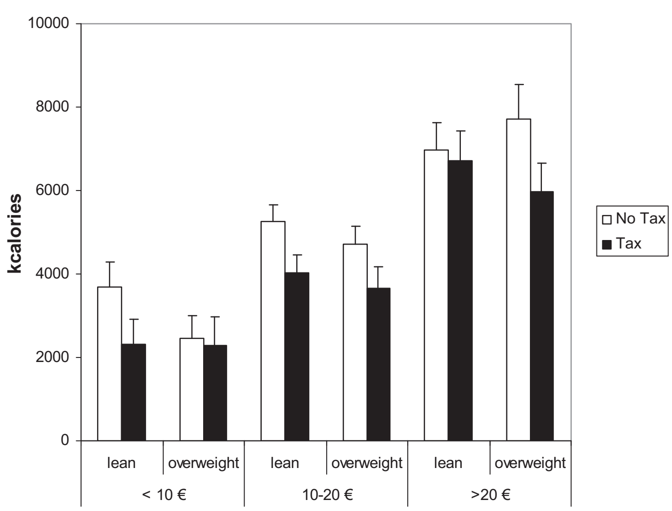

Fig. 1. The effect of budget, overweight and tax on purchased calories from high energy dense products (mean and S.E.M.).

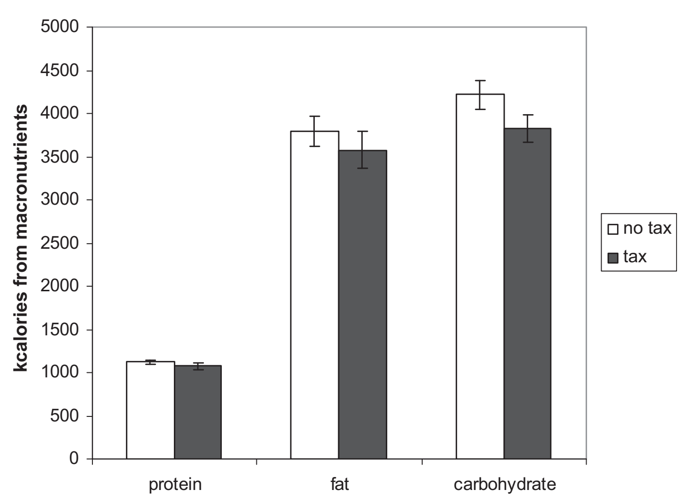

Fig. 2. The effect of tax on calories from carbohydrates, fat and protein (mean and S.E.M.).

Table 5
Hierarchical regression models predicting calories from carbohydrates, fat and protein.

	kcal from carbohydrates			kcal from fat			kcal from protein		
	B	S.E.	β	*B*	S.E.	β	*B*	S.E.	β
Step 1									
Age	−2.7	6.8	−.02	10.6	8.1	.065	−1.0	1.2	−.036
Family size	530.7	77.8	.36***	235.6	92.8	.14*	105.2	13.4	.36***
Income	−85.8	95.1	−.046	123.6	113.5	.057	41.0	16.4	.11*
Daily budget	1034.0	154.7	.35***	1498.7	184.5	.43***	261.3	26.7	.44***
Step 2									
Age	−2.1	6.7	−.015	11.0	8.1	.068	−.9	1.2	−.03
Family size	541.1	77.0	.36***	242.0	92.7	.14**	106.4	13.4	.36***
Income	−121.7	94.9	−.065	101.7	114.3	.047	36.8	16.5	.10*
Daily budget	1068.9	153.2	.36***	1516.4	184.6	.43**	264.7	26.7	.45***
HED tax	−559.8	197.6	−.14***	−341.2	238.0	−.071	−65.2	34.4	−.08

* $p < .05$.
** $p < .01$.
*** $p < .005$.

($t(304) = 0.9$, N.S.). On average, people had left €3.13 (S.D. = 5.1). Most people could therefore still buy more products, but choose not to.

Discussion

The results of this study show that a tax on high energy dense foods works, in the sense that people buy less calories, especially from HED foods. The effect of the pricing is substantial: a 50% increase in price of HED products led to a 16% reduction of purchases. The tax appeared equally effective for people with high and low daily budgets and was not influenced by BMI. Further, the tax did not influence the purchase of low energy dense foods. The tax especially diminished the purchase of carbohydrates. The effects on calories from fat and protein were not significant.

From the standpoint of an economist, the present pattern of results shows a rather modest effect of an HED tax. However, from the standpoint of the health professional, the present results are anything but minor. Hill and colleagues (Hill, Wyatt, Reed, & Peters, 2003) argued that a consumption of 100 kcal per day for a year represents a body mass of 5.2 pounds, or 2.4 kg. Since people gain on average around 2 pounds per year in the USA and 90% gain 5.2 pounds or less, a decrease of 100 kcal per day would prevent weight gain in 90% of this population. In the present study, the imposed HED tax caused a decrease in purchases of on average 419 kcal per person on a daily base, mainly from HED products. This is more than sufficient not only to prevent weight gain, but also to establish a considerable weight loss.

The established decrease in purchased calories by the tax was not moderated by BMI, suggesting that overweight/obese persons are just as sensitive to a price increase of high calorie foods as normal-weight persons.

In terms of policy, the present results are reassuring in the sense that it affected the purchase of foods equally among people varying in the amount of money they had available for buying food. Note that the effect of the tax did not limit purchases of HED foods because participants were simply unable to buy them, but because they willfully chose not to buy these foods. On average people spend almost three times more money on LED foods than on HED foods and both in the tax and no tax condition most people had a considerable amount of money left after they finished their purchases. People were therefore able to buy more HED foods in the tax condition if they wanted, but apparently decided the foods were not worth the high price. Still, people in the tax condition spend more money compared to the control condition and this seems inevitable because certain HED products (e.g., oil) are part of a normal healthy diet, albeit in limited amounts. The tax can therefore be considered to be regressive: it affects people with low daily budget relatively more. Careful countermeasures should be taken to compensate for this effect. Money earned by the tax could for example be returned to the people by subsidizing healthy food or health costs, ensuring that a food tax does not increase poverty. Price changes should make a healthier diet and lifestyle accessible for people with low and very low income.

The participants in the tax condition appeared to partly compensate for the high prices of HED foods by buying the cheaper HED foods, instead of just purchasing LED alternatives. It is not clear what this change in purchase pattern would mean for intake and if the purchase of cheaper HED products would increase or decrease actual consumption on the longer term. Nonetheless, the present results strongly suggest that cheaper generic HED products will likely grow more popular with the introduction of an HED tax. Note that a relative tax as used in the present study promotes such a compensation strategy because it leads to a larger price increase for the already more expensive products in absolute terms. Another disadvantage of an energy density tax is that it cannot be used to tax beverages, since beverages are low in energy density relative to most solid foods. Therefore, other type of taxes might need to be considered. Brownell et al. (2009) proposed a tax based on volume or weight instead of price, an excise tax. Another way of taxing is by looking at calories-for-nutrients (Drewnowski, 2005; Epstein et al., 2010). This indicates how many calories are required to obtain an additional 1% of the recommended daily values of 13 key nutrients. Finally, the current tax followed the all-or-nothing rule: a product was considered either high or low energy dense. A tax in which the height of a tax is related to energy density or calories-for-nutrients might encourage companies more to produce healthier products.

In the present experiment, participants were tested in a 'closed economy': they could only choose between different types of food products. In real life, there are far more options in and outside the supermarket, which can alter the effect of a food tax. Moreover, if a tax on high energy dense food will also lead to a healthier diet with more fruits and vegetables is still an empirical question.

Besides the price, other factors influence purchase and consumption of products. Advertisements and commercials, availability, variety, size and knowledge of products also play a role. In addition to adjusting the price of products, other possible measures to reduce consumption are restrictions in advertizing high caloric foods, limiting selling points and increasing knowledge of food. In addition, facilitating sports and exercise can contribute to a healthier life style. Probably a combination of several adjustments is needed to curb the obesity epidemic.

In conclusion, a HED tax appears effective in reducing the purchase of calories, especially from HED foods. In terms of health benefits, this reduction is substantial and equally successful in people with high and low BMI and in people with high and low budgets. The tax appeared effective in reducing calories from carbohydrates, but did not influence the purchased calories from fat. In addition, participants did show a slight tendency to substitute more expensive HED foods for cheaper HED products. As such, different types of taxing need to be considered. Still, we believe that a HED tax can be a beneficial tool, along with other measures, in promoting a diet with fewer calories.

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