Determinants of BMI and Obesity in England

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Abstract

Epidemic of obesity has emerged to be a major issue in the developed world. Taking that into account, this article focuses on demographic, socioeconomic, and lifestyle factors which might help determine key areas of focus for purposes of guiding an approach against obesity in England, using the data from 2011 Health Survey for England (NatCen Social Research, 2013). It proves that both Body Mass Index and the rate of obesity can be, to some extent, estimated using the underlying factors, pointing out the conflicting perspectives on individuals from different ethnic backgrounds, differences between genders and attempts to approximate lifestyle of the given individual through instrumental variables. Majority of the relationships predicted based on recent research was confirmed. The key recommendations include increase of the length of compulsory education, promotion of healthy lifestyle, therapeutic help with cessation of smoking habits and more generally, distinct approach to individuals of individual ethnics.

1 Introduction

The epidemic of obesity has been emerging since late 1970s (OECD 2010, Chou et al. 2004) in both developed and developing countries. Since 1990s, it has become one of the major non-communicable diseases among western population. Furthermore, it has become to emerge in the developing world including the countries, where malnutrition and prevalence of underweight population remain an issue.

According to Hlúbik (2002), OECD (2010), it is crucial to understand increasing average BMI and rate of obesity in populations as a serious medical condition. It has been proven by numerous clinical studies that it leads to overall decrease in health status and quality of life as well as median lifespan in individuals while inducing broader societal issues. These primarily include substantial increase in medical spending (Hlúbik 2002, Martinez 2000, Cawley & Meyerhoefer 2012) as well as indirect costs associated with decrease in productivity resulting from higher susceptibility of higher BMI individuals to illness(WHO, 2000).

Consequently, a global appeal for an importance of reduction of this population sickness has arisen. Since the mid 1990s, international organizations such as WHO and OECD have taken lead in this initiative, providing a broad research background for the purposes of development of suitable policies and strategies on more specific geographic levels.

2 Literature review

2.1 Measuring Obesity

Based on ongoing medical research, it has been universally proven that deviation from the healthy weight leads to increased risk of cardiovascular diseases as well as type 2 diabetes, chronic hypertension, atherosclerosis, and other comorbidities. A measure of this deviation, the Body Mass Index is identified as "the most useful, albeit crude population-level measure of obesity" by WHO, (2000). Despite variations in the body composition in individuals of the same BMI value, it offers an adequate proxy for likelihood of occurrence of health risks related to weight change. Additionally, it is the least invasive and easiest method for use in surveillance and data monitoring (NOO 2009).

Furthermore, use of BMI ranges are used to categorize individuals of similar level of health risks. Although these ranges vary among sources (York 2004), WHO, (2000) proposes use of universal classification shown in table 1, defining obesity as a state at which an individual presents with Body Mass Index of 30.00 or higher.

Clasification	BMI range
Underweight	00.00 - 18.49
Normal range	18.50 - 24.99
Preobese	25.00 - 29.99
Obese class 1	30.00 - 34.99
Obese class 2	35.00 - 39.99
Obese class 3	40.00+

Table 1: Table of BMI ranges

2.2 Demographic dimension

2.2.1 Age

In relation to the life cycle theory of consumption first introduced by Franco Modigliani (Deaton 2005), part of the variation in the individual's consumption seems to be explained by their age. Individual's consumption increases in early stages of life, digresively growing up until the point of retirement and starts to decrease progressively in later years of life. In mathematical terms, the relationship between age and consumption is characterized by a downward-open quadratic function. As suggested by current research, BMI follows identical pattern. Furthermore, such observation has been consistent not only among countries (OECD 2010) but over time as well (Carreira et al. 2012).

2.2.2 Gender

The bodily differences between genders are an important aspect to consider while assessing any relation. Based on both long-term statistical evidence WHO, (2000) establishes that "women generally have higher rates of obesity than men, although men may have higher rates of overweight." This hypothesis is also

2.2.3 Race and ethnicity

According to York (2004), OECD (2010), there have been significant differences between both average BMI and rate of obesity between various ethnic groups. York (2004) further claims that this is due to "different ethnic groups hav[ing] different proportions of fat-to-lean tissues at equivalent BMIs." Ethnics originating from the Asian continent present with higher risk of chronic diseases and overweight-related mortality at lower BMI levels."(Roemling & Qaim 2012) Similarly, it has been proven that for people of African or Caribbean ethnic origin, risk of developing diabetes becomes significant at a lower BMI threshold compared to Caucasian population. (Resnick et al. 1998) Furthermore, China and Japan have nationally adopted BMI ranges for healthy weight, which differ from the ones proposed by WHO, (2000). (York 2004) Because of this discrepancy, it is appropriate to treat these ethnic groups separately from the Caucasian.

2.3 Socioeconomic dimension

In respect to the societal factors, BMI tends to rely among income classes as well as individuals of different level of education(OECD 2010). Income, for example, plays an important role in individuals choices of type and amount of foodstuff as well as other goods. Lower disposable income of an individual may cause the opportunity cost of healthy diet too high, which is why they choose to consume inferior goods. With an increase, two effects occur. Firstly, quantity of goods consumed increases and secondly, inferior goods are substituted for normal goods. This leads to an estimation of a quadratic relationship between disposable income and BMI conducted by Chou et al. (2004).

Further factors of this theme play role in determining a typical BMI of an individual. For example, information and education also play an important role in this case, which is why a likelihood of obesity is likely to decrease with increasing years of schooling. Similarly, an unemployed individual might exhibit lower BMI, as their opportunity costs of investing time into healthier way of life is lower. (OECD 2010, Mavromaras 2008) Others might argue that unemployment may indicate lower motivation to any sort of activity and therefore increase this indicator.

2.4 Lifestyle dimension

Despite the current trend of tolerance towards obesity in population, it is necessary not to forget it's adverse effects on lives of both individuals and the society. Inversely, it is important to consider how lifestyle affects the presence of obesity. Numerous studies agree on the fact that smoking, drinking, and dietary behaviors associated with unhealthy lifestyle contribute to the overall health status as well as, more specifically, the BMI. Furthermore, changes in such behaviors, may cause additional effects. Chou et al. (2004) for example argues that "relative price change [in cigarettes] may have reduced smoking, which tends to increase weight." Additionally, Mavromaras (2008) applies model of rational choice between an economic good and an economic bad on the decision between additional free time and the negative health effect of a meal alternative.

3 Economic theory

In order to summarize the possible determinants of BMI and propensity to overweight an obesity, three main dimensions of focus including demographics, socioeconomics, and lifestyle are set.

Considering demographics, there were multiple differences among individuals summarized and brought to attention mainly in publications of WHO, (2000) and their working groups. Life-cycle theory of consumption was both directly and indirectly identified to play an important role in BMI, as it is likely to be related to individual's long-term consumption. Furthermore, anatomical differences among earth's populations are well explained by ongoing research from biomedical field.

In respect to socioeconomic disparities, it was identified that individuals from households that accumulate higher human and financial capital tend to be in a better physical state.

Finally, lifestyle is suggested to play important role, as the physical state and overall condition of an individual is suggested to be influenced by the opportunity costs of their activity, which is mostly related to personal values. In turn, these mostly depend on mental health and any consequential coping or malcoping methods.

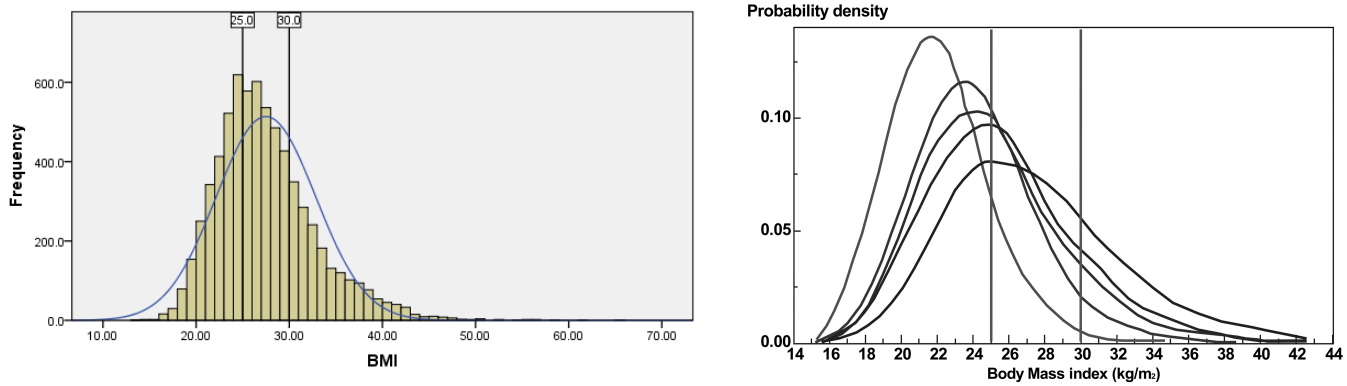
	Property	Variable	±	Values	Theory	Literature
Demographics	Age	age	+	scale	Life-cycle theory: before certain age, individual consumption increases, then it starts to decrease.	Carreira et al. (2012), Roemling & Qaim (2012), Deaton (2005)
		age^2	-	scale		
	Sex	sex	+	1: Male	"Males tend to have higher rates of overweight"	WHO, (2000), Chou et al. (2004)
	Ethnicity	eth_asian	-	1: Asian	Asian ethnics -> different lean-to-fat ratio at same BMI	York (2004), Roemling & Qaim (2012)
		eth_black	+	1: Black	Ethnic minorities are more susceptible to obesity.	OECD (2010), Resnick et al. (1998)
		eth_other	0	0: Caucasian	Other ethnic groups do not differ significantly.	-
	Region	reg_london	-	1: London	Urban population -> walking distance - proxy for active lifestyle	Chou et al. (2004), Mavromaras (2008), NOO (2009)
Socioeconomics	Equiv. Income	$income$	-	female income	healthier lifestyle more affordable. Males show lower interest this matter	OECD (2010), Chou et al. (2004)
		$income \times sex$	+	Male income		
	Education	$edu\_$ dummies	-	bench: below GCSE	Education increases awareness of lifestyle importance	OECD (2010), WHO, (2000)
	Marital	$marital\_part$	+	1: Partnered	Marriage: more tradeoffs between healthy and time-efficient alternative	Hlúbik (2002), Roemling & Qaim (2012), Mavromaras (2008)
	Economic Activity	$emp\_inactive$	+	1: inactive	Unemployed people live lead active life	
Lifestyle	Smoking	cig_q	-	ordinal: quantity of cigarettes; 4 bins (0 - 3)	Method of coping - alternative to overconsumption.	Chou et al. (2004), Sneve & Jorde (2008)
		cig_q^2	+			
		cig_stop	+	1: used to smoke	Cessation of smoking habit -> weight gain	
	Nutrition	$vegfr$	-	scale	Proxy for healthy lifestyle	Mavromaras (2008)

Table 2: Breakdown of theoretical dimensions into analyzed variables and proxies

4 Methodology and Data

The data for analysis provided by this contribution is sourced from the 2011 Health Survey for England database collected and assembled by NatCen Social Research, (2013). The set contains a total of 21 variables, of which 10 are included in this estimation.

The histogram of the data for predicted variable, i.e. BMI is shown in figure 1a, with the bottom cut-off thresholds for the overweight and obese dummy variables at values of 25 and 30 respectively. In comparison to figure 1b, the fitted normal distribution has further progressed following the set trend. It can also be observed that there is a range of extreme cases on the right side of the axis, which will cause mean to be higher than median.



(a) Actual data (NatCen Social Research, 2013)

(b) Over-time trend as illustrated by York (2004)

Figure 1: Histogram of BMI values

Table table 3 displays descriptive statistics for the dependent as well as independent scale variables. Both median of BMI suggests that more than half of the subjects is overweight. The distribution of the age of respondents is positively skewed with minimum at 18, mode between 45 and 50 years of age and maximum at 96. The equivalized income ranges from GBP 271 to GBP 262,000 a year, which provides representative range.

Variable	BMI	age	$income$	$vegfr$
Mean	27.494	49.803	31,575	3.671
Median	26.727	49	22,184	3.333
Minimum	13.551	18	271	0
Maximum	65.277	96	262,300	30
Std deviation	5.338	17.765	2.623	2.633

Table 3: Descriptive statistics for scale variables

For the purposes of model construction, the dimensions introduced in section 3 were broken down into individual variables as detailed in table 2. Appropriate for nominal variables sex, $ethnicity$, $region$, $marital\_status$, $econ\_activity$, and cig_state as well as for the ordinal variable $education$ were created as indicated therein. Furthermore, a slope dummy for separation of relationship between BMI and income in men from the benchmark, i.e. women. Lastly, the scale values in which it is expected to observe a quadratic relationship to the predicted variables need to be squared and saved into different variables for the purposes of the model. Hence, variables denoted as age^2 and $income^2$ are generated. After application of these transformations it is established that a benchmark individual is a single caucasian woman of 0 age, income, and fruits and vegetable consumption, who is employed, lives outside of London and never smoked.

Finally, the model is estimated using OLS method including all independent variables for each of the three dependent variables.

5 Results

The output of linear regression built up through the previous sections is presented in table 4. Column labeled as 1b is of most interest, as it estimates the tested determinants of BMI and hence is the most relevant for proofs of hypotheses set in table 2

Dependent Variable:	**BMI**		**Overweight likelihood**		**Obesity likelihood**	
Formula	1a	1b	2a	2b	3a	3b
Constant	21.422400 0.000	21.416900 0.000	0.043281 0.363	0.026576 0.544	−0.051651 0.251	−0.076307 0.082
Demographics						
age	0.299209 0.000	0.299119 0.000	0.024858 0.000	0.024762 0.000	0.016805 0.000	0.017739 0.000
age^2	−0.002685 0.000	−0.002682 0.000	−0.000206 0.000	−0.000204 0.000	−0.000157 0.000	−0.000166 0.000
sex	−0.360457 0.056	−0.363916 0.054	0.014470 0.390	-	−0.029807 0.061	-
eth_asian	−0.937829 0.000	−0.921693 0.001	−0.054404 0.022	−0.054628 0.021	−0.063333 0.005	−0.061870 0.006
eth_black	1.343390 0.000	1.360070 0.000	0.116851 0.001	0.114769 0.001	0.079386 0.013	0.078301 0.014
eth_other	−0.605047 0.360	-	0.020607 0.727	-	−0.011506 0.836	-
reg_London	−0.710974 0.001	−0.729196 0.001	−0.036886 0.050	−0.037730 0.044	−0.029954 0.092	−0.031097 0.079
Socioeconomics						
$income$	−0.000017 0.000	−0.000017 0.000	−0.000001 0.000	−0.000002 0.000	−0.000001 0.003	−0.000001 0.012
$income \times sex$	0.000020 0.000	0.000020 0.000	0.000002 0.000	0.000003 0.000	0.000001 0.131	-
edu_olvl	−0.774720 0.000	−0.770690 0.000	−0.043303 0.011	−0.035113 0.024	−0.059962 0.000	−0.059604 0.000
edu_alvl	−1.057930 0.000	−1.052320 0.000	−0.071293 0.000	−0.062651 0.000	−0.082576 0.000	−0.083657 0.000
$edu\_someuni$	−0.719759 0.001	−0.718179 0.002	−0.026363 0.190	-	−0.046848 0.014	−0.048129 0.011
edu_degree	−1.710980 0.000	−1.716400 0.000	−0.125488 0.000	−0.115866 0.000	−0.125315 0.000	−0.125496 0.000
$marital\_part$	0.265302 0.060	0.264825 0.061	0.036428 0.004	0.038333 0.002	0.018110 0.128	-
$emp\_inactive$	0.277762 0.079	0.272213 0.085	−0.004220 0.765	-	0.045302 0.001	0.045950 0.001
Lifestyle						
cig_q	−1.165650 0.000	−1.163510 0.000	−0.074299 0.003	−0.035699 0.000	−0.049689 0.035	−0.032510 0.000
cig_q^2	0.224552 0.033	0.224322 0.033	0.014052 0.134	-	0.007590 0.391	-
cig_stop	0.348898 0.016	0.350770 0.016	0.025420 0.050	0.029102 0.023	0.039052 0.001	0.038870 0.001
$vegfr$	−0.044634 0.071	−0.045497 0.065	−0.002774 0.208	-	−0.004676 0.025	−0.004623 0.026
Model assessment						
p(F-statistic)	1.4e-110	3.5e-111	2.7e-122	8.6e-126	1.69e-55	1.69e-57
R^2	0.0809	0.0808	0.0883	0.087	0.0448	0.0440
p(RESET)	0.252	0.208	0.681	0.534	0.010	0.0294
Breusch Pagan	FAIL	FAIL	-	-	-	-
Normality of residuals	FAIL	FAIL	-	-	-	-

Table 4: Resulting set of models

General assessment of the individual models shows that presence of any functional misspecification by the RESET test. Although the independence of the error term is highly significant, the model exhibits very low R^2, which is together with the result of the Breusch Pagan Heteroskedasticity indicative of high likelihood of omitted variables. This is completely reasonable and consistent with the complexity of obesity as a problem.

For the case of the likelihood of overweight and obesity estimates, the heteroskedasticity and Breusch Pagan tests are meaningless due to the binary nature of the dependent variable.

To begin with, the life-cycle theory of consumption is proven to have a significant effect on predicted BMI of an individual. The estimated negative coefficient of age^2 suggest that there is indeed a negative quadratic relationship, while the positive coefficient of age suggests an upward-right shift of the parabola. As demonstrated in figure 2, the function of this effect within the has a local maximum at point A, meaning that all other things constant, the peak BMI of an individual occurs at 55.72 years of age. Furthermore, similar statement will be valid for both overweight and obesity likelihood.

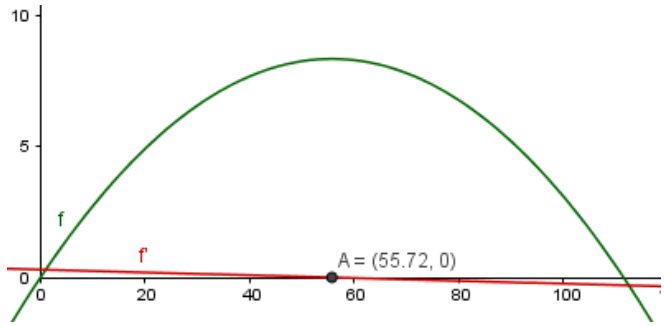


Figure 2: Plot of effect of age within equation 1b

Secondly, the difference in intercept value of BMI between men and women is proven to exist with 90% confidence. While the constant for women was estimated at 21.417, for men, it is by $0.364\frac{kg}{m^2}$lower, i.e. 21.082. This proves that women are more likely to reach higher values than men. Coefficient of the same variable in models 2a however disproves the hypothesis that males are more likely to be overweight, at least in the context of England. Model 3a, on the other hand provides evidence that females are more likely to be obese than men with 90% confidence. This, however, was likely caused by the presence of insignificant coefficient of a cointegrated variable $sex \times income$, removal of which caused this significance to cease existence.

It is however necessary to consider the effect of equivalized annual household income, which seems to not only differ among the genders, but to be opposite. In women, the BMI decreases by 0.017 points with additional GBP 10,000 of income, while for a man, it would typically increase by 0.003 points in result of the same change.

Returning to the demographic theme, particularly the differences among ethnicities, the intercept BMI seems to be lower for population of Asian ethnic origin with over 99.9% confidence, which in addition to research suggestions justifies the use of different classification ranges in China and Japan. On the other hand, people of African and Caribbean ethnic origin have significantly higher intercept BMI, which may, consistently with the theory indicate that they form one of the minorities where obesity needs more attention.

Finally, the coefficient of reg_London, which is highly significant, speaks in favor of the hypothesis that urban population is more physically active due to the availability of factors such as public factors.

In the socioeconomic dimension, an additional level of education is proven to decrease the intercept BMI significantly, with the highest step observed at the GCSE/O-Level qualification as compared to no or grade school qualification. The only exception from this is the group of people who have studied at a university but have not achieved a degree.

Then, partnered individuals are proven to be more likely to be overweight compared to singles with 99% confidence but seem to be just as likely to be obese. For economically inactive people, they are on the one hand exhibit higher BMI on average but less likely to be obese on the other. Unfortunately, this might be caused by inclusion of retired people among them.

Looking at lifestyle dimension, the most notable effect is increased base BMI as well as overweight and obesity likelihood in individuals who have stopped smoking at any point in their life, proving hypothesis of Chou et al. (2004). Furthermore, the quadratic relationship of quantity of cigarettes smoked is estimated with 90% significance, showing some statistical evidence for what Sneve & Jorde (2008) suggested, i.e. that smoking tends to decrease obesity at moderate quantity of cigarettes per day. However, because the data provided for this analysis supports the quantity only in four relatively wide bins, which needs to be understood while interpreting the results. Lastly, a negative effect on BMI of consumption of additional portion of fruits and vegetables daily is proven with 90% significance. Furthermore, the same increase causes obesity likelihood in an individual by 0.4%, which makes it relatively suitable as a proxy for diet that is part of a healthy lifestyle.

6 Conclusions and recommendations

Drawing from the evidence of this analysis, few main conclusions are made that support the universal guidelines of WHO, (2000) prevention and management of the global epidemic of obesity.

One of reasonable steps on the country-level in case of England would for example be an increase in the length of compulsory education to the age of A-level qualification. Although this measure was not in place at the time of collection of the data, it was adopted over years 2013 through 2015 as a part of the Education and Skills Act 2008. (Her Majesty's Government, 2016) Then, further promotion of healthy lifestyle and focus on its affordability is in place, mainly due to the increasing opportunity cost of time and decrease of the real price of ready-made and fast food. (Mavromaras 2008, Chou et al. 2004) Thirdly, should the reaction of BMI on quitting smoking be an increase, appropriate therapy should be provided to individuals who are attempting this change, as it is necessary to give the habit up instead of replacing it with a malcoping method in form of increased calorie intake. (Sneve & Jorde 2008)

On an international level, considering the ethnic differences, focus on populations with increased prevalence of obesity is encouraged. In contradiction to the WHO stance towards the obesity and overweight thresholds, these should be readjusted for each ethnic origin, as there is firstly medical research proving a different health risk at the same BMI in different ethnic origin alongside a strong statistical evidence.(York 2004, Resnick et al. 1998)

It is necessary to mention that in order for regional-level measures to be applied, further focused analyses need to be made in order to find the local causes which might vary. Although all factors that research suggests were found to be relevant determinants of increase in BMI and many of them even appropriate determinants of obesity likelihood, more specific causes need to be found, as the model is inaccurate mainly in predicting extremely high values of BMI. Furthermore, it is recommended to repeat this survey and develop a panel data analysis for purposes of suggestion of effective measures for reduction of rate of obesity and overweight with respect to the dynamics over time.

Ultimately,WHO, (2000) stresses that "Effective management of obesity cannot be separated from prevention." The same collective of authors provides a complex theory on development of effective interventions leading to prevention. Because of the negative quadratic nature of the relationship of BMI on age, the younger generation should be targeted.

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