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Childhood obesity's influence on socioeconomic disparities in young adolescents' mental health

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ABSTRACT

Purpose: We investigated whether socioeconomic inequalities in young adolescents' mental health are partially due to the unequal distribution of childhood obesity across socioeconomic positions (SEP), i.e. differential exposure, or due to the effect of obesity on mental health being more detrimental among certain SEPs, i.e. differential impact.
Methods: We studied 4660 participants of the Generation R study, a population-based study in the Netherlands. SEP was estimated by mother's education and household income at age five of the child. We estimated the contribution of the mediating and moderating effects of high body fat percentage to the disparity in mental health. This was done through a four-way decomposition using marginal structural models with inverse probability of treatment weighting.
Results: Comparing children with the least to most educated mothers and the lowest to highest household income, the total disparity in emotional problems was 0.98 points (95%CI:0.35–1.63) and 1.68 points (95%CI:1.13–2.19), respectively. Of these total disparities in emotional problems, 0.50 points (95%CI:0.15–0.85) and 0.24 points (95%CI:0.09–0.46) were due to the differential exposure to obesity. Obesity did not contribute to disparities in behavioural problems.
Conclusion: Addressing the heightened obesity prevalence among children in low SEP families may reduce inequalities in emotional problems in early adolescence.

Introduction

The majority of mental disorders have their onset before mid-adolescence [1–3], which makes early adolescence an important window of opportunity for preventing the onset of mental health problems [4].

Children who grow up in families with a lower socioeconomic position (SEP) are more likely to have mental health problems than children who grow up in more privileged settings [5]. This might be explained by the adverse social and physical contexts that can accompany low SEP, including higher odds of parental mental health problems, financial stress, lower access to mental health care and neighbourhoods with less advantageous conditions [5–7]. These factors may create an environment that fails to provide children with adequate resources to cope with adversity, which can, in turn, increase the risk that they will develop mental health problems.

This adversity experienced by low socioeconomic groups may also contribute to higher levels of childhood obesity [8,9]. Indeed, there is evidence that comorbidity of obesity and mental health problems in adolescents is higher in low socioeconomic settings [10]. In particular, obesity was shown to increase the risk of developing mental health problems [11]. This might be explained through biological pathways, such as stress or inflammatory responses; behavioural pathways, such as low physical activity, sedentary behaviour, poor diet, or poor sleep; [12]

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or psychosocial pathways, such as discrimination based on weight [13,14] and negative self-image [15]. In early adolescence, the psychosocial pathway might be a particularly important contributor to the effect of obesity on mental health due to adolescents' increased sensitivity to social evaluation [4].

Gaining more insight into the underlying pathways of the role of obesity in socioeconomic inequalities in young adolescents' mental health will improve our understanding of how these inequalities can be addressed. Ward et al [16]. define three guiding questions that are of interest for gaining a deeper understanding of the causes of health inequalities. First, is there a difference in the outcome across groups? Second, is there a difference in the prevalence of the exposure across groups, i.e. differential exposure? Third, is there a difference in the effect of the exposure on the outcome across groups, i.e. differential impact? The question of whether mental health differs across SEP is already confirmed by previous research, but the other two guiding questions remain unexplored. In fact, the co-occurrence of obesity and mental health problems in low socioeconomic settings [10] indicates that socioeconomic inequalities in young adolescents' mental health may be partially due to obesity being more prevalent among certain SEP. This suggests evidence for differential exposure. However, the effect of obesity may also be more detrimental to the mental health of adolescents with a lower SEP, because they have fewer resources to cope with the negative psychosocial effects of obesity. This would suggest evidence for differential impact, but was not explored in previous research according to our knowledge [17]. Therefore, we investigate to what extent the differential exposure to and the differential impact of obesity contribute to socioeconomic inequalities in young adolescents' mental health.

Materials and methods

Data

We conducted our analysis as part of the Generation R Study [18]. Generation R is a multi-ethnic population-based prospective cohort study based in Rotterdam, the Netherlands, that spans from foetal life until young adulthood. Pregnant women with an expected delivery date between April 2002 and January 2006 were invited to participate. Of these women, 9778 participated in the study and gave birth to 9749 children, 7893 of whom enrolled in the study. We included children with complete data on mental health at around age 13 and maternal education (N = 4660) (supplementary Figure S.1). The Generation R Study was approved by the Medical Ethical Committee of Erasmus MC, University Medical Centre Rotterdam. The participants (parents until age 12, parents and children from age 12) gave written consent for each phase of the study.

Exposure

We assessed the children's SEP based on their mother's highest educational attainment and household income, reported at age 5 of the child. Maternal education was measured using a self-reported questionnaire, and was categorised into low, medium, or high, in accordance with the International Standard Classification of Education [19]. Household income was reported by the mother as the monthly household net income from work, benefits, and/or assets in euros, and was divided into the following categories: < 3200, 3200–4800, or > 4800.

Outcome

We assessed each child's emotional and behavioural problems around age 13 using the validated, parent-reported Child Behavior Checklist (CBCL/6–18 [20]). The checklist consists of 112 items that assess problem behaviour, which can be divided into emotional problems/internalizing symptoms and behavioural problems/externalizing symptoms subscales [20,21]. The main caregiver rated all problem items as either 0 (not true), 1 (somewhat or sometimes true), and 2 (very true or often true) [22]. The items were summed per subscale and used as a continuous variable in our analysis. Because the link between SEP and mental health may differ between externalizing and internalizing symptoms [5,22], we ran the analysis for both problem subscales separately.

Mediator

We calculated the body fat percentage at age nine based on total fat mass, measured through dual X-ray absorptiometry (DXA); and body weight, measured with light clothing using a mechanical personal scale. To aid the analysis, we categorised body fat percentage into quartiles (Q1: <21.1%, Q2: 21.1–25.2%, Q3: 25.3–30.6%, Q4: >30.6%). Q4 correlates strongly with overweight and obesity calculated using body mass index (supplementary Figure S.2). For the subgroup analysis, we calculated sex-specific body fat percentage quartiles (girls: Q1:<23.8%, Q2:23.8–27.4%, Q3:27.4%−32.4%, Q4:>32.4%; boys: Q1:<18.9%, Q2:18.9–22.4%, Q3:22.4%−27.4%, Q4:>27.4%).

Confounders

The sex and birth weight of the child were obtained from hospital/midwife registries. Maternal age was recorded at intake. The child's migration background was reported by the mother at baseline. The mother's partnership status, family functioning, and the child's mental health were measured at the child's age five; the mother's depressive symptoms, financial stress and child's school problems were assessed at the child's age nine (Supplement section 1). We controlled for the child's age at the time the outcome was measured; although the assessment was aimed around age 13 years, in this way we account for potential small variations in age at measurement.

Statistical analysis

We performed a four-way decomposition approach developed by VanderWeele [23]. Rather than investigating the causal effect of socioeconomic status on mental health, we were interested in examining how obesity interventions might affect inequalities in young adolescents' mental health. To achieve this, we calculated the interventional analogues of the four effect components, as described by Jackson and VanderWeele, and defined SEP as a disparity measure [24]. Maternal education and household income may still be considered causes of obesity and mental health but – in the context of this study – we were not interested in estimating their causal effects. Instead, we aimed to describe the total disparity in mental health between groups defined by maternal education and household income, and to what extent these disparities could be reduced by eliminating socioeconomic differences in the exposure to and the impact of obesity.

We defined the total disparity (TD) as the absolute difference in internalizing and externalizing symptoms between SEPs expressed as

$$TD = E[Y_a - Y_{a^*}]$$

Where Y is internalizing or externalizing symptoms, a is either low or middle maternal education or a household income of either < 3200 EUR or 3200–4800 EUR, and a^* is high maternal education or a household income of > 4800 EUR.

The total disparity is comparable to the total effect, but requires no assumptions about the absence of exposure-outcome or exposure-mediator confounding [25,26]. The resulting conceptual framework can be found in Figure 1.

We decompose the total disparity into the analogues to the controlled direct effect (CDE), reference interaction (INT_{ref}), mediated interaction (INT_{med}) and pure indirect effect (PIE) (a more detailed description is provided in Supplement section 2). We calculated the

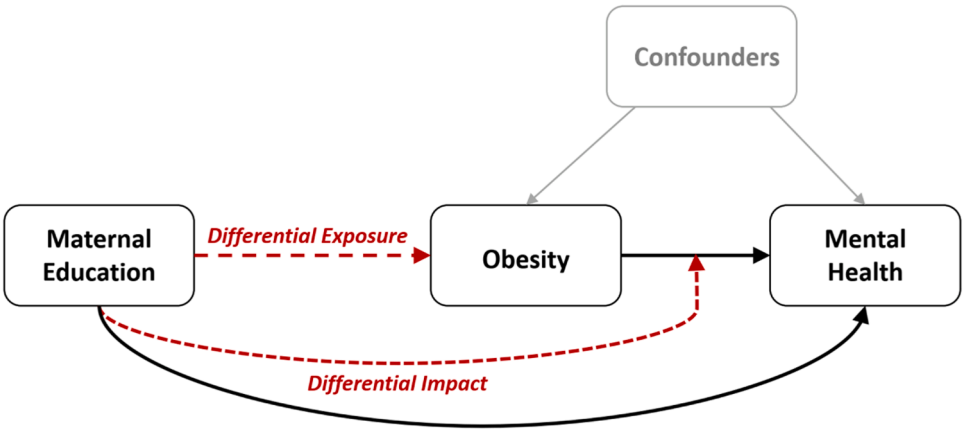

Fig. 1. Conceptual Framework. We indicate differential exposure and differential impact through the red arrows. Confounders: gender, child's migration background, mother's age at intake, birth weight, mother's mental health, family functioning, marital status, financial stress, school problems, CBCL/1.5–5. We omit exposure-outcome and exposure-mediator confounding because education and income are defined as a disparity measure.

differential exposure as the sum of the PIE and INT_{med}, and the differential impact as the sum of INT_{ref} and INT_{med}, as proposed by Diderichsen et al [17]. The differential exposure indicated to what extent educational or income inequalities in young adolescents' mental health could be reduced by eliminating unequal exposure to obesity. The differential impact indicated to what extent the total disparity in young adolescents' mental health could be reduced by eliminating the interaction between education or income and childhood obesity. We calculated the relative contribution of the differential exposure or the differential impact to the TD by dividing each estimate by the TD.

To calculate the interventional analogues, we fit marginal structural models with inverse probability of treatment weighting for the mediator, while controlling for the confounders listed above. We used the CMAverse R package developed by Shi et al [27]., but omitted exposure weighting to estimate the TD, introduced Monte Carlo error reduction (60 iterations) for the simulation step, and calculated the differential exposure and the differential impact. We used multiple imputation by chained equations (M=50) to impute missing data on body fat percentage and confounders. We used 399 bootstrap iterations to obtain the 95% confidence intervals. We performed subgroup analysis by sex.

Results

Most of the children had a mother with high educational attainment and a household income of > 4800 EUR/month (Table 1). The children in the low-education group had a higher prevalence of high body fat percentage and higher mean internalizing and externalizing symptoms scores at age 13 than the children in the high-education group. Among household income groups, the middle-income group had the highest prevalence of high body fat percentage and internalizing symptom scores, followed by the low-income group. Externalizing symptoms were lower in the high-income group compared to the low- and middle-income groups.

Figure 2 shows the mean scores for internalizing (upper panels) and

Table 1
Sample characteristics by maternal education and household income.

	Maternal Education			Household Income		
	high	middle	low	> =4800	3200 to 4800	< 3200
N	2843	1323	494	1577	930	1516
Girl N(%)	1420 (49.9)	667 (50.4)	254 (51.4)	791 (50.2)	459 (49.4)	767 (50.6)
Migration background N(%)						
Dutch	2114 (74.4)	773 (58.5)	185 (37.8)	1299 (82.4)	355 (38.2)	1064 (70.2)
Western	315 (11.1)	85 (6.4)	26 (5.3)	149 (9.5)	84 (9.0)	150 (9.9)
Non-Western	413 (14.5)	463 (35.0)	279 (56.9)	128 (8.1)	490 (52.7)	302 (19.9)
Body fat percentage at age 9 N(%)						
<21%	741 (29.2)	241 (20.2)	58 (13.6)	422 (29.8)	166 (19.7)	328 (23.4)
21 to 25%	713 (28.1)	242 (20.3)	84 (19.6)	394 (27.8)	169 (20.0)	352 (25.1)
25 to 30.6%	607 (23.9)	333 (28.0)	99 (23.1)	372 (26.3)	196 (23.2)	347 (24.7)
>30.6%	478 (18.8)	375 (31.5)	187 (43.7)	227 (16.0)	313 (37.1)	376 (26.8)
CBCL score at age 13 (mean(SD))						
Internalizing symptom score	5.27 (5.6)	6.06 (5.8)	6.23 (6.7)	4.66 (5.0)	6.37 (6.2)	5.82 (5.9)
Externalizing symptom score	3.96 (5.0)	4.57 (5.4)	4.65 (6.4)	3.61 (4.7)	4.88 (5.9)	4.25 (5.0)
Confounders						
Age at CBCL measurement (mean (SD))	13.53 (0.4)	13.55 (0.4)	13.60 (0.4)	13.52 (0.4)	13.57 (0.4)	13.51 (0.4)
Age of mother at intake (mean (SD))	32.50 (3.9)	29.90 (5.1)	29.73 (5.9)	33.15 (3.37)	29.81 (5.5)	31.39 (4.5)
Birth weight in grams (mean (SD))	3481 (569)	3348 (601)	3340 (549)	3516 (553)	3340 (599)	3417 (582)
No partner/not living with partner N(%)	217 (7.6)	220 (16.7)	117 (24.0)	24 (1.5)	380 (41.0)	47 (3.1)
CBCL at age 5 (mean (SD))	17.27 (14.25)	20.15 (15.9)	24.07 (19.3)	15.98 (13.6)	23.22 (18.2)	18.74 (14.6)
School problems N(%)	560 (26.0)	273 (32.0)	74 (29.6)	294 (23.9)	179 (29.6)	357 (31.0)
Problematic family functioning N(%)	89 (3.4)	58 (5.0)	39 (11.0)	39 (2.5)	88 (9.9)	47 (3.1)
Trouble paying for food, rent, electricity bill N(%)						
No trouble	2223 (89.1)	829 (76.6)	238 (67.8)	1344 (95.3)	498 (64.4)	1141 (84.4)
A little trouble	246 (9.9)	219 (20.2)	97 (27.6)	63 (4.5)	237 (30.7)	189 (14.0)
A lot of trouble	26 (1.0)	34 (3.1)	16 (4.6)	3 (0.2)	38 (4.9)	22 (1.6)
Depressive symptoms of the mother at age 9 (mean (SD))	0.16 (0.3)	0.22 (0.4)	0.24 (0.4)	0.13 (0.3)	0.29 (0.5)	0.18 (0.4)

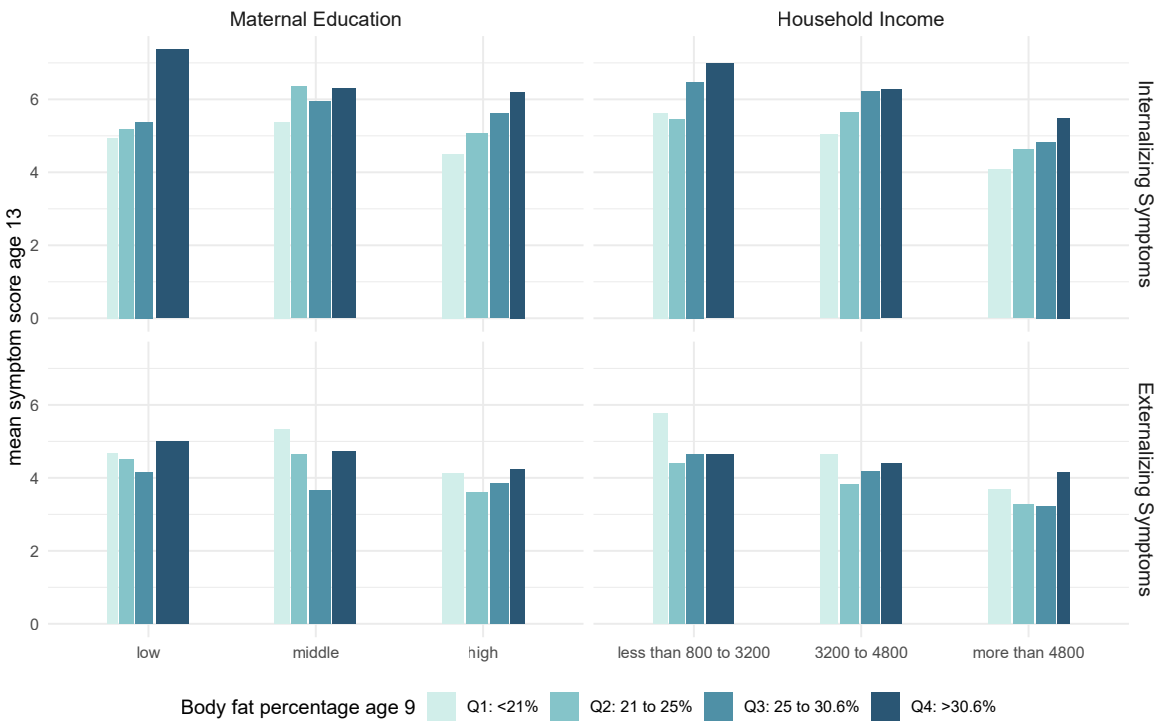

Fig. 2. Descriptive mean internalizing and externalizing symptom score at age 13 by body fat percentage quartiles at age 9, stratified by maternal education and household income. The bar width represents the relative group size of each body fat percentage quartile in relation to the other quartiles, within each education or income group.

externalizing (lower panels) symptoms per quartile of body fat percentage, stratified by maternal education (left panels) or household income (right panels). It provides a descriptive illustration of the association between body fat and internalizing and externalizing symptoms within each education or income group (represented by the height of the bars; indicative of the differential impact), and of the prevalence of body fat percentage within each education or income group (represented by the width of the bars; indicative of the differential exposure). This figure indicates that children in the highest body fat percentage quartile had more internalizing and externalizing symptoms if they were living in a family with a lower maternal education or income level. Furthermore, children in the highest body fat percentage quartile were more likely to be living in a family with a lower maternal education or income level.

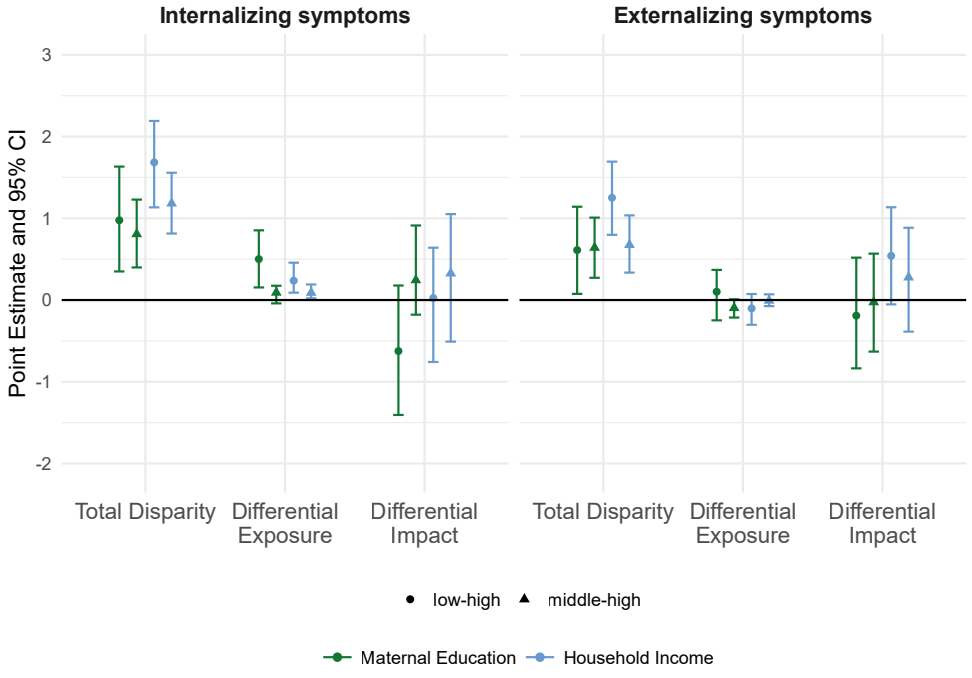

Fig. 3. Total disparity in internalizing and externalizing symptoms by maternal education and household income, and the contribution of differential exposure to or impact of high body fat percentage to these disparities.

Main results by maternal education and household income can be found in Figure 3 and supplementary Table S.1. For maternal education, we estimated a total disparity in internalizing symptoms of 0.98 (95% CI 0.35, 1.63) points for low compared to high maternal education and of 0.81 (95% CI 0.40, 1.23) points for middle compared to high maternal education; and a total disparity in externalizing symptoms of 0.61 (95% CI 0.08, 1.14) points for low compared to high maternal education and of 0.64 (95% CI 0.27, 1.01) points for middle compared to high maternal education. Furthermore, we found that 0.50 (95% CI 0.15, 0.85) points or 51 % of the total disparity in internalizing symptoms could be accounted for by the differential exposure to high body fat percentage in the low- compared to the high-educated group. Our results also indicated that -0.62 (95%CI -1.41 to 0.17) or 64 % of this disparity in internalizing symptoms could be accounted for by the differential impact, although confidence intervals included the null.

For household income, we found a total disparity in internalizing symptoms of 1.68 (95%CI 1.13, 2.19) points and 1.18 (95%CI 0.81, 1.56) points for low and middle versus high-income; and a total disparity in externalizing symptoms of 1.25 (95%CI 0.8, 1.69) points and 0.68 (95%CI 0.34, 1.04) points for low and middle compared to high-income. We also observed that 0.24 (95%CI 0.09, 0.46) points or 14% and 0.09 (95%CI 0.02, 0.19) points or 8% of the total disparity in internalizing symptoms between the low- and middle-income groups compared to the high-income group could be attributed to the differential exposure. Our findings further indicated that 0.54 points (95%CI -0.05, 1.14) or 43% of the disparity in externalizing symptoms between the low- and the high-income group was due to the differential impact, although the confidence intervals included the null.

Subgroup analysis

Stratified by sex, we found disparities in internalizing and externalizing symptoms for both girls and boys (Figure 4, supplementary Table S.2). For girls, 0.62 (95%CI 0.06, 1.25) points or 57% of the total disparity in internalizing symptoms in the low- compared to the high-educated group could be accounted for by differential exposure to high body fat percentage. For boys, the TDs in internalizing and externalizing symptoms were not accounted for by the differential exposure. For household income, we found disparities among both girls and boys for both internalizing and externalizing symptoms but the differential exposure to body fat percentage did not seem to account for these disparities.

Discussion

Summary of findings

This study found educational and income inequalities in emotional and behavioural problems in early adolescence which could be partly explained by socioeconomic inequalities in obesity at age nine. For emotional problems, we estimated that 50% of the total disparity between the low and high maternal education group and 14% of the total disparity between the low and high household income group were due to differential exposure to high body fat percentage at age nine. For behavioural problems, we found no evidence that a high body fat percentage explained part of the educational or income inequalities. We observed differences by sex, with high body fat percentage contributing to educational inequalities in emotional problems among girls only. Conversely, the differential exposure to or the impact of emotional and behavioural problems at age nine did not explain educational and income inequalities in high body fat percentage at age 13.

Strengths and limitations

This study has several advantages. First, we had objective measurements of fat mass, which allowed us to calculate body fat percentage. While BMI is commonly used to study the effects of obesity on various outcomes, BMI may underestimate the socioeconomic gradient in obesity [28]. Furthermore, fat mass is a more accurate measure of body composition than BMI [29]. Second, this is, to our knowledge, the first study to perform a four-way decomposition where the exposure is considered as a disparity measure. This provided us with a unique opportunity to assess the underlying mechanisms that explain how intervening in obesity can reduce socioeconomic inequalities in young

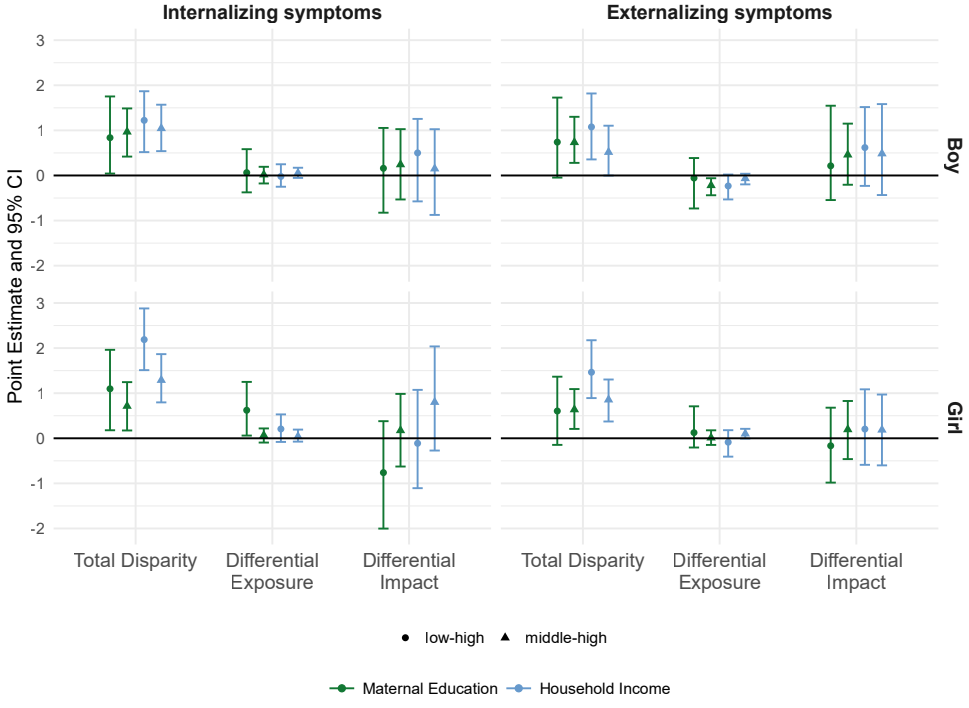

Fig. 4. Total disparity in maternal education and household income and the contribution of differential exposure to or impact of high body fat percentage by gender.

adolescents' mental health.

This paper has a number of limitations that we would like to highlight. First, Generation R Study participants were higher educated and healthier than the underlying study population [30] and information on the adolescents' mental health was only available for about 40% of the participants (supplementary Figure S.1). Hence, the underlying sample, which was already affected by health selection, might suffer from additional selection bias if children with worse mental health dropped out at higher rates. This selection bias may differ across education or income groups [31], which might lead us an underestimation of the true socioeconomic gradient in young adolescents' mental health in the Rotterdam region [22]. This might bias the differential exposure and the impact towards the null. Second, based on the large confidence intervals surrounding our differential impact estimates, there was too much uncertainty to draw conclusions about to what extent the differential impact of high body fat percentage explained socioeconomic inequalities in emotional or behavioural problems. Third, we compare the high body fat percentage groups to the non-high body fat percentage groups. However, Figure 2 indicates a potential u-shaped relationship between body fat percentage quartiles and externalizing symptoms, with a larger prevalence of externalizing symptoms in the low and high body fat percentage groups. We therefore ran a sensitivity analysis which showed that our results are robust to including low body fat percentage in the main analysis (supplement section 5). Fourth, our analysis assumed no unmeasured confounding of the obesity-mental health relationship. Obesity and mental health share a number of risk factors, and even though we carefully selected relevant confounders, other factors not considered in this analysis might play a role. This could lead to an overestimation of the causal effect of obesity on mental health.

Lastly, this study also assumes that the consistency assumption holds. Consistency describes that the hypothetical intervention of how we reduce the differential exposure or differential impact of high body fat percentage across SEPs is well-defined. Obesity may be reduced in many different ways, not all of which are desirable or will affect the outcome the same way [32]. Well-defined interventions for reducing high body fat percentage would here primarily be individual-level interventions, such as increasing physical activity or improving diet. However, it is important to note that these types of interventions are not always successful in reducing the differential exposure or differential impact of obesity across SEPs because they ignore the broader social, economic and political context that children grow up in [33]. In turn, low socioeconomic groups are less likely to adhere [34] to or attend [35] individual-level interventions because of fewer resources and capabilities to respond to such interventions, and because such interventions are often too far detached from the life-worlds of lower SEP groups [17,36]. Hence, rather than introducing individual behavioural interventions, population-based (preventive) interventions targeted at multiple health and social dimensions might lead to the largest reduction in socioeconomic inequalities in both obesity and mental health.

Comparison with previous literature

We found evidence that a higher prevalence of body fat percentage in the low- compared to the high-education and income groups explained part of the total disparity in emotional problems. Previous research showed that obesity is more strongly associated with emotional problems than with behavioural problems [37,38], which might explain why we found that the differential exposure to obesity contributed to emotional problems only. While it was previously reported that obesity and mental health problems are more likely to co-occur in households with a low than a high SEP [10], our study is novel in that it found evidence that obesity played a mediating role in socioeconomic inequalities in emotional problems. The possibility that differential exposure to obesity might explain socioeconomic inequalities in emotional problems in childhood was indirectly suggested by Zhou et al [38]. and Patalay et al [39]., who found an attenuation of the link between obesity and emotional problems after controlling for SEP, and concluded that SEP is a shared origin for both. We added to this finding by quantifying the actual contribution of the differential exposure to high body fat percentage to socioeconomic inequalities in young adolescents' mental health. Stratified by sex, we found that the differential exposure to obesity contributed to socioeconomic inequalities in emotional problems among girls only. This suggests that reducing the prevalence of high body fat percentage among girls with less educated mothers to the same level as that of girls with highly educated mothers would result in a 57% decrease in the total disparity in emotional problems. This finding is supported by previous research showing that the socioeconomic gradient in obesity tends to be larger in women than in men [40,41], though evidence in children and adolescents was mixed [9,42].

We are not able to make any substantiated inferences about the extent to which the differential impact of obesity contributes to educational or income inequalities in emotional and behavioural symptom scores. While there is some evidence that obesity affects health outcomes more strongly in individuals with low SEPs [43,44], evidence on whether this holds for emotional and behavioural problems in young adolescents is lacking. Nonetheless, addressing obesity in early adolescence may be particularly important due to the increased sensitivity of children in this age group to social evaluation [4], which may amplify the consequences of weight-based stigma and discrimination, and, in turn, negatively affect their mental health. Future research that is able to draw on larger samples is needed to more thoroughly test these potential associations.

Mental health problems and obesity co-occur more often among low socioeconomic groups [10]. We found that while the differential exposure to obesity explained part of the educational and income inequalities in young adolescents' mental health, socioeconomic inequalities in emotional or behavioural problems did not explain socioeconomic inequalities in obesity (supplement section 5). In fact, the co-occurrence of obesity and mental health problems may be partially a result of the overlapping share of risk factors [10] that are also more likely to be present among children and adolescents who grow up in lower SEPs. These factors include family-level factors, such as financial stress and hardship, parental mental health problems, and poor parenting practices; as well as more structural factors, like inadequate access to facilities for physical activity, green space, and mental health care [5,6,8,45]. Tackling these root causes of both obesity and mental health problems in young adolescents is a promising strategy for reducing health inequalities early in life.

Conclusion

Using a novel four-way decomposition approach, we found that the higher prevalence of high body fat percentage in the low compared to the high education and income groups partly accounted for the higher emotional symptom scores in those groups, particularly among girls. Hence, reducing the prevalence of obesity or the exposure to shared risk factors for mental health problems and obesity may help to reduce educational and income inequalities in young adolescents' mental health.

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CRediT authorship contribution statement

Maria Gueltzow: Conceptualization, Formal analysis, Writing – original draft, Writing – review & editing, Investigation, Methodology, Visualization. **Joost Oude Groeniger:** Conceptualization, Funding

acquisition, Methodology, Supervision, Writing – review & editing, Validation. **Maarten J. Bijlsma:** Conceptualization, Supervision, Writing – review & editing. **Pauline W. Jansen:** Data curation, Writing – review & editing, Funding acquisition. **Tanja A.J. Houweling:** Conceptualization, Writing – review & editing. **Frank J. van Lenthe:** Conceptualization, Funding acquisition, Supervision, Writing – review & editing.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Joost Oude Groeniger reports financial support was provided by Netherlands Organisation for Health Research and Development. Frank J van Lenthe reports financial support was provided by Netherlands Organisation for Health Research and Development. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.annepidem.2024.04.003.

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