A Longitudinal View of the Relationship Between Social Marginalization and Obesity

Andrea Apolloni[1], Achla Marathe[2], and Zhengzheng Pan[2]

[1] Institut des Systèmes Complexes Rhône-Alpes(IXXI),and Laboratoire de Physique, École Normale Supérieure de Lyon 5, rue de Vercors, 69007 Lyon, France.
andrea.apolloni@ens-lyon.fr

[2] Network Dynamics and Simulation Science Laboratory, Virginia Bioinformatics Institute, Virginia Tech, Blacksburg, VA 24061, USA.
{amarathe, zzpan}@vbi.vt.edu

Abstract. We use 3 Waves of the Add Health data collected between 1994 and 2002 to conduct a longitudinal study of the relationship between social marginalization and the weight status of adolescents and young adults. Past studies have shown that overweight and obese children are socially marginalized. This research tests (1) if this is true when we account for the sample size of each group, (2) does this phenomenon hold over time and (3) is it obesity or social marginalization that precedes in time. Our results show that when the sample size for each group is considered, the share of friendship is conforming to the size of the group. This conformity seems to increase over time as the population becomes more obese. Finally, we find that obesity precedes social marginalization which lends credence to the notion that obesity causes social marginalization and not vice versa.

Keywords: Obesity, friendship, social marginalization, causality, Add Health

1 Introduction

Obesity has become a global epidemic. According to the World Health Organization (WHO), there are one billion overweight adults and at least 300 million of them are obese. The national health care cost projections show that by 2018, 21% of the health care spending will be on weight related medical bills, costing the nation $344 billion [12]. Studies have shown a positive relationship between childhood weight and adult weight, diseases, and mortality [5]. In the last three decades, the prevalence of obesity has at least tripled among children in the US, which has become a major public health concern.

The forces driving the obesity epidemic are multiple and complex. A complicated interplay of behavioral, environmental, social and economic factors is associated with weight gain. For example, social marginalization and peer rejection tend to increase sedentary behavior, reduce active leisure activities and encourage eating out of boredom. Adolescents and young adults often form peer

groups around shared behaviors such as watching TV, eating out, playing sports or video games etc. which often has either a direct or indirect effect on the weight status [13]. This homophily in behavior is likely to result in homophily in terms of the weight status. At the same time, researchers have shown that obese people form clusters with other obese people and this homophily in BMI (Body Mass Index) can cause homophily in behavior [3, 4, 7]. This clearly implies that the relationship between BMI, the behavior that leads to high BMI and social marginalization is complex and intertwined.

Previous studies have shown that overweight children and adolescents are often not favored in their social networks resulting in their social marginalization [11]. In this research, social marginalization is measured by the number of friendship links an individual has. These links are split by the BMI status and adjusted for the sample size in each category to account for the fact that fewer friendship links with overweight and obese may occur because there are less of them in the data. We also consider the role of race and gender in assessing individuals' tolerance of the friends' weight status [10, 2].

This research uses longitudinal data on friendship network from the National Longitudinal Study of Adolescents Health (Add Health). It compares the average number of friends a group (identified by race, gender and BMI) has to the sample size of the group to capture the bias in friendship links. This comparison is performed on individuals that are present across the 3 Waves to get a longitudinal view of the bias. The friendship data and BMI status for the 3 Waves is further used to extricate the causality relationship between social marginalization and obesity. The aim is to determine if social marginalization causes obesity or if obesity causes social marginalization among adolescents and young adults.

2 Data Description

Information about individual weight status and friendship network is obtained from the Add Health data [9]. This national longitudinal survey on adolescents started in 1994-95 and followed the same cohort from adolescence into young adulthood. Wave I and II data were collected in 1994-1996 and Wave III data were collected in 2001-2002. This study uses longitudinal data on 20,502 survey respondents who were present in all 3 Waves.

The survey collects data on respondents' physical, educational, and economical status, together with their friendship network. In each Wave, each respondent was asked to nominate 5 male and 5 female friends. Each nomination creates a directional link in the friendship network between the ego and the nominated person.

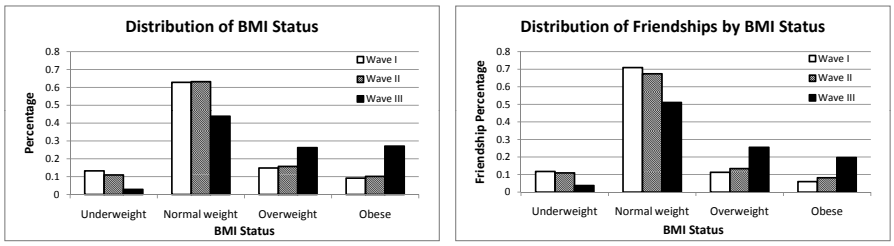
In this study, any two individuals are called "friends" when each individual nominates the other as his/her friend. This mutual-nomination measure of friendship differs from other notable research on this topic where friends are measured as the number of friendship nominations or the in-degree measure [11]. The reason for choosing mutual friends as the measure, as opposed to in-degree, is that studies have found that adolescents nominated by overweight and obese individ-

uals as friends are less likely to reciprocate the nomination as compared to the friends of the normal weight adolescents. Out-degree measures the self-reported friendship ties which is known to provide inaccurate number of friends [1]. This means both in-degree and out-degree can provide a biased view of the friendships since reciprocity is often missing among the friends of the obese individuals. Therefore we resort to bi-directional nominations to get a more realistic view of the friends.

3 Methodology

3.1 Weight Assessement

We use Body Mass Index (BMI) as the indicator of an individual's weight status. BMI (in kg/m^2) is defined as the weight in kilograms divided by the square of height in meters. We categorize an individual's BMI status into 4 classes i.e. 1 = underweight (BMI $<$ 18.5); 2 = normal (18.5 $\leq$ BMI $\leq$ 24.9); 3 = overweight (25 $\leq$ BMI $\leq$ 29.9); and 4 = obese (BMI $\geq$ 30) [6].



(a) BMI status (b) Friendship by BMI status

Fig. 1. Distribution of BMI status and friendships for Wave I, II, and III

Figure 1 shows the distribution of BMI status and friendships by BMI status for all 3 Waves. The comparison between Figure 1(a) and Figure 1(b) reveals the following findings. First, the normal weight people make the most friends in all 3 Waves. They are also the biggest group in all 3 Waves. Their share of friends is higher than the percentage of their BMI group, which suggests that they are indeed popular, although this difference declines over time. Second, underweight group has the most conforming share of friends since Figure 1(a) and Figure 1(b) have almost the same fractions for this group. In other words, they are neither favored nor discriminated against in the social networks. Third, overweight and obese individuals have less friends than the percentage of their sample. However, note that in Wave III, as there are more overweight individuals in the population, they also make more friends and the share of friends is roughly equal to the percentage of the group. This shows that social marginalization of

the overweight adolescents decreases as the percentage of overweight population increases.[1]

3.2 The Friendship Matrix

Next, we build a friendship matrix deduced from the mutual friendship nominations as given in the Add Health data. In this matrix, each row shows the distribution of friends across various classes for the row index, where the index represents a group.

For example, suppose we have a row for the underweight group and this group makes 100 friends total. Then the numbers in the row imply that 25 of these friends are underweight, or of BMI status 1; 50 are of normal weight; 15 are overweight; and 10 are obese.

	1	2	3	4
1	0.25	0.50	0.15	0.10

To further understand how each BMI status class performs given its sample size in the Add Health population, we take the friendship data and split it by race, gender and BMI status. We use a 3-digit system to categorize individuals. The first of the 3-digits shows the race of the individual which ranges from 1 to 5: 1 = White; 2 = Black; 3 = Asian; 4 = Native; 5 = Other. The second digit shows the gender and takes value 1 for male and 2 for female. The third digit is the person's BMI status which ranges from 1 to 4 as mentioned earlier: 1 = Underweight; 2 = Normal; 3 = Overweight; 4 = Obese. For instance, a category of 314 refers to the group of obese Asian boys, and 422 refers to the group of normal weight Native girls.

A complete friendship matrix has 40 rows and 40 columns for each of the 40 race-gender-weight categories, which is very hard to read. Therefore, to summarize the popularity of a race-gender-weight group, we use the average of each column. For instance, the following friendship matrix of 3 categories shows that the normal weight white boys (112) are the most popular with an average percentage of friends of 0.667 and the overweight white boys (113) are the least popular with the column average of 0.15. In the middle, the average percentage of friends made with underweight white boys (111) is 0.183.

However, this friendship matrix can provide a biased view if we do not account for the size of each group in the population. In order to understand this relationship better, we calculate the distribution of race-gender-weight categories as a reference. If there is no discrimination, then the average share of friendship of each category should be equal to the distribution of that category. For instance, assume that in the example shown above, there are 20% boys in category

	111	112	113
111	0.35	0.60	0.05
112	0.15	0.75	0.10
113	0.05	0.65	0.30

	111	112	113
avg	0.183	0.667	0.15
distri	0.20	0.60	0.20

[1] Note that Wave I and II data are not too different, since the data for the first two Waves were collected in quick succession (i.e. between 1994-1996) which probably did not allow enough time for variables such as BMI and number of friends to change significantly.

111, 60% in category 112, and 20% in category 113, then we see that both underweight and overweight white boys are not favored as friends (i.e., avg < distri), the overweight boys, even more so.

Figures 2 and 3 show the average share of friends and the size of the group in each category split by race, gender and BMI for Waves I and III. Since Wave I and II plots are very similar, we only show the plot for Wave I here.

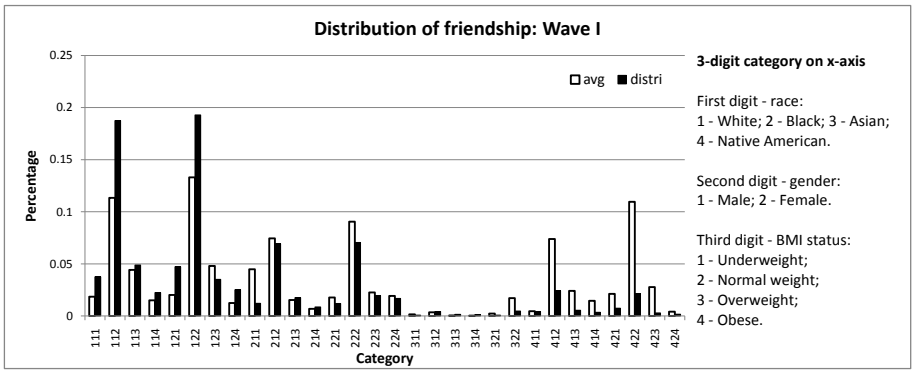


Fig. 2. Distribution versus average percentage of friends by each category split by race, gender and BMI status for Wave I

The plots show that (1) the fraction of Asians and Native Americans is small among the Add Health respondents, which causes low to zero friendship share in some cases. (2) In Wave I, Native Americans have a higher average number of friends than the distribution. But in Wave III, this difference drops. (3) In Wave I and III, almost all Whites' averages are less than the distribution which means they were not favored as friends. (4) In Wave III, all categories of Black except obese (i.e. 214 and 224) are slightly favored as friends. (5) The worst performer in terms of the number of friends is the white obese male category in Wave III where the average number of friends is only one third of the distribution. The obese group does fairly well in other categories in Wave III. This highlights the social stigma attached to the higher weight status among whites compared to other races.

Overall, these results show that whites are the least popular as friends among all the races. White obese males face the highest risk of social marginalization among all the categories. Native females of normal weight seem to be very popular as friends. These results give us insight on how the race, gender and BMI status are associated with the number of friends a person has. However, it is still not clear as to whether the lack of friends is causing the person to be overweight or it is the overweight that causes the person to not be able to make friends. We discuss this issue in the next section.

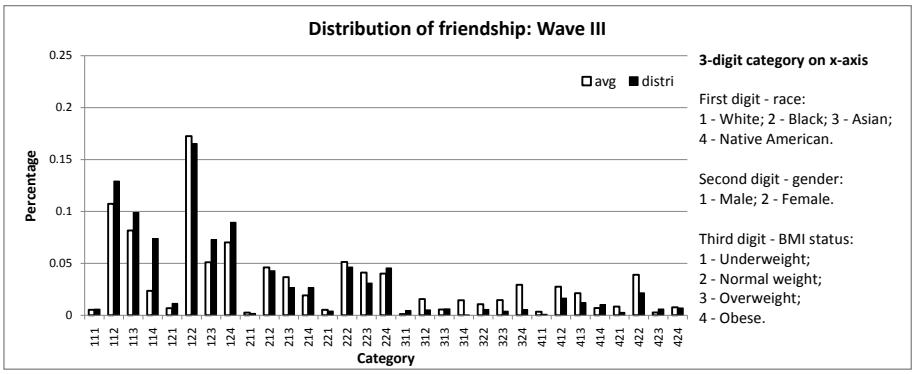


Fig. 3. Distribution versus average percentage of friends by each category split by race, gender and BMI status for Wave III

3.3 Causal Relationship

In this research, we test for the direction of causality to see whether social isolation causes obesity or obesity causes social marginalization, using the causality concept developed by Granger [8]. According to Granger, variable x causes variable y if past values of x contain information that helps explain the future values of y above and beyond the information contained in the past values of y alone. For instance, suppose we have

$$y_t = a_1 y_{t-1} + a_2 y_{t-2} + \ldots + b_1 x_{t-1} + b_2 x_{t-2} + \ldots + u_t.$$

Then x Granger causes y if $b_i \neq 0$, i.e., at least one coefficient of x is significantly different from zero. Another way to check whether x helps predict the future values of y is by testing if the variance of the residuals u_t drops when lagged values of x are included. For example when

$$y_t = a_1 + y_{t-1} + a_2 y_{t-2} + \ldots + v_t.$$

If x Granger causes y, variance of $(u_t) \leq$ variance of (v_t) since adding x in the regression increases the explanatory power and reduces the residuals.

The concept of Granger causality is particularly relevant here because it accounts for the timing of the events i.e. x causes y if changes in x precede changes in y. We measure social isolation or marginalization by the number of friends a person has and, obesity by the BMI status. The following model (as well as its counter model where BMI and friends were swapped) was estimated:

$$Friends_3 = c + a_1 Friends_1 + a_2 Friends_2 + b_1 BMI_1 + b_2 BMI_2 + u_t, \quad (1)$$

$$Friends_3 = c + a_1 Friends_1 + a_2 Friends_2 + v_t, \quad (2)$$

where $Friends_x$ is the number of friends in Wave x, and BMI_x is the BMI status in Wave x.

The results are as follows:

$$Friends_3 = 1.45 - 0.25Friends_1 + 0.24Friends_2 - 0.22BMI_1 - 0.06BMI_2 + \hat{u_t}, \tag{3}$$

$$Friends_3 = 0.82 - 0.24Friends_1 + 0.25Friends_2 + \hat{v_t} \tag{4}$$

The t-values of the estimated coefficients show that all coefficients in both equations are statistically significant at 5% level or less. The variance of $(\hat{u_t}) <$ variance of $(\hat{v_t})$. The coefficients of the lagged values of BMI show that the BMI status in Waves I and II negatively impacts the number of friends in Wave III in a statistically significant way. The observation that obesity precedes social marginalization lends credence to the notion that obesity causes social isolation rather than the other way around. We also tested the counter model where the BMI status and the friends were swapped in the above model to see if the lagged number of friends caused the future BMI status to change. The estimated coefficients were not statistically significant. The results are available from the authors upon request.

4 Summary and Conclusions

To address the relationship between weight and social marginalization, we first examine whether overweight and obese adolescents are discriminated in the friendship network. We stress that when discussing this issue, we need to account for the sample size of each category in the population, and consider if the seemingly lower popularity is simply representative of a smaller sample size. Using mutual nomination links as friends, over an 8-year period data from Wave I, II, and III, we conclude that overweight and obese adolescents and young adults have fewer friends, even after adjusting for their sample size. However, note that in Wave III, as the entire population is moving towards higher weight status, the overweight individuals' share of friends is roughly equal to the percentage of the group.

We further study the issue with divided race and gender groups and find distinctive patterns across different races. The most noticeable findings are the high popularity of Native American individuals of all BMI status, and low popularity of white obese individuals. This result highlights the cultural differences in the stigma associated with being overweight.

Most significantly, our results support the view that obesity causes social marginalization and not vice versa. This is an important finding for policy makers and planners who are looking for ways to reduce social marginalization of children. This research makes it clear that obesity not only has health consequences but also impacts the behavioral and social processes which are critical to the overall growth and development of children.

Acknowledgments: This research uses data from Add Health, a program project directed by Kathleen Mullan Harris and designed by J. Richard Udry, Peter S. Bearman, and Kathleen Mullan Harris at the University of North Carolina at Chapel Hill, and funded by grant P01-HD31921 from the Eunice Kennedy

Shriver National Institute of Child Health and Human Development, with cooperative funding from 23 other federal agencies and foundations. No direct support was received from grant P01-HD31921 for this analysis. The authors want to thank the reviewers for their helpful suggestions and comments. This work has been partially supported by NSF Nets Grant CNS- 0626964, NSF HSD Grant SES-0729441, NIH MIDAS project 2U01GM070694-7, NSF PetaApps Grant OCI-0904844, DTRA R&D Grant HDTRA1-0901-0017, DTRA CNIMS Grant HDTRA1-07-C-0113, NSF NETS CNS-0831633, DHS 4112-31805, DOE DE-SC0003957, NSF REU Supplement CNS-0845700, US Naval Surface Warfare Center N00178-09-D-3017 DEL ORDER 13, NSF Netse CNS-1011769, NSF SDCI OCI-1032677 and DynaNets. DynaNets acknowledges the financial support of the Future and Emerging Technologies (FET) program within the Seventh Framework Program for Research of the European Commission, under FET-Open grant number: 233847.

References

1. Bondonio, D.: Predictors of accuracy in perceiving informal social networks. Social Networks 20(4), 301–330 (1998)
2. Caprio, S., Daniels, S., Drewnowski, A., Kaufman, F., Palinkas, L., Rosenbloom, A., Schwimmer, J.: Influence of race, ethnicity, and culture on childhood obesity: Implications for prevention and treatment. Diabetes Care 31(11), 2211 (2008)
3. Christakis, N., Fowler, J.: The spread of obesity in a large social network over 32 years. N. Engl. J. Med. 357(4), 370–379 (2007)
4. Cohen-Cole, E., Fletcher, J.: Is obesity contagious? social networks vs. environmental factors in the obesity epidemic. Journal of Health Economics 27(5), 1382–1387 (September 2008)
5. Dietz, W.: Health consequences of obesity in youth: childhood predictors of adult disease. Pediatrics 101(3), 518 (1998)
6. Dietz, W., Bellizzi, M.: Introduction: the use of body mass index to assess obesity in children. American Journal of Clinical Nutrition 70(1), 123S (1999)
7. Fowler, J., Christakis, N.: Estimating peer effects on health in social networks. Journal of Health Economics 27(5), 1386–1391 (September 2008)
8. Granger, C.: Investigating causal relations by econometric models and cross-spectral methods. Econometrica 37, 424–438 (1969)
9. Harris, K.M.: The national longitudinal study of adolescent health (add health), waves i & ii, 1994c1996; wave iii, 2001c2002; wave iv, 2007-2009 [machine-readable data file and documentation]. Chapel Hill, NC: Carolina Population Center, University of North Carolina at Chapel Hill (2009)
10. Ritenbaugh, C.: Obesity as a culture-bound syndrome. Culture, Medicine and Psychiatry 6(4), 347–361 (1982)
11. Strauss, R., Pollack, H.: Social marginalization of overweight children. Arch Pediatr Adolesc Med 157, 746–52 (2003)
12. Thorpe, K.: The future costs of obesity: National and state estimates of the impact of obesity on direct health care expenses. A Collaborative Report from United Health Foundation (2009)
13. Valente, T., Fujimoto, K., Chou, C., Spruijt-Metz, D.: Adolescent affiliations and adiposity: A social network analysis of friendships and obesity. Journal of Adolescent Health 45, 202–204 (2009)