



Body mass index and bullying victimization as antecedents for depressive symptoms in a Swedish youth cohort

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Abstract

Aim The bidirectional association between obesity and depression seen in adults is not clearly established in adolescents. The aim of this study was to investigate the longitudinal association between body mass index (BMI), depressive symptoms and interactions between bullying victimization and BMI, taking gender differences into account.

Subjects and methods In a Swedish county, self-reported bullying victimization, BMI and depressive symptoms from 1729 adolescents ($\bar{y} = 14.4$, 56% females) were collected in 2012 (wave 1), in 2015 (wave 2) ($\bar{y} = 17.3$) and in 2018 (wave 3) ($\bar{y} = 19.9$). Longitudinal associations were assessed using binary logistic regression models controlling for confounding factors. Interaction effects between BMI and victimization on depressive symptoms were also assessed.

Results Wave 1 obese males had approximately six times increased odds ratio compared to normal weight, for wave 2 depressive symptoms. W1 overweight was associated with an odds ratio of 1.5 in all participants for wave 3 depressive symptoms. Victimization was consistently associated with higher odds ratio for future depressive symptoms. We found interaction effects between bullying victimization and BMI for future depressive symptoms with different patterns depending on sex.

Conclusion Given the present findings, bullying needs to be prevented, and, if it occurs, it needs to be stopped at an early stage to prevent future depressive symptoms.

Keywords Adolescents · Bullying victimization · Depressive symptoms · Overweight

Abbreviations

BDI	Beck Depression Inventory
BMI	Body mass index
CES-D	Center for Epidemiologic Studies Depression scale
CRP	C-reactive Protein
CSB	Characterological self-blame
DSM	Diagnostic and statistical manual
DSRS	Depression self-rating scale
MSN	Microsoft service network

SALVe	Survey of adolescent life in Västmanland
SMS	Short message service

Introduction

Research has shown a bidirectional association between depression and obesity in adults, but when it comes to research in the younger population, the results are mixed (Muhlig et al. 2016). Sutaria et al. found that obese females had a higher risk for future depression (Sutaria et al. 2018), while Robert et al. did not find any association between major depression and the risk for obesity in adolescents (Roberts and Duong 2015). Some authors have discussed the importance of body image for the link between major depression and body weight (Roberts and Duong 2015). Sjoberg et al. reported that obesity was indeed significantly related to depressive symptoms among 15 and 17 year-olds (Sjoberg et al. 2005), but that this association was explained by other factors, most importantly by overall ‘experiences of shame’ (such as being degraded, made fun of or ridiculed by others) (Sjoberg et al. 2005),

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which can be seen as bullying victimization. Because obesity is a visible trait with known stigmatization,¹ even within family (Puhl et al. 2013), this might explain these results.

Individuals with obesity are indeed often stigmatized in many different situations; that is, others often devalue them because of their weight (Puhl and King 2013). In school, obese children (8–16 years) were more often described by non-overweight children as socially withdrawn, less physically attractive, sicker, more often getting into fights or being teased by others, and being more absent from school (Zeller et al. 2008). Classmates also less often reported obese children as a best friend (Zeller et al. 2008).

Bullying among adolescents is common. In a longitudinal community-based study, half of the male 14 year-olds and one-third of females reported an experience of bullying in school (Mamun et al. 2013). In a European study, including more than 11,000 pupils from ten countries, the overall prevalence was 9.4% for physical, 36.1% for verbal and 33.0% for relational bullying, whereas only about half of the pupils (48.4%) had not experienced any type of victimization and 4.5% suffered from all types of victimization (Barzilay et al. 2017). Overweight and obese adolescents have been shown to be subjected to higher rates of bullying than their non-overweight peers (Puhl and King 2013).

Experiencing victimization, such as physical abuse or bullying, is highly associated with depression and anxiety, and the risk increases with additional forms of victimization (Mossige and Huang 2017). In a recent twin study including over 11,000 participants, Singham et al. showed that victimization by bullying at 11 years of age had a causal contribution to symptoms of depression and anxiety as well as to cognitive disorganization (Singham et al. 2017). The effects decreased over time, but persisted for at least two years regarding anxiety and for five years for cognitive disorganization (e.g. easily distracted, hard to make decisions, confusion when much happens at the same time) (Singham et al. 2017). In a study of adolescents in Taiwan, Yen et al. found that body mass index (BMI) was positively associated with the degree of victimization by bullying (both passive and active) (Yen et al. 2014), and that victimization by bullying had a mediating effect on the relation between BMI and depression (Yen et al. 2014). However, considering the cross-sectional design of their study, inferring causality was impossible. A negative perception of social acceptance and competence has previously been associated with depressive symptoms (Kistner et al. 2006; Lee et al. 2010). In addition, depressive symptoms have been associated with negatively biased perceptions of social acceptance (Kistner et al. 2006). Self-reported victimization by bullying might therefore be an important indicator of low social acceptance and could, thereby, be an early risk indicator of future depressive symptoms.

¹ The term *stigma* is when labelling, stereotyping, separation, status loss, and discrimination occur simultaneously (Link and Hatzenbuehler 2016).

It is well established that women are more likely than men to suffer from depression, and these *gender differences*² tend to emerge during adolescence (Hyde et al. 2008; Kuehner 2003). There are both biological and social pathways involved in the development of these gender differences, for example, pubertal timing and negative life events, such as sexual harassment (Byrne et al. 2015; Hyde et al. 2008). A recent meta-analysis found that gender differences for depression were already present at 12 years of age (OR 2.37) with increasing OR for the ages 13–15 years (3.02) and a decline in OR for the ages 16–19 years (Salk et al. 2017). A similar pattern was found for depressive symptoms. The effect sizes increased from 0.09 (Cohen's *d*) for 8–12 year-olds to 0.35 at ages 13–15 years, and again to 0.41 for ages 16–19 years (Salk et al. 2017). The effect size then declined to 0.30 for ages 20–29 years where it remained statistically stable (Salk et al. 2017). Therefore, the time period starting from 12 years, or even younger, is a sensitive time period for all adolescents, but with important gender differences that need to be considered when assessing the development of depressive symptoms. Therefore, it is important to conduct research in these age groups to find causal factors behind this prevalent disorder.

Bidirectional links between obesity, bullying, and depression have been previously shown, and cross-sectional studies have suggested that experiences of victimization may influence the association between BMI and depression in youth (Sjoberg et al. 2005; Yen et al. 2014). However, to our knowledge, there are no longitudinal studies that investigate interaction effects between bullying victimization and BMI on the development of future depressive symptoms in youth. Therefore, this study fills a gap in the research field regarding the risk factors for developing depressive symptoms in youth.

Aim

The aim of this study was to investigate whether excess BMI predicts future depressive symptoms, and if this relation is further modified by bullying victimization in adolescence.

Method

Subjects

All adolescents born in 1997 and in 1999 living in Västmanland in 2012 ($N = 5233$), were selected to participate in the SALVE

² Differences that are influenced by, e.g. different cultural or societal norms for females and males, compared to *sex differences* that we in this context consider sexual dimorphism where the differences in appearance between females and males of the same species (e.g. colour, shape, size, and structure) are caused by the inheritance of different sexual patterns in the genetic material (The Editors of Encyclopaedia Britannica 2020). We want to highlight that the terms are used interchangeably in the literature.

cohort (Vadlin et al. 2018). Exclusion criteria were individuals who had lived in Sweden for <5 years, mental disabilities/severe illness and language difficulties. Eligible participants (4712 adolescents) were contacted by regular mail and completed a self-report questionnaire at each time point. The first assessment was conducted in 2012, wave 1 (W1), the second in 2015, wave 2 (W2), and the third in 2018, wave 3 (W3). The participants (and legal guardian for individuals <15y) signed an informed consent form at W1. In total, 1868 participants responded at W1 (39.6% of the eligible participants), 1644 participants responded at W2 (85.0% of 1933 eligible participants) and 1212 participants responded at W3 (63.8% of 1901 eligible participants). Owing to missing data on any of the study variables, the final sample of the present study consisted of 1729 participants at W1, 1481 participants at W2 and 1111 participants at W3. The study was performed according to the Declaration of Helsinki and approved by the Ethical Review Board of Uppsala (dnr 2012/187). A detailed description of the study sample is presented in Table 1.

Assessment of BMI

We calculated adolescent’s BMI from self-reported data on weight and height at all three time points. For the current study, we used international age- and sex-specific cut-offs

for the categories normal weight, overweight or obese (Cole et al. 2000).

Assessment of bullying victimization

For the present study, we used a modernized version of the bullying instrument by Alsaker and Brunner from 1999 (Alsaker and Brunner 1999). To the original scale we added questions on bullying via technology/social media and bullying by an adult at school. The adolescents were instructed to report the presence and frequency of bullying victimization during the past 12 months (5 questions) at W1 and W2. The questions were the following: (1) ‘During the past year, have you been hit, kicked, or exposed to other violence by any/some of your peers?’ (2) ‘Have you been seriously teased, for example, been accused of things you did not do, been threatened, or been called ugly things by any/some of your peers during the past year?’ (3) ‘During the past year, have any/some of your peers lied about you, talked about you behind your back, pretended you were not there, or excluded you from the group?’ (4) ‘During the past year, have you been exposed to bullying, threats, or harassments through cell phone and/or Internet/SMS, MSN, e-mail, or similar?’ (5) ‘Have you been severely violated or badly treated by any adult

Table 1 Demographic and clinical characteristics of the sample

	Wave 1 (N=1729)			Wave 2 (N=1481)			Wave 3 (N=1111)		
	Females N (%)	Males N (%)	Chi ² /Z (p)	Females N (%)	Males N (%)	Chi ² /Z (p)	Females N (%)	Males N (%)	Chi ² /Z (p)
Mean age	962 (55.6)	767 (44.4)		856 (57.8)	625 (42.2)		683 (61.5)	428 (38.5)	
Age range	14.4	14.4	-.99 (.32)	17.3	17.3	-.49 (.62)	19.9	19.9	-.74 (.46)
Age range	12.8–16.4	12.8–16.3		15.8–18.8	15.8–18.8		18.9–22.0	18.9–22.0	
Non-Nordic ethnicity ^a	187 (19.5)	147 (19.2)	.02 (.89)	165 (19.6)	117 (19.1)	.07 (.79)	119 (18.9)	69 (18.4)	.03 (.87)
Body mass index ^b range	14–41	12–34		15–48	15–43		15–47	16–37	
Normal weight	770 (82.9)	586 (79.7)	4.0 (.14)	669 (81.6)	474 (79.8)	1.1 (.59)	477 (71.8)	308 (72.6)	.30 (.86)
Overweight	129 (13.9)	128 (17.4)		115 (14)	95 (16.0)		144 (21.7)	92 (21.7)	
Obese	30 (3.2)	21 (2.9)		36 (4.4)	25 (4.2)		43 (6.5)	24 (5.7)	
Self-reported bullying ^c									
No bullying	530 (55.1)	504 (65.7)	20.2 (<0.001)	439 (51.8)	445 (71.8)	59.5 (<0.001)			
Low bullying	222 (23.1)	131 (17.1)		213 (25.1)	91 (14.7)				
High bullying	210 (21.8)	132 (17.2)		195 (23.0)	84 (13.5)				
Depressive symptoms range	0–14	0–12		0–13	0–12		0–14	0–14	
Showing depressive symptoms ^d	160 (16.6)	47 (6.1)	44.7 (<0.001)	277 (32.4)	84 (13.4)	70.1 (<0.001)	235 (34.4)	80 (18.7)	32.0 (<0.001)

Chi² test for categorical variables and Mann–Whitney Z for continuous variables, significant results reported in bold

^a Ethnicity – one or two parents from non-Nordic countries

^b According to Cole et al. 2000

^c Bullying total binned into ‘no bullying’ (<= 0) as reference, ‘low bullying’ (1) or ‘high bullying’ (>= 2). Information not collected at W3

^d Based on the DSM-IV A-criterion for major depression

at school during the past year?’ For W1, the response options for questions 1 to 4 were ‘No/Never’/‘Yes, some/a few times’/‘Yes, 1 to 3 times per month’/‘Yes, at least once a week’ (0 to 3 p) and for question 5 ‘No/Never’/‘Yes, once’/‘Yes, several times’ (0 to 2 points (p)). At W2, the possible responses were ‘No/Never’/‘Some/a few times’/‘1 to 3 times per month’/‘At least once a week’ (0 to 3 p) for all questions. The Cronbach’s alpha; i.e. the internal consistency, for this scale was .63 for W1 and .64 for W2. Factor analysis of the scale (principal components, based on eigenvalue >1, varimax rotation) revealed one component. This scale covers several aspects of bullying, including physical, verbal, relational and cyberbullying, but does not necessarily show imbalance of power, which often is included in the definition.

The total bullying victimization scores were summed separately for the two time points into two variables (W1 total bullying, W2 total bullying). These variables were used in the binary logistic regression analyses (see section Statistical analyses). The continuous variables were also visually binned using 2 cut points and equal percentiles based on scanned cases and thereby recoded into ‘no bullying’ (0 p), ‘low bullying’ (1 p), or ‘high bullying’ (≥ 2 p) for descriptive purpose. Bullying information was not obtained for W3 and was, subsequently, not included in the analyses.

Assessment of depressive symptoms

The adolescent participants were instructed at all three time points to self-rate (yes or no) experiences of depressive symptoms during the past two weeks, using the Depression Self-Rating Scale (DSRS) (Svanborg and Ekselius 2003). The 14 questions were based on the DSM-IV A criterion for major depression; symptom criteria 1: (q1) depressed mood and (q2) irritation/anger, criteria 2: (q3) loss of interest, criteria 3: (q4) weight loss/loss of appetite and/or (q5) weight gain/increased appetite, criteria 4: (q6–7) reduced or increased sleep, criteria 5: (q8–9) psychomotor agitation or retardation, criteria 6: (q10) lack of energy, criteria 7: (q11) low self-esteem and/or (q12) feelings of guilt/worthlessness, criteria 8: (q13) difficulties to think or concentrate and finally criteria 9: (q14) suicidal thoughts. Cronbach’s alpha for the scale was .81 for W1, .83 for W2 and .86 for wave 3. If at least one of the general criteria (symptom criteria 1 or 2) was present and the individual reported ≥ 5 symptom criteria out of 9 in total, they were classified as showing depressive symptoms in the binary variable ‘depressive symptoms’ (yes/no). The binary variables were created in the same manner for all three time points.

Confounders

Age was a proximation, calculated using the date the form was sent out and the date of birth. Ethnicity was regarded as Nordic if both parents were reported to be born in any of the

Nordic countries. Sex was coded according to the participant’s social security number, that includes information on the assigned birth sex.

Sociodemographic indicators

Parental role in the labour market was recorded as ‘both parents working’ or ‘at least one parent outside labour market’.

Statistical analyses

We used χ^2 to test the association between BMI categories, bullying victimization categories and depressive symptoms. We also assessed sex differences using χ^2 for these variables.

Longitudinal analysis of W1 bullying victimization, W1 BMI categories and W2 depressive symptoms was conducted using binary logistic regression analysis. The interaction effect between bullying victimization and BMI was conducted in separate analyses by adding the variable ‘Bullying * BMI category’. Using W3 depressive symptoms as outcome, we first analysed W1 BMI and bullying victimization using binary logistic regressions. Second, W2 BMI and bullying victimization were analysed; and third, data from both W1 and W2 were included in a binary logistic regression. Interaction effects between bullying victimization and BMI categories on W3 depressive symptoms were also conducted using separate binary logistic regressions. To further assess gender differences in these relationships, we conducted the binary logistic regression analyses additionally in females and in males separately. The statistical models were controlled for age, sex (if applicable) and Nordic ethnicity.

Data were analysed using the Statistical Package for the Social Sciences (SPSS, version 24, Armonk, NY).

Results

Analysis of dropouts between 2012 and 2018 showed that males (44.2% of males compared to 29.0% of females, $\chi^2 = 42.9$, $p < 0.001$) and older participants were more likely to discontinue the study (Mann–Whitney, $Z = -2.4$, $p = .019$). Controlling for levels of bullying victimization and BMI category in a binary logistic regression, sex and age were still associated with dropout while ethnicity was not. The main variables of interest in this study were not associated with dropout: W1 bullying categories ($\chi^2 = 1.9$, $p = .39$), W2 bullying categories ($\chi^2 = .20$, $p = .91$), W1 depressive symptoms ($\chi^2 = .60$, $p = .44$), W2 depressive symptoms ($\chi^2 = .01$, $p = .91$), W1 BMI category ($\chi^2 = 4.0$, $p = .13$) and W2 BMI category ($\chi^2 = .96$, $p = .62$).

Crude analyses

At W1, 83.8% of the participants had both their parents working. Parental labour role was not associated with depressive symptoms (W1, W2 or W3) in crude analysis using χ^2 tests and was subsequently not included in further analysis to reduce the number of included variables.

Using χ^2 tests, we found that females were more likely than males to report bullying victimization at both W1 and W2 (Table 1). They were also more likely to show depressive symptoms at all three time points (Table 1). The BMI categories were not associated with future depressive symptoms in the crude analyses using χ^2 . W1 bullying victimization was associated with W2 depressive symptoms; within the high bullying category, 41.6% showed W2 depressive symptoms compared with 27.6% in the low bullying category and 18.1% in the no bullying category ($\chi^2 = 65.5, p < 0.001$). In the W2 high bullying category, 45.8% showed depressive symptoms at W3 compared with 37.3% for the low and 20.4% for the no bullying categories ($\chi^2 = 55.0, p < 0.001$).

Depressive symptoms at W2

Using binary logistic regression, we assessed the longitudinal importance of W1 BMI categories and bullying victimization for W2 depressive symptoms. We found that female sex and older age were associated with higher odds for depressive symptoms in the longitudinal analyses (Tables 2 and 3). Bullying victimization was associated with higher odds for future depressive symptoms when analysing all participants, as well as in females and males separately (Table 2). The same was true when adding the interaction effect between bullying victimization and BMI categories (Table 3). W1 obesity among males was associated with a higher odds ratio for W2 depressive symptoms (Table 2). W1 BMI category was not associated with depressive symptoms in females. The interaction effect between W1 obesity and bullying victimization was associated with lower odds ratio for W2 depression (Table 3). Scatter plots of W1 BMI and W2 total symptoms of depression indicated that with higher levels of bullying victimization, the importance of BMI was lower for future depressive scores (Fig. 1). The slope for no bullying individuals was increasing with BMI for both females and males, but for low and for high bullying scores, the slopes were decreasing with BMI for females, and increasing with BMI for males (Fig. 1).

Depressive symptoms at W3

W3 depressive symptoms were assessed in a similar manner as for W2. We included W1 data in model 1, W2 data in model 2, and data from both time points in model 3 (Table 4). Females had consistently higher odds for future

depressive symptoms. W1 overweight was associated with increased odds for W3 depressive symptoms in model 1 (Table 4). In the sex specific analyses, W1 BMI was not associated with W3 depressive symptoms in females or in males. W2 BMI category was not associated with future depressive symptoms in any of the analyses.

Bullying (W1 and W2) was associated with increased odds for future depressive symptoms in all three models (Table 4). In the sex specific analyses, the results for bullying were similar as for the whole sample for model 1 and model 2, but in model 3 W1 bullying victimization was associated with W3 depressive symptoms for females, but not for males ($p = .33$).

The interaction term between W1 BMI category and bullying victimization was not associated with W3 depressive symptoms in any of the analyses. Separate analyses showed a borderline statistically significant interaction effect between W2 BMI category and bullying victimization on future depressive symptoms for all and for males (Table 5). Scatter plots of W2 BMI and W3 total symptoms of depression showed an overall additive effect between BMI and increasing bullying levels on future depressive scores (Fig. 2). The pattern for females indicated that with higher levels of bullying, the importance of BMI was lower for future depressive scores than for individuals with no bullying. For males, the slopes diverged from approximately 2.5p on the y-axis in a fan shaped pattern and the steepest increasing slope was seen for high bullying individuals, for whom the positive effect of BMI on depressive symptoms were the strongest (Fig. 2).

Discussion

In this study, we analysed the longitudinal associations between BMI, bullying victimization and interaction effects in relation to future depressive symptoms in adolescents. Overall, we found that higher BMI was associated with increased odds for depressive symptoms long term with indications of gender differences. We also found support for a longitudinal association between bullying victimization and future depressive symptoms. We further found an interaction effect between bullying and BMI in relation to future depressive symptoms, but with different patterns for males and females.

The mixed results reported previously might be explained by a joint development of obesity and depression in predisposed subjects (Muhlig et al. 2016). More recently, a higher BMI at age 14 was associated with more depressive symptoms, measured using the Beck Depression Inventory (BDI) for Youth, at age 17 (Oddy et al. 2018). Although Oddy et al. discussed the role of inflammation, for example, C-reactive protein (CRP) levels in depression, they did not include bullying as an important factor in their study. However, it is important to take bullying into account when

Table 2 Binary logistic regression investigating W1 BMI category and bullying in all adolescents, in girls and in boys, in relation to odds for depressive symptoms at W2

	All <i>N</i> =1428		Females <i>N</i> =826		Males <i>N</i> =602	
	<i>p</i>	OR (95% C.I.)	<i>p</i>	OR (95% C.I.)	<i>p</i>	OR (95% C.I.)
Sex	<0.001	2.94 (2.22 to 3.91)				
Age	0.01	1.18 (1.05 to 1.34)	0.03	1.18 (1.02 to 1.37)	0.20	1.17 (0.92 to 1.47)
Ethnicity (1) ^a	0.10	1.31 (0.95 to 1.79)	0.44	1.16 (0.79 to 1.7)	0.03	1.85 (1.06 to 3.22)
W1 normal weight – reference ^b	0.54		0.62		0.004	
W1 overweight (1)	0.69	1.08 (0.75 to 1.55)	0.39	0.82 (0.52 to 1.29)	0.06	1.76 (0.97 to 3.18)
W1 obese (2)	0.28	1.47 (0.73 to 2.98)	0.62	0.8 (0.33 to 1.95)	0.003	5.58 (1.8 to 17.27)
W1 bullying	<0.001	1.32 (1.22 to 1.44)	<0.001	1.39 (1.24 to 1.56)	0.002	1.25 (1.09 to 1.44)
Constant	<0.001	0.01	0.002	0.02	0.02	0.01

Abbreviations: BMI, Body mass index; OR, Odds ratio. Significant values $p < 0.05$ reported in bold

Variable(s) entered in a binary logistic regression, method enter, using depressive symptoms at W2 as outcome: sex, age, ethnicity, W1 BMI category, W1 bullying total

^a One or two parents from non-Nordic countries

^b According to Cole et al. 2000

interpreting findings, as childhood bullying, adjusted for BMI, has been shown to predict long-term increases in CRP levels (Copeland et al. 2014).

Several studies point towards an important social component in the path to depression. A study from 2013 showed that the perceived weight, irrespective of the actual weight, was associated with depression (Roberts and Duong 2013). Duong and Roberts (Duong and Roberts 2016) found that healthy-weight females had approximately twice the odds,

compared with healthy-weight males, of perceiving themselves as overweight, but overweight or obese males had about twice the odds, compared with females, of misperceiving themselves as being of healthy weight (Duong and Roberts 2016). This indicates that females' higher level of depressive symptoms might be due, in part, to their misperception of their own weight. This in turn might be explained by higher levels of self-evaluation, or *self-objectification*, described as a form of self-consciousness

Table 3 Binary logistic regression investigating interaction between W1 BMI category and bullying in relation to odds for W2 depressive symptoms

	All <i>N</i> =1428		Females <i>N</i> =826		Males <i>N</i> =602	
	<i>p</i>	OR (95% C.I.)	<i>p</i>	OR (95% C.I.)	<i>p</i>	OR (95% C.I.)
Sex	<0.001	2.95 (2.22 to 3.92)				
Age	0.01	1.19 (1.05 to 1.35)	0.02	1.19 (1.03 to 1.38)	0.14	1.2 (0.94 to 1.52)
Ethnicity (1) ^a	0.11	1.3 (0.94 to 1.78)	0.58	1.12 (0.76 to 1.64)	0.02	2.0 (1.14 to 3.5)
W1 normal weight – reference ^b	0.06		0.27		0.001	
W1 overweight (1)	0.64	1.11 (0.72 to 1.7)	0.26	0.72 (0.4 to 1.28)	0.02	2.2 (1.16 to 4.2)
W1 obese (2)	0.02	2.73 (1.19 to 6.3)	0.27	1.78 (0.64 to 4.97)	0.003	9.04 (2.13 to 38.41)
W1 bullying	<0.001	1.36 (1.24 to 1.51)	<0.001	1.41 (1.24 to 1.62)	<0.001	1.32 (1.14 to 1.54)
W1 normal weight * W1 bullying	0.08		0.12		0.24	
W1 overweight(1) by W1 bullying	0.79	0.97 (0.78 to 1.21)	0.51	1.11 (0.82 to 1.5)	0.15	0.7 (0.43 to 1.14)
W1 obese(2) by W1 bullying	0.03	0.59 (0.37 to 0.94)	0.06	0.49 (0.24 to 1.02)	0.32	0.66 (0.3 to 1.49)
Constant	<0.001	0.01	0.002	0.02	0.010	0.004

Abbreviations: BMI, Body mass index; OR, Odds ratio. Significant values $p < 0.05$ reported in bold

Variable(s) entered in a binary logistic regression, method enter, using depressive symptoms at W2 as outcome: sex, age, ethnicity, W1 BMI category, W1 bullying total and interaction between W1 BMI category and W1 bullying

^a One or two parents from non-Nordic countries

^b According to Cole et al. 2000

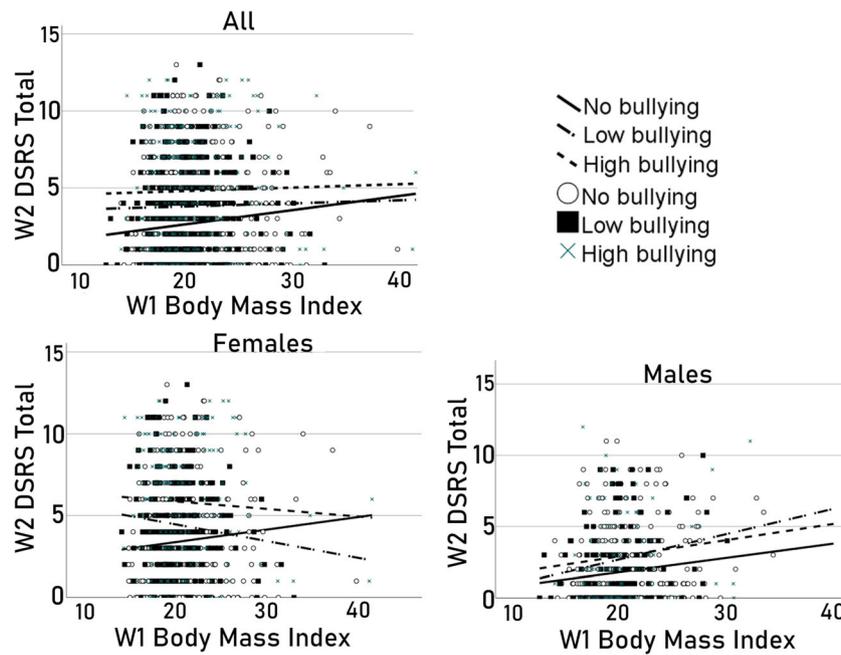


Fig. 1 Charts showing scatter plots on W1 body mass index and W2 total symptoms of depression, plus W2 body mass index in all, in females and in males separately depending on bullying level where ‘no bullying’ is marked by a circle and a continuous regression line, low bullying by a filled box and a short/long-dashed regression line while high bullying is marked by a cross and a short-dashed regression line. Figure 1 shows 3 scatter plots on the relation between body mass index (BMI) on the x-axis (scale from 10 to 40) and the total symptoms of depression on the y-axis (scale from 0 to 15) with indications of different levels of bullying marked by a circle for no bullying, a square for low bullying and a cross for high bullying for the individual values. Each graph indicates the slopes for the different bullying levels with a continuous regression line for no bullying, short/long-dashed regression line for low bullying and a short-dashed regression line for high bullying. The first plot shows W1 BMI and W2 total symptoms of depression among all participants. The slope for high

bullying starts slightly below 5p on the y-axis and has a minor positive slope. The line for low bullying is parallel to the high bullying, but starts at about 4p on the y-axis. The no bullying line starts at about 2.5p on the y-axis and increases, overlaps with the low bullying line at BMI 35. The second plot shows W1 BMI and W2 Total symptoms of depression among females. The high bullying and the low bullying slopes are negative as BMI increases while the no bullying slope is positive. High bullying starts at about 6p on the y-axis, and reaches about 5p on the y-axis for BMI 40. Low bullying starts at about 5p on the y-axis and reaches about 2.5p on the y-axis at BMI 40. No bullying starts at about 3p and increases to about 5p at BMI 40. The third plot shows W1 BMI and W2 Total symptoms of depression among males. All lines start at between 1-2p on the y-axis and have a positive slope with increasing BMI. No bullying reaches about 2.5 on y-axis at BMI 35, while low bullying reaches about 2.5 and high bullying about 4.5p at the same point

characterized by the habitual monitoring of one’s outward appearance (Slater and Tiggemann 2010). Ideals linked to body build are already present at a very young age (Lerner 1985). Body size, body shape and attractiveness are among the first attributes we come in contact with in new social contexts (Gilbert 1997) and can therefore easily be judged by ourselves or by others just by a glance. This can affect individuals differently depending on the groups they are involved with, the present societal norms, individual preferences, as well as their sex. Weight stigma is subsequently present already at preschool age (Pont et al. 2017), and not only occurs among peers, but is also affected by parents, schoolteachers and health-care staff (Pont et al. 2017). An internalization of these ideals leads to ‘significant discrepancies between women’s perceived real and ideal body shapes’ (Rosenblum and Lewis 1999) and behaviours such as dieting and exercise in attempts to reach these ideals (Rosenblum and Lewis 1999). The internalization of weight stigma is associated with lower self-esteem (Puhl and Latner 2007). Concerning adolescents, Rosenblum and Lewis found that

during the same time period (13–15 years old), the body image of females worsened while that of males improved (Rosenblum and Lewis 1999). Bullying could, of course, increase the awareness of the present ideals and be an important factor in these relationships. Overall, men have more muscle mass and females more fat mass (Karastergiou et al. 2012). Because we did not assess body composition or weight stigma in this study, this interpretation is speculative.

In this study, bullying victimization was associated with increased odds for depressive symptoms three years later as well as six years later. Previous studies have reported inconclusive findings in this area as well. In a sample of 880 Swedish 12–16 year-olds, Kendrick et al. (Kendrick et al. 2012) found that victimization by bullying was associated with depression one year later, measured by an adapted form of the Center for Epidemiologic Studies Depression Scale (CES-D) (Radloff 1977), which is in line with our findings. In addition, ‘experiences of shame’ analysed by Sjöberg et al. (Sjöberg et al. 2005), which explained the findings between obesity and depressive symptoms, could be considered another way of measuring bullying (Sjöberg et al.

Table 4 Binary logistic regression investigating BMI category and bullying from W1, W2 and both waves in relation to odds for depressive symptoms at W3

	Model 1		Model 2		Model 3	
	<i>p</i>	OR (95% C.I.)	<i>p</i>	OR (95% C.I.)	<i>p</i>	OR (95% C.I.)
Sex (1)	<0.001	2.15 (1.6 to 2.9)	<0.001	2.25 (1.62 to 3.13)	<0.001	2.22 (1.59 to 3.11)
Age	0.65	0.97 (0.85 to 1.1)	0.48	1.05 (0.92 to 1.2)	0.95	1.0 (0.87 to 1.16)
Ethnicity (1) ^a	0.47	0.87 (0.61 to 1.25)	0.72	0.93 (0.63 to 1.37)	0.60	0.9 (0.6 to 1.34)
W1 normal weight – reference ^b	0.09				0.27	
W1 overweight (1)	0.04	1.49 (1.02 to 2.17)			0.23	1.36 (0.82 to 2.24)
W1 obese (2)	0.51	0.74 (0.31 to 1.8)			0.41	0.58 (0.16 to 2.08)
W1 bullying	<0.001	1.28 (1.16 to 1.42)			<0.001	1.19 (1.06 to 1.34)
W2 normal weight – reference ^b			0.29		0.76	
W2 overweight (1)			0.12	1.36 (0.92 to 2.02)	0.59	1.14 (0.7 to 1.86)
W2 obese (2)			0.62	1.2 (0.58 to 2.48)	0.54	1.37 (0.5 to 3.78)
W2 bullying			<0.001	1.35 (1.21 to 1.5)	<0.001	1.31 (1.16 to 1.48)
Constant	0.42	0.34	0.05	0.06	0.17	0.14

Abbreviations: BMI, Body mass index; OR, Odds ratio. Significant values $p < 0.05$ reported in bold

Variables entered in a binary logistic regression, method enter, using W3 depressive symptoms as dependent variable, on step 1 in model 1 ($N = 1075$): sex, age, ethnicity, W1 BMI category, W1 bullying. In model 2 ($N = 965$): sex, age, ethnicity, W2 BMI category, W2 bullying, and in model 3 ($N = 935$): sex, age, ethnicity, W1 BMI category, W1 bullying, W2 BMI category and W2 bullying

^a One or two parents from non-Nordic countries

^b According to Cole et al. 2000

2005). In contrast, a study of Finnish 13–16 year-olds showed that depression predicted future victimization but not the other way around (Sentse et al. 2017). This difference might have arisen because although that study used the BDI (Beck and

Steer 1984), some questions were removed (e.g. regarding suicidal ideation/attempt and appetite/weight changes). In the present study, we included all depressive symptoms listed in the DSM-IV in our assessment. The CES-D scale used by

Table 5 Binary logistic regression investigating interaction between W2 bullying and BMI category in all and separately in girls and boys in relation to odds for depressive symptoms at W3

	All=965		Females $N=612$		Males $N=353$	
	<i>p</i>	OR (95% C.I.)	<i>p</i>	OR (95% C.I.)	<i>p</i>	OR (95% C.I.)
Sex (1)	<0.001	2.23 (1.6 to 3.1)				
Age	0.46	1.05 (0.92 to 1.21)	0.22	1.11 (0.94 to 1.3)	0.44	0.9 (0.69 to 1.18)
Ethnicity (1) ^a	0.67	0.92 (0.62 to 1.36)	0.61	0.89 (0.56 to 1.4)	0.86	1.07 (0.51 to 2.24)
W2 normal weight – reference ^b	0.39		0.42		0.21	
W2 overweight (1)	0.78	1.07 (0.66 to 1.76)	0.28	1.37 (0.77 to 2.44)	0.25	0.53 (0.18 to 1.58)
W2 obese (2)	0.17	1.75 (0.78 to 3.9)	0.39	1.54 (0.58 to 4.14)	0.21	2.41 (0.62 to 9.41)
W2 bullying	<0.001	1.34 (1.18 to 1.51)	<0.001	1.32 (1.15 to 1.52)	0.01	1.44 (1.1 to 1.88)
W2 normal weight * W2 bullying	0.05		0.34		0.05	
W2 overweight(1) by W2 bullying	0.10	1.35 (0.94 to 1.92)	0.55	1.13 (0.77 to 1.65)	0.06	2.41 (0.98 to 5.94)
W2 obese(2) by W2 bullying	0.11	0.74 (0.51 to 1.07)	0.20	0.73 (0.44 to 1.19)	0.22	0.71 (0.4 to 1.24)
Constant	0.05	0.06	0.07	0.05	0.91	1.35

Abbreviations: BMI, Body mass index; OR, Odds ratio. Significant values $p < 0.05$ reported in bold

Variable(s) entered in a binary logistic regression, method enter, using depressive symptoms at W3 as outcome: sex (when applicable), age, ethnicity, W2 BMI category, W2 bullying total and interaction between W2 BMI category and W2 bullying

^a One or two parents from non-Nordic countries

^b According to Cole et al. 2000

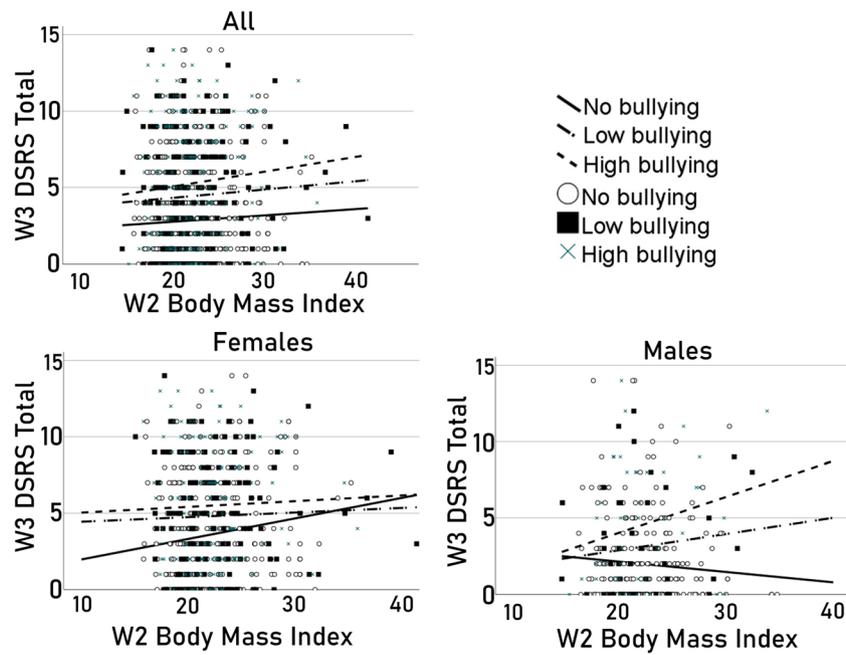


Fig. 2 Charts showing scatter plots on W2 body mass index and W3 total symptoms of depression, in all, in females and in males separately depending on bullying level where ‘no bullying’ is marked by a circle and a continuous regression line, low bullying by a filled box and a short/long-dashed regression line while high bullying is marked by a cross and a short-dashed regression line. Figure 2 shows 3 scatter plots on the relation between W2 body mass index (BMI) on the x-axis (scale from 10 to 40) and W3 total symptoms of depression on the y-axis (scale from 0 to 15) with indications of different levels of bullying marked by a circle for no bullying, a square for low bullying and a cross for high bullying for the individual values. Each graph indicates the slopes for the different bullying levels with a continuous regression line for no bullying, short/long-dashed regression line for low bullying and a short-dashed regression line for high bullying. BMI and total symptoms of depression among

all participants can be seen in the first plot. All slopes are positive with no overlaps between them. No bullying slope starts at about 2.5p on the y-axis and reaches about 3p at BMI 40. Low bullying starts at about 4p and reaches about 5p at BMI 40. High bullying starts at about 5.5p and reaches about 6.5 at BMI 40. The second plot shows W2 BMI and W3 total symptoms of depression among females. The slopes for low and high bullying start at about 5p on the y-axis with a minor increase, while the slope for the no bullying start at about 2.5p and increases to meet the high bullying at about BMI 40. The third plot shows W2 BMI and W3 total symptoms of depression among males. The regression lines forming a sun feather pattern, starts at about 2.5p on the y-axis, with a steep increase for the high bullying slope, a small increase for low bullying and a small decrease for no bullying

Kendrick et al. (Kendrick et al. 2012) also includes appetite but not suicidal ideation or attempt. This indicates that the results, at least in part, depend on the constructs of the bullying and depressive symptom scales, and that victimization by bullying is associated with some, but not all, depressive symptoms. Sentse et al. (Sentse et al. 2017) reported that depressive symptoms predicted future bullying. The idea that victimization and shame exacerbate one another in a cyclical process (Irwin et al. 2019a, b) would indeed explain these findings.

The need to belong and to form close relationships is fundamental for human behaviour (Baumeister and Leary 1995). Because adolescence is associated with many different stressors through biological, psychological as well as socio-cultural changes, the individual’s ability to cope with and adapt to these changes is key for their ability to *fit* in their individual contexts (Lerner 1985). For instance, relations outside the family become more important than before (Irwin et al. 2019a). Acceptance in these new social contexts is important (Irwin et al. 2019a), which is associated with increased social comparison and self-evaluation (Rosenblum and Lewis 1999). Adolescence is also a sensitive period for in-group biases, which are linked to amygdala

activation as shown through functional magnetic resonance imaging, and to the recognition of socially important values and attitudes (Moreira et al. 2017). Shame is considered the premier social emotion (Scheff 2003) and is associated with the perception of social status (Gilbert 1997). Threats to the social self give rise to feelings of shame as well as pro-inflammatory cytokines and cortisol in the same manner as threats to the physical body elicit fear (Dickerson et al. 2004). Shaming practices can be aimed at groups, such as a specific sex or race (Gilbert 1997). If an individual perceives themselves as a member of a targeted group, this perception, the *group identity*, affects his/her emotions (Gilbert 1997), and also their behaviour and friendships (Rutland et al. 2012). Tilghman-Osborne et al. found that shame and characterological self-blame (CSB), a cognitive style where individuals blame themselves, ‘converge into a common construct’, which was related to depressive symptoms (Tilghman-Osborne et al. 2008). With this in mind, bullying can be seen as a threat to the social self with increased stress levels (Zarate-Garza et al. 2017). Bullying has indeed been associated with increased feelings of shame (Irwin et al. 2019a).

A twin study assessing possible associations between bullying and depressive symptoms found that additive genetic influences accounted for 65% of the variance in symptoms of depression and anxiety (Connolly and Beaver 2016). At the same time, this genetic influence might also contribute to the risk of bullying victimization through, for example, the serotonin system and problem-solving strategies (Connolly and Beaver 2016). Regarding the former, genetic variations have been linked to differences in stress resilience (Southwick et al. 2005). For the latter, adolescent victims of bullying have reported more emotional coping than non-victims (Undheim et al. 2016). This was in turn linked to depressive symptoms (Undheim et al. 2016). Interestingly, shame, bodily shame in particular, was shown to increase the risk for chronic peer victimization (Irwin et al. 2019a), which supports the idea of a self-reinforcing loop between bullying and depressive symptoms, with shame at the centre. Shame of one's body may have serious effects on behaviour and confidence in social contexts (Gilbert 1997). Body surveillance, considered a behavioural manifestation of self-objectification, was suggested to be associated with disordered eating via body shame (Slater and Tiggemann 2010). We did not assess eating behaviour in this study, which should be taken into account when interpreting the study results. Although this topic lies beyond the scope of the present study, it should be emphasized that depressive symptoms are not the only, or worst, consequence of victimization by bullying (Rafiq et al. 2018; Zarate-Garza et al. 2017).

Considering the additive effect of genetic vulnerabilities (which we cannot change) and the environment (which we might be able to change), we should focus on reducing bullying irrespective of its nature, and provide adolescent bullying victims with tools to cope with their situation without blame on the victim or on the perpetrator (Weber et al. 2013). Researchers should consider including bullying when investigating BMI and depressive symptoms in future studies. It might also be fruitful to investigate the association of different depressive symptoms separately to elucidate these relationships.

Strengths and limitations

One of the major strengths of this study is the longitudinal design with three time points of data collection that encompassed most of the adolescent years up to adulthood. In addition, we analysed the association between the parameters of interest separately in females and in males, which revealed different patterns. Another strength was that we used international age- and sex-specific cut-offs for BMI, which are important during the adolescent years when the body changes, sometimes rapidly. When analysing W3 dropouts, results showed that none of the most important study variables (BMI category, depressive symptoms, high bullying scores or ethnicity) had any significant impact. One limitation of this study was the use of self-evaluation reports, which could

either under- or overestimate key variables. Body composition or disordered eating was not assessed and could therefore not be taken into account. The response frequency was low (about 39.6%) for W1. The dropout analyses showed that more males than females had missing data for W3, which could have affected the level of significance for the observed differences.

Conclusion

Overall, we found overweight and obesity associated with future depressive symptoms in this sample of Swedish adolescents deriving from the community. The strength of this association was minor, compared to self-reported bullying victimization that was an important risk factor for future depressive symptoms, even after six years. Bullying and BMI showed an interaction effect on future depressive symptoms, but with indications of different patterns for females and males. With this in mind, further action needs to be taken to stop ongoing and to prevent future bullying. One highly speculative issue that should be investigated concerns whether the focus on weight reduction in schools or at home increases the perceived stigma for adolescents, who are in a sensitive period during their life. Despite the good intentions, could this focus lead to lower self-esteem, increased shame, or have an impact on perceived weight, and, therefore, be harmful?

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Authors' contributions All authors designed the study, CÅ and KWN provided the data, SHK analysed the data, all authors interpreted the data, and SHK drafted the manuscript. All authors contributed to critical revisions and have approved the final manuscript.

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Data availability Data are not available due to confidentiality.

Compliance with ethical standards

Ethics approval The study was performed according to the Declaration of Helsinki and approved by the Ethical Review Board of Uppsala (dnr 2012/187).

Conflict of interest The authors declare that they have no conflict of interest.

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