Obesity and Depression

Florence Yeung

Described by the World Health Organisation (WHO) as "globesity" (World Obesity Federation, 2020), the rapid growth of worldwide obesity has resulted in a multitude of psychological and physical issues that have significantly deteriorated the society's standard of living. A strong predictor of adult obesity is childhood obesity (World Obesity Federation, 2020), where, the global number of individuals aged 5 to 19 with obesity increased from 11 to 124 million in four decades, according to Imperial College London (Garwood, Chaib and Brogan, 2017). The fundamental reason for obesity is a long-term imbalance of calorie consumption and expenditure, and many studies have investigated the causes that increase the probability of the imbalance and bidirectional associations between them. One of the associations that have been explored is depression. Despite the rapid awareness of depression, it is the primary cause of disability (James, 2018) and can lead to lasting lifestyle changes in dietary intake and physical activity. The reversed directionality of obesity to depression has been considered in many research papers as well. The objective of this paper is to examine the co-occurrence of depression and obesity for a sample of secondary school students in the US controlling for predicted confounders in Wave I of the AddHealth Dataset. Further analysis will explore the prevalence of the association in adulthood.

Many researchers have conducted in-depth investigations on the correlations between depression and obesity for adolescents, to not only determine mediator and moderator variables, but also the pathway between the two illnesses. In a paper conducting a meta-analysis across 15 studies and over 58,000 samples of the time-variant relationship between obesity and depression (Luppino et al., 2010), there was a bilateral association between obesity and depression over time, where obese people had a 55% increased chance of developing depression and 58% for the opposite pathway. Moreover, the odds ratio (OR) of the diseases' co-occurrence were higher across longitudinal studies compared to cross-sectional ones. Research on individuals at early and late adolescents and early adulthood extends the previous study by indicating that depression during early teenage years predicted obesity at the later teenage years (OR = 3.76) and obesity during late adolescence predicted depression during adulthood (OR = 5.89) for women. This was hypothesized to be the case because eating and exercise patterns are usually cemented below the age of 14, therefore, unhealthy diets and habits of inactivity developed then would persist later in life. Furthermore, late adolescence is when many experience the vulnerability from pressures about body shape and weight-related insecurities, potentially leading to an onset of depression (Marmorstein, Iacono and Legrand, 2014). Beydoun and Wang (2010) suggested that the causality between obesity and

depression stems from one's socioeconomic status which affects BMI through food insecurity, depression, and changes in the amount of physical activity.

Descriptive Statistics

It is widely recognized that overweight adults are those with a BMI >25 and obese when BMI >30. Due to the growth rate and differences in body fatness across genders in youths, BMI categories are estimated with distribution ranges within their age and gender bracket. The WHO method of scaling and classifying childhood BMI percentiles was used (Nutrition and Food Safety, 2006) and summarised in Appendix I. To compare BMI between adulthood and adolescence, a scaled BMI was estimated based on the age and gender-adjusted BMI ranges in proportion to adult ranges. Depression is typically determined through a clinical diagnosis or self-reported surveys about mood and other symptoms of depression. For both Wave I and II, questions similar to the 20-question CES-D test were used to score an individual's severity of depression. In Waves III and IV, a 10-question variation was used (Andresen, Malmgren, Carter and Patrick, 1993). A brief investigation into the use of the adolescent-adapted PHQ-9 depression test (Kroenke, Spitzer and Williams, 2001) was also used to compare results (Appendix II). As per the author's instructions, when four or more questions were not answered the observation be removed (Radloff, 1977). The equation used to calculate scores for individuals who had non-responses is stated in Appendix III.

The other endogenous variables included were the individual's characteristics, socioeconomic background, and traits mentioned in the above literature reviews that influence the likelihood of depression or obesity. The socio-economic background was assumed to be accounted for with the individual's parent's reported total household income which ranged from $0 to $999,000USD per year. The assumption is that higher household income parents will be able to afford better quality healthcare to manage their child's weight and nourish them with more nutritious food (Beydoun and Wang 2010). The gender and race were both identified by many as variables that highly affect one's response to depression and obesity, additionally, the effect of an individual's depression severity on BMI was found to be dependent on their gender. As mentioned before, the propensity of a female adolescent to be obese given they had depressive symptoms were different between early and late adolescence, therefore, age was also considered. The individual's lifestyle (physical and dietary) and social mistreatment and peer victimization (Nemiary, Shim, Mattox and Holden, 2012) were strong mediators between depression and obesity and therefore was also included as confounders. The selected AddHealth questions used as variables are summarised in Appendix IV and descriptive statistics of the variables in Appendix V.
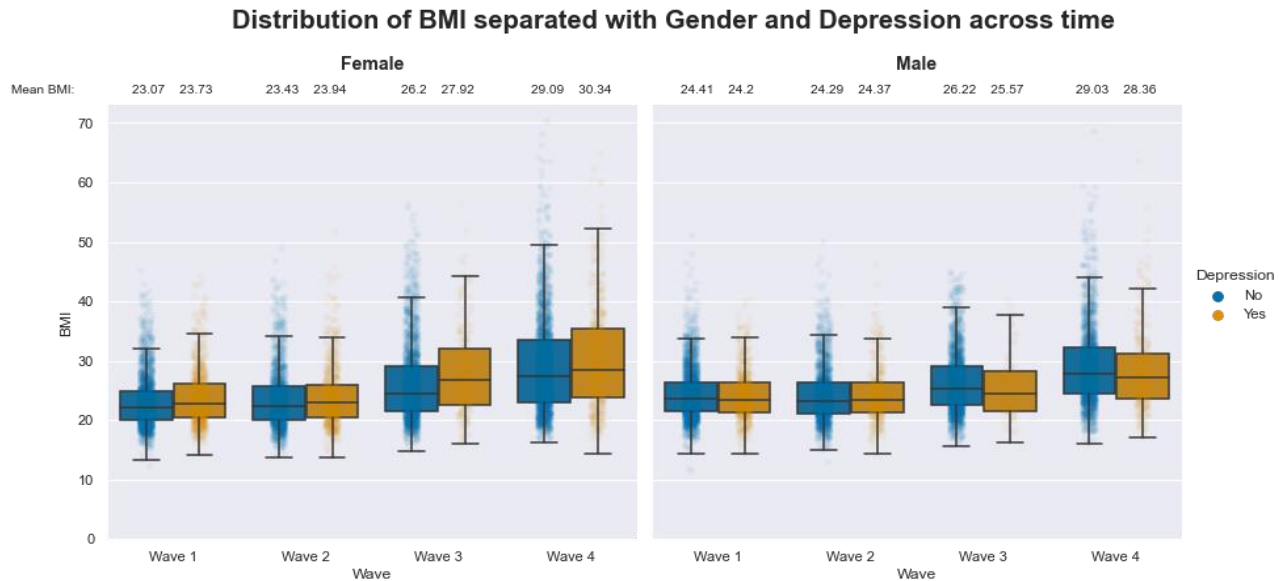
Figure 1 Distribution of BMI separated by Gender and Depression [1]

Figure 1 illustrates the distribution of BMI divided between gender and whether the individual had depression across waves. The mean values of each division are noted along the top of the graph and scatters beneath the box-plot highlights the distribution of data points. A positive trend between time and BMI for both depressed and non-depressed individuals and genders is evident. Wave I and II were measured one year apart, therefore the similarity of BMIs was expected and only differed by 1.34 units. Contrary to the hypothesis, the mean BMI of males with depression in Waves III and IV are lower than those without. For females, depressed individuals had a distinguishably higher BMI compared to their counterparts without. Comparing males and females in Waves III and IV, non-depressed individuals have similar BMIs, but depressed females have a higher mean and a greater range of BMIs. The initial analysis of the variables suggests a relationship between depression and higher BMIs with differences between males and females.

Regression

The linear regression, Logit and Probit models were used to determine the associations between BMI and depression severity, and the effects of the mentioned confounders were accounted for. Multiple variations of the three models were used to validate the results and identify variables of high significance (95% C.I). To account for model biases, the SMOTE oversampling technique was used to treat the imbalance dataset between the ratio of obese and non-obese participants in binary models. The list of all models and outcomes are detailed in Appendix VI and Python code.

BMI as an Exogenous Variable

As a control, the first set of models between depression scores and BMI and without confounders were conducted and reveals that depression only accounts for 0.1-0.2% of the changes in the adjusted BMI. Combinations of three types of the regression model were conducted, one accounts

---

[1] Note that the mid-line of graph represents median and therefore should not be the same as numerical mean value above graph.

for any interaction between gender and depressive symptoms/gender and BMI, the second predicting that BMI and depressive scores are not linearly correlated but has a quadratic relationship where both underweight and overweight patients can have depressive symptoms and one where a simple linear relationship is assumed. When the chosen individual's characteristics were included, the explanatory power of the models increased to 5.7% and further increased by 0.3% when the difference between males' and females' interaction with depression was considered. When using a binary output variable, the model's sensitivity was measured with McFadden's pseudo R^2, and values between 0.2 to 0.4 represent a good model (Mangiafico, 2015). The pseudo R^2 for binary models were all approximately 0.16, which suggest that the variables were unable to fully capture changes in BMI. A crucial finding is that in all models, depression scores and BMI had positive correlations and were statistically significant. When determining obesity as a binary variable, many confounders were statically significant, however, suggests that better diets, more parental support, self-esteem and peer support did not show compelling results suggesting any reduction in BMI.

Depression as an Exogenous Variable

When using depression as the endogenous variable, the BMI and the selected confounders were able to explain 33.7% of the CES-D depression score when a gender-BMI interaction was included. The increase in predictability was validated with the results of using depression as a binary variable, which suggested that the model was within the threshold of a "good" model (pseudo $R^2 = 0.25$). The observable rise in model fit implies that BMI and a student's characteristics may have been more indicative of whether they are depressed or not. As expected, factors like parental support, peer support and self-esteem showed a clear negative relationship with depression and were highly statistically significant, most significantly, an individual with low self-esteem compared to one with high self-esteem increases their odds of being depressed by 3.75 times (Tables of OR in code). However, BMI did not appear to predict depression well.

Waves I and II on Waves III and IV

As depression is a long-term disorder, using one self-reported interview during one wave to dictate depression will likely be prone to misclassification. As Waves I and II were conducted a year apart, the average score of both waves were used when using depression as a continuous variable and categorical variable, and only when both waves indicate a score suggesting noticeable depressive symptoms (CES-D >16), would an individual be classed as "depressed". As numerous research highlighted the interaction between gender to depression and gender to BMI's effect on BMI and depression and Wave I results suggesting potentially significant interactions, this was incorporated

into analysis with Wave III and IV data. Regressing Wave I & II depression scores to Wave III BMI suggest that males without depression have a higher BMI, but when accounting for depression, the average BMI falls, and for females, depressed females were more correlated with higher BMIs compared to their non-depressed peers. Predominantly, the severity of depression, gender, race, age (at Wave I) and parental income were statistically significant. Similar predictions were found when regressed with Wave IV data, however, the interaction between gender and depression were highly statistically insignificant which is most likely due to the large range of BMI across females as illustrated from Figure 1. Contrary to the literature review, covariates on self-esteem, physical activity, diet and peer/family support did not show sufficient evidence that they impact early and later adulthood. When predicting depression scores in Wave III and IV with BMI and endogenous factors from Wave I, the only covariate that consistently suggested statistical significance was the level of peer support, in which more support led to lower depression score.

Limitations

One major limitation when extracting sample data is to minimise biases with the choice of individuals to ensure collectively, the individuals represent the population. Weights for every individual were included in this analysis as per AddHealth dataset instructions. By implementing weights, the results in this report better reflect the relationships in the general population, although, from a brief comparison (Appendix VII), the difference appears to be insignificant. In Wave I, the BMI was determined with self-reported height and weight, but measurements were taken for other waves. The graph in Appendix VIII illustrates the difference between them and suggests that self-reported BMIs were on average lower than measured. Another drawback of the AddHealth dataset is that the majority of the variables are self-reported and therefore depended on the honesty of the interviewee. As a result, questions related to exercise, diet, peers and depressive symptoms are likely skewed towards the more socially preferred option to avoid judgement by the interviewer.

Conclusion

The co-occurrence of obesity and depression appear to be prevalent in female participants especially when regressed with their situation in adulthood. Although the relationship does not signify causation, in all models, the chosen variables were able to better predict the onset of depression compared to obesity. As obesity and depression are such detrimental illnesses, further research on the mechanisms and potential mediator variables should be investigated with hierarchical models, pathway analysis and structural equation modelling to provide better behavioural, cognitive and physiological treatments to reduce the two conditions.

References

1. Andresen, E., Malmgren, J., Carter, W. and Patrick, D., 1993. Screening for Depression in Well Older Adults: Evaluation of a Short Form of the CES-D. American Journal of Preventive Medicine, 10(2), pp.77-84.

2. Beydoun, M. and Wang, Y., 2010. Pathways linking socioeconomic status to obesity through depression and lifestyle factors among young US adults. Journal of Affective Disorders, 123(1-3), pp.52-63.

3. Garwood, P., Chaib, F. and Brogan, C., 2017. Tenfold Increase In Childhood And Adolescent Obesity In Four Decades: New Study By Imperial College London And WHO. [online] World Health Organization. Available at: <https://www.who.int/news/item/11-10-2017-tenfold-increase-in-childhood-and-adolescent-obesity-in-four-decades-new-study-by-imperial-college-london-and-who> [Accessed 2 December 2020].

4. James, S., 2018. Global, regional, and national incidence, prevalence, and years lived with disability for 354 diseases and injuries for 195 countries and territories, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017. The Lancet, [online] 392(10159), pp.1789-1858. Available at: <https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(18)32279-7/fulltext#sec1> [Accessed 17 November 2020].

5. Jaret, P., 2010. Eating Disorders And Depression. [online] WebMD. Available at: <https://www.webmd.com/mental-health/eating-disorders/features/eating-disorders#1> [Accessed 2 December 2020].

6. Kroenke, K., Spitzer, R. and Williams, J., 2001. The PHQ-9. Journal of General Internal Medicine, [online] 16(9), pp.606-613. Available at: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1495268/> [Accessed 21 November 2020].

7. Luppino, F., de Wit, L., Bouvy, P., Stijnen, T., Cuijpers, P., Penninx, B. and Zitman, F., 2010. Overweight, Obesity, and Depression. Archives of General Psychiatry, [online] 67(3), p.220. Available at: <https://pubmed.ncbi.nlm.nih.gov/20194822/> [Accessed 17 November 2020].

8. Mangiafico, S., 2015. An R Companion For The Handbook Of Biological Statistics. 1st ed.

9. Marmorstein, N., Iacono, W. and Legrand, L., 2014. Obesity and depression in adolescence and beyond: reciprocal risks. International Journal of Obesity, 38(7), pp.906-911.

10. Moon, J., Huh, J., Song, J., Kang, I., Park, S., Chang, S., Yang, J. and Jun, T., 2017. The Center for Epidemiologic Studies Depression Scale is an adequate screening instrument for depression and anxiety disorder in adults with congential heart disease. Health and Quality of Life Outcomes, 15(1).

11. Nemiary, D., Shim, R., Mattox, G. and Holden, K., 2012. The Relationship Between Obesity and Depression Among Adolescents. Psychiatric Annals, 42(8), pp.305-308.

12. Nutrition and Food Safety, 2006. WHO Child Growth Standards. 1st ed. Geneva: World Health Organization, Department of Nutrition for Health and Development, p.312.

13. Radloff, L., 1977. The CES-D Scale. Applied Psychological Measurement, [online] 1(3), pp.385-401. Available at: <https://journals.sagepub.com/doi/10.1177/014662167700100306#:~:text=The%20CES%2DD%20scale%20is,in%20previously%20validated%20longer%20scales.&text=The%20scale%20should%20be%20a,epidemiologic%20studies%20of%20de%20pression.> [Accessed 5 December 2020].

14. World Obesity Federation, 2020. Controlling The Global Obesity Epidemic. [online] World Health Organization. Available at: <https://www.who.int/activities/controlling-the-global-obesity-epidemic> [Accessed 1 December 2020].

15. World Obesity Federation, 2020. Obesity And Overweight. [online] World Health Organization. Available at: <https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight> [Accessed 1 December 2020].

Appendix I – Method of Scaling BMI from Ages 5 – 19 (World Health Organisation)

$$z_{ind} = \frac{\left[\dfrac{y}{M(t)}\right]^{L(t)} - 1}{S(t)L(t)}$$

Where:

z_{ind} is the individual z-score for a measurement y at age t

$L(t), M(t), S(t)$ are the Box-Cox power, median and coefficient of variation corresponding to age t

BMI Categories	Standard Deviations for each gender and age category
Obese	> 2 SD
Overweight	1 SD – 2 SD
Average	-2 SD – 1SD
Underweight	-3 SD – -2 SD
Severely Underweight	< -3 SD

<u>Appendix II</u> – Comparison of Coefficient between PHQ-9 (Patient Health Questionnaire) Depression Index and CES-D (Center for Epidemiological Studies Depression) Depression Index

	PHQ-9		CES-D		
	Coefficient	P-Values	Coefficient	P-Values	Coefficient Difference
Intercept	27.87	0.00	27.61	0.00	0.26
Male	1.49	0.00	1.54	0.00	-0.05
Moderate Self Esteem	0.49	0.49	0.76	0.28	-0.28
High Self Esteem	-0.24	0.73	-0.05	0.94	-0.18
Very High Self Esteem	-0.74	0.29	-0.47	0.50	-0.27
Mildly Active	0.25	0.45	0.08	0.80	0.16
Moderately Active	0.23	0.47	0.17	0.61	0.06
Very Active	0.06	0.83	-0.13	0.67	0.19
Checkup (< 1 year)	0.08	0.60	0.11	0.49	-0.02
Checkup (>2 years)	0.17	0.52	0.28	0.27	-0.11
Never had checkup	0.66	0.16	0.83	0.07	-0.17
1 Portion of vegetable/fruit	-0.49	0.05	-0.53	0.03	0.04
2 Portions of vegetable/fruit	-0.49	0.04	-0.50	0.03	0.01
3 Portions of vegetable/fruit	-0.41	0.09	-0.39	0.11	-0.02
4 Portions of vegetable/fruit	-0.47	0.07	-0.54	0.04	0.06
Parental Support (Somewhat)	-2.07	0.06	-0.89	0.46	-1.18
Parental Support (Quite a bit)	-1.90	0.07	-0.90	0.44	-1.00
Parental Support (Very much)	-1.59	0.13	-0.60	0.61	-0.99
Friendship (Somewhat)	0.55	0.57	-0.27	0.76	0.82
Friendship (Quite a bit)	0.68	0.48	-0.05	0.95	0.73
Friendship (Very much)	0.52	0.58	-0.10	0.91	0.63
American Indian	2.68	0.00	1.46	0.03	1.22
Asian	-1.84	0.00	-1.81	0.00	-0.02
Hispanic	-0.38	0.10	-0.30	0.24	-0.09
Other Race	-1.59	0.02	-1.47	0.04	-0.12
White, non-Hispanic	-1.08	0.00	-0.99	0.00	-0.09
Depression Score	0.04	0.07	0.01	0.17	0.02
Age	-0.15	0.00	-0.16	0.00	0.01
Parental Income	0.00	0.00	0.00	0.00	0.00
R^2	0.06		0.053		
Adjusted R^2	0.05		0.047		

*Green Highlighted p-values represent significant variables (at 95% C.I)

<u>Appendix III</u> – Modification of Non-Responses for CES-D (20 question) Depression Index and Categorisation of Depression

Equation to modify partial raw score to total raw score:

$$\frac{Raw\ Sum \times 20}{Number\ of\ questions\ answered\ by\ individual}$$

Interpretation table of Depression Score by CES-D (20 Question)

Score	Severity of Depressive Disorder
0-9	Not Depressed
10-15	Mildly Depressed
16-24	Moderately Depressed
25-60	Severely Depressed

*16 < is the common threshold for Depression.

(Moon et al., 2017)

Appendix VI – All AddHealth Variables used

	Variable	Question	Coding	Method of Data Collection
			All Waves	
Individual Identifier	AID	Respondent Identifier	-	Interviewer
BMI	H1GH60	What is your weight?	50 to 430 - 50 pounds to 430 pounds 996 - Refused 998 - Don't know 999 - Not applicable	Self Reported
	H1GH59A	What is your height in feet and inches?	. - Missing 4 to 6 - 4 feet to 6 feet 96 - Refused 98 - Don't know 99 - Not applicable	Self Reported
	H1GH59B	What is your height in feet and inches?	. - Missing 0 to 11 - 0 inches to 11 inches 96 - Refused 98 - Don't know 99 - Not applicable	Self Reported
	H1GI1Y	What is your birth date? [month and year]. Year	74 - 1974 and earlier 75 to 82 - 1975 to 1982 83 - 1983 and later 96 - Refused	Self Reported
	BIO_SEX	Biological Sex	1 - Male 2 - Female 6 - Refused 8 - Don't know	Self Reported and confirmed by interviewer
	IYEAR	Year of Interview	94 - 1994 95 - 1995	Interviewer

PHQ-9 Depression Index				
	H1FS6	How often was each of the following things true during the past week? You felt depressed.		Self Reported
	H1FS8	How often was each of the following things true during the past week? You felt hopeful about the future.	0 - Never/Rarely	Self Reported
	H1FS11	How often was each of the following things true during the past week? You were happy.	1 - Sometimes 2 - A lot of the time 3 - Most of the time or all of the time	Self Reported
	H1FS16	How often was each of the following things true during the past week? You felt sad.	6 - Refused 8 - Don't Know	Self Reported
	H1FS19	How often was each of the following things true during the past week? You felt life was not worth living.	9 - Not Applicable	Self Reported
	H1FS18	How often was each of the following things true during the past week? It was hard to get started doing things.		Self Reported
	H1GH18	Please tell me how often you have had each of the following conditions in the past 12 months. Trouble falling asleep or staying asleep	0 - Never 1 - Just a few times 2 - About once a week 3 - Almost every day 4 - Every day 6 - Refused 8 - Don't Know	Self Reported
	H1FS2	How often was each of the following things true during the past week? You didn't feel like eating, your appetite was poor.		Self Reported
	H1FS7	How often was each of the following things true during the past week? You felt that you were too tired to do things.	0 - Never/Rarely 1 - Sometimes 2 - A lot of the time	Self Reported
	H1FS9	How often was each of the following things true during the past week? You thought your life had been a failure.	3 - Most of the time or all of the time 6 - Refused 8 - Don't Know 9 - Not Applicable	Self Reported
	H1FS5	How often was each of the following things true during the past week? You had trouble keeping your mind on what you were doing.		Self Reported

	H1FS1	How often was each of the following things true during the past week? You felt fearful.		Self Reported
	H1SU2	During the past 12 months, how many times did you actually attempt suicide?	0 - 0 times 1 - 1 time 2 - 2 or 3 times 3 - 4 or 5 times 4 - 6 or more times 6 - Refused 7 - Legitimate skip 8 - Don't know	Self Reported
CES-D Depression Index	H1FS1	How often was each of the following things true during the past week? You felt fearful.		Self Reported
	H1FS2	How often was each of the following things true during the past week? You didn't feel like eating, your appetite was poor.		Self Reported
	H1FS3	How often was the following true during the past week? You felt that you could not shake off the blues, even with help from your family and your friends.		Self Reported
	H1FS4	How often was each of the following things true during the past week? You felt that you were just as good as other people.	0 - Never/Rarely	Self Reported
	H1FS5	How often was the following true during the past week? You had trouble keeping your mind on what you were doing.	1 - Sometimes 2 - A lot of the time	Self Reported
	H1FS6	How often was the following true during the past week? You felt depressed.	3 - Most of the time or all of the time 6 - Refused	Self Reported
	H1FS7	How often was the following true during the past week? You felt that you were too tired to do things.	8 - Don't Know 9 - Not Applicable	Self Reported
	H1FS8	How often was the following true during the past week? You felt hopeful about the future.		Self Reported
	H1FS9	How often was the following true during the past week? You thought your life had been a failure.		Self Reported
	H1FS10	How often was the following true during the past week? You felt fearful.		Self Reported
	H1FS11	How often was the following true during the past week? You were happy.		Self Reported

H1FS12	How often was the following true during the past week? You talked less than usual.		Self Reported	
H1FS13	How often was the following true during the past week? You felt lonely.		Self Reported	
H1FS14	How often was the following true during the past week? People were unfriendly to you.		Self Reported	
H1FS15	How often was the following true during the past week? You enjoyed life.		Self Reported	
H1FS16	How often was the following true during the past week? You felt sad.		Self Reported	
H1FS17	How often was the following true during the past week? You felt that people disliked you.		Self Reported	
H1FS18	How often was the following true during the past week? It was hard to get started doing things.		Self Reported	
H1GH21	In the past 12 months, how often have you cried frequently?	0 - Never 1 - Just a few times 2 - About once a week	Self Reported	
H1GH18	In the past 12 months, how often have you had trouble falling asleep or staying asleep?	3 - Almost every day 4 - Every day 6 - Refused 8 - Don't Know	Self Reported	
Confounders	BIO_SEX	Biological Sex	1 - Male 2 - Female 6 - Refused 8 - Don't know	Self Reported and confirmed by interviewer
	PA55	About how much total income, before taxes did your family receive in 1994? Include your own income, the income of everyone else in your household, and income from welfare benefits, dividends, and all other sources.	. - Missing or no parent questionnaire 0 to 999 - Range $0 to $999 thousand 9996 - Refused	Parent
	H1GI1Y	What is your birth date?	74 - 1974 and earlier 75 to 82 - 1975 to 1982 83 - 1983 and later 96 - Refused	Self Reported

H1PF33	Do you agree or disagree with the following statement? You like yourself just the way you are.	1 - Strongly agree	Self Reported
		2 - Agree	
H1PF30	Do you agree or disagree with the following statement? You have a lot of good qualities.	3 - Neither agree nor disagree	Self Reported
		4 - Disagree	
		5 - Strongly disagree	
		6 - Refused	
		7 - Legitimate Skip	
		8 - Don't Know	
H1DA6	During the past week, how many times did you exercise, such as jogging, walking, karate, jumping rope, gymnastics or dancing?	0 - Not at all	Self Reported
		1 - 1 or 2 times	
H1DA4	During the past week, how many times did you go roller-blading, roller-skating, skate-boarding, or bicycling?	2 - 3 or 4 times	Self Reported
		3 - 5 or more times	
H1DA5	During the past week, how many times did you play an active sport, such as baseball, softball, basketball, soccer, swimming, or football?	6 - Refused	Self Reported
		8 - Don't know	
H1GH24	When did you last have a physical examination by a doctor or nurse?	1 - Less than a year ago	Self Reported
		2 -1 to 2 years ago	
		3 - More than 2 years ago	
		4 - Never	
		6 - Refused	
		8 - Don't know	
		9 - Not applicable	
H1GH34	How often did you eat vegetables yesterday?	0 - Didn't eat	Self Reported
H1GH33	How often did you eat fruit or drink fruit juice yesterday?	1 - Ate once	Self Reported
		2 - Ate twice or more	
		6 - Refused	
		8 - Don't know	
H1PR5	How much do you feel that people in your family understand you?	1 - Not at all	Self Reported
H1PR3	How much do you feel that your parents care about you?	2 - Very little	Self Reported

H1PR8	How much do you feel that your family pays attention to you?	3 - Somewhat	Self Reported
		4 - Quite a bit	
		5 - Very much	
		6 - Does not apply	
		96 - Refused	
		98 - Don't know	
H1WP14	How much do you think he [resident father] cares about you?	1 - Not at all	Self Reported
H1WP10	How much do you think she [resident mother] cares about you?	2 - Very little	Self Reported
		3 - Somewhat	
		4 - Quite a bit	
		5 - Very much	
		6 - Refused	
		7 - Legitimate skip	
		8 - Don't know	
		9 - Not applicable	
H1PF25	Do you agree or disagree with the following statement? Overall, you are satisfied with your relationship with your father.	1 - Strongly agree	Self Reported
		2 - Agree	
H1PF5	Do you agree or disagree with the following statement? Overall, you are satisfied with your relationship with your mother.	3 - Neither agree nor disagree	Self Reported
		4 - Disagree	
H1PF1	Do you agree or disagree with the following statement? Most of the time, your mother is warm and loving toward you.	5 - Strongly disagree	Self Reported
		6 - Refused	
H1PF23	Do you agree or disagree with the following statement? Most of the time, your father is warm and loving toward you.	7 - Legitimate Skip	Self Reported
		8 - Don't Know	
		9 - Not applicable	
H1ED18	Since school started this year/During the 1994-1995 school year, how often have you had trouble getting along with other students?	0 - Never	Self Reported
		1 - Just a few times	
		2 - About once a week	
		3 - Almost every day	
		4 - Every day	
		6 - Refused	
		7 - Legitimate skip	
		8 - Don't Know	

	H1PR4	How much do you feel that your friends care about you?	1 - Not at all	Self Reported
			2 - Very little	
			3 - Somewhat	
			4 - Quite a bit	
			5 - Very much	
			6 - Does not apply	
			96 - Refused	
			98 - Don't know	
	H1ED22	How much do you agree or disagree with the following statements: You are happy to be at your school. Last year, you were happy to be at your school.		Self Reported
			1 - Strongly agree	
	H1ED21	How much do you agree or disagree with the following statements: Students at your school are prejudiced. Last year, students at your school were prejudiced.	2 - Agree	Self Reported
			3 - Neither agree nor disagree	
			4 - Disagree	
	H1ED20	How much do you agree or disagree with the following statements: You feel like you are a part of your school. Last year, you felt like you were a part of your school.	5 - Strongly disagree	Self Reported
			6 - Refused	
			7 - Legitimate Skip	
	H1ED19	How much do you agree or disagree with the following statements: You feel close to people at your school. Last year, you felt close to people at your school.	8 - Don't Know	Self Reported
	H1FS14	How often was the following true during the past week? People were unfriendly to you.	0 - Never	Self Reported
			1 - Just a few times	
			2 - About once a week	
			3 - Almost every day	
			4 - Every day	
			6 - Refused	
			8 - Don't Know	
BMI	H2WS16HF	Record respondent's height and weight. [feet]	. - Missing	Measured
			4 to 6 - 4 feet to 6 feet	
			96 - Refused	
			98 - Don't know	

	H2WS16HI	Record respondent's height and weight. [inches]	. - Missing	Measured
			0 to 11 - 0 inches to 11 inches	
			96 - Refused	
			98 - Don't know	
	H2WS16W	Record respondent's height and weight. [weight]	. - Missing	Measured
			50 to 531 - 50 pounds to 531 pounds	
			996 - Refused	
			998 - Don't know	
	H2GH52F	What is your height in feet [and inches]?	. - Missing	Self Reported
			0 to 11 - 0 inches to 11 inches	
			96 - Refused	
			98 - Don't know	
	H2GH52I	What is your height in [feet and] inches?	. - Missing	Self Reported
			4 to 6 - 4 feet to 6 feet	
			96 - Refused	
			98 - Don't know	
	H2GH53	What is your weight?	50 to 450 - 50 pounds to 450 pounds	Self Reported
			996 - Refused	
			998 - Don't know	
	BIO_SEX2	Biological Sex	1 - Male	Self Reported and confirmed by
			2 - Female	interviewer
CES-D Depression Index	H1FS1	How often was each of the following things true during the past week? You felt fearful.		Self Reported
	H1FS2	How often was each of the following things true during the past week? You didn't feel like eating, your appetite was poor.	0 - Never/Rarely 1 - Sometimes	Self Reported
	H1FS3	How often was the following true during the past week? You felt that you could not shake off the blues, even with help from your family and your friends.	2 - A lot of the time 3 - Most of the time or all of the time 6 - Refused	Self Reported
	H1FS4	How often was each of the following things true during the past week? You felt that you were just as good as other people.	8 - Don't Know 9 - Not Applicable	Self Reported
	H1FS5	How often was the following true during the past week? You had trouble keeping your mind on what you were doing.		Self Reported

H1FS6	How often was the following true during the past week? You felt depressed.		Self Reported
H1FS7	How often was the following true during the past week? You felt that you were too tired to do things.		Self Reported
H1FS8	How often was the following true during the past week? You felt hopeful about the future.		Self Reported
H1FS9	How often was the following true during the past week? You thought your life had been a failure.		Self Reported
H1FS10	How often was the following true during the past week? You felt fearful.		Self Reported
H1FS11	How often was the following true during the past week? You were happy.		Self Reported
H1FS12	How often was the following true during the past week? You talked less than usual.		Self Reported
H1FS13	How often was the following true during the past week? You felt lonely.		Self Reported
H1FS14	How often was the following true during the past week? People were unfriendly to you.		Self Reported
H1FS15	How often was the following true during the past week? You enjoyed life.		Self Reported
H1FS16	How often was the following true during the past week? You felt sad.		Self Reported
H1FS17	How often was the following true during the past week? You felt that people disliked you.		Self Reported
H1FS18	How often was the following true during the past seven days? It was hard to get started doing things.		Self Reported
H2GH23	During the past 12 months, how often have you had trouble falling asleep or staying asleep?	0 - Never 1 - Just a few times	Self Reported
H2GH26	During the past 12 months, how often have you cried frequently?	2 - About once a week 3 - Almost every day 4 - Every day 6 - Refused 8 - Don't Know	Self Reported

Others	BIO_SEX2	Biological Sex		Self Reported and confirmed by interviewer
			1 - Male	
			2 - Female	
BMI	H3HGT_F	Measured height [feet]	. - Missing	Measured
			4 to 7 - 4 feet to 7 feet	
			96 - Refused	
			98 - Don't know	
			99 - Not applicable	
	H3HGT_I	Measured height [inches]	. - Missing	Measured
			0 to 11 - 0 inches to 11 inches	
			96 - Refused	
			98 - Don't know	
			99 - Not applicable	
	H3HGT_PI	Measured height [partial inches]	. - Missing	Measured
			0 to 0.875 - 0 inches to 0.875 inches	
			6 - Refused	
			8 - Don't know	
			9 - Not applicable	
	H3WGT	Measured weight	. - Missing	Measured
			78 to 330 - 78 pounds to 330 pounds	
			888 - Over 330 pounds	
			996 - Refused	
	H3DA43F	How tall are you in feet [and inches]?	. - Missing	Self Reported
			4 to 7 - 4 feet to 7 feet	
			96 - Refused	
			98 - Don't know	
			99 - Not applicable	
	H3DA43I	How tall are you in [feet and] inches?	. - Missing	Self Reported
			0 to 11 - 0 inches to 11 inches	
			96 - Refused	
			98 - Don't know	
			99 - Not applicable	

	H3DA44	What is your current weight in pounds?	. - Missing 60 to 450 - 60 pounds to 450 pounds 996 - Refused 998 - Don't know 999 - Notapplicable	Self Reported
Others	H2GI1Y	What is your birth date?	74 - 1974 and earlier 75 to 82 - 1975 to 1982 83 - 1983 and later 96 - Refused	Self Reported
	H3ID15	Have you ever been diagnosed with depression?	0 - No 1 - Yes 6 - Refused 8 - Don't know 9 - Not applicable	Self Reported
CES-D Depression Index	H3SP5	How often was the following true during the past seven days? You were bothered by things that usually don't bother you.		Self Reported
	H3SP8	How often was the following true during the past seven days? You had trouble keeping your mind on what you were doing.	0 - Never/Rarely 1 - Sometimes 2 - A lot of the time 3 - Most of the time or all of the time 6 - Refused 8 - Don't Know 9 - Not Applicable	Self Reported
	H3SP9	How often was the following true during the past seven days? You were depressed.		Self Reported
	H3SP10	How often was the following true during the past seven days? You were too tired to do things.		Self Reported

H3SP2	In the past 12 months, how often have you cried a lot?		Self Reported
H3SP12	How often was the following true during the past seven days? You were sad.		Self Reported
H3SP11	How often was the following true during the past seven days? You enjoyed life.		Self Reported
H3SP13	How often was the following true during the past seven days? You felt that people disliked you.		Self Reported
H3GH15	In the past seven days, how often did you fall asleep when you should have been awake (for example, during class or at work)?	0 - Never 1 - Just a few times 2 - About once a week 3 - Almost every day 4 - Every day 6 - Refused 8 - Don't Know 9 - Not applicable	Self Reported
H3SP3	How satisfied are you with your life as a whole?	1 - Very satisfied 2 - Satisfied 3 - Neither satisfied nor dissatisfied 4 - Dissatisfied 5 - Very dissatisfied 96 - Refused 98 - Don't know	Self Reported

Other	BIO_SEX3	Respondent's Gender		Interviewer
			1 - Male	
			2 - Female	
BMI	H4BMI	Body Mass Index	14.4 to 97.4 - 14.4 to 97.4	Measured
			888 - Over limit	
			889 - Weight inconsistent with height, waist and sex	
			996 - Refused	
			997 - Legitimate skip	
			999 - Invalid data	
	H4BMICLS	BMI Classification	1 - Underweight	Measured
			2 - Normal 18.5 - < 25	
			3 - Overweight	
			4 - Obese I	
			5 - Obese II	
			6 - Obese III	
			88 - Over limit	
			89 - Weight inconsistent with height, waist and sex	
			96 - Refused	
			97 - Legitimate skip	
			98 - Don't know	
	H4ID5H	Has a doctor, nurse or other health care provider ever told you that you have or had: depression?	0 - No	Self Reported
			1 - Yes	
			6 - Refused	
			8 - Don't know	
	BIO_SEX4	Respondent's Gender	1 - Male	Interviewer
			2 - Female	
	H4GH5I	What is your height in feet and inches?	0 to 11 - 0 inches to 11 inches	Self Reported
			96 - Refused	
			98 - Don't know	

	H4GH5F	What is your height in feet and inches?	4 to 7 - 4 feet to 7 feet	Self Reported
			96 - Refused	
			98 - Don't know	
	H4GH6	What is your weight?	0 to 617 - 0 pounds to 617 pounds	Self Reported
			996 - Refused	
			998 - Don't know	
CES-D Depression Index	H4MH18	How often was the following true during the past seven days? You were bothered by things that usually don't bother you.		Self Reported
	H4MH21	How often was the following true during the past seven days? You had trouble keeping your mind on what you were doing.		Self Reported
	H4MH22	How often was the following true during the past seven days? You felt depressed.	0 - Never/Rarely	Self Reported
	H4MH23	How often was the following true during the past seven days? You felt that you were too tired to do things.	1 - Sometimes 2 - A lot of the time	Self Reported
	H4MH24	How often was the following true during the past seven days? You felt happy.	3 - Most of the time or all of the time 6 - Refused	Self Reported
	H4MH25	How often was the following true during the past seven days? You enjoyed life.	8 - Don't Know	Self Reported
	H4MH26	How often was the following true during the past seven days? You felt sad.		Self Reported
	H4MH27	How often was the following true during the past seven days? You felt that people disliked you.		Self Reported
	H4MH2	How often do you feel isolated from others?	0 - Never	Self Reported
			1 - Rarely	
			2 - Sometimes	
			3 - Often	
			6 - Refused	
			8 - Don't Know	

H4SP6	Over the past four weeks, how often did you have trouble staying asleep through the night? For example, you woke up several times at night or woke up earlier than you planned to?	0 - Never in the past four weeks 1 - Less than once a week 2 - 1 or 2 times a week 3 - 3 or 4 times a week 4 - 5 or more times a week 6 - Refused 8 - Don't Know	Self Reported

Appendix V – Descriptive Summary of Variables in Main Regression

Categorical Variables

Gender

Categories	Count	Proportion
Female	2522	0.51
Male	2405	0.49

Parental Income (Binned)

Categories ($ Thousands)	Count	Proportion
0-10	498	0.10
11-20	689	0.14
21-30	779	0.16
31-40	721	0.15
41-50	651	0.13
51-60	505	0.10
61-70	302	0.06
71-80	270	0.06
81-90	141	0.03
91-100	157	0.03
101-200	161	0.03

Self Esteem

Categories	Count	Proportion
Very High	2125	0.43
High	2268	0.46
Moderate	491	0.10
Low	43	0.01

Exercise

Categories	Count	Proportion
Very Active	3307	0.67
Moderately Active	755	0.15
Mildly Active	598	0.12
Inactive	267	0.05

Last Check-up

Categories	Count	Proportion
< 1 year	3400	0.69
1 – 2 years	1024	0.21
> 2 years	402	0.08
Never	101	0.02

Parental Support

Categories	Count	Proportion
Very Much	3682	0.75
Quite a Bit	1059	0.21
Somewhat	165	0.03
Very Little	21	0.00

Peer Support

Categories	Count	Proportion
Very Much	1969	0.40
Quite a Bit	2552	0.52
Somewhat	385	0.08
Very Little	21	0.00

Race

Categories	Count	Proportion
White, Non-Hispanic	3084	0.63
Hispanic	1085	0.22
African American	520	0.11
American Indian	143	0.03
Asian	50	0.01
Other Race	45	0.01

Diet – Portions of Fruits/Vegetable per day

Categories	Count	Proportion
1 Portion	963	0.22
2 Portions	1417	0.32
3 Portions	1255	0.28
4 Portions	831	0.19

Continuous Variables

	Age	Parental Income
Count	4927	4927
Mean	15.92	47.72
Std	1.75	56.36
Min	12	0
25%	15	22
50%	16	40
75%	17	60
Max	21	999

Depression

Wave II

Percentage of Observation in each Depression Category (Self Reported) per BMI Category

Percentage of Observation in each Depression Category (Self Reported) per BMI Category

Wave III

Percentage of Observation in each Depression Category (Diagnosed) per BMI Category

Percentage of Observation in each Depression Category (Diagnosed)
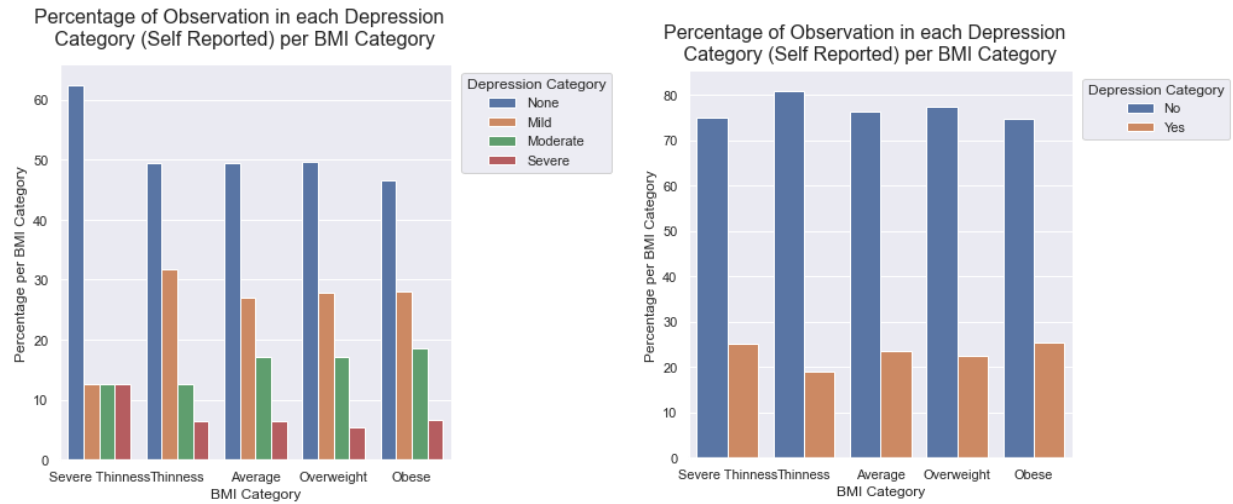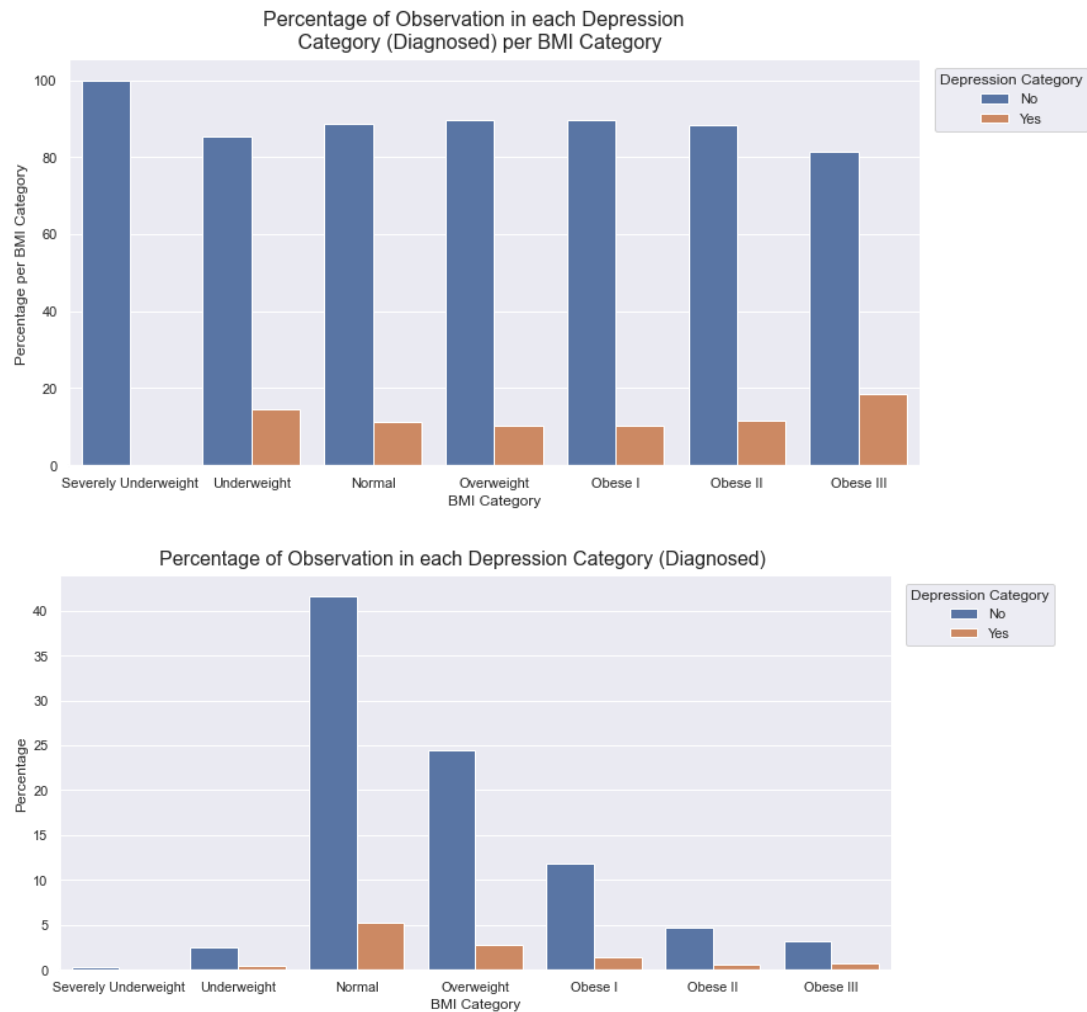
Wave IV

Percentage of Observation in each Depression Category (Diagnosed) per BMI Category

Percentage of Observation in each Depression Category (Diagnosed)
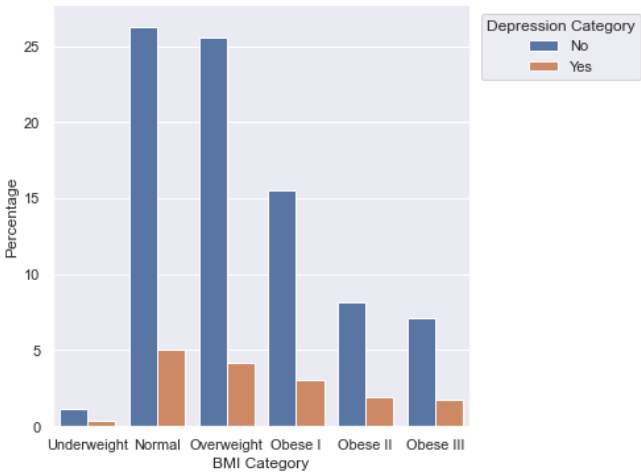
Appendix VI – Model Output Details

Part 1: BMI as Endogenous Variable

   a. Using Severity to measure Depression

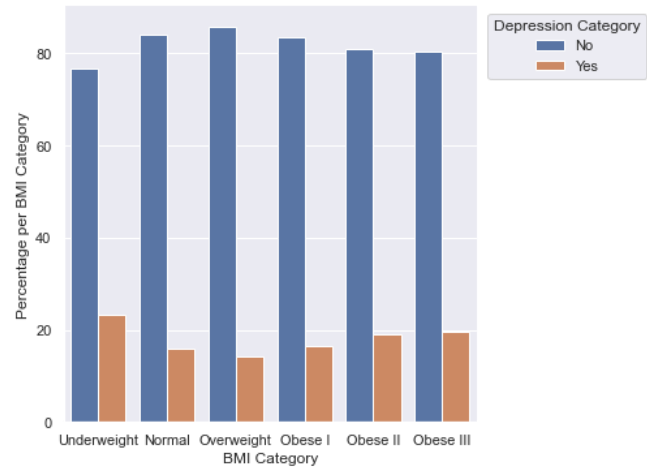|	OLS Model		OLS Model		Logit Model		Probit Model		OLS Model with Interaction Variable between Gender and Depression		Logit Model with Interaction Variable between Gender and Depression	
	Coefficient	P-Values	Coefficient	P-Values	Coefficient	P-Values	Coefficient	P-Values	Coefficient	P-Values	Coefficient	P-Values
Intercept	28.47	0.00	23.65	0.00	-2.17	0.00	-1.22	0.00	28.17	0.00	-2.31	0.00
Depressive Symptoms (None)					0.22	0.00	0.12	0.00				
Depressive Symptoms (Mild)	0.13	0.39	0.26	0.09					0.33	0.13		
Depressive Symptoms (Moderate)	0.38	0.05	0.55	0.00	0.03	0.76	0.02	0.68	0.68	0.01		
Depressive Symptoms (Moderately Severe)	-0.08	0.80	0.16	0.56	-0.02	0.91	-0.01	0.92	0.74	0.04		
Male	1.48	0.00			0.46	0.00	0.28	0.00	1.79	0.00	0.59	0.08
Low Self Esteem					-1.02	0.06	-0.45	0.11			1.34	0.00
Moderate Self Esteem	0.32	0.65			-0.11	0.31	-0.05	0.45	0.42	0.55	0.66	0.00
High Self Esteem	-0.44	0.53							-0.30	0.67		
Very High Self Esteem	-0.93	0.19			-0.50	0.00	-0.30	0.00	-0.80	0.25	-1.11	0.00
Mildly Active	0.24	0.46			1.08	0.00	0.56	0.00	0.22	0.51	0.36	0.03
Moderately Active	0.22	0.48			1.08	0.00	0.57	0.00	0.20	0.53	0.17	0.29
Very Active	0.06	0.84			1.59	0.00	0.87	0.00	0.03	0.91	1.03	0.00
Checkup (< 1 year)	0.08	0.59			0.53	0.00	0.32	0.00	0.07	0.65	0.69	0.00
Checkup (>2 years)	0.19	0.47			-0.49	0.00	-0.28	0.00	0.19	0.46	-0.29	0.03
Never had checkup	0.66	0.16			-0.95	0.00	-0.49	0.00	0.67	0.15	-0.48	0.08
1 Portion of vegetable/fruit	-0.49	0.05			0.13	0.22	0.07	0.27	-0.49	0.05	-0.16	0.14
2 Portions of vegetable/fruit	-0.49	0.04			0.12	0.24	0.07	0.26	-0.48	0.04	-0.36	0.00
3 Portions of vegetable/fruit	-0.42	0.09			0.24	0.02	0.13	0.03	-0.42	0.08	-0.35	0.00
4 Portions of vegetable/fruit	-0.47	0.07			-0.40	0.00	-0.24	0.00	-0.45	0.08	-1.02	0.00
Parental Support (Very little)					0.16	0.81	0.13	0.74			0.79	0.24
Parental Support (Somewhat)	-2.18	0.05			-0.66	0.03	-0.28	0.06	-2.11	0.05	0.21	0.28

*Green Highlighted p-values represent significant variables (at 95% C.I)
**Green text in coefficient column indicate a positive relationship between independent and dependent variable
***Red text in coefficient column indicate a negative relationship between independent and dependent variable

Parental Support (Quite a bit)	-2.08	0.05							-1.97	0.06		
Parental Support (Very much)	-1.78	0.09			1.42	0.00	0.83	0.00	-1.66	0.12	-0.69	0.00
Friendship (Very little)					-17.20	0.99	-6.46	1.00			0.25	0.65
Friendship (Somewhat)	0.40	0.68			-1.36	0.00	-0.77	0.00	0.28	0.78	0.48	0.00
Friendship (Quite a bit)	0.49	0.60							0.37	0.70		
Friendship (Very much)	0.34	0.72			-0.42	0.00	-0.26	0.00	0.23	0.81	-1.43	0.00
American Indian	2.68	0.00			-0.34	0.28	-0.17	0.37	2.73	0.00	-0.24	0.47
Asian	-1.82	0.00			-2.79	0.00	-1.62	0.00	-1.84	0.00	0.60	0.00
Hispanic	-0.38	0.10			-1.21	0.00	-0.71	0.00	-0.41	0.08	-0.37	0.00
Other Race	-1.57	0.02			-2.20	0.00	-1.22	0.00	-1.59	0.02	-1.45	0.00
White, non-hispanic	-1.07	0.00			-0.20	0.00	-0.13	0.00	-1.07	0.00	-0.06	0.39
Age	-0.15	0.00			0.00	0.90	0.00	0.92	-0.14	0.00	0.11	0.00
Parental Income	0.00	0.00			-0.01	0.00	-0.01	0.00	0.00	0.00	0.00	0.00
Depressive Symptoms (Mild) x Male									-0.36	0.23		
Depressive Symptoms (Moderate) x Male									-0.58	0.10		
Depressive Symptoms (Severe) x Male									-2.15	0.00		
Adjusted BMI											0.05	0.00
Adjusted BMI x Male											-0.05	0.00
R²	0.06		0.00						0.06			
Adjusted R²	0.05		0.00						0.05			
Pseudo R²					0.16		0.16				0.17	

b. Using Score to Measure Depression

	OLS Model		OLS Model		Logit		Probit		OLS Quadratic		Logit Quadratic	
	Coefficient	P-Values	Coefficient	P-Values	Coefficient	P-Values	Coefficient	P-Values	Coefficient	P-Values	Coefficient	P-Values
Intercept	27.61	0.00	23.59	0.00	-2.84	0.00	-1.65	0.00	28.14	0.00	-3.27	0.00
Depression Score	0.01	0.17	0.02	0.01	0.04	0.00	0.02	0.00	0.03	0.20	0.12	0.00
Male	1.54	0.00	-	-	0.46	0.00	0.28	0.00	1.48	0.00	0.45	0.00
Low Self Esteem		-	-	-	-1.62	0.00	-0.80	0.00	-	-	-1.23	0.02
Moderate Self Esteem	0.76	0.28	-	-	-0.30	0.00	-0.17	0.01	0.38	0.59	-0.27	0.01
High Self Esteem	-0.05	0.94	-	-	-	-	-	-	-0.36	0.61	-	-
Very High Self Esteem	-0.47	0.50	-	-	-0.58	0.00	-0.35	0.00	-0.84	0.23	-0.55	0.00
Mildly Active	0.08	0.80	-	-	1.00	0.00	0.51	0.00	0.25	0.44	0.99	0.00
Moderately Active	0.17	0.61	-	-	1.26	0.00	0.68	0.00	0.23	0.47	1.26	0.00
Very Active	-0.13	0.67	-	-	1.60	0.00	0.88	0.00	0.06	0.83	1.60	0.00
Checkup (<1 year)	0.11	0.49	-	-	0.65	0.00	0.39	0.00	0.09	0.59	0.65	0.00
Checkup (>2 years)	0.28	0.27	-	-	-0.42	0.00	-0.24	0.00	0.17	0.50	-0.39	0.00
Never had checkup	0.83	0.07	-	-	-0.70	0.01	-0.37	0.02	0.66	0.16	-0.70	0.01
1 portion of vegetable/fruit	-0.53	0.03	-	-	0.02	0.85	0.00	0.98	-0.49	0.05	0.04	0.69
2 portion of vegetable/fruit	-0.50	0.03	-	-	0.02	0.86	0.01	0.91	-0.48	0.04	0.03	0.73
3 portion of vegetable/fruit	-0.39	0.11	-	-	0.14	0.16	0.07	0.25	-0.41	0.09	0.17	0.08
4 portion of vegetable/fruit	-0.54	0.04	-	-	-0.45	0.00	-0.27	0.00	-0.47	0.07	-0.42	0.00
Parental Support (Very Little)	-	-	-	-	-0.18	0.80	-0.03	0.93	-	-	0.17	0.80
Parental Support (Somewhat)	-0.89	0.46	-	-	-0.84	0.00	-0.38	0.01	-2.14	0.05	-0.76	0.01
Parental Support (Quite a bit)	-0.90	0.44	-	-	-	-	-	-	-2.00	0.06	-	-
Parental Support (Very much)	-0.60	0.61	-	-	1.61	0.00	0.94	0.00	-1.70	0.11	1.57	0.00
Friendship (Very Little)	-	-	-	-	-24.94	1.00	-6.04	0.98	-	-	-17.20	0.99
Friendship (Somewhat)	-0.27	0.76	-	-	-1.49	0.00	-0.85	0.00	0.41	0.67	-1.40	0.00
Friendship (Quite a bit)	-0.05	0.95	-	-		-		-	0.52	0.58	-	-
Friendship (Very much)	-0.10	0.91	-	-	-0.27	0.00	-0.16	0.00	0.38	0.69	-0.23	0.00
American Indian	1.46	0.03	-	-	0.20	0.47	0.15	0.35	2.68	0.00	0.20	0.48
Asian	-1.81	0.00	-	-	-2.57	0.00	-1.50	0.00	-1.83	0.00	-2.60	0.00

Hispanic	-0.30	0.24	-	-	-1.28	0.00	-0.75	0.00	-0.39	0.10	-1.30	0.00
Other Race	-1.47	0.04	-	-	-1.86	0.00	-1.06	0.00	-1.58	0.02	-1.83	0.00
White, non-Hispanic	-0.99	0.00	-	-	-0.21	0.00	-0.13	0.00	-1.07	0.00	-0.22	0.00
Age	-0.16	0.00	-	-	0.00	0.78	0.00	0.70	-0.15	0.00	0.00	0.79
Parental Income	0.00	0.00	-	-	-0.01	0.00	-0.01	0.00	0.00	0.00	-0.01	0.00
Depression Score²	-	-	-	-	-	-	-	-	0.00	0.36	0.00	0.00
R²	0.053		0.001						0.056			
Adjusted R²	0.047		0.001						0.05			
Pseudo R²					0.1716		0.1684				0.1769	

c. Wave I & II regressed with Waves III and IV

| | Wave III | | | | | | Wave IV | | | | | |
| | OLS with Depression Score | | OLS with Depression Severity | | OLS with Depression/ Not Depression | | OLS with Depression Score | | OLS with Depression Severity | | OLS with Depression/ Not Depression | |
	Coefficient	P-Values	Coefficient	P-Values	Coefficient	P-Values	Coefficient	P-Values	Coefficient	P-Values	Coefficient	P-Values
Intercept	21.99	0.00	22.46	0.00	24.05	0.00	24.20	0.00	24.58	0.00	25.64	0.00
Male	1.77	0.00	1.27	0.00	0.58	0.02	1.24	0.01	1.02	0.01	0.56	0.06
Moderate Self Esteem	0.38	0.73	0.53	0.63	0.03	0.98	2.10	0.13	2.28	0.10	1.86	0.18
High Self Esteem	-0.15	0.89	0.03	0.98	-0.65	0.55	0.84	0.54	1.03	0.46	0.48	0.72
Very High Self Esteem	-0.75	0.49	-0.61	0.59	-1.31	0.23	0.50	0.72	0.64	0.65	0.10	0.94
Mildly Active	0.17	0.78	0.21	0.74	0.13	0.83	0.11	0.88	0.18	0.80	0.12	0.87
Moderately Active	-0.09	0.88	-0.05	0.94	-0.14	0.82	-0.03	0.97	0.05	0.95	-0.01	0.99
Very Active	0.06	0.91	0.10	0.86	0.02	0.97	-0.21	0.75	-0.13	0.84	-0.20	0.76
Checkup (< 1 year)	-0.38	0.18	-0.37	0.19	-0.33	0.25	-0.52	0.13	-0.50	0.14	-0.50	0.14
Checkup (>2 years)	-0.74	0.10	-0.74	0.11	-0.68	0.14	0.03	0.96	0.02	0.97	0.06	0.91
Never had checkup	0.64	0.47	0.66	0.46	0.64	0.47	0.89	0.40	0.89	0.40	0.88	0.40
1 Portion of vegetable/fruit	-0.77	0.08	-0.85	0.06	-0.81	0.07	-0.60	0.26	-0.68	0.20	-0.61	0.25
2 Portions of vegetable/fruit	-0.79	0.06	-0.86	0.04	-0.83	0.05	-0.89	0.08	-0.98	0.06	-0.93	0.07
3 Portions of vegetable/fruit	-0.82	0.06	-0.89	0.04	-0.86	0.05	-0.91	0.08	-1.01	0.05	-0.96	0.06
4 Portions of vegetable/fruit	-0.96	0.04	-1.02	0.03	-1.03	0.02	-1.50	0.01	-1.61	0.00	-1.55	0.01
Parental Support (Somewhat)	-2.35	0.24	-2.46	0.22	-2.69	0.18	-0.42	0.85	-0.59	0.79	-0.65	0.77
Parental Support (Quite a bit)	-2.14	0.26	-2.27	0.24	-2.63	0.17	0.49	0.81	0.37	0.86	0.18	0.93
Parental Support (Very much)	-1.51	0.43	-1.66	0.39	-2.08	0.28	0.83	0.69	0.67	0.75	0.45	0.83
Friendship (Somewhat)	1.13	0.47	1.14	0.47	1.15	0.46	2.65	0.12	2.64	0.12	2.70	0.12
Friendship (Quite a bit)	1.42	0.35	1.44	0.35	1.30	0.40	2.14	0.20	2.15	0.20	2.10	0.21
Friendship (Very much)	1.76	0.25	1.77	0.25	1.55	0.32	2.48	0.14	2.44	0.15	2.37	0.16
American Indian	4.80	0.00	4.87	0.00	4.63	0.00	2.89	0.09	2.90	0.09	2.76	0.11
Asian	-2.20	0.00	-2.21	0.00	-2.09	0.00	-3.60	0.00	-3.57	0.00	-3.54	0.00
Hispanic	-0.73	0.09	-0.77	0.07	-0.67	0.12	-1.08	0.04	-1.10	0.04	-1.04	0.05
Other Race	-1.99	0.06	-1.91	0.08	-2.00	0.06	-3.03	0.02	-2.95	0.03	-3.04	0.02
White, non-hispanic	-0.90	0.00	-0.90	0.00	-0.95	0.00	-2.04	0.00	-2.05	0.00	-2.07	0.00

Wave 1 & 2 Depression Score	0.10	0.00	-	-	-	-	0.07	0.02	-	-	-	-
Wave 1 & 2 Depression Score x Male	-0.12	0.00	-	-	-	-	-0.06	0.12	-	-	-	-
Age	0.31	0.00	0.31	0.00	0.33	0.00	0.19	0.03	0.19	0.03	0.20	0.02
Parental Income	0.00	0.04	0.00	0.04	0.00	0.03	-0.01	0.00	-0.01	0.00	-0.01	0.00
Depressive Symptoms (Mild)	-	-	1.14	0.00	-	-	-	-	0.83	0.06	-	-
Depressive Symptoms (Moderate)	-	-	0.99	0.03	-	-	-	-	0.24	0.65	-	-
Depressive Symptoms (Severe)	-	-	3.11	0.00	-	-	-	-	1.88	0.02	-	-
Depressive Symptoms (Mild) x Male	-	-	-1.52	0.00	-	-	-	-	-1.08	0.08	-	-
Depressive Symptoms (Moderate) x Male	-	-	-1.23	0.05	-	-	-	-	-0.62	0.41	-	-
Depressive Symptoms (Severe) x Male	-	-	-3.47	0.00	-	-	-	-	-0.49	0.72	-	-
Wave 1 & 2 Depression Score	-	-	-	-	0.91	0.04	-	-	-	-	0.44	0.40
Wave 1 & 2 Depression Score x Male	-	-	-	-	-1.58	0.03	-	-	-	-	-0.10	0.91
R²	0.04		0.05		0.04		0.04		0.05		0.04	
Adjusted R²	0.03		0.03		0.03		0.03		0.03		0.03	

Part 2: Using Depression as Endogenous Variable

a. Main analysis of Wave I

	OLS with BMI as continuous variable		OLS with BMI as categorical variable		Logit with BMI as continuous variable		Logit with BMI as categorical variable		OLS with Interaction variable	
	Coefficient	P-Values	Coefficient	P-Values	Coefficient	P-Values	Coefficient	P-Values	Coefficient	P-Values
Intercept	38.41	0.00	37.89	0.00	-1.73	0.00	-0.78	0.03	37.35	0.00
Male	-0.93	0.00	-0.92	0.00	-0.63	0.00	-0.50	0.00	1.01	0.32
Low Self Esteem	-	-	-	-	1.32	0.01	1.28	0.01	-	-
Moderate Self Esteem	-6.44	0.00	-6.48	0.00	0.66	0.00	0.71	0.00	-6.47	0.00
High Self Esteem	-10.38	0.00	-10.43	0.00	-1.11	0.00	-	-	-10.39	0.00
Very High Self Esteem	-12.63	0.00	-12.68	0.00	-	-	-1.16	0.00	-12.64	0.00
Mildly Active	0.66	0.17	0.66	0.17	0.35	0.03	0.32	0.06	0.66	0.17
Moderately Active	0.36	0.43	0.36	0.43	0.16	0.31	0.21	0.20	0.36	0.43
Very Active	0.64	0.13	0.63	0.13	1.02	0.00	1.04	0.00	0.64	0.13
Checkup (< 1 year)	0.26	0.26	0.26	0.26	0.68	0.00	0.68	0.00	0.26	0.25
Checkup (>2 years)	0.54	0.15	0.54	0.15	-0.30	0.02	-0.12	0.37	0.55	0.15
Never had checkup	0.30	0.66	0.32	0.64	-0.47	0.08	-0.51	0.07	0.29	0.66
1 Portion of vegetable/fruit	-0.46	0.21	-0.46	0.20	-0.15	0.15	-0.06	0.60	-0.46	0.20
2 Portions of vegetable/fruit	-1.54	0.00	-1.55	0.00	-0.35	0.00	-0.27	0.01	-1.55	0.00
3 Portions of vegetable/fruit	-1.50	0.00	-1.50	0.00	-0.34	0.00	-0.30	0.01	-1.51	0.00
4 Portions of vegetable/fruit	-1.80	0.00	-1.80	0.00	-1.02	0.00	-0.81	0.00	-1.80	0.00
Parental Support (Very Little)	-	-	-	-	0.76	0.26	0.93	0.17	-	-
Parental Support (Somewhat)	-4.71	0.00	-4.70	0.00	0.21	0.27	0.27	0.17	-4.68	0.00
Parental Support (Quite a bit)	-7.83	0.00	-7.81	0.00	-	-	-	-	-7.79	0.00
Parental Support (Very much)	-10.89	0.00	-10.87	0.00	-0.69	0.00	-0.64	0.00	-10.85	0.00

	Coef.	p	Coef.	p	Coef.	p	Coef.	p	Coef.	p
Friendship (Very Little)	-	-	-	-	0.29	0.61	0.19	0.73	-	-
Friendship (Somewhat)	-3.93	0.01	-3.90	0.01	0.49	0.00	0.48	0.00	-3.90	0.01
Friendship (Quite a bit)	-7.54	0.00	-7.50	0.00					-7.49	0.00
Friendship (Very much)	-10.29	0.00	-10.25	0.00	-1.43	0.00	-1.50	0.00	-10.23	0.00
American Indian	0.16	0.87	0.18	0.85	-0.23	0.49	-0.13	0.70	0.16	0.87
Asian	1.75	0.00	1.73	0.00	0.59	0.00	0.24	0.22	1.78	0.00
Hispanic	0.27	0.42	0.25	0.46	-0.37	0.00	-0.52	0.00	0.29	0.40
Other Race	-1.20	0.21	-1.16	0.23	-1.46	0.00	-1.62	0.00	-1.16	0.22
White, non-Hispanic	-1.29	0.00	-1.30	0.00	-0.07	0.36	-0.25	0.00	-1.27	0.00
Adjusted BMI	0.02	0.26		-	0.03	0.00	-	-	-	-
BMI (Severely Underweight)	-	-	-	-	-	-	-1.20	0.16	-	-
BMI (Underweight)	-	-	1.11	0.56	-	-	-0.91	0.00	-	-
BMI (Average)	-	-	1.00	0.57	-	-	-	-	-	-
BMI (Overweight)	-	-	1.35	0.44	-	-	-0.33	0.00	-	-
BMI (Obese)	-	-	1.16	0.51	-	-	-0.81	0.00	-	-
Age	0.20	0.00	0.20	0.00	0.11	0.00	0.10	0.00	0.20	0.00
Parental Income	-0.01	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	-0.01	0.00
	-	-	-	-	-	-	-	-	0.07	0.03
	-	-	-	-	-	-	-	-	-0.08	0.05
R²	0.34		0.34		-		-		-	0.34
Adjusted R²	0.33		0.33		-		-		-	0.33
Pseudo R²	-		-		0.24		0.25		-	-

b. Wave I & II regressed with Waves III and IV

	Wave III OLS with BMI as a continuous variable		Wave III OLS with BMI as a categorical variable		Wave IV OLS with BMI as a continuous variable		Wave IV OLS with BMI as a categorical variable	
	Coefficient	P-Values	Coefficient	P-Values	Coefficient	P-Values	Coefficient	P-Values
Intercept	11.31	0.00	11.94	0.00	14.99	0.00	13.83	0.00
Male	1.22	0.14	1.50	0.56	0.85	0.35	5.16	0.10
Moderate Self Esteem	-0.47	0.50	-0.42	0.54	-0.96	0.25	-0.81	0.33
High Self Esteem	-1.46	0.03	-1.43	0.03	-1.63	0.04	-1.49	0.07
Very High Self Esteem	-1.69	0.01	-1.67	0.01	-2.18	0.01	-2.03	0.01
Mildly Active	-0.38	0.32	-0.39	0.31	0.21	0.63	0.21	0.64
Moderately Active	-0.17	0.66	-0.18	0.63	0.42	0.33	0.40	0.35
Very Active	-0.24	0.49	-0.24	0.48	0.25	0.52	0.25	0.52
Checkup (< 1 year)	-0.07	0.68	-0.07	0.68	-0.11	0.58	-0.12	0.54
Checkup (>2 years)	-0.08	0.78	-0.09	0.75	-0.37	0.27	-0.39	0.24
Never had checkup	0.13	0.82	0.16	0.78	0.35	0.58	0.38	0.55
1 Portion of vegetable/fruit	-0.44	0.11	-0.45	0.11	-0.51	0.11	-0.49	0.13
2 Portions of vegetable/fruit	-0.45	0.09	-0.46	0.08	-0.36	0.24	-0.35	0.25
3 Portions of vegetable/fruit	-0.25	0.36	-0.26	0.34	-0.25	0.42	-0.23	0.45
4 Portions of vegetable/fruit	-0.50	0.08	-0.51	0.08	-0.54	0.11	-0.52	0.12
Parental Support (Somewhat)	-0.77	0.54	-0.82	0.51	0.48	0.72	0.53	0.69
Parental Support (Quite a bit)	-0.47	0.69	-0.50	0.67	-0.81	0.52	-0.80	0.53
Parental Support (Very much)	-1.56	0.19	-1.58	0.19	-2.01	0.11	-1.99	0.11
Friendship (Somewhat)	-1.32	0.18	-1.31	0.18	-2.73	0.01	-2.82	0.01
Friendship (Quite a bit)	-2.63	0.01	-2.62	0.01	-3.53	0.00	-3.60	0.00
Friendship (Very much)	-3.00	0.00	-3.00	0.00	-4.40	0.00	-4.48	0.00
American Indian	-0.02	0.98	0.00	1.00	-0.56	0.58	-0.62	0.55
Asian	0.89	0.04	0.88	0.04	0.02	0.97	-0.04	0.94
Hispanic	0.14	0.60	0.14	0.60	-0.62	0.05	-0.61	0.05
Other Race	0.18	0.79	0.12	0.86	-0.07	0.93	-0.14	0.87
White, non-Hispanic	-0.47	0.01	-0.47	0.01	-0.81	0.00	-0.81	0.00
Adjusted BMI	0.07	0.00	-	-	0.04	0.11	-	-

Adjusted BMI x Male	-0.08	0.02	-	-	-0.05	0.15	-	-
Age	-0.14	0.00	-0.14	0.00	-0.09	0.10	-0.09	0.11
Parental Income	0.00	0.28	0.00	0.25	0.00	0.06	0.00	0.06
BMI (Underweight)	-	-	0.62	0.78	-	-	2.12	0.43
BMI (Average)	-	-	0.94	0.65	-	-	1.95	0.44
BMI (Overweight)	-	-	1.55	0.45	-	-	2.01	0.42
BMI (Obese)	-	-	1.64	0.43	-	-	2.69	0.29
BMI (Underweight) x Male	-	-	-1.89	0.50	-	-	-5.56	0.11
BMI (Average) x Male	-	-	-1.91	0.46	-	-	-5.53	0.08
BMI (Overweight) x Male	-	-	-2.80	0.28	-	-	-5.56	0.08
BMI (Obese) x Male	-	-	-2.70	0.31	-	-	-6.26	0.05
R^2	0.10		0.10		0.09		0.09	
Adjusted R^2	0.08		0.08		0.08		0.08	

Appendix VII – Comparison of Coefficients between OLS with and without AddHealth Weights

	No Weights	Weights	Coefficient
	Coefficient	Coefficient	Difference
Intercept	28.01	27.61	0.41
Male	1.48	1.54	0.06
Moderate Self Esteem	0.47	0.76	0.30
High Self Esteem	-0.27	-0.05	0.22
Very High Self Esteem	-0.76	-0.47	0.29
Mildly Active	0.25	0.08	0.16
Moderately Active	0.23	0.17	0.06
Very Active	0.06	-0.13	0.19
Checkup (< 1 year)	0.08	0.11	0.02
Checkup (>2 years)	0.17	0.28	0.10
Never had checkup	0.66	0.83	0.17
1 Portion of vegetable/fruit	-0.49	-0.53	0.03
2 Portions of vegetable/fruit	-0.49	-0.50	0.01
3 Portions of vegetable/fruit	-0.41	-0.39	0.03
4 Portions of vegetable/fruit	-0.48	-0.54	0.05
Parental Support (Somewhat)	-2.08	-0.89	1.19
Parental Support (Quite a bit)	-1.91	-0.90	1.01
Parental Support (Very much)	-1.62	-0.60	1.02
Friendship (Somewhat)	0.48	-0.27	0.75
Friendship (Quite a bit)	0.60	-0.05	0.65
Friendship (Very much)	0.44	-0.10	0.54
American Indian	2.68	1.46	1.22
Asian	-1.82	-1.81	0.01
Hispanic	-0.39	-0.30	0.09
Other Race	-1.59	-1.47	0.12
White, non-hispanic	-1.07	-0.99	0.09
Depression Score	0.01	0.01	0.00
Age	-0.15	-0.16	0.01
Parental Income	0.00	0.00	0.00

- All coefficients are less than 1.22

Self-Reported BMI and Measured BMI
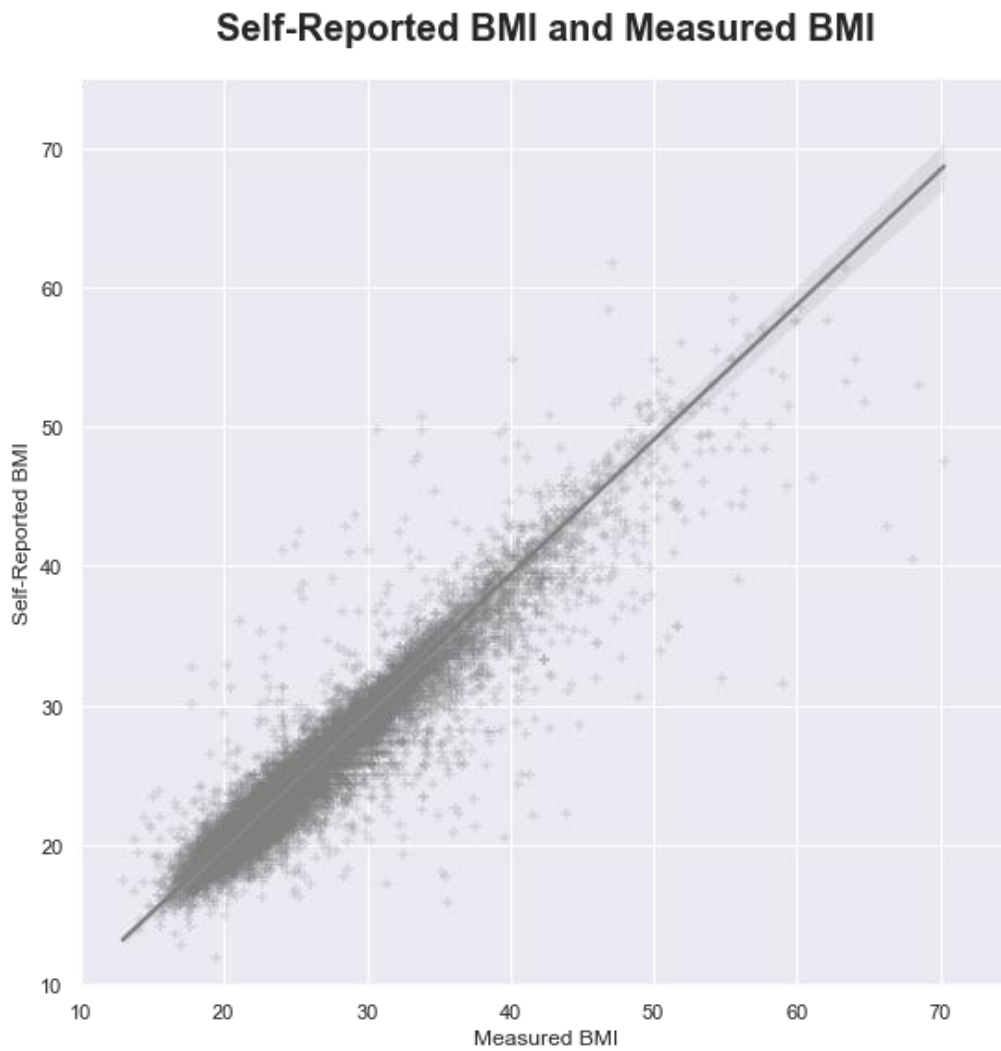
Measuring depression both as categories and a numeric score suggested that gender, nutrition, race, parental income and age were statistically significant and

- Talk about which covariates were significant across the board
- Using severity as a depression metric was more predictive
- Wave 1
    - BMI vs Depression – extremely low R-squared when using both depression measured as a categorical variable and continuous variable, R-squared and adjusted R-squared of 0.001-0.002, depression only accounts for 0.1-0.2% of the changes in BMI.
    - With included covariates, the variables explain 5.7% of the changes in BMI when depression was measured as a category which suggest that the chosen covariates are able to better explain the changes in BMI, and age, parental income, race, nutrition and gender were significant at the 95% confidence level.
    - When determining whether an individual is obese or not instead of using a continuous BMI variable, the model's sensitivity can be measured with the McFadden's pseudo r-squared. The pseudo r-squared is around 0.16 for both probit and logit models models. According to (15), values between 0.2 to 0.4 represent a good model, therefore this is not a good model and most likely not representative.
    - However, when using bmi as an independent variable and depression as the endogenous variable, the R-squared significantly increases to 0.336, which performs much better and many more confounders are significant to the model. This can suggest that the BMI combined with the individual's characteristics is better able to describe the changes in depression score, although the R-squared value is still low.
    - Looking at probit and logit model, the pseudo R-squared is again much higher.
- Interaction variable:
    - Highly severe and gender is highly significant for dependent is bmi, bmi and gender is marginally significant for when dependent is depression score
    - The correlation between no severity and gender//severe and gender and obese and not obese is significant
    - Determining yes or no depression with the interaction of bmi and gender is very very significant

- Wave 1 to wave 3 and 4
    - As depression is a long term disorder, one simple self-reported interview that takes into account of the past week's events during one wave cannot determine whether someone has depression. Because wave 1 and wave 2 are only one year apart, the average score of both waves was used when using depression as a continuous variable and categorical variable and only when both waves indicate a score of more than 16 (typical threshold for depression diagnosis) would an individual be considered depressed.
    - In Wave I, the BMI was determined with self-reported height and weight, because measurements were not taken. However, for the other three waves, The differences between using a measured and self-reported BMI was also accounted for and the difference between the measurements are shown in graphs (APPENDIX)

https://jbhender.github.io/Stats506/F18/GP/Group14.html

As none of the questions for Wave I in the Add Health dataset screened for depression, questions similar to an adolescent-adapted version of the PHQ-9 depression test (9) was used as an indication of the severity of depression. A cumulative score of the responses were used to categorise the child into five classes ranging from no depressive symptoms to severe symptoms.

Limitation

- Weights were used according to the instructions of the Add Health guide– show table indicating the difference in model between no weight and weights
- Depression interviews do not give indication that someone is actually depressed – tried use of PHQ-9 results which yielded similar results table of results in appendix
- Self reported data – according to "overweight, obesity and depression", there was a stronger association through clinical interview rather than self-reported
    - Self reported exercise amont and food intake
- Difference between depression question – especially for ninth question (because there was no question about self-harming) and none within a 7-day period, as well as question 3 because there is no question about over sleeping

- Include perception of weight
- Difference in overweight and obesity differs between ethnicity – overweight is 23-24.9kg/m^2 and obese is > 25kg/m^2
- Multi-level biases
- Adjusted BMI