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Abstract

The last 40 years have seen an alarming increase in obesity rates all around the world. Unhealthy levels of weight gain negatively impact nearly all physiological functions of the body and, on a macro level, weaken the population in the face of other public health issues. Given obesity's ability to significantly increase mortality from COVID-19, identifying potential solutions should receive more attention than ever. Academic research continues to study the relationship between a variety of potential biological, environmental, and socioeconomic causes and rising obesity rates. However, a growing literature is also beginning to examine the impact of social influence on unhealthy behavior in an effort to understand how to take advantage of peer effects in creating potential solutions. This thesis expands on such literature to examine the psychological mechanisms behind such peer effects on healthy behavior by offering an economic model of an interaction between two peers.

The Forgotten Pandemic: A Game Theoretic Analysis of the Role of Social Norms in Obesity

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ABSTRACT

The last 40 years have seen an alarming increase in obesity rates all around the world. Unhealthy levels of weight gain negatively impact nearly all physiological functions of the body and, on a macro level, weaken the population in the face of other public health issues. Given obesity's ability to significantly increase mortality from COVID-19, identifying potential solutions should receive more attention than ever. Academic research continues to study the relationship between a variety of potential biological, environmental, and socioeconomic causes and rising obesity rates. However, a growing literature is also beginning to examine the impact of social influence on unhealthy behavior in an effort to understand how to take advantage of peer effects in creating potential solutions. This thesis expands on such literature to examine the psychological mechanisms behind such peer effects on healthy behavior by offering an economic model of an interaction between two peers.

INTRODUCTION

1.1: Introduction

On March 11, 2020, the World Health Organization (WHO) declared COVID-19 a global pandemic, effectively symbolizing the beginning of what has at this moment been a year-long international battle against lethal viral waves. With its propensity to leave vulnerable portions of the population hooked to ventilator machines and unable to breathe properly, the virus has upended every part of our lives. In allowing COVID-19 to take the spotlight in policy, media, and medicine, however, people have failed to look behind the virus at the vulnerabilities which are able to increase its mortality rate. Society is no longer giving proper attention to the public health crises which have been permeating it for decades and have created an environment ripe for ravaging by such a virus. One of these is obesity, a complex multifactorial disease, the rate of which has increased dramatically since 1980. According to the CDC, being both obese or overweight greatly increases the risk of severe illness and may even triple the risk of hospitalization from COVID-19.[1] Given, not just its crucial role in the fight against the current viral pandemic, but also its countless other deleterious health consequences, a better understanding of the causes of obesity is vital in developing successful prevention and intervention policies.

Obesity is a medical condition defined by the WHO as excessive fat accumulation which may adversely impact health.[2] It usually ensues as a result of a caloric imbalance caused by excess energy intake relative to energy expenditure, and is most commonly defined in terms of a measure known as BMI, or Body Mass Index. BMI is a measure of overall body fatness, found

[1] Kompaniyets L, Goodman AB, Belay B, et al. (2021).
[2] Ogden et al. (2007).

by dividing weight in kilograms over height in meters squared. The standard diagnosis of obesity is a BMI over 30, while one above 25 indicates overweight status.[3] Though the etiology of obesity is a notably complex interaction among biological and environmental factors, it is not clear why obesity rates have risen so dramatically in the last 40 years. An unprecedented level of people in the world can now be considered overweight, a rate which has almost doubled since 1980.[4] Similar upsurge amounts have been found in many countries, across many varied demographic groups which span age, gender, race, region, and socioeconomic status.[5] Biological factors can explain individual differences in weight gain, but it is ultimately socioeconomic factors that must be examined and targeted in order to understand why, as a society, obesity is at an all-time high.

Though myriad researchers have investigated potential social and economic reasons for the rise in the rates of unhealthy weight gain, there are only a handful of papers concerning the impact of social influence. Research does suggest that social networks are, in fact, "clustered by weight."[6] Obese individuals are more likely to be connected to other obese individuals. The purpose of this paper is to expand on the literature concerning the impact of social influence on fitness by providing a behavioral economic model. Before doing so, the paper will provide an overview of the size and scale of the obesity crisis to emphasize its gravity. Section 2 conducts a literature review to outline the various biological, economic, and sociopolitical explanations researchers have identified for the rise in obesity. Section 3 focuses on previous work done to identify the link between social networks and obesity and its impact on policy-making. Section 5 provides a model, along with its results. Section 6 discusses policy implications and concludes.

[3] World Health Organization (2020).
[4] Ogden et al. (2007).
[5] Wright, S. M., & Aronne, L. J. (2012).
[6] Christakis & Fowler (2007).

1.2: Epidemiology

The rates of overweight and obese portions of the population have reached unprecedented levels, and what is most disturbing about this growing health crisis, as pointed out by the World Health Organization, is that it is entirely preventable.[7] According to a 2015 survey done by the WHO, approximately 1.9 billion adults, more than 1/3rd of the world's adult population, are estimated to be overweight, and 609 million of them classify as obese.[8] For the first time in history, the number of overweight people is greater than the number of undernourished, underweight people.[9] According to the WHO, as a result of modernization and economic restructuring, most people now live in countries where obesity has a higher lethality rate than malnourishment and hunger.[10] These rates are nearly doubled from those of 1980, and studies have examined these trends to find an increase amongst most demographic groups, regardless of age, geographical region, race, gender, or socioeconomic status.[11] Childhood obesity has seen similar global increases, with more than 38 million under the age of 5 and 340 million between the ages of 5-19 being overweight or obese.[12]

In the U.S., a 2020 WHO Study found that 71.6% of adults above the age of 20 are overweight, and almost 40% are obese.[13] These rates are already several percentage points higher than the data presented by a 2015 study and is up from the 1980 rates of 45% for overweight individuals and 12.9% for obese individuals.[14] While North America and Europe are the regions with the highest prevalence of obesity, with the European continent seeing similar rates of

[7] World Health Organization (2020).
[8] World Health Organization (2020).
[9] Rosin, O. (2008).
[10] World Health Organization (2020).
[11] Chooi, Y. C., Ding, C., & Magkos, F. (2019); Global Burden of Disease Study 2015. (2015).
[12] World Health Organization (2020).
[13] World Health Organization (2020).
[14] Wright, S. M., & Aronne, L. J. (2012), Ogden et al. (2007).

increase since the 1980's, this crisis is by no means limited to the advanced industrialized countries of the western hemisphere. In Africa, rates of overweight and obesity in this time period have similarly doubled, and are increasing in the West Pacific region as well, according to data collected by the Institute for Health Metrics and Evaluation in Seattle. China, which has overall lower rates, has actually seen the overweight portion of their population triple from 7.9% in 1980 to 29.9% in 2015 and the obesity rates increase by a multiple of 9 in this same time period from 0.6% to 5.3%. While this seems relatively low, the population of China is so large that they actually comprise the greatest net population of obese people in the world.

Though the last ten years has seen an apparent levelling off of obesity levels in developed countries, rates continue to rise dramatically in developing countries, where most of the world's population lives, as they adopt the more sedentary lifestyles associated with industrialization and higher energy diets. An illustration of the public health failure of the current system of most developed countries is how the rates of obesity are much higher in modern-day Eastern Europe than they were before the region adopted democracy and capitalism.[15] Something else of note is that the portions of individuals comprising the highest BMI levels (above 40) have increased proportionately more than those in lower levels.[16] The rates are also generally higher amongst older people and slightly higher on average in women.[17] Data also shows that in developing countries there are higher percentages of obesity amongst higher-income earners, while developed countries see their highest rates among more disadvantaged groups.[18]

The size of this issue cannot be truly understood without outlining the countless adverse consequences it has on the individual and on society. Obesity negatively affects almost all

[15] Rosin, O. (2008).
[16] Wright, S. M., & Aronne, L. J. (2012).
[17] Chooi, Y. C., Ding, C., & Magkos, F. (2019).
[18] Kuczmarski MF, Kuczmarski RJ, Najjar M. (2001).

physiological functions of the body and shortens life expectancy considerably. According to various studies, it increases the risk of mortality from all causes by almost 50%-100%, which has become more visible since the beginning of the COVID-19 pandemic.[19] It also increases the risk of several serious and chronic illnesses, starting with type-2 diabetes, cardiovascular diseases (such as heart attack and stroke which have repeatedly been the leading cause of death in the U.S.), degenerative musculoskeletal disorders (such as osteoarthritis), and several types of cancer.[20] These are only a few of the diseases which show a positive correlation with higher BMI. Studies provided by the WHO also illustrate an association between childhood obesity and premature death and disability in adulthood.[21] For its impact on overall health as well as its detrimental psychological effects, abnormal weight gain significantly lowers quality of life. Its economic cost on governments is quite large as well, given the increased medical costs and lower labor productivity. Several studies found that obese adults in the U.S. under the age of 65 spend about 37% more annually on medical care than their normal weight counterparts.[22] For its critical impact on societal health and economic consequences, governments should more intensely investigate the reasons for this rise in obesity and devise innovative solutions.

[19] Mokdad et al. (2004); Flegal et al. (2005).
[20] World Health Organization. (2020).
[21] World Health Organization. (2020).
[22] Sturm, (2002); Finkelstein et al. (2003); Raebel et al. (2004).

Literature Review

Obesity results from a notably complex interaction among uncontrollable biological factors, such as genetics, and more manageable factors such as one's environment and behavior. Even though obesity rates have recently begun levelling off in high-income countries, no nation has managed to successfully reverse the increase that started in the 1970s. Its complexity has made it very difficult to manage, as certain individuals with biological predisposition are exposed to a lifestyle which, as a result of so many different aspects of modern life, makes them susceptible to a level of weight gain that is detrimental to health. This must culminate from an imbalance between overeating and low energy expenditure, but what is it about modern society that prompts so much more over eating and so much less physical activity than before? Academics in a variety of fields have sought to answer this question, pointing out myriad potential causes which may interact to incite this crisis. In investigating underlying medical reasons or pointing out patterns about modern life and behaviors which seem to coincide with weight gain, scientists and researchers are attempting to identify areas that could be targeted to curtail obesity.

2.1: Biological Explanations

2.1a: Evolutionary Theory

Various scientists have pointed out the mismatch between our current environment and that of our ancient predecessors in order to develop an evolutionary hypothesis to explain the trends in obesity. It is true that, evolutionarily, humans evolved as hunter-gatherers, who were only able to eat when they found food. For this reason, genes were probably selected which coded for the overeating necessary to store fat and nutrients as well as an aversion to energy

expenditure in order to survive during periods of undereating. Those who were better able to store and mobilize energy levels in times of famine had greater reproductive success, leading to an overrepresentation of genetic variants which code for overeating and storing fat in adipose (fat-storing) tissue. Smith (2004) finds that trends in modern life confirm his evolutionary hypothesis, as obesity appears to be "exacerbated by poverty, by food insecurity, by the length of the winter months, and by malnutrition early in life."[23] It is also true that, historically, starvation is a much greater threat than overeating; a reality in which more people die from being overweight than underweight is a very recently developed problem.[24] Society has changed too rapidly in too short of a time for evolutionary adaptations to realign humanity with its environment.

2.1b Genetics & Endocrinology & Neurology

It is genetic susceptibility in the presence of an environment which promotes energy imbalance that often leads to disproportionate weight gain. However, parents influence both inherited traits and behavior, so it is difficult to estimate heritability in many cases. Adoption studies and twin studies are used by various scientists in order to estimate a heritability for BMI of between 40-70%.[25] For example, one study published in the New England Journal of Medicine classified 540 adopted Danish adults into groups according to BMI and found a much stronger relationship with the BMI class of their birth parents than that of their adopted parents.[26] A study of 12 pairs of Canadian monozygotic twins, in which they were fed 1000 extra calories 6 days a week for 100 days, found very similar weight gain patterns within the pairs.[27] Differences

[23] Rosin, O. (2008).
[24] Rosin, O. (2008).
[25] Börjeson, M. (1976); Stunkard, et al. (1990).
[26] Stunkard, et al. (1986).
[27] Bouchard, et al. (1990).

in obesity levels between ethnicities also emphasizes the role genes play in weight gain; for example, in countries like Japan and Vietnam, obesity rates rest below 5% of the population, while some Polynesian and Micronesian islands are seeing rates upwards of 50%.[28]

Certain genes have been identified which code for energy modulation in the forms of food intake and response to satiety. According to Dr. Tahir Omer, a genetic predisposition to obesity may be polygenic, monogenic, or syndromic.[29] A well-known monogenic condition which leads to obesity is a polymorphism resulting in Melonocortin 4 receptor deficiency.[30] More examples include research findings of increased obesity and appetite resulting from mutations in genes which normally code for hunger-inhibiting hormones, such as leptin and leptin receptors, among others, and from carriers of the FTO risk allele.[31] Individuals with decreased levels of leptin, which comes from adipose cells, will have an increased appetite, and dysfunction of adipose tissue is, as a result, also problematic. A few rare genetic syndromes resulting from genetic or chromosomal mutations can also lead to obesity, such as Cohen syndrome, Albrights hereditary osteodystrophy, and Prader-Willi syndrome.[32] Other endocrinological conditions such as Cushing's disease, polycystic ovaries in women, and abnormally low thyroid activity can as well.[33] Epigenetic methylations of DNA due to external factors, such as the maternal diet during pregnancy or usage of certain chemicals, may also be inherited by offspring for generations and explain patterns in obesity heredity as well.[34]

Complex neural networks involving various hormone feedback mechanisms control both appetite and satiety, as well as thermogenesis and metabolism. Some of these systems include the

[28] NCD Risk Factor Collaboration. (2016).
[29] Adam R, et al. (2006).
[30] Adam R, et al. (2006).
[31] Montague, C. T. et al. (1997); Farooqi, I. S. et al. (1999); Clément, K. et al. (1998); Farooqi, I. S. et al. (2000); Gilbert-Diamond, D. et al. (2017); Wardle, J. et al. (2008); Tanofsky-Kraff, M. et al. (2009).
[32] Webb T, Clarke D, Hardy CA, et al. (1995).
[33] Legro, RS. (2012).
[34] Ruiz-Hernandez, A. et al. (2015).

opioid, endocannaboid, and melonocortin systems and the dopamine mesolimbic circuit.[35] If functioning correctly, they should help defend the body against weight gain, so it is when they are disrupted, either due to genetic or external factors, that unusual weight gain may occur. For example, brain lesions or tumors in animals and humans have made apparent the importance of certain parts of the brain on weight regulation. Endocrine disruptors- hormone-disrupting artificial chemicals found in various industrially produced products- may also contribute to obesity by interfering with these complex pathways.[36]

2.1c: Secondary Health Conditions

Some other secondary conditions have also been associated with unhealthy weight gain. For example, one German health survey found high birthweight to have one of the highest correlations with childhood obesity among the factors they examined.[37] Several researchers have pointed out the impact of various commonly prescribed medications on weight as well, such as certain steroids, anti-depressants, and antipsychotics.[38] Even infections can be linked to weight gain, as adenovirus-36 has been shown to cause obesity.[39]

One's biological composition clearly plays a role in inherited traits which influence BMI and metabolism, as both are in large part under the control of the central nervous system. However, these traits are governed by voluntary behavior as well, which can determine whether a genetically susceptible individual will develop obesity.

[35] Richard, D. (2015).
[36] Keith SW, Redden DT, Katzmarzyk PT, et al. (2006).
[37] Beyerlein, et al. (2014).
[38] Aronne, LJ& Segal, KR. (2003).
[39] Pasarica M, et al. (2006).

2.2: Environmental & Economic Explanations

2.2a: Changes in the Global Food System & Food Environment

The obesity pandemic is the result of an imbalance between increased energy intake and decreased energy expenditure, and environmental changes are largely at fault. Modernization and industrialization have induced much of the world to live in environments which make overeating an option by making food more accessible.[40] Throughout history, human societies have been searching for ways to combat hunger and stabilize the food system, while at the same time reducing the energy expenditure required for labor.

The industrial and agricultural revolution of the last century has increased the global food supply to a previously unimaginable level. However, high caloric and fat-laden foods are often easier to produce and thus more accessible and affordable. It was in the 1960s and 1970s that, as a result of policies and new technology, the world saw a considerable increase in the supply of fats and refined carbohydrates.[41] In Britain, for example, one study found that the amount of fat in an average person's diet has increased by over 50% over the previous 50 years.[42] This new profit-driven food industry sought to make money through promoting increased portion sizes, "frequent snacking, and the normalization of sweets, soft drinks and fast food in our daily lives."[43] Over the last 50-60 years, new innovations and appliances allowed this industry to change the way food is being consumed at home. While meals used to be prepared mostly at home, there is now a much greater reliance on more convenient, mass-manufactured food, which has greatly reduced the time cost of eating.[44] Given that many people are struggling to meet the

[40] Wright, S. M., & Aronne, L. J. (2012).
[41] Wright, S. M., & Aronne, L. J. (2012).
[42] Prentice AM, Jebb SA. (2002).
[43] Chan, R. S. & Woo, J. (2010).
[44] Rosin, O. (2008).

increasingly difficult time demands of modern life, especially in urban environments, these products which are easy to prepare are understandably attractive.

These cheaper, mass-produced, and highly caloric foods are not just more affordable but also more accessible, whether via vending machines, fast food restaurants, or grocery stores. A number of studies have found increases in the prevalence of restaurants, supermarkets, and, in particular, fast-food places and hypothesize an association between their prevalence and higher BMI.[45] In fact, one study found that, in the U.S., the number of fast-food restaurants per person doubled between 1972 and 1997.[46] Researchers Lakdawalla and Philipson pointed out that unhealthy weight gain has been in part attributable to an expanded supply of these high caloric, low nutrient foods as a result of agricultural innovation and in part to demand given the changing external factors of modern life.[47]

2.2b: Built Environment

Modernization and technology have brought about, not just changes in the food system, but also alterations in the built environment – our physical surroundings- which demand less energy expenditure. For example, several scientists have connected the obesity crisis with the increasing use of central heating and cooling systems, leading to less energy spent maintaining body temperature.[48] There are also now a vast variety of labor-facilitating devices which can substitute what used to be hours of physical work spent on tasks such as household chores.

Motorized forms of transportation have also been pinpointed as leading to a stark reduction in physical activity globally.[49] One review on the relationship between physical

[45] Chou et al. (2004), & Rashad, Grossman, and Chou, (2006).
[46] Chou et al., (2004).
[47] Lakdawalla, D. and Philipson, T. (2002).
[48] Wright, S. M., & Aronne, L. J. (2012).
[49] Swinburn, B. A. et al. (2011).

surroundings and obesity identified a positive association between high BMI and vehicle miles traveled.[50] The built environment can either work against or with this trend, given that where someone lives can influence travel and commuting choices, as well as leisure activities. Population density is found to be negatively associated with high BMI, while urban sprawl encourages vehicle transportation.[51] Other aspects of the residential environment which have been identified as factors in determining energy expenditure are the quality of public transit, presence of sidewalks, access to parks or recreational activities, the walkability and safety of a neighborhood, and proximity to necessities.[52]

While some scientists, such as Cutler et al., disagree that changing commuting patterns explain rising obesity levels, there is a wide level of consensual blame of general urbanization across studies and papers. For example, Cutler et al. claim that the elements of modern life in the U.S. which have altered transportation occurred well before the 1980s saw its worrisome increase in obesity levels. However, Ewing's conclusion was in fact that "urbanization increased weight" in the U.S. in his study of how the U.S. built environment encouraged an energy misbalance.[53] China's rapid increases in obesity levels have also been attributed in large part to the swift demographic change from rural to urban residents and the increasing use of motorized transportation.[54] Of course, there is a confounding of factors which have come with modernization which makes it different to identify the impact of any individual change, but it is helpful to consider how the interaction between these changes influence fitness.

These technological changes combined with altered preferences for living environment have immensely reduced overall energy expenditure despite increased trends of recreational

[50] Pappas M, Alberg A, Ewing R, et al. (2007).
[51] Zhang Y, Wu W, Li Y, et al. (2014).
[52] Papas M, Alberg A, Ewing R, et al., (2007); Rosin, O. (2008).
[53] Ewing, et al. (2003).
[54] Bell, A. C., Ge, K. & Popkin, B. M. (2002).

exercise in most developed countries.[55] The significance of the environment in fitness is clear when examining genetically alike populations living in different places. Nigerian immigrants living in the US, for example, actually have an average BMI 20-25% higher than their ethnic counterparts living in Nigeria.[56] More evidence of this lies in observation of the Pima Native Americans living in Mexico, who have a much lower rate of obesity than those living in Arizona.[57]

2.2c: Workplace Environment

Again, due largely to technological change, the nature of labor has shifted in ways which reduce overall physical activity. Many of the people who previously might have been employed in mining, manufacturing, or other manual work, are now involved in more sedentary jobs in the service industry, and a variety of studies partially blame this change for rising obesity.[58] Over the last few decades, the demographics of the work force have also shifted, including more women than ever. In fact, one survey found that between 1970 and 1999, the labor force participation rate for women with children under the age of 6 had doubled from 30% to 62%.[59] Anderson points out that this may impact fitness in that mothers have less time to prepare home cooked meals for their children, and the study did find an association but only for lower socioeconomic groups.[60] Longer working hours, which are increasingly demanded by modern life, are also associated in a variety of studies with higher BMIs, given the decreased time for exercise, cooking, and sleep. For example, a study of 4700 working adults in Hong Kong found a

[55] Rosin, O. (2008).
[56] Rotimi, C. N. et al. (1995).
[57] Schulz, L. O. et al. (2006).
[58] Philipson and Posner. (1999); Philipson. (2001); Lakdawalla & Philipson. (2007).
[59] Anderson, et al. (2003a,b).
[60] Anderson, et al. (2003a,b).

significant association between longer working hours and BMI.[62] Thus, changes in the context and composition of the labor market may contribute to a degenerating level of fitness.

2.2d: Poverty & Inequality

One of the most important environmental conditions which contribute to fitness is, of course, the economy; socioeconomic status largely determines the lifestyle one is able to afford. The German Health Interview and Examination Survey found low socioeconomic status to be one of the strongest risk factors for obesity.[63] However, this phenomenon occurs mainly in advanced industrialized countries, given that in lower-income, lesser developed countries food scarcity paired with more physical labor keeps the rates of obesity lower among these groups. In fact, in societies in which food is scarce, being overweight can be considered a sign of affluence. Nevertheless, data from developing countries reveals that, as economies industrialize, obesity occurs first in the state's urban wealthy and then begins to shift with economic growth to lower-income and rural populations.[64] In developed countries, the highest rates of obesity can be found synchronously where there are the highest rates of poverty, and, in the U.S., they are found predominantly among minority and low socioeconomic groups.[65] Inequality itself also seems to be associated with diversity, as societies with heightened disparities in income have higher rates of obesity than those with lower inequality, such as Japan and Scandinavian countries.[66]
The reason behind these trends, as pointed out by Drewnowski and Specter, is that there is an "inverse relationship between energy density and energy cost." Healthier diets are more expensive and as a result less accessible to lower-income groups, so, as Basiotis and Lino point

[62] Ko G, Chan J, Chan A, et al. (2006).
[63] Beyerlein, et al (2014).
[64] Swinburn, B. A. et al. (2011); Monteiro, C. A., et al. (2007); Mariapun, J., Ng, C. W. & Hairi, N. N. (2018); Gebrie, A., et al. (2018).
[65] Drewnowski, A. and Specter, S.E. (2004); Wang & Beydoun. (2007).
[66] Sarget, M. (2009).

out, poorer people are more likely to consume cheaper and more calorie-dense foods.[67] Though prices differ around the world, one Cornell study of U.S. prices concluded that moving to a healthier diet which meets "dietary guidelines" does indeed cost more, and another study in rural South Africa found that committing to healthier food could mean up to 60% higher expenses.[68] Obesity actually often coexists with food insecurity, and the relative prices of food products are the main reason for this correlation. However, another reason, at least in the U.S., as Sallis and Glanz pointed out, is that lower-income neighborhoods often have less access to recreational spaces and facilities as well as to supermarkets supplied with fresh and healthy produce.[69] Regardless, it is clear that, at least in developed economies, low socioeconomic status positively coincides with unhealthy weight gain.

2.3: Social & Behavioral Explanations

2.3a: Habits & Behavior

Behavior may in one part be encouraged and shaped by uncontrollable aspects of the environment, but it is also an individual choice, which can be purposefully altered. For this reason, it is relevant to note distinctive habits which are associated with weight gain and distinct from the context of a built environment or socioeconomic situation which might encourage them. Sedentary behavior, for example, is increasing in many countries, with one study citing that "less than half of U.S. adults engaged in recommended levels of physical activity in 2005."[70] Of course aspects of one's environment may encourage this behavior, such as less access to recreational facilities, but it is also an individual choice. Television consumption and its

[67] Basiotis& Lino. (2002).
[68] Ranney & McNamara. (2002); Temple NJ, Steyn NP, Fourie J, et al. (2011).
[69] Sallis & Glanz. (2006).
[70] Centers for Disease Control and Prevention. (2007).

sedentary nature is also being linked to rising obesity rates in many studies. One study of more than 8000 children in the U.K. found time spent watching television to be one of the strongest factors correlated with obesity.[71] Large amounts of time spent playing video games or surfing the internet is similarly a subject of concern among researchers focused on childhood obesity.[72]

The same study of 8000 UK children also found short sleep duration (at the age of 3) to be among the highest correlates with childhood obesity.[73] The importance of sleep both in general and in the specific context of body weight is noteworthy; lack of sleep can ultimately disrupt neural functioning due to a resulting hormonal imbalance.[74] The inverse relationship between sleep duration and body weight has been found in countless studies around the world. One such study also pointed out increased feelings of hunger and appetite in participants with less hours of sleep.[76]

In 1964, the US Surgeon General introduced the beginning of a decades-long campaign against smoking and the US government instituted its first tax on cigarettes; since then, smoking has steadily decreased. However, it is in these same years that obesity rates have shot up, leading many academics to associate the two. Various studies do point out that smoking does indeed suppress appetite, and that smokers weigh less on average than non-smokers.[77] The toxins in cigarettes may also affect body weight by "altering insulin homeostasis, lipoprotein lipase activity, the activity of the sympathetic nervous system, physical activity, and preferences in food consumption."[78] Rashad et al. measured price effects to find that BMI in females was

[71] Reilly, J. J. et al. (2005).
[72] Andersen RE, et al. (1998).
[73] Reilly, J. J. et al. (2005).
[74] Vorona R, et al. (2005).
[76] Spiegel K, et al. (2004).
[77] Stamford et al. (1986); Williamson et al. (1991); Wright, S. M., & Aronne, L. J. (2012).
[78] Williamson et al. (1991).

indeed responsive to increases in cigarette taxes, leading to their conclusion that decrease in smoking habits over time did in fact have a hand in rising obesity rates in the US.[79]

2.3b: Food Marketing & Eating Habits

Situational and environmental factors in our modern lifestyles do encourage increased food consumption, especially of convenient, but unhealthy food products. However, buying this food is also a choice, and even with increased information from, for example, nutrition labeling, consumers are still making the choice to purchase unhealthy items. Econcomist Lisa Moncino points out that the average American does care about eating healthy but the effect of immediate gratification in the presence of time pressure and hunger often is stronger.[80]

Another reason for this contradiction may be the manipulative marketing techniques of the food industry, which now uses targeted neuroscience to influence buyer choice and enhance profits. Advertisements of products high in fat and sugar targeted at children are cited as having a high association with childhood obesity. A meta-analysis of randomized trials concluded that children's dietary preferences for obesogenic foods and beverages increase during and for a short while after watching advertisements for them.[81] Another 2015 study by Chou et al. also found fast food advertising to be positively correlated with BMI in children.[82] Since the 1970s, marketing has become more targeted and more strategic, and the food industry has switched to spending a majority of their marketing budgets on in-store marketing, as people are more likely to make impulsive purchase decisions in the store.[83] Another marketing technique involves the idea that before industrialization allowed for unhealthy manufactured salts and sugars, these

[79] Rashd, et al. (2006).
[80] Mancino, L. (2003).
[81] Sadeghirad, et al. (2016).
[82] Rosin- Chou et al 2015
[83] Cohen & Lesser. (2016).

flavors signified nutritional value. Companies use a variety of complex strategies that are not easily recognizable, such as social and chemical signals which appeal to our evolutionary instincts for safe and nutrient-dense food.[84]

2.3c: Education

Education impacts obesity rates in multiple ways. On the one hand, health education does lower one's probability of being obese, according to Rosin's behavioral economic model.[85] Another study found that policies targeting education as an informational tool to help lower obesity are in fact able to lower rates.[86] On the other hand, schools are also the environment in which children spend the largest part of their day, and a large fraction of students eat school-provided lunches. However, as pointed out by Rosin, few of these lunch programs regularly meet nutrition requirements.[87] A study of a group of children by Whitmore in 2004 found that students who brought their own lunches from home were in fact slightly less likely to be obese.[88]

2.3d: Policies

A variety of policies put in place since the 1960s are pointed out in the literature as having had an impact on rising obesity levels in the US. One category of these are the anti-smoking intervention policies which have already been mentioned. Another is a series of agricultural subsidy policies instituted in 1970s to combat hunger by increasing and stabilizing the food supply which have contributed to the over-abundance of cheaper, less nutritious foods.[89]

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[84] Rosin, O. (2008).
[85] Rosin, O. (2008).
[86] Loureiro, M. L., & Nayga Jr, R. M. (2004).
[87] Rosin, O. (2008).
[88] Whitmore, D. (2004).
[89] Wright, S. M., & Aronne, L. J. (2012).

The program which has come under the most scrutiny recently is the one associated with the Food Stamp Act of 1964. This law guarantees some minimum level of food consumption for those under a certain income level and makes the monetary cost of food for them zero, which could encourage over-consumption.[90] The other issue is that only certain food products are made available for purchase with food stamps, many of which are cheaper, more easily manufactured goods. In fact, Wilde et al. 1999 found that American children partaking in these government food programs were not meeting dietary recommendations for nutrient groups.[91] Various other studies have investigated and found a positive association between food stamp participation and obesity, with one concluding that it increased obesity between 6.7% and 13.5% in low-income women.[92]

[90] Baum, C. & Chou, S. (2011).
[91] Wilde, et al. (1999).
[92] Gibson. (2003); Chen, Yen, & Eastwood. (2005); Meyerhoefer & Pylyphuck (2008); Baum (2011).

The Influence of Social Networks

The role our communities play in our behavioral choices extends far beyond just the built environment; the people in them define a culture which sets social norms and expectations. Different behavior is elicited from a rural small-town community than from an urban one, and even social networks within the same city may see different sets of norms and cultural beliefs. Culture and social networks influence social standards such as body type norms and eating behavior norms. One paper by the Brookings Institute pointed out that two other social pathways which may impact obesity include social capital, or the "resources, information, and people accessible through a social network" and social stress "generated by social relations or hierarchies."[93]

A number of studies have begun investigated the impact of norms concerning body type and eating habits on overall fitness levels within social networks. Anomaly's essay in *Public Health Ethics* argues that obesity cannot be considered a symptom of social contagion as smoking is, given that obesity is not regarded as attractive.[94] The paper points out evidence from studies of obese people being discriminated against and even one study which claims that people are biologically wired to regard extreme weight levels as unattractive.[95] However, in many food-insecure societies in which starvation was a threat historically, being overweight was actually a symbol of affluence, health, and prosperity and being thin signaled poor health and malnutrition. In some cultures, women were even actually plumped up before marriage in order to find a good mate.[96] Even today in some poorer countries and in places like the Polynesian islands, being

[93] Hammond, R.A. (2010).
[94] Anomaly, J. (2012).
[95] Miller, (2001) & Puhll, (2011).
[96] Lundborg, P., Nystedt, P. & Lindgren, B. (2007).

overweight is considered more beautiful, so the obesity rate is much higher there.[97] Intervention policies in these places have been less effective because they often attempt to alter the inherent norms and ideas about beauty.[98]

Several recent studies measure the impact of body norms on weight distribution and perception in given groups in the US. One such study by Brown et al. measured the weight distribution of a group of grade school children in Texas and then surveyed self-perceptions of their fitness.[99] Their logistic regression found that the students whose grade-level specific 85th percentile BMI was higher were more likely to underestimate their own weight. Another study wanted to discern how body norms have changed with increasing obesity rates in the US.[100] They found evidence of a generational shift in body norms between the periods of 1988-1994 and 1999-2004. There was a decreased likelihood of classifying oneself as overweight in the later period despite overall rising levels of obese and overweight Americans.

Other studies attempt to identify the relationship between social influence and eating habits. Salvy *et al.*, for example, paired 72 individuals of different BMIs to eat in a laboratory setting and found that overweight participants paired with overweight partners ate more than those paired with non-overweight people. Another study examined whether people would choose a healthy snack or an unhealthy snack following being told what a previous person chose. Choices were most often consistent with that which they believed others had chosen.[101] These provide evidence of the way social norms change our perception of appropriate eating behavior.

The people we surround ourselves with influence us. There is ample evidence of this in patterns of weight gain and fitness, and a variety of studies have attempted to quantify it. A

[97] McCabe, M. P. et al. (2011).
[98] Hardin, J., McLennan, A. K. & Brewis, A. (2018).
[99] Brown et al., (2009).
[100] Burke et al., (2010).
[101] McFerran et al., (2010).

social experiment performed by Ludwig et al. found that moving residents of a low-income neighborhood with a high incidence rate of obesity to a higher-income one actually reduced the level of extreme obesity in the subjects. The results display the importance of the built environment in combination with the social network. There is a significant correlation between parental obesity and high BMI in their children, and while there is a genetic component to this, heredity explains only a fraction of it.[102] One study which evaded biology altogether by examining friends and partners was Christakis and Fowler's famed study evaluating a social network of more than 12,000 people over a period of 32 years as a part of the Framingham Heart Study. Their model controls for both genetic components and the possibility that obese people may choose to consort among themselves by controlling for an ego's previous weight status. The results found that a person was 57% more likely to also become obese in a given period if his or her friend did so too. There was also a 37% increase in likelihood if one's spouse became obese.[103] The mechanism of this effect is most likely due more to change in one's perception of general body type norms rather than behavioral imitation, though both play a role. Their findings of the greater importance of social distance over geographical distance on resulting weight gain patterns even suggest a common environment to be subordinate to social influence. Christakis and Fowler conclude their study by proposing that both good and bad behaviors can spread through a social network and public health policy should harness this social power to slow the spread of obesity. Studies have in fact found greater success in smoking, alcohol, and weight-loss intervention programs which alter one's social network by providing peer support.[104]

[102] Reilly, J. J. et al. (2005).
[103] Christakis, N.A., Fowler, J.H. (2007).
[104] Wing RR & Jeffery RW. (1999); Malchodi CS, et al. (2003); McKnight AJ & McPherson K. (1986); Wechsler H, et al. (1995).

Agent-based models, which are often used to understand the spread of infectious disease, can computationally simulate an "artificial society" to study the interaction between individual decision-making and population-level influences and outcomes.[105] This method is now being applied to the interaction between social influence and obesity. One such model by Zhang and his colleagues used the BMI data from a school with n= 624 agents.[106] Their results showed the effect of peer influence on weight to usually be negative, except in the presence of a group with a higher underlying BMI distribution, which turned it positive. The study's conclusion was thus that interventions should seek to strengthen social networks, but only when the overall obesity distribution is low.

Another economic model by Trogdon and Allaire quantifies the benefit of using "information about the social network" in targeted anti-obesity intervention and policy design.[107] This model assumes that people form social networks which end up clustered by weight using two mechanisms- by impacting their friends' weights and habits with their own, as Christakis and Fowler found they do, and by tending to choose their friends based on weight. Their results communicate the effectiveness and importance of collecting and considering information about a social network in obesity intervention policy design. They were able to show how much the effectiveness of a "population-level intervention" is determined by the underlying social network, with the likelihood of a successful reduction in obesity rate improving the more strongly that network is clustered around weight. They also conclude that using the most popular agents in a social network for an intervention culminates in more effective weight-loss results in the entire group. This paper speaks to the social multiplier effect- policies will have a larger

[105] Shoham et al. (2015).
[106] Zhang et al. (2015).
[107] Trogdon, J. G., & Allaire, B. T. (2014).

impact on the aggregate than on any one individual given the peer influence on weight gain.[108] The impact of such an effect is significant, given a previous model had concluded that even small social multipliers could alter weight distribution in the population.[109] Social networks should be taken advantage of both in the design phase of policy-making and in calculating the benefit of interventions and programs.

[108] Glaeser, et al. (2002).
[109] Burke, M.A., Heiland, F., (2007).

Game Theoretic Model

5.1: Description

In order to take advantage of social networks to improve policy design, it is helpful to understand the mechanisms through which social forces may influence fitness. While many studies suggest a few possible pathways in their conclusions, they have not based their models on surmised psychological reasons for peer influence. I will do so by creating a dyadic model of how two rational actors may interact. This is just one small component of an overall network, but hypothesizing the mechanisms by which any two people may influence each other's habits and desire for fitness forms the basis for understanding the higher level social impact on a population. Our two players may be coworkers, friends, roommates, partners, or in any other situation which may bring people to repeatedly interact; they are agents in a larger social network.

Of course, there are uncontrollable situations which play into weight gain and health, the main one being the speed at which the body regulates energy expenditure. The basal metabolic rate (BMR) is the amount of energy expended in maintaining the body's functions at rest. Some other forms of energy expenditure, such as the energy required for breaking down food, are also controlled by the central nervous system. Some people's bodies metabolize energy quicker than others, allowing them to consume more calories or engage in less physical activity while maintaining fitness. The speed of this process is largely determined by genetics and other endowed traits such as height, age, and gender. For this reason, the players will be given either a fast or slow metabolism and combined into 3 games to examine how these uncontrollable factors may influence the payoffs from eating healthy or unhealthy in the presence of one another. This is based off of Zhang's model, which suggests that the underlying weight distribution determines

the direction of the relationship between peer influence and weight gain. However, whatever genetic predisposition a person may have to obesity, it is voluntary behaviors and choices that ultimately impact fitness, and the game acknowledges this.

Though there are a variety of choices people make each day which impact fitness, for simplicity, these decisions will be encompassed in and represented by two specific options- to eat healthy or to eat unhealthy. If a person with a fast metabolism chooses to eat healthy, he or she will end up "fit." However, if that person chooses to eat unhealthy, his/her outcome will be "neutral", rather than "unfit," given his/her greater biological capacity for fitness. On the other hand, a person with a slow metabolism who chooses to act in the interest of good health will become only "neutral," and, as a result of an unhealthy choice, he or she will be "unfit." These simultaneous games surmise how two people of similarly fast or slow metabolism or of different metabolisms may influence each other to understand the power of peer impact on fitness behavior.

5.2: Table of Payoffs

Metabolism	Choice	Fitness	Other Player's Fitness	Payoff
Fast	Healthy	Fit	Unfit	5
Fast	Healthy	Fit	Neutral	6
Fast	Healthy	Fit	Fit	4
Fast	Unhealthy	Neutral	Unfit	3
Fast	Unhealthy	Neutral	Neutral	2
Fast	Unhealthy	Neutral	Fit	1
Slow	Healthy	Neutral	Unfit	5
Slow	Healthy	Neutral	Neutral	4
Slow	Unhealthy	Unfit	Unfit	6
Slow	Healthy	Neutral	Fit	1
Slow	Unhealthy	Unfit	Neutral	3
Slow	Unhealthy	Unfit	Fit	2

5.3: Understanding the Payoffs

Most rational people generally prefer being fit rather than unfit, given the vast physical and psychological benefits. However, the conscious sacrifices required for a strategy which achieves a higher level of fitness, such as eating healthier or engaging in more exercise, may decrease the payoffs one gets from achieving such an outcome. As noted in the studies mentioned above, peer influence also plays a role in how much someone values fitness and the amount of effort people will be willing to make to engage in healthier habits.

A new and bountiful literature is emerging on the topic of homophily in social networks, focusing on the idea that, as McPherson and his colleagues put it, "similarity breeds connection."[114] This mechanism for friend selection is now being studied in relation to obesity as well. One such social network analysis studied how obesity structures friendships among young people and did in fact conclude that homophily plays a role, especially in the avoidance of overweight friends.[115] Another controlled experimental study by MIT scientists examined the spread of healthy behavior through a social network to find that homophily greatly increased its adoption.[116] It also found that similarities with a friend especially strengthen adoption of healthy behavior on a dyadic level, such as that of this game. One downside to this phenomenon is that those who are the most unfit are probably the least likely to be able to leverage this benefit from strengthened social influence, given that they are more likely to exclude themselves from interaction with healthier individuals. This particular experiment also concluded that the behavior of obese individuals is more influenced by those similar to them than average, indicating greater dependence on their social networks in decision-making. Homophily, in

[114]McPherson, M., Smith-Lovin, L., & Cook, J. M. (2001)
[115] Schaefer, D & Simpkins, S. (2014).
[116] Centola, D. (2011).

combination with normative influences and behavioral imitation, contributes to the impact of social influence on behavior.

In the payoffs indicated above, a person with a naturally faster metabolism will always engage in healthy choices, because he or she prefers to be fit. This is because, at least within the context of this simple game, the level of effort required by a strategy which achieves the highest level of fitness is relatively low, and any person he will interact with thereafter will be as fit, or less, fit than him. This person will always value being fit enough to offset the sacrifices which might come from achieving it. He will always prefer to be at least as fit as his peer, and will get the greatest outcome from interacting with someone who is actually slightly less fit, but not completely unfit, given that the principle of homophily indicates desire to be around those similar to us. This hypothesis is supported by the Better-than-Average Effect of Social Comparison Theory, which states that people commonly tend to make slight downward comparisons in order to perceive themselves superior to their average peer.[117]

Similarly, a person with a slow metabolism will prefer to end up with a neutral level of fitness, which is his best possible outcome from choosing healthy behavior, rather than becoming unfit. This person will usually get higher payoffs from making healthy rather than unhealthy choices, but only when the person with whom he or she is interacting is of the same or of a lesser fitness level. One must also consider that a person with a slower metabolism has to exert more of an effort for this higher level of fitness, such as dieting or engaging in physical exercise; in some cases, this may not seem worth it. His payoff is particularly low when making the effort to engage in healthy behavior but interacting with someone who is fit, which is unattainable for a person with a slower metabolism. Another exception is the high payoff this person can get from

[117] Alicke, M. D., & Govorun, O. (2005).

choosing unhealthy behavior while being paired with a similarly unfit peer. This is assumed because of the effect of homophily inducing social contagion of behavior among the pair and a skewed understanding of body type standards towards acceptance of a higher BMI. Because of this, being fit in this case would be valued less, and the benefits of unhealthy choices, such as less food preparation time, better taste, and saved money, lead to a higher outcome.

5.4: Model

A. Nature gives both players fast metabolisms

		PLAYER 2	
		Eat Healthy	Eat Unhealthy
PLAYER 1	Eat Healthy	4,4	6,1
	Eat Unhealthy	1,6	2,2

B. Nature gives both players slow metabolisms

PLAYER 1 \ PLAYER 2	Eat Healthy	Eat Unhealthy
Eat Healthy	4,4	5,3
Eat Unhealthy	3,5	6,6

C. Nature gives Player 1 a fast metabolism, but Player 2 a slow one

PLAYER 1 \ PLAYER 2	Eat Healthy	Eat Unhealthy
Eat Healthy	6,1	5,2
Eat Unhealthy	2,4	3,3

5.5: Discussion

The first game- two players with fast metabolisms interacting in a dyadic relationship- results in an equilibrium in which both will make healthy choices and end up "fit," given that one does not want to be less fit than the other. They are also both able to achieve high levels of

fitness with relatively little effort. This equilibrium makes sense given previous empirical studies as well, since Zhang's study showed that a social network with lower weight distribution levels will negatively impact weight gain.[118] Healthy peers will continue to influence each other's behaviors and have similar fit body norm standards.

The second game between two players with slower metabolisms has two equilibria; one in which both engage in healthy behavior and one in which both do not. If one decides to be healthy, the other will be encouraged to do so too, and the previously mentioned MIT study on the power of homophily supports this idea.[119] Intervention programs should seek to harness social power to keep unfit groups at the healthier equilibrium and discourage unhealthy behavior. Changing the behavior of specific agents in a social network or altering body norm standards to make it seem that people will start changing can make the greatest difference.

The third game models how people with different capacities for weight gain and fitness will interact with one another, again on a dyadic level. The game reaches the conclusion that a person with a fast metabolism interacting with someone with a slower metabolism will always make healthy choices. By doing this, Player 1 will always be fitter than his or her peer and with a relatively lower amount of effort. Player 2, on the other hand, will not gain enough from exerting the effort needed to make healthier choices, because he will never be as fit as his peer. This demonstrates the lack of motivation people with low levels of fitness may have to begin changing their habits, especially within a naturally dissimilar peer group. The MIT study again supports this equilibrium with its results about the significant impact of homophily on adapting behavior change, especially with obese people.[120]

[118] Zhang et al. (2015).
[119] Centola, D. (2011).
[120] Centola, D. (2011).

Conclusion

Simple behavioral models such as this one are useful in the policy design process and in understanding its implications. There is an endless amount of collected data available about past choices and their aftermath, but making a policy change in the present requires considering models of human behavior, such as the one I have provided. From here one can consider how people's choices will differ as a result of a possible change in the environment or in the set of available actions. For example, in a country with a threateningly high obesity rate, a government might consider changing or removing food options, by perhaps subsidizing healthier food products or taxing, or even prohibiting, unhealthier ones. According to the social multiplier effect, once one person is incentivized, more and more people will follow along. This is one way to keep such a country's generally unfit society at the healthier equilibrium in which citizens are driven to it by a combination of price and peer incentives. From altering elements of economic models to illustrate their intended policies, leaders can consider what behavior people will thereafter resort to.

In seeking to curb this growing public health crisis, leaders should leverage the evidently strong peer effects by targeting specific agents within social networks and leveraging the current power of social media. Considering the underlying distribution of a social network is also important, however, in leveraging the benefits and evading the drawbacks of homophily. The game finds multiple equilibria when two players who have less capacity for fitness interact. Interventions can attempt to target or bring together groups with similarities in order to enhance the degree of social influence in improving fitness and use incentives to keep such peer groups at a healthier equilibrium. One might believe that bringing together dissimilar groups will result in more positive behavior change by the making less fit members view the condition of their

healthier peers as more attainable. This game and the MIT paper on homophily find this to be an inefficient solution.[121] Peers should only differ, if they do, to a small degree. Something that can be empirically tested in the future is whether combining peers who differ in fitness but share some other unrelated similarity increases adaptation of healthier behaviors related to fitness as well.

A common argument against using game theoretic models is the criticism of economists' assumption that people are rational decision-makers. It is true that we are not always rational, especially when partaking in behaviors obstructive to health and well-being. However, people are a confluence of both unconscious and conscious choices which they make knowing the likely results. Conscious choices constitute a large reason for the culmination of our fitness outcome. Even though mechanisms such as peer effects and preferences often operate on a subconscious level, economists attempt to understand and potentially alter conscious behaviors and choices. These models can help policy-makers rationalize how incentives combine to inform a conscious choice, even if it may not be rational at first glance.

As obesity rates continue to rapidly increase, especially in developing countries, policy-makers should alter features of our modern environments to discourage unhealthy choices. Economic models can help them understand what to alter and how people will react to a change, and this model emphasizes the necessity of considering the role and taking advantage of social influence.

[121] Centola, D. (2011).

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