


RESEARCH ARTICLE

Body mass index and weight gain in pregnancy and cardiovascular health in middle age: A cohort study

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Abstract

Objective: To examine associations between body mass index (BMI) in early pregnancy and gestational weight gain (GWG) with cardiovascular health in middle age using the 'Life's Essential 8' (LE8) concept of the American Heart Association (AHA).

Design: Population-based cohort study.

Setting: Swedish CardioPulmonary bioImage Study (SCAPIS).

Population: A total of 8871 women from SCAPIS were included.

Methods: Information on cardiovascular health in middle age was collected from SCAPIS and linked to pregnancy weight data obtained from the Swedish Medical Birth Register, with an average follow-up time of 24.5 years. An LE8 score between 0 and 100 was determined, where a score under 60 points was defined as poor cardiovascular health. Binary logistic regression and restricted cubic splines were used.

Main outcome measures: Cardiovascular health according to LE8 in middle age.

Results: The odds of having poor cardiovascular health in middle age were significantly higher in women who had overweight (adjusted odds ratio, aOR 3.30, 95% CI 2.82–3.88) or obesity (aOR 7.63, 95% CI 5.86–9.94), compared with women classified as being of normal weight in pregnancy. Higher odds were also found for excessive GWG (aOR 1.31, 95% CI 1.09–1.57), compared with women who gained weight within the recommendations.

Conclusions: A high BMI in early pregnancy and excessive GWG were associated with greater odds of poor cardiovascular health in middle age. Although further

studies are needed, our results highlight pregnancy as an important period to support long-term cardiovascular health.

KEY WORDS

body mass index, gestational weight gain, Life's Essential8, pregnancy, pregnancy as a window for future health

1 | INTRODUCTION

Pregnancy is commonly a period where substantial weight is gained to support maternal requirements and ensure fetal growth.¹ However, having overweight before pregnancy and excessive gestational weight gain (GWG) have been associated with long-term maternal adiposity,^{2–4} and the issue seems to be on the rise; it has been reported that almost half of women worldwide exceed the guidelines for appropriate weight gain during pregnancy.⁵ Previous studies suggest that excessive GWG is associated with perinatal complications, such as macrosomia and preterm delivery,⁶ and along with a high prepregnancy body mass index (BMI) have been shown to increase the risk of cardiometabolic conditions in both the mother and the offspring.^{7,8} The negative effects of excessive body weight and GWG thus present a major public health concern, making pregnancy a potential target for obesity prevention and the promotion of long-term cardiovascular health. For this reason, an effort to evaluate the impact of pregnancy weight patterns on future maternal cardiovascular risk is important, to counteract these alarming trends. Although studies have confirmed the unfavourable effect of obesity on long-term cardiometabolic status,^{9–12} the association between weight status in pregnancy and cardiovascular health has not been sufficiently explored, particularly from a longitudinal perspective. One way to study the impact of maternal weight status and GWG on later cardiovascular health is to examine the association between gestational weight and the concept of 'Life's Essential8' (LE8) developed by the American Heart Association (AHA) to assess and improve cardiovascular health in a given population.¹³ It is based on a risk score system consisting of eight metrics of known risk components, corresponding to health behaviours and health factors. Importantly, LE8 has been strongly related to later all-cause and cardiovascular mortality,^{14,15} making it a suitable proxy for general cardiovascular health. However, little is known regarding the risk factors for poor cardiovascular health as measured by LE8. More specifically, there is a great lack of studies examining the longitudinal associations of BMI in early pregnancy and GWG with later LE8, despite the proven relevance of the score and the modifiable nature of its components.^{13–15} The aim of this study was therefore to investigate the association between BMI in early pregnancy and GWG with cardiovascular health (measured as LE8) in middle-aged women.

2 | METHODS

2.1 | Study population

This cohort study linked information on cardiovascular health in middle age, utilising data from SCAPIS, to BMI in early pregnancy and GWG, obtained from the Swedish Medical Birth Register.¹⁶ The study participants in SCAPIS ($n = 30\,154$, 51.4% women), aged 50–64 years, were randomly selected from the Swedish population register between 2013 and 2018. Six university hospitals in Sweden (Gothenburg, Linköping, Malmö/Lund, Stockholm, Umeå and Uppsala) collaborated in performing the recruitment and examinations for SCAPIS.¹⁷ We linked data from women in SCAPIS ($n = 15\,508$) with data from the Swedish Medical Birth Register using the unique personal IDs that every citizen in Sweden has.

2.2 | Derivation of the analytical sample

To minimise the impact of consecutive pregnancies, information from the participant's most recent pregnancy was collected. If data were missing from the most recent pregnancy, information from the second latest pregnancy was used, and so forth. A flow chart illustrating the recruitment and inclusion criteria of the study participants is presented in Figure S1. Women from SCAPIS who had delivered at least one child in Sweden and who had data available on BMI in early pregnancy and the LE8 score were included in the analyses ($n = 8871$). Thus, women with missing data on any of the covariates (age at SCAPIS examination, age at index pregnancy, educational level, parity and study site) were excluded. We also excluded individuals whose index pregnancy was a twin pregnancy ($n = 117$), as they have different recommendations on GWG compared with women carrying singleton fetuses.¹⁸ In total, 3693 of the women with data from the Swedish Medical Birth Register were excluded, and thus 8871 women were included in the analysis with BMI. Of these women, 6264 women had a weight measured at delivery and were included in the analysis of GWG.

2.3 | Primary exposures

Pregnancy weight data were collected from the Swedish Medical Birth Register, to which the SCAPIS study was linked.¹⁷ BMI (kg/m^2) in early pregnancy was measured at

the first prenatal visit (usually occurring before 12 weeks of gestation) or estimated as the difference between weight at delivery and self-reported weight gain if the pregnancy occurred between 1982 and 1989. It was categorised according to current classifications: underweight ($<18.5 \text{ kg/m}^2$), normal weight ($18.5\text{--}24.9 \text{ kg/m}^2$), overweight ($25.0\text{--}29.9 \text{ kg/m}^2$) and obesity ($\geq 30 \text{ kg/m}^2$). GWG was calculated as the difference between the weight recorded at the first prenatal visit and the weight before delivery. The derived weight difference was categorised as having inadequate, adequate or excessive GWG, as defined by the BMI-specific guidelines from the Institute of Medicine (IOM).¹⁸ For additional analyses independent of BMI, classifications of GWG were also made based only on kilograms gained during pregnancy (<5.0 , $5.0\text{--}9.9$, $10.0\text{--}14.9$, $15.0\text{--}19.9$ and $\geq 20.0 \text{ kg}$).

2.4 | Life's Essential 8

Information regarding cardiovascular health status in middle age was collected from the SCAPIS project. The available data, including information of all components in LE8, were described previously in detail.¹⁹ As for the behavioural components, the diet score was calculated based on the criteria for the Mediterranean Eating Patterns for Americans,²⁰ assessed through the web-based questionnaire MiniMeal-Q.^{21,22} Physical activity levels were estimated using triaxial accelerometers (GT3X, wGT3X+ and wGT3X-BT; ActiGraph LLC, Pensacola, FL, USA).²³ Nicotine exposure and sleep health were measured using self-reported questionnaires. The LE8 health factors (BMI, non-HDL (high-density lipoprotein) cholesterol, blood glucose and blood pressure) were calculated using standardised laboratory and clinical procedures. Based on these assessments, each metric was given a score ranging from 0 to 100 using the AHA's definitions, where 100 is seen as an ideal value. By summing the scores of each component and dividing it by the number of metrics present, an unweighted average cardiovascular score of 0–100 was generated. In this study, LE8 was calculated when data were available for seven or eight of the components. The classifications and arithmetic score are all categorised in accordance with the AHA's definition of the concept.¹³ LE8 scores below 60 points were classified as poor, whereas scores of 60 points or higher were coded as 'not poor', as we have previously shown that an LE8 score below 60 is strongly related to atherosclerosis.¹⁹ The usefulness of LE8 as a proxy of cardiovascular health has been confirmed in several studies.^{19,24}

2.5 | Covariates

Information on all covariates except age at index pregnancy was collected at the SCAPIS examination. Educational status was categorised as 'did not finish primary education', 'primary education level', 'high school level' or 'higher educational level' (university or equivalent). Parity was defined

as the number of times the woman had given birth and was classified as 1, 2, 3, 4 or ≥ 5 births. Birth region was categorised as: Central Europe, Eastern Europe and Central Asia; high-income countries excluding Sweden; Latin America and The Caribbean; North Africa and the Middle East; South Asia; Southeast and East Asia; Sub-Saharan Africa; or Sweden. Current menopausal status during the outcome measurements was classified as a dichotomised answer of 'yes' or 'no'.

2.6 | Statistical analysis

Descriptive statistics are presented as means and standard deviations (SDs) for continuous variables and frequencies and percentages for categorical variables. The associations between BMI in early pregnancy and GWG with later cardiovascular health were analysed using binary logistic regression models. We present an unadjusted model and a main adjusted model, which includes age at SCAPIS examination, educational level, age at index pregnancy, parity and study site as covariates. Results are presented as adjusted odds ratios (aORs) with 95% confidence intervals (95% CIs). When analysing GWG, adjustments were also made for BMI in early pregnancy. Analyses of BMI in early pregnancy and GWG were performed separately. Statistical significance was set as $P < 0.05$ in all analyses, and the analyses were conducted in SPSS 28.0 (IBM, Armonk, NY, USA). To further study a potential nonlinear relationship between LE8 and the exposure variables, we used restricted cubic splines with four knots located at the 5th, 35th, 65th and 95th percentiles in Stata 17 (StataCorp LLC, College Station, TX, USA).²⁵ We performed all analyses as 'complete cases', and in Table S3 we present descriptive statistics on women who were excluded from the study.

We conducted a series of sensitivity analyses to examine whether the observed associations were robust. First, an analysis with additional adjustments for menopausal status and maternal birth region was performed. Second, to exclude any influence of previous pregnancies, we analysed women that gave birth to only one child. Third, analyses excluding women whose index pregnancy was a preterm birth were executed. Fourth, to ensure that consecutive pregnancies after measurements did not affect the outcome, another sensitivity analysis of only women whose index pregnancy was their last was made. Analyses where women with pre-eclampsia were excluded were also performed. Moreover, a new LE8 score was calculated including a stricter cut-off level for physical activity, where the highest score was achieved at 300 minutes (instead of 150 minutes) of moderate (or greater) intensity activity per week. Each minute of moderate activity was counted as 1 minute and each minute of vigorous activity was counted as 2 minutes.²³ We also examined the influence of two other LE8 cut-off levels for poor cardiovascular health (50 and 70 points). We performed an analysis excluding the participants from the years where the pregnancy BMI (and consequently GWG) were estimated.

Furthermore, additional adjustments for a history of gestational diabetes and maternal hypertension, gestational age, polycystic ovarian syndrome (PCOS), smoking at pregnancy admission and hormone replacement therapy (HRT) were performed separately. To address potential selection bias, we conducted logistic models that incorporated inverse probability weighting to account for missing data in exposures, outcomes and the covariates used in the analysis.²⁶ Finally, we also calculated the goodness of fit for our main models.

3 | RESULTS

3.1 | Descriptive characteristics

Table 1 presents the descriptive characteristics of the study participants. The mean age at the index pregnancy was 32.3 (SD 4.8) years and the age at SCAPIS was on average 56.8 (SD 4.1) years, resulting in a mean follow-up time of 24.5 (SD 6.1) years. In total, 398 (4.5%) women were classed as underweight, 6689 (75.4%) women were classed as normal weight, 1460 (16.5%) women were classed as having overweight and 324 (3.7%) women were classed as having obesity. Based on the IOM categories of GWG,¹⁸ 1676 (26.8%) women were classed as having inadequate weight gain in their index pregnancy, 2687 (42.9%) women were classed as having adequate weight gain in their index pregnancy and 1901 (30.3%) women were classed as having excessive weight gain in their index pregnancy. At the outcome assessments in SCAPIS, the mean LE8 score was 73.6 (SD 11.5) points out of 100. Of all participants, 1107 (12.5%) had a score under 60, which was set as the cut-off point for having poor cardiovascular health. Table S1 depicts the distribution of GWG in relation to BMI categories and Table S2 shows the gestational age at delivery by GWG and BMI categories. Compared with those excluded from the study, the women included were slightly younger at the SCAPIS assessment, had a lower BMI and a higher mean LE8 score, but the differences between the groups were small (Table S3).

3.2 | Associations between BMI in early pregnancy and LE8 in middle age

Poor cardiovascular health in middle age was strongly associated with BMI in early pregnancy (Figure 1A). As presented in Figure 1B, when using BMI categories, the aOR of poor cardiovascular health in middle age was significantly greater in women who had overweight (aOR 3.30, 95% CI 2.82–3.88) or obesity (aOR 7.63, 95% CI 5.86–9.94), compared with women classified as being of normal weight. The odds of having poor cardiovascular health were lower in the underweight group as compared with individuals of normal weight in the adjusted model (aOR 0.67, 95% CI 0.46–0.96). The estimates for both the unadjusted and the adjusted models are presented in Table S4. When BMI was analysed as a continuous variable with linear regression, the

odds of having poor cardiovascular health increased by 21% for each increase in BMI unit (aOR 1.21, 95% CI 1.19–1.24). When analysing the LE8 health factors and behaviours separately, BMI in early pregnancy was more strongly associated with LE8 factors as compared with behaviours in middle age (Figure 2). Associations of BMI with each individual LE8 component are enclosed in Table S5.

3.3 | Associations between GWG and LE8 in middle age

A U-shaped association illustrates that the odds of having poor cardiovascular health were greater when gaining both more or less than the recommended weight in pregnancy (Figure 3A). In Figure 3B, aORs are shown both for categories according to weight gain in kilograms as well as the IOM classifications that also include the prepregnancy BMI category. For those who gained <5.0 kg during their pregnancy, the odds of having poor cardiovascular health were 2.6 times higher compared with those who gained between 10.0 and 14.9 kg, which was set as the reference group. For those who gained 5.0–9.9 kg, the odds of having poor cardiovascular health were 1.2 times higher, for those who gained 15.0–19.9 kg, the odds were 1.3 times higher, and for those who gained 20 kg or more during pregnancy, the odds were 1.8 times higher than for the reference group. When categorising according to the IOM classifications, the women who gained excessively during pregnancy had 31% higher odds of having poor cardiovascular health (aOR 1.31, 95% CI 1.09–1.57), compared with those who gained weight within the recommendations, whereas the result for those who gained inadequate weight was not statistically significant after adjustments (aOR 1.12, 95% CI 0.92–1.37). The estimates for both the unadjusted and the adjusted models are presented in Table S6. Finally, the U-shape in the association between GWG and LE8 was evident for both factors and behaviours (Figure S2). Associations of GWG with each individual LE8 component are enclosed in Table S7.

3.4 | Sensitivity and complementary analysis

In general, the results in all sensitivity analyses were comparable with our main analyses and the conclusions were similar (Tables S4, S6, S8 and S9). However, when excluding births with estimated GWG, associations with excessive GWG were attenuated. Nevertheless, conclusions regarding the associations with GWG in kilograms (e.g. <5.0, 5.0–9.9, 10.0–14.9, 15.0–19.9 and ≥20.0 kg) remained similar to our main results. Regarding selection bias, the analysis using inverse probability weighting to account for missing data rendered similar results compared with the main analysis (Tables S8 and S9). We also calculated the goodness of fit for our main models (Table S10), and the results showed that the addition of BMI, not GWG, to the models increased the explained variance.

TABLE 1 Descriptive characteristics of the study sample.

	<i>n</i>	Total	Good LE8 ^a (<i>n</i> = 7764)	Poor LE8 ^a (<i>n</i> = 1107)
Age at inclusion in SCAPIS (years)	8871	56.8 ± 4.1	56.6 ± 4.1	57.5 ± 3.9
Maternal age at delivery (years)	8871	32.3 ± 4.8	32.4 ± 4.8	31.4 ± 4.9
Gestational age (weeks)	8063	40.1 ± 2.3	40.1 ± 2.3	40.0 ± 2.4
Follow-up time (years)	8871	24.5 ± 6.1	24.3 ± 6.1	26.1 ± 5.7
BMI in early pregnancy (kg/m ²)	8871	22.8 ± 3.4	22.5 ± 3.1	24.6 ± 4.3
BMI category in early pregnancy, <i>n</i> (%)				
Underweight	8871	398 (4.5)	364 (4.7)	34 (3.1)
Normal weight		6689 (75.4)	6059 (78.0)	630 (56.9)
Overweight		1460 (16.5)	1138 (14.7)	322 (29.1)
Obese		324 (3.7)	203 (2.6)	121 (10.9)
Gestational weight gain (kg)	6264	13.7 ± 4.5	13.6 ± 4.3	14.0 ± 5.3
Gestational weight gain per week (kg)	5729	0.34 ± 0.11	0.34 ± 0.11	0.35 ± 0.13
Gestational weight gain category, <i>n</i> (%)				
Inadequate	6264	1676 (26.8)	1488 (27.5)	188 (22.1)
Adequate		2687 (42.9)	2384 (44.0)	303 (35.6)
Excessive		1901 (30.3)	1541 (28.5)	360 (42.3)
Maternal education, <i>n</i> (%)				
Did not finish primary education	8871	39 (0.4)	25 (0.3)	14 (1.3)
Primary education level		557 (6.3)	402 (5.2)	155 (14.0)
High school level		3687 (41.6)	3104 (40.0)	583 (52.7)
Higher educational level (university or equivalent)		4588 (51.7)	4233 (54.5)	355 (32.1)
Parity, <i>n</i> (%)				
1	8871	1065 (12.0)	914 (11.8)	151 (13.6)
2		4655 (52.5)	4137 (53.3)	518 (46.8)
3		2378 (26.8)	2068 (26.6)	310 (28.0)
4		588 (6.6)	496 (6.4)	92 (8.3)
≥5		185 (2.1)	149 (1.9)	36 (3.3)
Menopause at SCAPIS, <i>n</i> (%)				
Yes	8765	6207 (70.8)	5379 (70.0)	828 (76.7)
No		2558 (29.2)	2307 (30.0)	251 (23.3)
LE8 score (0–100)	8871	73.6 ± 11.5	76.5 ± 8.9	53.2 ± 5.8
Diet	8650	44.7 ± 16.2	45.7 ± 16.2	38.0 ± 14.9
Physical activity	8608	97.0 ± 11.0	98.0 ± 8.5	89.7 ± 20.4
Nicotine exposure	8767	77.0 ± 31.7	81.2 ± 27.7	47.6 ± 40.8
Sleep health	8769	84.5 ± 21.9	86.6 ± 19.9	69.4 ± 28.1
BMI	8871	74.9 ± 28.2	79.6 ± 24.7	41.7 ± 28.8
Non-HDL cholesterol	8860	62.9 ± 30.2	66.2 ± 29.2	39.7 ± 27.3
Fasting glucose	8811	81.0 ± 21.7	83.6 ± 20.7	62.7 ± 19.7
Blood pressure	8853	66.0 ± 33.9	70.3 ± 32.1	36.0 ± 30.8

Note: Results are presented as mean ± SD for continuous variables or numbers and percentages for categorical variables.

Abbreviations: BMI, body mass index; GWG, gestational weight gain; HDL, high-density lipoprotein; LE8, Life's Essential 8; SCAPIS, Swedish CARDioPulmonary bioImage Study; SD, standard deviation.

^a'Good' is categorised as ≥60 points in LE8; 'Poor' is categorised as <60 points in LE8.

4 | DISCUSSION

In this large population-based cohort study, BMI in early pregnancy and GWG were associated with future

cardiovascular health, measured through the AHA's LE8 construct. Women classified as having overweight or obese at the beginning of pregnancy had significantly greater odds of a poor LE8 score (<60 points) later in life, whereas those

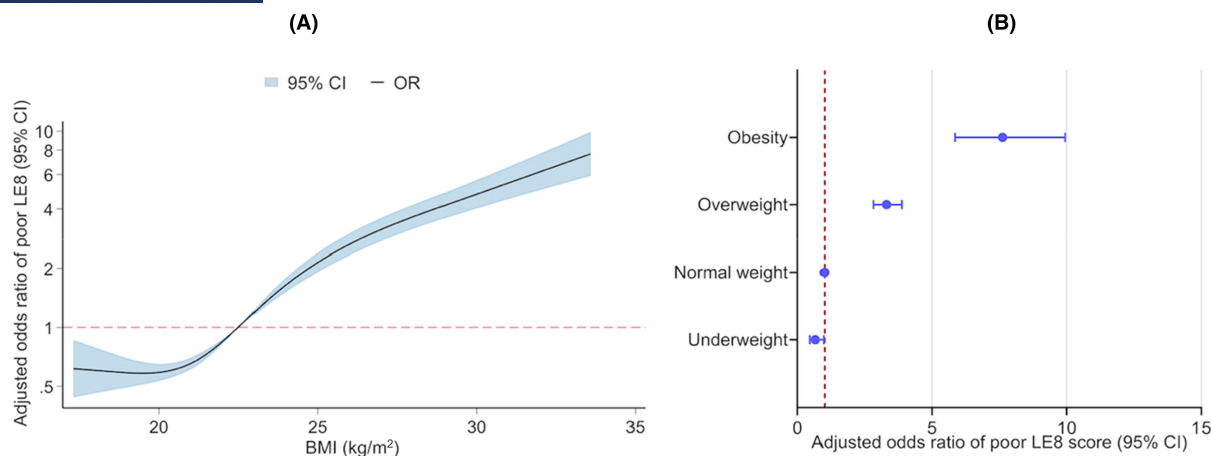


FIGURE 1 Associations between BMI in early pregnancy and LE8 in middle age. The associations of BMI in early pregnancy with aORs for a poor LE8 score in middle age were examined using cubic splines (A) and binary logistic regression according to BMI categories (B). Adjustments were made for age at index pregnancy, age at SCAPIS assessment, educational level, parity and study site. aOR, adjusted odds ratio; BMI, body mass index; CI, confidence interval; LE8, Life's Essential 8.

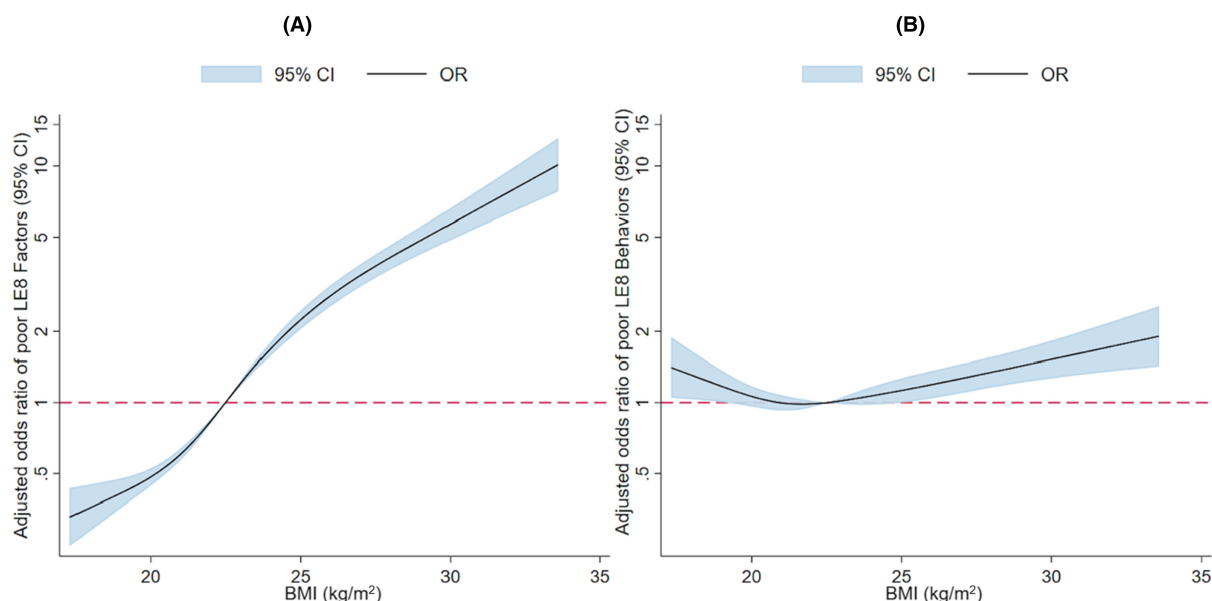


FIGURE 2 Associations between BMI in early pregnancy and LE8 factors and behaviours. The associations of BMI in early pregnancy with aORs for a poor LE8 factor score (A) and LE8 behaviour score (B) were examined using cubic splines. Adjustments were made for age at index pregnancy, age at SCAPIS assessment, educational level, parity and study site. aOR, adjusted odds ratio; BMI, body mass index; CI, confidence interval; LE8, Life's Essential 8.

who were underweight had lower odds of a poor LE8 score than the women classified in the normal weight category, after adjustments. The relationship between a higher BMI in early pregnancy and an unfavourable score proposes a cumulative negative effect on later cardiovascular health when exceeding the BMI recommendations. For GWG, higher odds of poor cardiovascular health were seen in the group who gained excessive weight during pregnancy, but these odds were not of the same magnitude as the odds for a high BMI in early pregnancy. In contrast to low BMI in early pregnancy, both low and high GWG were associated with higher odds of having poor cardiovascular health, indicating a U-shaped association. The relationship between

inadequate GWG and high odds of a poor LE8 score may reflect the general health consequences of gaining too little weight during pregnancy.¹⁸

Previous research has clearly shown that prepregnancy BMI carries a significant influence for future cardiovascular health. Several studies have found strong associations between prepregnancy weight and a higher risk of several adverse cardiometabolic outcomes, such as diabetes, hypertension and cardiovascular events in midlife.^{3,8,27} A cumulative impact on cardiometabolic factors, such as diabetes, hypertension and vascular diseases, with each pregnancy in which excessive weight was retained has also been observed.²⁸ However, associations between gestational BMI

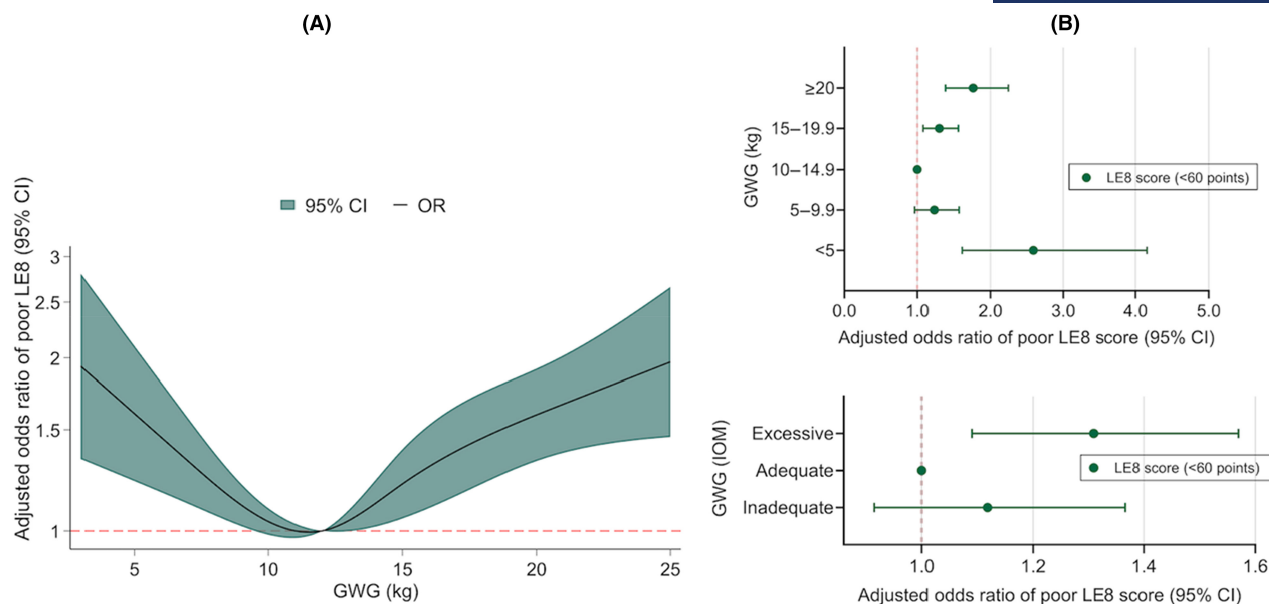


FIGURE 3 Associations between GWG and LE8 in middle age. (A) The associations of GWG in early pregnancy with aORs for a poor LE8 score in middle age were examined using cubic splines. (B) Binary logistic regressions were made for estimating aORs according to GWG categories classified after IOM recommendations (lower panel) or kilograms (upper panel). Adjustments were made for age at index pregnancy, age at SCAPIS assessment, educational level, parity, BMI at index pregnancy and study site. aOR, adjusted odds ratio; CI, confidence interval; GWG, gestational weight gain; IOM, Institute of Medicine; LE8, Life's Essential 8.

and LE8 have not been investigated. Thus, our study provides novel evidence for the role of BMI in early pregnancy for future cardiovascular health as measured by LE8 in middle age.

Although our associations between overweight or obesity in early pregnancy and a high risk for cardiovascular disease may be reconciled with previous research, tendencies towards an increased risk when being underweight have also been observed, contrary to our results. One study found an increased risk of major cardiovascular events later in life for both the underweight and obese BMI category during pregnancy.²⁹ In our study, being underweight first indicated lower odds for poor cardiovascular health, but after examining the individual components (Table S5) it was clear that this association was mainly due to a better LE8 score in the BMI component. Thus, as having a low BMI can be detrimental to many aspects of a women's health, maintaining a normal and stable BMI over the years should be emphasised.³⁰ Furthermore, our analyses demonstrate that obesity is more strongly linked to individual LE8 factors, compared with individual LE8 behaviours (Table S5), which explains the stronger associations observed for LE8 factors.

While previous studies have confirmed associations between prepregnancy BMI and later cardiovascular risk, the importance of GWG is more controversial. In one study, no associations were found between excessive GWG and higher lipid levels, blood pressure, glucose, insulin or metabolic syndrome at 8 years postpartum.² In contrast, another study found that excessive GWG was followed by a small but significant increase in atherosclerotic cardiovascular disease risk, compared with those who did not gain weight excessively

during pregnancy.³¹ Similarly, when examining the risk of later cardiovascular disease and hypertension related to perinatal weight change, another study found that an increase of one BMI unit or more increased the risk of hypertension for all weight categories, as well as the cardiovascular risk among those who were of normal weight or underweight before pregnancy.³² As obesity is known to be associated with a greater cardiovascular risk,³³ the association between GWG and poor cardiovascular health is presumably mediated by the increased risk of obesity that GWG brings. In our study, a GWG of <5 kg was associated with a poor LE8 score, whereas inadequate GWG defined by the IOM guidelines did not exhibit any association. Discrepancies between these results could be because a GWG of <5 kg is far more uncommon than having an inadequate GWG. Interestingly, when analysing the associations of GWG (in kg) with the LE8 components (Table S7), it was evident that both low (<5 kg) and high (≥20 kg) GWG were inversely associated with several individual components. These results may explain the observed U-shaped associations of GWG with LE8 total, factor and behaviour scores.

Although several pregnancy-related disorders, such as preterm birth,³⁴ gestational hypertension and PCOS, are linked to a greater risk for cardiovascular disease, screening is currently only recommended for women with pre-eclampsia.³⁵ Future studies may further explore the independent and combined effects of different adverse pregnancy outcomes that are linked to BMI and cardiovascular health, such as pre-eclampsia and preterm birth, although our sensitivity analysis excluding pregnancies with pre-eclampsia and preterm birth provided very similar conclusions as our main analyses. Furthermore, it is important to

be aware of the potential presence of omitted variable bias that this study carries arising from its long-term perspective. Unaccounted confounding variables may have influenced cardiovascular outcomes later in life. This does not dismiss the findings but highlights the possibility of pregnancy as an important window of opportunity to identify individuals for health screening and supportive interventions. Potential strategies for optimising weight gain in pregnancy could, for example, include counselling and interventions on behavioural components such as diet and exercise.³⁶ Thus, in conjunction with the increased prevalence of being overweight or obese,³⁷ it is essential to focus on pregnancy weight optimisation to reduce the future risk of cardiovascular disease.

4.1 | Strengths and limitations

This study consisted of a large population-based sample and involved a rich source of information on participant characteristics, which allowed us to account for a variety of possible confounding factors. Additionally, the results are further strengthened by the fact that all LE8 components that the AHA recommends were included in the analysis. Another strength is the longitudinal nature of the study, allowing us to examine associations over an average follow-up time of 24 years.

Limitations in this study included its observational design, which limits causal inferences. Some of the participants that reported BMI in early pregnancy did not have data on delivery weight, which represents another limitation. Another limitation was that body weight was estimated using self-reported weight gain and delivery weight in the early years of the Swedish Medical Birth Register, although excluding these women in a sensitivity analysis did not change our main findings. Furthermore, as postpartum weight trajectories were not available in this study, we are unaware of any longitudinal weight changes after pregnancy that could have affected the outcome. Finally, the moderate level of missing data in our study and the subtle variations in the characteristics of those included and excluded from the study indicate that missingness could potentially impact our estimates. Nevertheless, we conducted a series of sensitivity analyses including inverse probability weighting to account for selection bias, and the main conclusions remained.

5 | CONCLUSION

Our study demonstrates that women with a high BMI in early pregnancy and women with excessive GWG have a greater risk of a poor cardiovascular health in middle age than women who were of normal weight and who gained weight within the recommendations. Although further research is needed to assess the impact of body weight during

pregnancy on later cardiovascular health, these findings support the notion that obesity and excessive GWG are important risk factors for poor cardiovascular health decades later. Additional pregnancy weight optimisation initiatives should be considered to promote future cardiovascular health.

AUTHOR CONTRIBUTIONS

LW, AH-A, VHA, SH-F, DB, CJÖ, KR and PH: contributed to the conception and design of the study. JS, CJÖ and KR: contributed to data acquisition. LW, AH-A, VHA and PH: conducted the statistical analysis. SH-F, DB, PW, BD, CL, JS, CJÖ and KR: contributed to data analysis and interpretation. LW, AH-A and PH: drafted the article, which was reviewed and revised by SH-F, VHA, DB, PW, BD, CL, JS, CJÖ and KR. All authors contributed to the article and approved the final version for publication.

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CONFLICT OF INTEREST STATEMENT

JS reports stock ownership in Anagram Kommunikation AB and Symptoms Europe AB. The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflicts of interest.

DATA AVAILABILITY STATEMENT

The data used in this article cannot be shared publicly, to protect the privacy of the participants in this study as well as for legal reasons. However, by contacting the SCAPIS (www.scapis.org) or the corresponding author, information will be provided regarding the procedures for accessing data following Swedish legislation. Requests to access data can be directed to pontus.henriksson@liu.se.

ETHICS APPROVAL

The studies involving human participants were reviewed and approved by the Swedish Ethical Review Authority (ref. 2021-06408-01). The participants provided their written informed consent to participate in this study.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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