

Early-life Poverty, Social Disadvantage and Adiposity from Childhood to Young Adulthood

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Research Article

Keywords: poverty, social disadvantage, childhood obesity, body fat distribution, life course, birth cohort

Posted Date: August 21st, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-10470763/v1>

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Additional Declarations: No competing interests reported.

Abstract

Background

Early-life family poverty and social disadvantage status may affect body mass index (BMI) and body fat distribution in offspring across the life course. We assessed the associations of early-life poverty and social disadvantage with adiposity measures from early childhood to young adulthood.

Methods

We performed a population-based prospective cohort study among 7,389 parents and children in the city of Rotterdam, the Netherlands. Exposures were pregnancy parental educational level, low household income, and poverty, defined as low income and experiencing financial difficulties, assessed by questionnaires. Childhood body mass index, total fat mass, visceral adipose tissue, and hepatic fat were assessed by physical examinations, dual-energy X-ray absorptiometry, and magnetic resonance imaging at the ages of 2, 6, 10, 14, and 18 years.

Results

As compared to children not exposed to early-life poverty, those exposed had a higher offspring BMI from the age of 6 years onwards (difference in BMI standard deviation score [SDS] at the age of 18 years 0.17, 95% confidence interval [CI] 0.01, 0.32), a higher risk of overweight and obesity at ages 6 and 18 years (odds ratio at the age of 18 years 1.45, 95% CI 1.06, 2.00), and a higher total fat mass from the age of 10 years onwards (difference in total fat mass SDS at the age of 18 years 0.17, 95% CI 0.02, 0.33). We observed tendencies for similar associations for household income and both maternal and paternal education. Also, as compared to children not exposed to low household income and lower maternal education, those exposed had a higher android/gynoid fat mass ratio from the age of 10 years onwards (p -values < 0.05). Measures of poverty and social disadvantage were not associated with childhood and visceral fat or liver fat.

Conclusions

Early-life poverty and social disadvantage are associated with a higher BMI and adverse body fat distribution from early-childhood to young adulthood. Addressing social inequalities in pregnancy and early childhood may contribute to reducing adiposity across the life course.

BACKGROUND

Poverty has major effects on health and disease risk across the life course(1, 2). These effects may be intergenerational, starting from early-life onwards. Previous studies have shown that parental poverty

and lower educational level are associated with increased risks of obesity in offspring(3, 4). A registry-based study from Finland showed that parental education and household income were the strongest social indicators linked to offspring obesity risk(3). A population-based cohort study from Taiwan showed that children aged 2–7 years from low-income families had a 44% higher increased risk of developing overweight or obesity during follow-up(4). These findings highlight that socioeconomic disadvantage early in life is an important determinant of childhood obesity, which may have long term consequences since obesity tracks from childhood into adulthood(5). Although body mass index (BMI) is widely used to assess obesity, it is a less precise indicator of total body fat and does not reflect adipose tissue distribution(6). It does not distinguish between subcutaneous and visceral fat, with visceral fat being more strongly linked to metabolic risk(7, 8). Understanding how early-life poverty influences BMI and fat distribution across childhood and adolescence may provide important insights into the development of health inequalities over time and help to identify groups at risk and develop targeted prevention strategies.

We hypothesized that growing up in an early-life environment of parental poverty and social disadvantage has persistent consequences for BMI and body fat distribution from childhood to young adulthood. In a population-based cohort study from pregnancy onwards among 7,389 parents and children, we assessed the associations of poverty and social disadvantage with BMI, total body fat, visceral adipose tissue and hepatic fat, assessed by dual-energy X-ray absorptiometry and magnetic resonance imaging from early childhood to young adulthood.

METHODS

Design and study population

The current study was embedded in the Generation R Study, a population-based prospective cohort study from fetal life until adulthood in Rotterdam, The Netherlands(9). Study approval was obtained by the Medical Ethical Committee of the Erasmus MC, University Medical Center, Rotterdam (MEC 198.782/2001/31)(9). Written informed consent was obtained from all mothers. The study has been described in detail previously(9). Briefly, all participating children were born between April 2002 and January 2006. Enrollment was aimed at early pregnancy but possible until birth. In total, 9,778 mothers and children were enrolled. We excluded mothers with no data on poverty or social disadvantage, non-singleton livebirths and children with no adiposity data. We used data of 7,389 mothers and their children with information about poverty or social disadvantage parameters and at least one BMI measure at the age of 2, 6, 10, 14 or 18 years. (Flowchart in **Additional File 1: Figure S1**).

Poverty and social disadvantage

Information on maternal and paternal educational level, household income, and experiencing financial difficulties was obtained through self-reported questionnaires during pregnancy. Educational level was

categorized as low (International Standard Classification of Education [ISCED] 0–5) or high (ISCED 6–8), with low including both the original low and middle education groups(10). Mothers reported difficulties paying for food, rent, electricity bill, and suchlike to assess experiencing financial difficulties. Household income during pregnancy was categorized as <€1600 euros or ≥€1600 euros per month, reflecting the poverty level in 2004(11, 12). Poverty was defined as a household income below the poverty level combined with financial difficulties. We defined four early-life exposures: 1) poverty; 2) household income; 3) maternal educational level; 4) paternal educational level.

General and abdominal body fat distribution assessments at different ages

Children's body composition was measured by trained staff in our research center. Height and weight were measured without shoes and heavy clothing, and BMI (kg/m²) was calculated at the ages of 2, 6, 10, 14 and 18 years. Total fat mass, android fat mass and gynoid fat mass were measured in a subset of 6, 10, 14 and 18 years old with a DXA scanner (iDXA, GE-Lunar, 2008, Madison, WI, USA) using enCORE software versions 13.6 and 17 SP5, following the standard manufacturer protocols, as previously described (9, 13). Children removed accessories and clothing that could influence measurement. Scans with artefacts were, if possible, adjusted for, and otherwise excluded. From the whole-body DXA scans, we derived total fat mass (FM;kg), fat mass index (FMI;fat mass(kg)/height(m²)), and android and gynoid fat mass. The android/gynoid fat ratio (A/G ratio) was calculated as android divided by gynoid fat mass, with higher values indicating a relatively more central fat distribution. All DXA-derived measures were converted into Z-scores ((observed value – mean)/SD). Visceral fat and liver fat were obtained from MRI scans at age 10 (3-T MRIs scanner, Discovery MR750w; GE Healthcare) as previously described(9, 14). To create fat measures independent of height, we used log-log regression to determine optimal adjustment, dividing total fat mass by height⁴ (fat mass index) and visceral fat mass by height³ (visceral fat indexes) (15, 16). For liver fat assessment, an axial 3-point Dixon acquisition for fat and water separation (IDEAL IQ) was used. An axial abdominal scan from the lower liver to the pelvis and a coronal scan centered at the head of the femurs were performed with a 2-point DIXON acquisition (LavaFlex)(17). The MRI fat scans were analyzed by the Precision Image Analysis company (PIA, Kirkland, Washington, United States), using the sliceOmatic (TomoVision, Magog, Canada) software package. All extraneous structures and any image artifacts were removed manually(14). Visceral fat volumes ranged from the dome of the liver to the superior part of the femoral head. Fat masses were obtained by multiplying the total volumes by the specific gravity of adipose tissue, 0.9 g/ml. Liver fat fraction was determined by taking four samples of ≥4cm² from the central portion of the hepatic volume. Mean signal intensities were averaged to generate an overall liver fat fraction estimate.

Covariates and explaining variables

Information on age was assessed through questionnaires during pregnancy and at childhood.

Ethnicity: Ethnicity was based on questions regarding participants' and their parents' birth country, classified according to Statistics Netherlands(18). If either parent was born abroad, participants were classified as having a non-Dutch ethnicity. If both parents were born abroad, the mothers' birth country defined the participants' ethnicity. **Prenatal factors:** Information on pre-pregnancy BMI, parity, smoking, alcohol consumption, marital status and duration of breastfeeding in months were assessed by questionnaires during pregnancy. **Childhood factors:** Birth weight and gestational age were obtained from midwives. Physical activity at age 10 was assessed as average weekly hours of structured and unstructured sports or active play. Screen time at age 10 was assessed as average daily hours spent watching television, using a computer, or playing video games. Data from the age of 10 were used as a proxy for habitual lifestyle behaviours during childhood. Based on a Directed Acyclic Graph (DAG), our models were adjusted for child sex, age, ethnicity, maternal age, maternal BMI, educational level, alcohol and smoking use during pregnancy, parity, birthweight, gestational age, duration of breastfeeding, television watching, and sports or active play (**Additional File 1: Figure S2**).

Statistical analyses

First, baseline characteristics were described using means (standard deviation (SD)), medians (inter quartile range (IQR)), or frequencies (%). We performed a non-response analysis by comparing characteristics of women with and without offspring follow-up measurements available using t-tests, Mann–Whitney U tests, and chi-square tests. Second, we examined associations of socioeconomic indicators during pregnancy (poverty status, household income, maternal educational level and paternal educational level) with childhood age- and sex-standardized body mass index standard deviation scores (BMI-SDS) as a continuous outcome at ages 2, 6, 10, 14, and 18 years. We conducted separate multivariable linear regression models for each age to assess age-specific associations. Logistic regression models were used to assess associations with the odds of overweight and obesity at each age point. Third, we assessed the associations of socioeconomic indicators with total fat mass and android/gynoid fat mass at ages 6, 10, 14, and 18 years, and visceral fat mass and liver fat fraction at age 10 using age specific linear regression models. We applied a stepwise hierarchical modeling approach to explore the contribution of different confounding and explanatory domains. We constructed three models: (1) a basic model adjusted for the child's sex and age, unless the variable was already standardized for these factors (BMI-SDS, IOTF grade); (2) a confounder model additionally adjusted for maternal age at childbirth and child ethnicity; (3) a fully adjusted model additionally adjusted for maternal smoking and alcohol use during pregnancy, pre-pregnancy BMI, parity, gestational age, birth weight, breastfeeding duration and childhood lifestyle behaviours (television viewing, physical activity). All covariates were entered separately into the models. The primary analyses were performed at each age separately. We performed sensitivity analyses using general linear mixed models to assess the overall effect estimates based on the repeated measurements. Missing data were handled using multiple imputation by chained equations (R package *mice*). Exposure variables (poverty and social disadvantage indicators) were not imputed. Estimates from imputed datasets were pooled using Rubin's

rules. All analyses were performed using R version 4.5.2 (R Foundation for Statistical Computing, Vienna, Austria). A two-sided p-value < 0.05 was considered statistically significant.

Use of artificial intelligence

The authors used Claude to assist with formatting the manuscript and abstract according to journal-specific submission requirements. The AI tool was not used to generate, analyze, or interpret study data or results. All content was reviewed and verified by the authors, who take full responsibility for the accuracy and integrity of the manuscript.

RESULTS

Study participant characteristics

Table 1 shows that the mean maternal age at the child's birth was 30.8 years (SD 5.1). In total, 10.2% of the families experienced poverty, 28.0% had a low income, 54.3% had a low maternal education level and 47.8% had a low paternal education level. Table 2 gives the childhood characteristics. Non-response analysis showed that as compared to mothers not included in the analyses, those included in the analysis were older, higher educated, experienced less poverty and their offspring had a higher birthweight. (**Additional File 1: Tables S1-S2**).

Table 1
Maternal and paternal characteristics

Maternal characteristics	N = 7389
Age at birth child in years, mean ($\pm$ SD)	30.8 (5.1)
Pre-pregnancy BMI (kg/m ²), median (IQR)	22.6 (20.8, 25.4)
Parity, n(%)	
Nulliparous	4097 (56.7)
Multiparous	3129 (43.3)
Ethnicity, n(%)	
European	4491 (61.6)
Non-European	2803 (38.4)
Smoking during pregnancy, n(%)	
Continued smoking in pregnancy	1149 (17.1)
Smoked until pregnancy was known	586 (8.7)
Never smoked during pregnancy	4986 (74.2)
Alcohol use during pregnancy, n(%)	
Yes	3538 (54.7)
No	2935 (45.3)
Folic acid started preconceptionally, n(%)	
Yes	2275 (42.3)
No	3107 (57.7)
Educational level	
Low (primary or lower secondary, high school, associate degree)	3873 (54.3)
High (higher education phase 1 or 2)	3254 (45.7)
Household income, n(%)	
Low (< 1600 euros/month)	1642 (28.0)
Based on non-imputed data.	
Values are means (standard deviations) or medians (IQR) or observed numbers (valid percentages)	
Valid percentages represent the percentage of only non-missing cases in each category of categorical variable	

Maternal characteristics	N = 7389
High (≥ 1600 euros/month)	4223 (72.0)
Financial difficulties during pregnancy, n(%)	
Yes	935 (17.2)
No	4488 (82.8)
Poverty	
Yes	575 (10.2)
No	5055 (89.8)
Marital status	
Married	3580 (50.8)
Unmarried	3466 (49.2)
Paternal characteristics	
Age biological father in years, mean ($\pm$ SD)	33.2 (5.9)
Educational level during pregnancy, n(%)	
Low (primary or lower secondary, high school, associate degree)	2202 (47.8)
High (higher education phase 1 or 2)	2406 (52.2)
Ethnicity, n(%)	
European	4273 (61.7)
Non-European	2647 (38.3)
BMI (kg/m ²), mean ($\pm$ SD)	25.3 (3.4)
Smoking 2 months before pregnancy, n(%)	
Yes	1950 (43.6)
No	2525 (56.4)
Alcohol use 2 months before pregnancy, n(%)	
Yes	3804 (84.3)
Based on non-imputed data.	
Values are means (standard deviations) or medians (IQR) or observed numbers (valid percentages)	
Valid percentages represent the percentage of only non-missing cases in each category of categorical variable	

Maternal characteristics	N = 7389
No	709 (15.7)
Based on non-imputed data.	
Values are means (standard deviations) or medians (IQR) or observed numbers (valid percentages)	
Valid percentages represent the percentage of only non-missing cases in each category of categorical variable	

Table 2
Childhood characteristics

Birth	N = 7389
Gestational age at birth (weeks), median (IQR)	40.1 (39.1, 41.0)
Preterm birth (< 37 weeks), n(%)	355 (5.2)
Term birth (≥ 37 weeks), n(%)	6518 (94.8)
Sex, n(%)	
Male	3718 (50.3)
Female	3671 (49.7)
Birth weight (grams), mean (± SD)	3429 (557)
Duration of breastfeeding (months), n(%)	
< 3 months	1691 (41.1)
≥ 3 months	2423 (58.9)
Ethnicity, n(%)	
European	4723 (64.6)
Non-European	2584 (35.4)
2 years	
Age (months), median (IQR)	24.8 (24.2, 25.8)
Sex, n%	
Male	2518 (50.7)
Female	2450 (49.3)
BMI (kg/m ²), mean (± SD)	16.6 (1.4)
6 years	
Age (years), median (IQR)	6.0 (5.9, 6.3)
Sex, n%	
Male	3063 (50.0)
Female	3067 (50.0)
Based on non-imputed data. Values are means (standard deviations) or medians (IQR) or observed numbers (valid percentages). Valid percentages represent the percentage of only non-missing cases in each category of categorical variable.	

Birth	N = 7389
BMI (kg/m ²), median (IQR)	15.9 (15.0, 17.0)
Total fat mass (kilograms), median (IQR)	5.3 (4.4, 5.5)
Android/gynoid fat mass index, median (IQR)	0.24 (0.21, 0.28)
10 years	
Age (years), median (IQR)	9.7 (9.6, 9.9)
Sex, n(%)	
Male	2676 (49.7)
Female	2707 (50.3)
BMI (kg/m ²), median (IQR)	16.9 (15.7, 18.8)
Total fat mass (kilograms), median (IQR)	8.5 (6.6, 11.9)
Android/gynoid fat mass index, median (IQR)	0.24 (0.21, 0.31)
Visceral fat mass (grams), median (IQR)	358 (264, 495)
Liver fat fraction (%), median (IQR)	2.0 (1.7, 2.5)
Liver fat fraction, categories	
Normal liver fat fraction (< 2%)	1520 (50.5)
Mildly elevated liver fat fraction (2-4.9%)	1408 (46.8)
High liver fat fraction (≥ 5%)	82 (2.7)
Physical activity level (e.g., hours/week), n(%)	
0–4	3166 (77.1)
> 4	939 (22.9)
Hours of television watching, n(%)	
< 2 hours per day	3024 (69.5)
≥ 2 hours per day	1329 (30.5)
14 years	
Age (years), median (IQR)	13.5 (13.4, 13.7)
Sex, n(%)	
Based on non-imputed data. Values are means (standard deviations) or medians (IQR) or observed numbers (valid percentages). Valid percentages represent the percentage of only non-missing cases in each category of categorical variable.	

Birth	N = 7389
14 years	N = 7389
Male	2240 (49.3)
Female	2308 (50.7)
BMI (kg/m ²), median (IQR)	19.1 (17.5, 21.4)
Total fat mass (kilograms), median (IQR)	12.3 (9.2, 17.0)
Android/gynoid fat mass index, median (IQR)	0.24 (0.20, 0.30)
18 years	
Age (years), median (IQR)	18.4 (18.0, 18.8)
Sex, n(%)	
Male	1576 (47.0)
Female	1776 (53.0)
BMI (kg/m ²), median (IQR)	22.0 (20.1, 24.5)
Total fat mass (kilograms), median (IQR)	17.0 (12.6, 22.7)
Android/gynoid fat mass, median (IQR)	0.29 (0.24, 0.36)
Based on non-imputed data. Values are means (standard deviations) or medians (IQR) or observed numbers (valid percentages). Valid percentages represent the percentage of only non-missing cases in each category of categorical variable.	

Body Mass Index and Risks of Overweight and Obesity

Figure 1 shows that as compared to offspring from parents who did not experience poverty, those from parents who experienced poverty had higher BMI SDS at all ages from the age of 6 years onwards, with effect estimates increasing from early childhood into young adulthood (difference in BMI-SDS 0.17, 95% CI; 0.01, 0.32 at the age 18 years). Also, children from parents who experienced poverty had higher odds of overweight and obesity at ages 6 and 18 years (Odds Ratio (OR) 1.35, 95% CI; 1.07, 1.71 and 1.45, 95% CI; 1.06, 2.00, respectively). We observed tendencies for similar effect estimates for the other ages, but these were not statistically significant. In contrast, as compared to offspring of parents with high maternal and paternal educational levels, those from parents with low educational levels initially had a lower BMI at the age of 2 years, but showed a higher BMI from the age of 10 years onwards (p-value < 0.05). We observed tendencies for similar associations for household income and both maternal and paternal education (Fig. 1). **Additional File 1, Figure S3 and S4** give results from the basic and confounder models and show similar results as the fully adjusted models. **Additional File 1, Table S5** give the results from the linear mixed models showed that BMI-SDS trajectories increased more steeply over time among children exposed to poverty, low household income, and low maternal and paternal educational level.

Body Fat Mass

Figure 2 shows that as compared to offspring from parents who did not experience poverty, those from parents who experienced poverty had higher total fat mass from the age of 10 years onwards leading to a difference in total fat mass SDS of 0.17 (95% CI; 0.02, 0.33) at the age of 18 years. Similar results were observed for low household income and low maternal and paternal education during pregnancy, with the strongest associations at the age of 14 years, particularly for household income and maternal education level. **Additional File 1, Table S6** give results from the basic and confounder models and show similar results as the fully adjusted models. **Additional File 1, Table S7** give the results from the linear mixed models showing that children exposed to poverty, low household income, and low maternal and paternal educational level had higher total fat mass SDS throughout childhood and adolescence. Not poverty, but low household income and low maternal education were associated with higher android/gynoid fat mass ratio from age 10 onwards (difference in android/gynoid fat mass SDS at the age of 10 years 0.11, 95% CI; 0.04, 0.19 and 0.16, 95% CI; 0.10, 0.22, respectively) (**Additional File 1, Table S8**). Basic and confounder models showed similar results as the fully adjusted models (**Additional File 1, Table S8**). **Additional File 1, Table S9** give results from the linear mixed models showing that differences in android/gynoid fat mass ratio SDS were already present at age 6 for income and parental education, but not for poverty, and appeared to increase over time for all four socioeconomic indicators. Measures of poverty and social disadvantage were not associated with childhood and visceral fat or liver fat (**Additional File 1, Table S10**).

DISCUSSION

In this population-based prospective cohort study, we observed that early-life markers of poverty and social disadvantage were associated with a higher BMI and an adverse body fat distribution outcomes in children aged 2–18 years. We did not observe associations between early-life poverty and liver fat and visceral fat in children.

Early-life poverty and social disadvantage are important determinants of childhood health and wellbeing(19). We hypothesized that growing up in an early-life environment of parental poverty and social disadvantage has persistent consequences for childhood BMI and body fat distribution from childhood to young adulthood. A large population-based cohort study reported that cumulative exposure to neighborhood socioeconomic disadvantage was associated with adverse BMI trajectories from birth to age 7, with children from disadvantaged neighborhoods showing a steeper increase in BMI and a higher risk of overweight and obesity compared to children from more affluent neighborhoods(20). In addition, a pooled analysis of seven population-based prospective cohorts from six high-income countries showed social gradients in childhood obesity, with lower maternal education and household income associated with a higher risk of overweight and obesity at 8–11 years(21). Our results are in line with these findings by showing that early-life poverty and lower parental education are already associated with higher BMI and increased risk of overweight and obesity from early childhood onwards. This elevated risk of obesity at this young age likely reflects a trajectory that tracks into late childhood

and adolescence. Thus, early-life poverty and social disadvantage are consistently associated with higher BMI and increased risk of overweight and obesity from early childhood onwards.

Most studies used BMI as the primary outcome, while less is known about the association between early-life poverty and social disadvantage and more detailed fat distribution measurements. This is relevant as fat distribution is more strongly related to cardiometabolic risk than BMI alone(22). Staatz et al observed in a cohort study in 15,131 children that socioeconomic position recorded at 9 months was associated with a higher body fat percentage between ages 7 and 17. In line with this study, we observed that children with adverse parental pregnancy socioeconomic indicators had a higher total fat mass and a higher android/gynoid fat mass ratio in childhood. We did not observe associations with liver fat fraction or visceral fat mass in children at age 10 years. Our findings support previous evidence showing that early-life socioeconomic disadvantage is associated with higher adiposity and a more adverse fat distribution in offspring.

Early-life poverty and social disadvantage may already exert effects during pregnancy, as previous studies suggest that adverse prenatal exposures can induce long-term changes in metabolic pathways regulating adiposity and energy balance through intra-uterine programming mechanisms(23). The stronger effect estimates observed for maternal compared with paternal education may partly reflect the more prominent role mothers often have in shaping offspring eating behaviours and weight-related lifestyle patterns(24). The increasing strength of associations with age may further suggest cumulative risk processes, whereby early exposures continue to accumulate and become more pronounced over time. In addition, as children grow older, maternal influences and shared lifestyle patterns may become more evident.

These findings highlight the importance of early preventive strategies aimed at reducing socioeconomic inequalities already during pregnancy and early childhood. Targeted interventions may be needed to support families in disadvantaged neighborhoods. These results indicate that early-life poverty and social disadvantage may influence offspring adiposity through both prenatal programming and postnatal cumulative processes, highlighting pregnancy and early childhood as key windows for preventing socioeconomic inequalities in obesity and fat distribution.

The strength of this study is that we used a population-based prospective cohort design including a large number of subjects whom we studied from early fetal life onwards. We had a large number of fetal and infant anthropometric data available. The repeated anthropometric measurements enabled us to explore protentional critical periods for the development of body fat distribution in children. Some limitations should be discussed. Selection bias in studies mainly arises from loss to follow up rather than from non-response at baseline. Of all children with information on BMI, 45.4% did participate in the follow up measurements at the age of 18. Non-response analysis showed that mothers with offspring participating in follow-up measurements in our outcomes of interest had a higher income, were experiencing less poverty and had a higher educational level compared to mothers whose offspring did not participate in follow-up. As a result, there may have been an underestimation of effect estimates.

Due to the study design, information on experiencing financial difficulties was obtained with questionnaires. Assessing experiencing financial difficulties by questionnaire is accepted in epidemiological studies, but may still have led to misclassification by underreporting. We performed detailed measurements of childhood body fat distribution. DXA quantifies fat content with high precision and has the capacity for regional analysis but cannot differentiate the amount of the two abdominal fat compartments(25, 26). We could not adjust for detailed measures of childhood diet, as this information was available only in a small subgroup of the study population. Although we performed an extensive adjustment for a large number of potential confounders, residual confounding might still occur, as in any observational study.

CONCLUSION

Early-life poverty and social disadvantage are associated with a higher BMI and adverse body fat distribution outcomes from childhood to young adulthood. Addressing social inequalities in pregnancy and early childhood may contribute to reducing adiposity across the life course.

Abbreviations

A/G ratio: Android/gynoid fat mass ratio

BMI: Body mass index

BMI-SDS: Body mass index standard deviation score

CI: Confidence interval

DAG: Directed acyclic graph

DXA: Dual-energy X-ray absorptiometry

ERC: European Research Council

FM: Fat mass

FMI: Fat mass index

IOTF: International Obesity Task Force

IQR: Interquartile range

ISCED: International Standard Classification of Education

MRI: Magnetic resonance imaging

NWO: Netherlands Organization for Scientific Research

OR: Odds ratio

SD: Standard deviation

ZonMw: The Netherlands Organization for Health Research and Development

Declarations

- **Ethics approval and consent to participate:** The general design, all research aims and the specific measurements in the Generation R Study have been approved by the Medical Ethical Committee of Erasmus MC, University Medical Center Rotterdam (MEC 198.782/2001/31). New measurements

are only introduced into the study after approval of the Medical Ethical Committee. Participants need to give written informed consent for each phase of the study (fetal, preschool, childhood and adolescence period). From the age of 12 years onwards, children must sign their own consent form, in accordance with Dutch Law. At the start of each phase, children and their parents receive written and oral information about the study. Even with consent, when the child or the parents are not willing to participate actively, specific measurements are skipped or no measurements at all are performed.

- **Consent for publication:** Not applicable
- **Availability of data and materials:** The data that support the findings of this study are not publicly available due to ethical and privacy restrictions. Data may be made available upon reasonable request and subject to approval by the Generation R Study Management Team, in accordance with the study's data access policies.
- **Competing interests:** The authors declare that they have no competing interests.
- **Funding:** The Generation R Study is financially supported by the Erasmus University Medical Centre, Rotterdam, the Erasmus University Rotterdam, and the Netherlands Organization for Health Research and Development. Romy Gaillard received funding from the Dutch Diabetes Foundation (Grant No. 2024.28.001), from the Netherlands Organization for Health Research and Development (NWO, ZonMW, grant number 05430052110007, and NWO, ZonMw VIDI Grant 09150172110034), and an European Research Council Starting Grant (ERC-2024-STG-101161004, OBESE-EMRYO). Vincent Jaddoe received an European Research Council Consolidator Grant (ERC-2014-CoG-648916, EMBRYOandLATERHEALTH) and European Research Council Advanced Grant (ERC-2025-Adv - 101265943, PreconceptionOrigins) and ZonMW, grant number 05430052110007. Romy Gaillard is part of the Healthy Start Convergence Programme from the Erasmus University Medical Center, Erasmus University, and Delft University of Technology. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Council. Neither the European Union nor the granting authority can be held responsible for them.
- **Authors' contributions:** VWVJ and RG conceived and designed the study. KJS performed the statistical analyses under the supervision of VWVJ and RG, and drafted the manuscript. VWVJ and RG contributed to the interpretation of the results and critically revised the manuscript for important intellectual content. All authors read and approved the final manuscript.
- **Acknowledgements:** We gratefully acknowledge the contribution of participating mothers, fathers, and their children, general practitioners, hospitals and midwives and pharmacies in Rotterdam.

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Figures

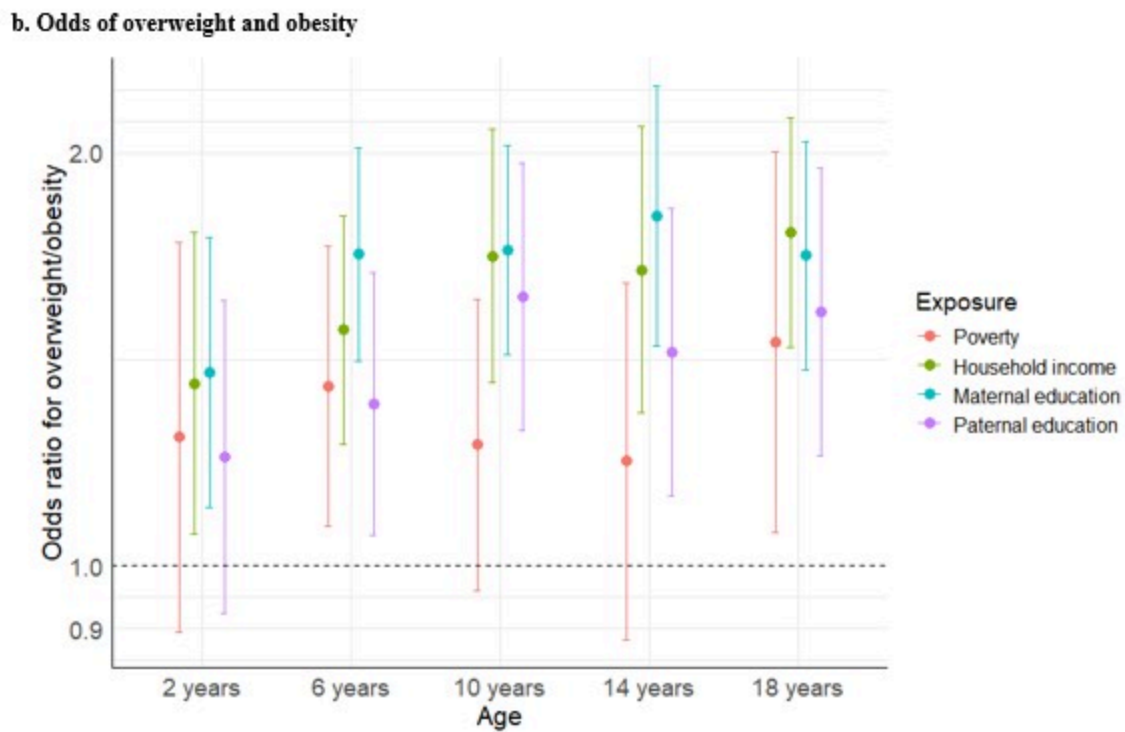
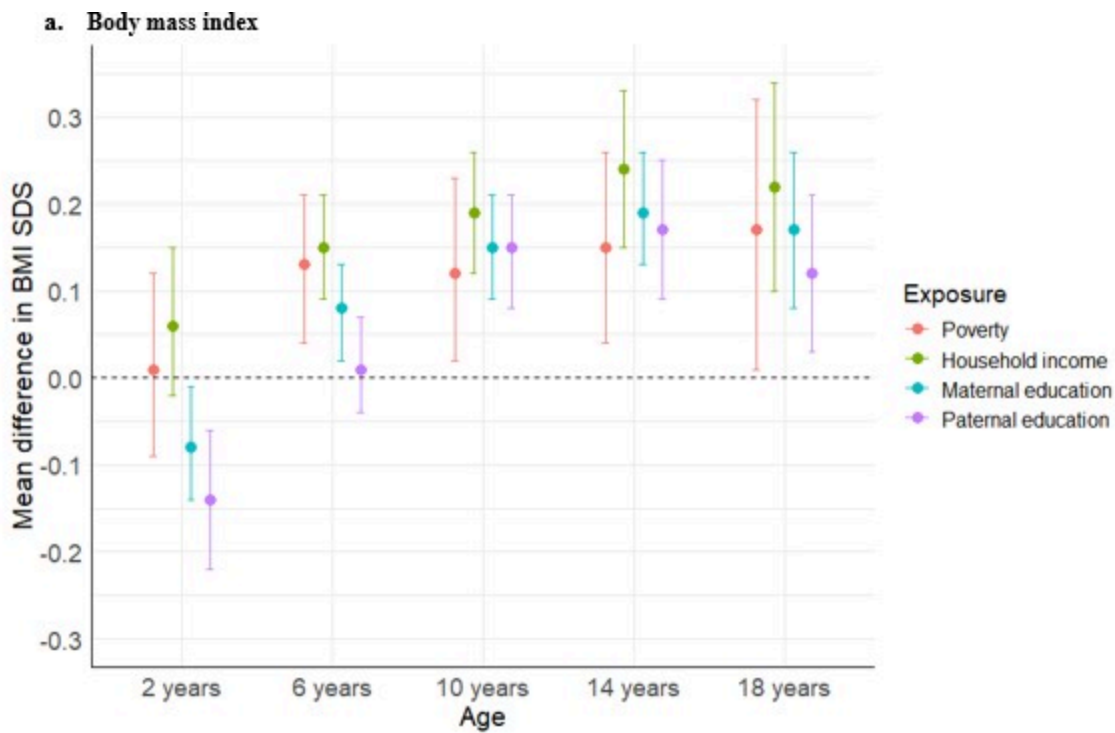


Figure 1

Parental pregnancy socioeconomic indicators and childhood BMI-related outcomes

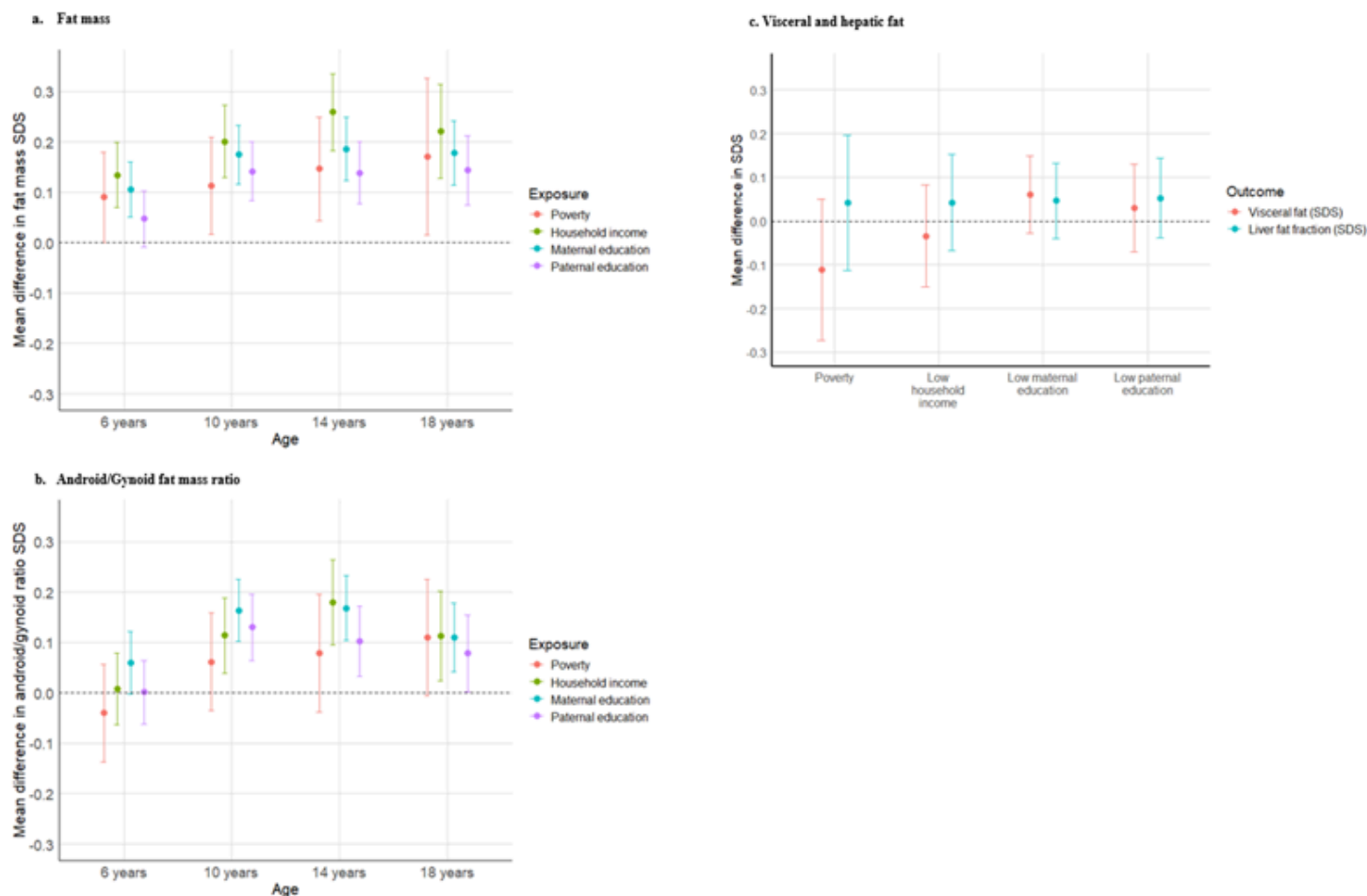


Figure 2

Parental pregnancy socioeconomic indicators and body fat outcomes from childhood to adulthood

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