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Association of Birth Weight with Body Mass Index at Age 42 in a Longitudinal Cohort

Introduction

Birth weight has long been studied as an early-life predictor of adult health. The "developmental origins of health and disease" hypothesis (Barker hypothesis) proposes that an adverse intrauterine environment, often reflected by low birth weight (LBW), can predispose individuals to chronic conditions in later life [1]. Indeed, some studies report that LBW is associated with higher risks of obesity, insulin resistance, and type 2 diabetes in adulthood [2]. Conversely, high birth weight (e.g. >4 kg) has been linked to greater body mass index (BMI) and higher odds of overweight or obesity in childhood and adult life [3]. For example, a large pooled analysis of twin cohorts found that each 1 kg increase in birth weight was associated with roughly a 0.5–0.9 kg/m^2 higher BMI in later life ($p < 0.001$) [4]. These findings suggest a positive linear tracking of body size from birth to adulthood.

However, the relationship is not entirely straightforward. Some evidence indicates a **J-shaped** or **U-shaped** association, where *both* low and high birth weights confer higher risk of adverse outcomes. A systematic review noted that individuals at the extremes of birth weight tend to have elevated odds of adult overweight/obesity [5]. In particular, while high birth weight infants are more likely to become obese, the impact of low birth weight on adult adiposity has been less clear and might depend on other factors [3]. It has been suggested that the association between low birth weight and adult obesity could be **obscured by sex differences** [6]. Males and females have different fetal growth patterns and metabolic responses; indeed, famine and cohort studies have found that in utero undernutrition affects later adiposity in a sex-specific manner [6]. For instance, one study observed that low birth weight was associated with *lower* adult BMI in men but a tendency toward *higher* adiposity in women [7]. This underscores the importance of analyzing sex-specific effects when examining birth weight and obesity outcomes.

In summary, prior research generally supports an association between higher birth weight and higher adult BMI [4] [3], whereas findings on low birth weight have been inconsistent, possibly showing increased obesity risk under certain conditions (e.g. rapid postnatal catch-up growth) but null or even inverse associations in some cohorts [7]. To contribute further evidence, we examined the association between birth weight and adult BMI in a longitudinal British cohort. We focused on BMI measured at 42 years (mid-adulthood) and used linear regression analyses adjusted for sex. Our aims were to determine if birth weight is associated with BMI in midlife and to assess whether any observed relationship is linear and consistent across sexes. We also considered potential confounding or modifying factors, such as socioeconomic status, in our analysis. By writing up the results in the style of an epidemiological paper, we aim to place our findings in context with the existing literature on early growth and adult obesity.

Methods

Study design and participants: We analyzed data from a longitudinal birth cohort study in Great Britain. The dataset included approximately 10,000 individuals with information on birth weight and adult anthropometry. For this report, we conducted a cross-sectional analysis of the association

between birth weight (recorded at birth) and BMI measured at 42 years of age (we assume all participants were age 42 at the time of BMI measurement, making this effectively a age-42 follow-up). This analysis is thus based on a single adult time-point (42 years), relating an early-life exposure to a mid-life outcome.

Variables and measurements: Birth weight (exposure) was measured in kilograms (kg) at the time of birth (presumably from medical records or parental report). Adult height and weight were measured at ~42 years. Height was recorded in meters (m) and weight in kg. We calculated adult **body mass index (BMI)** as weight (kg) divided by height (m) squared. BMI was analyzed primarily as a continuous outcome. We chose to treat BMI continuously to maximize statistical power and use the full variability of the data, rather than categorizing it (which can lead to loss of information and arbitrary cut-offs) [8]. For descriptive context, we also noted standard BMI categories (underweight, normal, overweight, obese) using World Health Organization cut-offs, but the regression analyses did not categorize BMI.

Data quality and exclusions: We performed basic data checks for biologically implausible values. In particular, 51 participants had recorded heights ≤ 0 or extremely high (out of realistic human range), which would yield invalid BMIs. These likely represented data entry errors. We excluded such cases from analysis. After exclusions, **N = 9,766** participants remained (approximately 49% female). This final sample was used for all analyses. All participants are assumed to be independent, singleton births (no twin pairs included, since twin status was not indicated).

Statistical analysis: We first examined descriptive statistics by sex, given the possibility of sex differences. We calculated mean birth weight (overall and by sex) and the distribution of birth weight categories: we defined **low birth weight (LBW)** as <2.5 kg, **normal** 2.5–3.99 kg, and **high** $\geq$4 kg. Similarly, we summarized mean BMI at age 42 (overall and by sex) and the proportion of participants classified as overweight (BMI 25–29.9) or obese (BMI $\geq$30). Next, we used linear regression to assess the association between birth weight and adult BMI. The primary model included birth weight as a continuous predictor and was adjusted for **sex** (male or female) a priori. Sex was coded as a binary indicator (0 = male, 1 = female) in the regression. This adjusts for any overall differences in BMI between men and women and accounts for the modest sex differences in birth weight.

Additionally, we conducted several secondary analyses. First, we tested for **effect modification by sex** by adding a birth weight × sex interaction term in the regression model. A significant interaction would indicate that the association between birth weight and BMI differs in men and women, so we could then examine stratified results by sex. Second, we explored potential confounding by socioeconomic status: the dataset included an education level variable (categorical 1–4, where 4 indicates higher education) and annual salary at 42, which could proxy adult socioeconomic position. We ran a sensitivity model adjusting for education (as an ordinal variable) to see if this altered the birth weight–BMI relationship. We did not adjust for current adult weight or height beyond using BMI, since BMI already incorporates height and adjusting for height again could introduce multicollinearity. Lastly, we checked for non-linearity in the birth weight–BMI association. This was done by (a) including a quadratic term for birth weight in the model, and (b) examining birth weight in categories (LBW, normal, high) to see if BMI differs in a non-linear pattern. All analyses were conducted using standard statistical software, with two-sided significance tests and a significance level of $\alpha = 0.05$.

Visualization: We created a scatter plot of BMI versus birth weight to visualize the relationship. Given the large sample size, we plotted individual data points with transparency and added fitted regression lines. To illustrate the sex interaction, we plotted separate trend lines for men and women. A figure was included to help interpret the magnitude and direction of the association (or lack thereof) in each sex.

Results

Participant characteristics: The mean birth weight in the cohort was 3.35 kg (standard deviation (SD) ≈0.50). Nearly all participants (86%) had birth weights in the "normal" range of 2.5–4 kg. About 4.4% were classified as low birth weight (<2.5 kg), and about 9.5% were high birth weight (≥4 kg). As expected, males were born slightly heavier on average than females (mean birth weight ~3.39 kg for males vs ~3.30 kg for females). By age 42, the cohort was generally heavy-set: the mean adult BMI was 29.4 kg/m² (SD ≈1.8), just below the obesity threshold. The vast majority of participants were overweight or obese at age 42. Specifically, approximately 64% had BMI in the overweight range (25–29.9) and an additional ~35% were obese (BMI ≥30). Fewer than 1% had a normal BMI (18.5–24.9), and virtually none were underweight. There was no substantial difference in average BMI between men and women (mean BMI ~29.40 for both sexes). Men were taller and heavier in absolute terms, but because BMI accounts for height, the sex difference in BMI was minimal (median BMI ~29.3 in both groups). This justifies our adjustment for sex in the regression analysis and also highlights that sex differences might emerge in more subtle ways than just mean BMI (e.g. in the birth weight relationship).

Association between birth weight and BMI (overall analysis): In the total sample (combining men and women), we found **no significant association** between birth weight and BMI at age 42 after adjusting for sex. The linear regression coefficient for birth weight was nearly zero: β ≈ 0.02 kg/m² higher adult BMI per 1 kg increase in birth weight (95% confidence interval ≈ –0.05 to +0.09). This effect estimate was **not statistically significant** ($p = 0.57$). In other words, a person who weighed, say, 4 kg at birth had on average only 0.02 units higher BMI at 42 than someone who weighed 3 kg at birth – essentially a negligible difference. Sex itself was not significant in this adjusted model ($p = 0.80$), consistent with the nearly identical mean BMIs noted above. We also checked for non-linearity: adding a quadratic term for birth weight did not improve model fit ($p > 0.5$ for the quadratic term), and categorizing birth weight into low/normal/high groups revealed no significant differences in mean BMI between the groups. Both low- and high-birth-weight individuals had roughly the same adult BMI as those born in the normal range (differences <0.1 BMI units, $p > 0.4$). Thus, in this cohort overall, **birth weight was not associated with mid-life BMI** in a straightforward way.

Figure 1: Scatter plot of birth weight and BMI at age 42, stratified by sex. Each point represents an individual's birth weight (x-axis) and BMI (y-axis). Blue points/line denote men, and red points/line denote women. The plot includes linear regression lines for each sex. *The figure illustrates that there is little to no overall correlation between birth weight and BMI in mid-adulthood. However, the fitted trend lines suggest opposite slopes for men and women (blue line sloping slightly downward, red line sloping upward).* The female line shows a positive slope (higher birth weight associated with higher BMI), whereas the male line shows a slight negative slope (higher birth weight associated with *lower* BMI). These sex-specific trends are subtle (the lines are nearly flat) but become significant with the large sample size.

Sex differences in the association: Although the combined analysis showed no overall effect, the results above hinted at a potential *interaction by sex*. We formally tested the birth weight × sex interaction in the regression model. This interaction was **statistically significant** ($p = 0.003$), indicating that the association between birth weight and BMI differed between men and women. Stratified analyses were then performed. Among **men**, the association was negative: each additional 1 kg of birth weight was associated with an average **0.11 kg/m² lower** BMI at 42 (β = –0.11, 95% CI –0.21 to –0.016; $p = 0.02$). In contrast, among **women**, the association was positive: each 1 kg higher birth weight corresponded to an average **0.15 kg/m² higher** BMI (β = +0.15, 95% CI +0.047 to +0.255; $p = 0.004$). These sex-specific effects, though modest in magnitude, were statistically reliable. For example, a woman born at 4.0 kg had on average about 0.6 units higher BMI at 42 than a woman born at 2.0 kg (since 2 kg difference * 0.15 ≈ 0.3, actually ~0.3 unit difference), whereas for men the relationship was

reversed (a man born at 4.0 kg would have about 0.44 units lower BMI than a man born at 2.0 kg, given the –0.11 slope). While differences of less than one BMI unit are small, they could reflect meaningful shifts in adiposity at the population level. It is the **opposite directions** of these slopes that are most noteworthy. Figure 1 visually demonstrates this crossover: the blue regression line (men) slightly declines as birth weight increases, whereas the red line (women) rises with birth weight.

Adjusted analyses and sensitivity checks: We examined whether adjusting for socioeconomic factors would change the results. Including education level (as a four-category variable for highest attained education) in the regression had little impact. The birth weight–BMI coefficients remained nearly identical and non-significant in the combined model (β ~0.02, p ~0.57) and the sex-interaction pattern persisted. Education itself was not significantly associated with BMI in this cohort (p ~0.40), which is somewhat surprising (one might expect lower education to correlate with higher BMI, but that was not clearly seen here). We also tried adjusting for participants' salary (annual income) as an alternative SES measure; again, the birth weight effect did not materially change (results not shown). These analyses suggest that confounding by socioeconomic status is unlikely to explain the observed (lack of) association. Finally, as noted, we found no evidence of non-linear effects when using a quadratic term or birth weight categories. Both extremely low and high birth weight groups showed BMI outcomes comparable to the reference (normal birth weight) group. For instance, mean BMI was 29.34 in the low birth weight group vs 29.41 in the normal group, a difference that was not significant. This indicates that, within this cohort, there was no strong J-shaped relationship in terms of BMI (though such patterns have been reported for other outcomes like blood pressure in other studies [9]).

In summary, our primary findings are: (1) overall, birth weight was not significantly associated with BMI at age 42 when both sexes were analyzed together; (2) there was a significant sex interaction, with higher birth weight predicting slightly higher BMI in women but slightly lower BMI in men.

Discussion

In this large British cohort followed to age 42, we did not observe a clear overall association between birth weight and adult BMI. On its face, this null result contrasts with several earlier studies that found higher birth weights to be associated with higher BMI or obesity risk later in life [4] [3]. However, our analysis revealed an important nuance: the relationship differed by sex, with opposite trends in men and women effectively canceling each other out in the combined data. In women, our results support a **positive association** between birth weight and mid-life BMI, whereas in men we found a modest **inverse association**. We discuss these findings in light of existing literature and consider possible explanations and implications.

Comparison with previous studies: The positive birth weight–BMI association observed in women aligns with the general pattern reported in many studies (often without sex stratification) – namely, that larger size at birth tracks with greater body mass or obesity risk in adulthood [4]. A pooled analysis of 27 twin cohorts, for example, reported a strong linear relationship between birth weight and later BMI (approximately +0.5 to +0.9 BMI units per kg) that was similar in both sexes [4]. Our estimate in women (+0.15 BMI units per kg) is smaller in magnitude, but the direction is consistent (higher birth weight, higher BMI). It is plausible that the effect size attenuates by mid-adulthood; indeed, the twin study noted that the association was stronger in childhood and tended to diminish in adulthood [10]. The women in our cohort, at 42 years, might exhibit a weakened residual effect of birth weight on BMI compared to younger ages. Still, the trend suggests that factors leading to higher birth weight (e.g. better intrauterine nutrition, genetic influences on body size) also predispose to having a higher BMI decades later. This could be due to *"tracking"* of growth: individuals who are heavier (and often longer) at birth usually remain relatively larger through infancy and childhood and into adulthood [11].

Additionally, high birth weight may be a marker of maternal factors (e.g. maternal obesity or gestational diabetes) that also increase offspring's long-term obesity risk [12].

In contrast, the negative association in men (higher birth weight predicting *lower* adult BMI) may seem counterintuitive against the backdrop of prior research. However, there is evidence that the influence of **low birth weight** on later obesity and metabolism can differ by sex. A recent Brazilian cohort study explicitly examined sex-specific effects: it found that men born with low birth weight had *lower* BMI and waist circumference in mid-life than men born normal weight, whereas low birth weight women had slightly higher central adiposity than their normal-weight counterparts [7]. That study reported a significant interaction, with the authors concluding that low birth weight was associated with adult adiposity in a sex-specific manner (protective in men, detrimental in women) [7] [6]. Our findings show a similar pattern qualitatively: although we analyzed birth weight as a continuous variable, the implication is that being at the lower end of birth weights tended to be associated with higher BMI in women but lower BMI in men. Another way to interpret our results is to consider the *extremes*: among men, those who were smallest at birth ended up with the highest BMIs at 42 (consistent with a **thrifty phenotype** or catch-up growth effect), whereas among women, those smallest at birth did not have elevated BMIs, and if anything it was the largest-at-birth women who maintained higher BMI. These sex differences might explain why some studies that pool sexes find no overall association or only a weak one – opposing forces are at play [6].

What biological or social mechanisms could produce an inverse birth weight–BMI relationship in men? One hypothesis stems from the **developmental origins** (DOHaD) concept: male fetuses may be more vulnerable to intrauterine growth restriction and, if born small, could undergo rapid postnatal "catch-up" growth that preferentially increases fat mass relative to lean mass [13]. This accelerated weight gain in childhood among low-birth-weight boys could lead to higher adult BMI (despite shorter stature). In contrast, female fetuses might have different adaptive responses; some studies suggest that females store fat more readily in utero and may be less metabolically taxed by undernutrition, meaning low-birth-weight girls who survive might not have the same drive for catch-up adiposity [6]. Additionally, cultural or life-course factors could play a role. For instance, it's possible that men who were small at birth come from socioeconomically disadvantaged backgrounds that persist into adulthood, influencing diet and activity in a way that promotes obesity. We attempted to control for adult SES (education, income) and saw no change, but early-life socioeconomic conditions (not measured here) could confound the relationship. It is also worth noting that our data showed birth weight correlating positively with adult height ($r \approx 0.35$) and weight. So heavier babies became taller adults on average. In men, much of the increase in weight with higher birth size might be proportional to height (larger skeletal and lean mass), yielding a lower BMI relative to shorter men. Meanwhile, smaller-born men might achieve sufficient weight through fat accumulation without a matching stature increase, resulting in higher BMI. This interplay of height could attenuate or flip the association when using BMI as the outcome, since BMI is weight adjusted for height. In women, adult height is also positively correlated with birth weight, but hormonal and behavioral factors (e.g. differences in diet or fat distribution) may have led the birth weight effect to manifest more as increased adiposity. Our findings, therefore, highlight the complexity of using BMI – a composite index – to capture the outcomes of early growth. BMI does not distinguish body composition, and a given BMI can result from different proportions of muscle and fat in men versus women.

Strengths and limitations: A strength of this study is the large sample size (~10,000 participants), which provided adequate power to detect even subtle associations and interactions. The use of a single age (42 years) for outcome measurement eliminated confounding by age and cohort effects; everyone was examined at the same life stage. We were also able to adjust for sex and test effect modification, which proved crucial in uncovering the pattern. However, there are several limitations. First, the data are cross-sectional with respect to adult BMI – we only have BMI at one point in mid-life. We cannot observe

trajectories of BMI change, which might be informative (for example, whether low birth weight individuals had rapid early adult weight gain). Second, birth weight information, while likely recorded at birth, could be prone to some error or, if retrospectively self-reported, recall bias. Any random misclassification of birth weight would attenuate true associations. Third, despite our adjustment for sex and education, we lacked detailed data on other confounders from the life course. Factors such as maternal prenatal health (e.g. gestational diabetes, smoking during pregnancy), infant feeding mode, childhood nutrition, and pubertal timing can all influence adult BMI and might be correlated with birth weight. Without these, our regression model may suffer from residual confounding. For example, high birth weight babies are often born to diabetic or obese mothers, who also might foster obesogenic environments – adjusting for sex alone doesn't capture that. Conversely, low birth weight could be associated with preterm birth or illness, which might have long-term effects on metabolism not accounted for here.

Another limitation is the generalizability. Our cohort is drawn from a specific population (born in a particular era and country – presumably 1970s UK if age 42 in 2012, for example). The prevalence of overweight was extremely high in this sample (mean BMI ~29.4, with ~99% overweight/obese), which is higher than national averages, raising the question of representativeness. It's possible the cohort members who remained in the study by age 42 were somewhat selective (for instance, those with healthier lives might drop out less, but here everyone is heavy, which is puzzling). The narrow range of BMI (almost no normal-weight individuals) may limit our ability to detect associations – essentially, when almost everyone is overweight, variation in BMI is slight (mostly 28–31). This homogeneity could explain the weak overall correlation: there simply may not be enough contrast in BMI outcomes. It also makes our findings more specific to populations with high obesity prevalence. In populations with more variation in BMI, birth weight effects might be more evident.

Finally, BMI itself is an imperfect proxy for adiposity. It does not distinguish fat mass from lean mass. It's conceivable that birth weight is more strongly related to lean mass (muscle, bone) than to fat. Prior research has found birth weight to correlate with adult **height and lean body mass** more than with fat mass [14]. If in our cohort higher birth weight led to bigger but not necessarily fatter individuals, using BMI could mask an association. For example, someone with high birth weight might be taller and have greater muscle mass, yielding a high weight but a moderate BMI. Future analyses could benefit from looking at waist circumference or body composition measures to see if birth weight predicts central obesity or percent body fat, which are more directly related to metabolic risk.

Implications: Despite the limitations, our findings contribute to the nuanced understanding of early growth and adult obesity. The lack of an overall association (after sex adjustment) suggests that, at least by mid-adulthood, birth weight alone is not a strong determinant of BMI for the cohort as a whole. This could be reassuring in that being born small or large is not destiny for one's BMI – many other factors over the life course have opportunities to influence weight status. However, the divergent male/female patterns imply that recommendations or interventions might need to be sex-specific. For example, low birth weight males might benefit from early interventions to prevent excessive catch-up weight gain (since they could be prone to adult overweight via rapid weight accrual), whereas for females, more attention might be paid to those born large who may have a trajectory toward higher BMI. Moreover, the evidence of sex modification underscores that researchers should stratify analyses by sex whenever plausible, rather than assuming uniform effects. As one paper noted, the impact of low birth weight on adult obesity risk may be **"obscured by sex differences"**, and examining males and females separately can uncover patterns that would otherwise be missed [6].

Conclusion: In conclusion, our study of ~9,700 42-year-old British cohort members found no overall association between birth weight and adult BMI when adjusted for sex, but a significant interaction by sex. Higher birth weight was linked to slightly higher BMI in women and slightly lower BMI in men.

These results highlight the complex role of early growth in shaping later obesity and the importance of considering sex-specific pathways. They are consistent with some prior research suggesting sex-dependent effects of fetal growth on adult adiposity [7], although the directions observed in our cohort (beneficial effect of higher birth weight in men, neutral-to-adverse in women) will need further confirmation. Overall, birth weight by itself explained less than 1% of the variance in mid-life BMI, emphasizing that adult obesity is a multifactorial condition. Public health efforts to curb obesity should therefore focus on known modifiable factors (such as diet, physical activity, and environment) across the life span. Nevertheless, our findings support the ongoing investigation of early-life influences – including fetal nutrition and growth – on long-term health, and they suggest that such influences may manifest differently in men versus women. Future studies with detailed longitudinal data (including childhood growth patterns and body composition measures) and diverse populations will be valuable to untangle the biological mechanisms underlying the birth weight–obesity relationship and to guide tailored interventions.

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- **Figure 1:** *Scatter plot of birth weight vs BMI by sex, with regression lines (study data).*

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