Linking Diet-Health Behaviour and Obesity using Propensity Score Matching

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Abstract

This paper quantifies the impact of consumer's diet-health behaviours on an important health outcome. We use data from the 2007-2008 U.S. NHANES to estimate the impact of dietary supplement intake on respondent's BMI outcomes, controlling for diet quality using Healthy Eating Index scores. The analysis applies propensity score matching (PSM) to account for selection bias and endogeneity between self-reported diet and health behaviour (treatment) and BMI outcomes. Dietary supplement choices are explained by demographic, lifestyle, food culture and food security variables. Matching results suggest that regular dietary supplement consumption is associated with significant lower BMI outcomes of almost 1 kg/m^2.

Keywords: Propensity Score Matching, Diet-health behaviour, Dietary supplements, Obesity, Healthy Eating Index-2010,

1. Introduction

Obesity is regarded as a major threat to public health in the United States (Baskin et al. 2005) and many other western economies. It is estimated that more than 30% of adults in the United States are obese (Baskin et al. 2005; Ogden 2006; Ogden et al. 2012). The impact of rising obesity and associated diseases on countries with epidemic dimensions include increasing health care costs, reduced economic output and reduced productivity (Allen et al. 2006; Ludwig 2009; Rosin 2008). Cawley and Meyerhoefer (2012) have estimated the cost of treating adult obesity in the U.S at 20.6% of national spending from 2000-2005. Even though genetics appears to play a crucial role in determining who becomes obese, research suggest that dietary choices driven by important environmental and economic factors are of crucial importance (Chou, Grossman, and Saffer 2004; Drewnowski and Darmon 2005; Etilé 2011; Mokdad et al. 2003; World Health Organization 2013).

The consumption of a diet rich in fruits and vegetables has long been known to reduce the risks of diet related health conditions including obesity, type-2 diabetes and certain types of cancers (Agudo 2005; Keen and Zidenberg-Cherr 1994; Pérez 2002). However, the average North American consumer only meets 40% of the daily recommended f&v intake (Guenther et al. 2006). Inappropriate diet behavior which characterises modern western diets is known to contribute to be among the root causes of the obesity epidemic, nutrient deficiencies and related public health issues. In response to the growing public awareness of what constitutes good nutrition consumer demand for fast, convenient and easy-to-use means to improve diets and health has been on the rise. Pharmaceutical companies have been quick to promote the diet-health benefits and convenience of synthetic nutrition supplements, which now a major area of industry growth and competition to f&v producers in the U.S. and elsewhere. Despite reports suggesting that nutrition supplements may be unnecessary and could even be detrimental to human health (Mursu et al. 2011), almost 50% of North American adults are reported to at least occasionally take dietary supplements (Dickinson and Shao 2006). According to Schroeter, Anders, and Carlson (2013) there is very little empirical evidence regarding the economics of individual’s nutrition supplement choices and particularly their impact on diet and health outcomes.

The objective of this paper is (1) to identify and quantify determinants of consumer's nutrition supplement intake choices, (2) to quantify whether and to what extent nutrition supplement intake has a measurable effect on individual's BMI (kg/body height in m2) outcome, when differences in diet quality are controlled for. To the best of our knowledge the only study that incorporates, lifestyle indicators and food culture variables in the study of nutrition supplement choice and food quality is Schroeter, Anders, and Carlson (2013). Their analysis is able to show a positive association between nutrition supplement intake and diet quality, but does provide evidence to whether improvements in diet behaviour do lead to measurable difference in a concrete diet-health outcome such as is the BMI. We apply Propensity Score Matching (PSM) to quantify the possible link between diet-health behaviour, represented by the decision to consume nutrition supplements, food quality and obesity. Nutrition supplement intake per se, does not directly affect BMI but is assumed to impact food quality, which in turn influences obesity outcomes. The creation of knowledge about this importance linkage may help to develop a clearer understanding of the factors that impact dietary choices, their overall health outcomes, both which may lead to a more efficient and effective promotion of healthy food choices and targeted consumer health and lifestyle policies.

2. Data

The analysis uses data from the U.S. National Health and Nutrition Examination Survey (U.S. NHANES) 2007-08. The NHANES is the primary, randomized, and nationally representative survey used to assess the health and nutritional status in the U.S. Data from the various NHANES survey cycles has been used in a number of economic studies focused on individual health behaviour, consumption choices, other related issues (Bailey et al. 2011; Balluz et al. 2000; Ervin, Wright, and Reed-Gillette 2004; Gahche et al. 2011; Rock 2007; Schroeter, Anders, and Carlson 2013). For the analysis in this paper, we select adult NHANES respondents aged 20 and older. From the large pool of information elicited though NHANES variables we select: socio-economic and demographic, lifestyle, food security, food culture, and health-status variables. As a measure of diet quality we computed Healthy Eating index-2010 (HEI) scores for all 2007-08 NHANES participants using the approach of Kahle and Buckman (2013). Descriptive statistics for the variables used in the analysis are summarized Table 1.

Table 1. Descriptive statistics of model variables

Variable	Description	Mean / (Std. Dev.)
	Demographics	
Male	=1 if respondent is male	0.49 (0.50)
Age	Age of respondent in years	50.37 (17.80)
Household Size	Total number of people in household	3.13 (1.66)
Married	=1 if respondent is married/common law	0.60 (0.49)
Divorced	=1 if respondent is divorced or separated	0.23 (0.42)
Single	=1 if respondent is single/never married	0.17 (0.37)
High School	=1 if respondent went to high school	0.25 (0.43)
Some College	=1 if respondent went to some college	0.26 (0.44)
Graduate	=1 if respondent graduated from college and above	0.19 (0.39)
Household Inc 1	=1 if annual household income is between $0-$24,999	0.35(0.48)
Household Inc 2	=1 if annual household income is between $25000-$49,999	0.22(0.42)
Household Inc 3	=1 if annual household income is between $50,000 - $ 74,999	0.19(0.39)

Table 1 Continued

Variable	Description	Mean / (Std. Dev.)
	Demographics cont'd	
Household Inc 4	=1 if annual household income is between $75,000 - $ 99,999	0.09(0.28)
Household Inc 5	=1 if annual household income is $100,000 and over	0.12(0.33)
	Lifestyle	
Very active	=1 if respondent's self-rated daily activity is very vigorous	0.19(0.41)
Smoker	=1 if respondent has smoked at least 100 cigarettes in entire life and is currently smoking	0.48(0.56)
Alcohol	=1 if respondent has consumed at least 12 Alcoholic beverages in last year	0.71(0.51)
	Health status	
Body Mass Index	Weight (kg)/ (Height (m))^2	28.99(6.67)
Diabetes	=1 if respondent has been told by doctor or health professional to have diabetes	
Blood Pressure	=1 if respondent has been told by doctor or health professional to have high blood pressure	0.96(0.21)
	Food Culture	
White	=1 if respondent is non-Hispanic white	0.47(0.50)
Black	=1 if respondent is non-Hispanic Black	0.21(0.41)
Hispanic	=1 if respondent is Hispanic	0.11(0.32)
Other race	=1 if respondent is none of the races above	0.21(0.41)
Citizen	=1 if respondent was born in the USA	0.87(0.34)
	Nutrition Supplement Intake	
Supplement	=1 if respondent has taken any dietary supplements in past 30 days	0.46(0.50)
	Diet Quality	
HEI-total	Healthy Eating Index 2010[1)]	54.6(1.09)
	Food Security	
Food-stamps	=1 if respondent has ever received food-stamps	0.24(0.48)

[1)] A full definition of the HEi-2010 can be found at: *www.cnpp.usda.gov/Publications/HEI/HEI-2010/HEI2010-UpdatePaper.pdf*.

3. Model

Building on Becker's model of investment in human capital model, Grossman's seminal work on health capital describes and formalizes the process by which people are endowed with a certain stock of health which is said to deteriorate over a person's life time (Grossman 1972). How fast a person's health status deteriorates depends, among other things, on investments in health through certain health behaviours. In Grossman's model good health is a source of utility as a consumption good and investment good. "Good health" can be attained through a variety of ways including nutrition, medical care and other relevant lifestyle choices. In the context of nutrition, the frequent consumption of fresh fruits and vegetables or alternatively the intake of nutrition supplements could be thought of as an investment in nutritional health. As such the individual will derive utility from the consumption of nutrition supplements, which in the long run may contribute to overall utility derived from good health.

The empirical analyses of individual's diet-or health behaviour in the context of specific health outcomes is typically complicated by potential problems of endogeneity between key variables of interest and measurement error resulting from self-selection bias, a problem often encountered in consumer survey studies. The use of ordinary least square (OLS) usually leads to biased results due to potential misspecification errors (Grilli and Rampichini 2011). A common econometric solution to problems of endogeneity is the use of instrumental variable estimators (IV). However, it is often difficult if not impossible to find suitable instruments in the context of studies in the area of food, diet, and health behaviour (Park and Davis 2001), which render difference-in-difference (DID) and Heckman-type switching regression models less suitable. We therefore choose PSM to account for the possible selection bias in the self-reported dietary, supplement intake data and possible endogeneity of diet quality, supplement intake and obesity outcome (BMI).

The rationale behind PSM, originally developed by Rosenbaum and Rubin (1983) is to estimate treatment effects in the context of interventions (medical, policy or otherwise) when standard randomized control trail methods aren't feasible (Becker and Ichino 2002). In the economics literature PSM has been employed to determine the effects of labour market and training courses on individual's wage earnings (Dehejia and Wahba, 2002; Heckman, Ichimura, and Todd, 1998; Lechner, 1999; Smith and Todd, 2005). In health economics and field of food consumption studies, PSM methods have been employed to analyze how consumers that were exposed to a particular treatment (e.g. food label usage) differed from those who reportedly did not receive the same treatment (Abebaw, Fentie, and Kassa, 2010; Campbell et al., 2011; Drichoutis, Nayga, and Lazaridis, 2009).

In this paper, NHANES respondents who reported regular nutrition supplement intake over the past 30 are classified as the treatment group (supplement takers), with all other respondents representing the control group (non-takers). The propensity score function or treatment selection model, which describes the conditional probability of taking dietary supplements giving equality in pre-treatment characteristics between both groups, is estimated as a binary logit:

Supplement = f(male, white, hispanic, other race, high school, Some college, graduate, married, divorced, age, household size, hhinc2, hhinc3, hhinc4, hhinc5, alcohol, smoker, very active , food stamp, diabetes, blood pressure, hei-total)

Where 'supplement' is the binary dependent variable of nutrition supplement choice. We estimate the above propensity score function with the main purpose of balancing the characteristics of respondents in the treatment and control groups. After balancing any unobserved heterogeneity between supplement takers and non-takers is minimized so that the comparison of BMI outcomes across both groups is unbiased and merely a function of their treatment status. We estimate the average treatment effect of nutrition supplement intake on the treated (AAT) (supplement takers) using different matching algorithms: Nearest Neighbour, Caliper (Radius), Stratification and Kernel matching.

4. Results

The relationship between dietary supplement intake and BMI is not a causal one. Dietary supplement intake however may have an effect on the overall diet quality of users which may in turn have a visible effect on a diet health outcome indicator such as BMI. It is therefore hypothesized that dietary supplement takers will have a lower BMI than non-takers of dietary supplements. The Table 2 below shows the factors associated with selection into the treatment group of dietary supplement taker.

Table 2. Average treatment effects (ATT), Nutrition Supplement Takers

Variables	**Coefficient**	**Standard error**
Constant	-4.727***	1.575
Socio-demographics		
Male	-0.577***	0.066
Age	0.035***	0.002
Household size	-0.074***	0.023
Married	0.105	0.097
Divorced	0.007	0.113
High school	0.328***	0.088
Some college	0.700***	0.089
Graduate	0.825***	0.106
Household income 2	0.148*	0.085
Household income 3	0.233**	0.092
Household income 4	0.370***	0.121
Household income 5	0.564***	0.114
Lifestyle		
Smoker	-0.152	0.063
Alcohol	0.097	0.065
Very active	0.495***	0.086
Diabetes	0.003	0.095
Blood pressure	-0.222	0.243
Food Culture		
White	0.414***	0.084
Hispanic	0.349***	0.120
Other race	0.272***	0.105
Citizen	0.331***	0.114
Diet Quality		
Total HEI-2010	0.041	0.028
Food Security		
Food stamps	-0.173**	0.075
Observations, n = 5063	**Pseudo R^2** = 0.124	
Log-likelihood = -3075.81		

***, **, and * indicate significance at the 99%, 95%, and 90% level

With the exception of marital status, all socio-demographic factors are significant at explaining the probability of selection into treatment (nutrition supplement taker). We find that males are 58% less likely to take nutrition supplements as compared to women. This finding is similar to what has been documented in previous studies (Bailey et al. 2011; Dickinson and MacKay 2014; Fennell 2004; Nayga and Reed 1999). The negative effect of household size on dietary choices is also well documented (Nayga and Reed 1999). In contrast the probability of taking supplements increases with education, age, and household income (Bailey et al. 2011; Dickinson and MacKay 2014; Ervin, Wright, and Kennedy-Stephenson 1999; Fennell 2004; Garside et al. 2005; Petrovici and Ritson 2006).

Several lifestyle variables that are significant at explaining the propensity to consume dietary supplements are smoking and active lifestyle. Smokers are 15% less likely to take nutrition supplements (Brownie 2005; Dickinson and MacKay 2014; Harrison et al. 2004; Ishihara et al. 2003; Li et al. 2010; Nayga and Reed 1999; Schroeter, Anders, and Carlson 2013). In contrast, respondents who exhibited active lifestyles (physical exercise, vigorous recreation, etc.) were 46% more likely to take dietary supplements (Dickinson and MacKay 2014; Foote et al. 2003; Harrison et al. 2004; Li et al. 2010; Lyle et al. 1998; Nayga and Reed 1999; Reinert et al. 2007; Rock 2007). Unlike reported by Lyle et al. (1998) drinking alcohol did not affect the propensity to take nutrition supplements.

Food stamp recipients were 17% less likely to take nutrition supplements. The literature is ambiguous regarding the association between health conditions (e.g. diabetes, hypertension and nutrition supplement intake (Harrison et al. 2004; Satia-Abouta et al. 2003; Balluz et al. 2000; Lyle et al. 1998). We found no association between nutrition supplement intake and HEI-2010 scores, a departure from Schroeter, Anders, and Carlson's (2013) using HEI-2005 scores. Finally, food culture and ethnic heritage seems to play an important role in determining the probability of nutrition supplement intake, with non-blacks and other races, as well as American citizenship explaining treatment selection.

The Table 3 below shows the results of different matching algorithms for the comparison of nutrition supplement takers and non-takers in regards to their BMI outcomes.

Table 3 Relationship between Dietary Supplement Intake and BMI

Matching Algorithm	**Coefficient**	**Standard Error**
Nearest Neighbour	-0.870***	0.172
Radius Matching (r=0.1)	-0.851***	0.169
Radius Matching (r= 0.001)	-0.851***	0.173
Kernel	-0.870***	0.182
Stratification	-1.096***	0.233

Note: ***, **, and * indicate significance at the 99%, 95%, and 90% level. A detailed description of the matching algorithms and their implementation in STATA following Becker and Ichino (2002) can be found at: www.stata-journal.com/sjpdf.html?articlenum=st0026.

The result in Table 3 clearly suggest that nutrition supplement takers differ from non-takers in in terms of their BMI. Across matching algorithms supplement takers have a lower body mass index of roughly 1.0 kg/m2. This similarity in outcome across all the matching algorithms is noteworthy as comparable studies using PSM have largely reported inconclusive results (Drichoutis, Nayga, and Lazaridis 2009). Our results suggest, for instance, that a person with a BMI of 29 kg/m2 is classified as overweight but another with a BMI of 30 kg/m2 is obese. Our results add to the mixed reports on the relationship between BMI and nutrition supplement intake in literature. Kimmons et al. (2006) found that people who are obese/overweight are less likely to take supplements, while Balluz et al. (2000) note that those overweight or obese may have a greater tendency to take supplements because they may be making weight loss attempts or follow a recommended diet.

The significant difference in BMI between takers and non-takers is striking especially because we find that diet quality and individual's total HEI-2010 score did not have a significant effect on selection into treatment group. Hence, even though total diet quality and nutrition supplement intake may not be associated, it may have an impact on other HEI components that have been found to be linked with lower BMI levels. For instance, in Guthrie and Lin (2014), eating fruits was found to be associated with a significantly lower BMI.

5. Conclusion

This study focuses on the linkage between diet-health behaviour and obesity. Motivated by dwindling levels of consumption of fruits and vegetables and growing demand for nutrition supplements we hypothesized that nutrition supplement takers would have a significantly lower BMI than non-takers due to the possible effect that nutrition supplement intake may have on various components of healthy eating, health behaviour and other elements of healthy lifestyles in general.

The study results suggest that the propensity to take nutrition supplements is significantly affected by several demographic, lifestyle, food security and food culture variables. Several Propensity Score Matching algorithms consistently estimate that white, highly educated, higher income and higher overall health status supplement takers to have significantly lower BMIs of roughly 1kg/m2. The innovative analysis carried out in this paper seeks to contribute to the current debate of whether actual changes in consumers' diet or health behaviour in response to diet-health education and other policy interventions do in fact lead to measurable and positive diet and health outcomes. In our case the choice of nutrition supplement intake serves as an indicator for an active decision to invest into better health (using Grossman and Becker’s language) and proxy for change in diet-health behaviour. We therefore believe that our study contributes valuable information to the formulation of policies towards more effective diet-health education and information campaigns, a topic that has attracted a number of applied economic studies in Europe and North America in recent years.

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