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Prenatal weight change trajectories and perinatal outcomes among twin gestations

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Abstract

OBJECTIVE: Despite an increase in twin pregnancies in recent decades, the Institute of Medicine twin weight gain recommendations remain provisional and provide no guidance for

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Conflict of Interest
The authors declare no conflicts of interest.

pattern or timing of weight change. We sought to characterize gestational weight change trajectory patterns and examine associations with birth outcomes in a cohort of twin pregnancies.

STUDY DESIGN: Prenatal and delivery records were examined for 320 twin pregnancies from a maternal-fetal medicine practice in Austin, TX 2011–2019. Prenatal weights for those with >1 measured weight in the first trimester and ≥3 prenatal weights were included in analyses. Trajectories were estimated to 32wk (mean delivery 33.7±3.3wk) using flexible latent class mixed models with low-rank thin plate splines. Associations between trajectory classes and infant outcomes were analyzed using multivariable Poisson or linear regression.

RESULTS: Weight change at delivery was 15.4±6.3kg for people with an underweight BMI, 15.4±5.8kg for healthy weight, 14.7±6.9kg for overweight, and 12.5±6.4kg for obesity. Three trajectory classes were identified: low (Class1), moderate (Class2), or high gain (Class3). Class1 (24.7%) maintained weight to 15wk, then gained an estimated 6.6kg at 32wk. Class2 (60.9%) exhibited steady gain with 13.5kg predicted total gain, and Class3 (14.4%) showed rapid gain across pregnancy with 21.3kg predicted gain. Compared to Class1, Class3 was associated with higher birthweight z-score (β =0.63, 95%CI 0.31,0.96), increased risk for large for gestational age (IRR=5.60, 95%CI 1.59, 19.67), and birth <32wk (IRR=2.44, 95%CI 1.10, 5.4) that was attenuated in sensitivity analyses. Class2 was associated with moderately elevated birthweight z-score (β=0.24, 95%CI 0.00, 0.48, p=0.050).

CONCLUSION: Gestational weight change followed a low, moderate, or high trajectory; both moderate and high gain patterns were associated with increased infant size outcomes. Optimal patterns of weight change that balance risk during the prenatal, perinatal, and neonatal periods require further investigation, particularly in high-risk twin pregnancies.

Keywords

pregnancy; gestational weight gain; prepregnancy body mass index; twins; adverse birth outcomes; neonatal morbidity; obesity; latent class mixed models; trajectory analysis

INTRODUCTION

Twin births, comprising 3.1% of US births in 2020,[1] are associated with increased risk for adverse pregnancy and infant outcomes compared to singletons,[2] including preterm birth (PTB) <37wk and low birthweight (LBW, <2500g). In the US in 2020, the proportion of twins born early preterm (<34 weeks gestation at delivery) was nearly 20%, and 9% of twins were born very low birthweight (<1500g) – approximately nine times the rate of both outcomes in singletons.[1]

Birthweight is an indicator of fetal growth, survival, and long-term health,[3] but is intertwined with gestational age since longer pregnancies allow for increased accrual of fetal tissue. On average twins are born at approximately 36 weeks,[4] although preterm and moderately preterm birth (32–34 weeks) are still common outcomes with a prevalence of 59.9% and 19.2%, respectiely.[5] Previous National Vital Statistics data demonstrate that twins have lower mean birthweight than singleton counterparts at 28 weeks,[6] and growth slows at the beginning of the third trimester potentially due to uterine space limitations[7] or placental function;[8,9] additionally, perinatal mortality increases at approximately 38 weeks.[6,7] Between 30–32 weeks of gestation growth trajectories for singleton and multiple gestations diverge,[10,11] while some data suggest fetal growth patterns in twins diverge between 17 and 19 weeks.[12] However, optimal gestational age at delivery to minimize adverse outcomes in twins is not known[10,12–16] although mixed evidence points to delivery 35 to 39 weeks to limit adverse infant outcomes.[6–8,13,17–19] If optimal growth and limited morbidity occur earlier for twins, then singleton growth standards[20] – including definitions for low birthweight and preterm delivery – likely do not apply.

The goal of gestational weight change (GWC) recommendations is to balance optimal development of the fetus with maintaining maternal health.[21] Evidence suggests GWC in twin pregnancies with better outcomes (i.e., delivery 37–42wk and birthweight ≥2500g) varies by prepregnancy BMI.[22] But, the Institute of Medicine (IOM) twin weight gain guidelines were based on evidence from only one available study,[22,23] and insufficient data prevented a recommendation for those with all BMI categories.. The current IOM recommendations for twin are 16.8–24.5kg for individuals with a healthy weight prepregnancy BMI, 14.1–22.7kg for overweight, and 11.3–19.1kg for obesity.

Twin gestation increases risk for adverse outcomes linked to weight gain outside the IOM recommendations,[23] but optimal fetal growth and timing of GWC have not been determined. Because more people with overweight or obesity enter pregnancy,[24] more individuals gain excess weight, and guidelines are provisional and undetermined for all sizes, research dedicated to this population is of the utmost public health significance. The objective of the current study was to provide further evidence that informs national guidelines and clinical practice related to the timing and pattern of weight change and associated risk for infant outcomes in twin pregnancies; we sought to estimate associations between prepregnancy BMI and patterns of GWC with infant size and gestational age outcomes in twin gestations.

METHODS

Study Design and Subjects

Pregnancy and delivery records for uncomplicated twin births at Austin Maternal-Fetal Medicine between 2010–2019 were abstracted for pregnancy characteristics, prenatal visit weights, and perinatal outcomes. Austin Maternal-Fetal Medicine provides comprehensive high-risk pregnancy care throughout central Texas, specializing in complex pregnancies including multifetal gestations. Uncomplicated pregnancies with the following criteria were included in primary analyses: a live twin birth, self-reported prepregnancy weight and height, a measured weight within the first trimester (<14wk), ≥3 prenatal weights, GA at delivery, and birthweight. Height and prepregnancy weight were used to calculate prepregnancy BMI. Total GWC was calculated by subtracting prepregnancy weight from the final prenatal weight. Since IOM recommendations do not exist for underweight BMI, GWC only for those with a BMI ≥18.5kg/m^2 was categorized as below, within, or above the recommended range. A Registered Dietitian examined all GWC values for clinical feasibility, and biologically implausible prepregnancy or pregnancy weights were excluded from trajectory analyses.

Statistical Analyses

GWC trajectories were identified using latent class mixed models (R,[25] function *hlme* in package *lcmm*)[26], as described in our previous work,[27,28] and censored to ≤32wk (mean delivery: 33.7±3.3wk) to prevent later GWC from skewing patterns or steering class predictions. The final weight in trajectory models may differ from total GWC described above (final prenatal weight – prepregnancy weight), since longer gestational duration may allow for further weight change. The three-class trajectory model was ultimately selected for analysis (Supplemental Table 1) based on the best overall fit statics as outlined below.

We examined models that identified two to four latent classes of GWC. Gestational age (weeks) was normalized (each visit in weeks divided by 32 total weeks) to improve model stability and the model intercept was suppressed to allow for the weight change estimates to biologically begin at 0kg weight change at 0wk gestation. Individual random slopes accounted for intrasubject correlation between measurements, and penalized, low-rank thin-plate splines[29] with equidistant knots at 0, 8, 16, 24, and 32 weeks gestation allowed for flexible, nonlinear classes of estimated weight change across pregnancy. Several criteria were utilized to assess goodness of fit: Akaike and Bayesian Information Criteria, mean post-probability of actually belonging to the assigned latent class (≥80%), sample size per latent class of ≥5%, and entropy that measures the model's discriminatory power to indicate robust class delineation (as values approach 1.0).[30] Although the four-class model yielded marginally lower AIC and BIC, the smallest latent class contained 1.6% of the sample (n=5). Overall, the three-class model exhibited the strongest overall fit and provided the most clinically useful estimates of GWC.

We estimated multivariable Poisson regression models with robust standard errors[31,32] for binary outcomes or linear regression models for continuous outcomes between GWC class and infant or perinatal outcomes clustered by pregnancy to account for the nonindependence of twins (Stata v14.2, Stata Corp, College Station, TX). Alpha was set at 0.05 a priori and 95% confidence intervals are reported throughout. Primary outcomes included infant birthweight, continuous birthweight adjusted for GA z-score (BWZ),[33] LBW, twin-specific small (SGA, birthweight <10th percentile) and large for GA (LGA, birthweight >90th percentile),[10] and PTB <32wk because infant morbidity is highest <32wk gestation.[34] Based on review of the twin literature, covariate adjustment included twin-sex pair and maternal age, height, ethnicity, and prepregnancy BMI category. Chorionicity data were not available. In addition to BMI, we adjusted for height since taller individuals may provide a functional or volume advantage for multiple fetuses, and because they are more likely to conceive twins[35] and experience a longer gestational duration of twin pregnancy.[36] Smoking status was excluded from analyses since these data were missing for 20% (n=63) of the analytic sample and only reported in 3% (n=8) of pregnancies. Currently, twin-specific BWZ do not exist; thus, we calculated z-scores based on singleton GA-specific percentiles[33] as in other twin studies.[37] and to alleviate issues associated with using absolute measures of birthweight that cannot differentiate infants born preterm from intrauterine growth restriction.[38] However, we computed twin-specific SGA and LGA based on twin fetal weight standards from intrauterine ultrasound, since postnatal size standards by GA do not exist.[10] We examined differences in outcomes by BMI category since this is how the IOM recommendations are delineated.

We conducted several sensitivity analyses. First, we modeled all pregnancies in an expanded sample with a first visit weight <21 weeks gestation (n=532) and compared results from multivariate Poisson or linear regression to the analytic sample to investigate for potential sampling bias due to entry in the clinic database at a later gestational age (Supplemental Table 3). Second, we compared results from our novel latent class models to existing methods by calculating continuous GWC z-scores adjusted for gestational age at delivery developed by Hutcheon et al.[12] These z-score calculations were based on successive prenatal weight measurements from 1109 uncomplicated, dichorionic twin pregnancies delivered at Magee-Womens Hospital in Pittsburgh, PA at a median (interquartile range) of 37 (36, 38) weeks gestation. However, this study was underpowered to developed z-score charts for those with an underweight BMI, thus, only those with a BMI ≥18.5 kg/m^2 were included in these analyses. Using GWC z-score instead of GWC latent class, we fit a model with the same adjustment set as our analytic sample and the 21-week expanded sample to compare findings between methods (Supplemental Tables 4–5). Third, we used inverse probability weighting (IPW) to assess the potential for sampling bias in the analytic sample (Supplemental Table 6). IPW estimates bias due to missing data by applying more weight to those included in the analytic sample based on characteristics of the entire sample, in this case, by applying weights to those with a first trimester visit who had characteristics similar to those without a first trimester visit. This method allowed for creation of a pseudo-population that would have been observed if everyone in the sample had the opportunity to attain earlier care during pregnancy, and, thus, would be eligible for inclusion in the primary analysis. Comparing effect sizes (≥10%) between the analytic sample and the weighted sample clarifies the potential effect of bias.

This study was approved by the Institutional Review Board at St. David’s Healthcare and The University of Texas at Austin.

RESULTS

Sample Characteristics

Of 770 twin pregnancies, 325 had a prenatal weight in the first trimester; 320 pregnancies (n=640 infants) met inclusion criteria for analysis (Figure 1). Sample characteristics are outlined in Table 1. Average GA at delivery was 33.7±3.3wk with a GWC of 14.4±6.4kg. Greater than 80% of infants were born LBW, 16.4% were classified as SGA, and incidence of PTB <32wk was 22.2%. Compared to excluded pregnancies, BMI was lower (27.2±6.9 vs. 28.5±7.0kg/m^2), GWC was higher (14.4±6.4 vs. 13.3±7.3kg), and more infants were born LBW (84.1% vs. 79.0%) or <32wk (22.2% vs. 15.1%) in the analytic sample (Supplemental Table 2).

Gestational Weight Change

Mean GWC and GWC z-score differed across BMI categories, with higher weight gain coinciding with lower BMI categories (Table 1). GWC was similar between underweight or healthy weight (15.4±6.3 and 15.4±15.8kg/m^2), but decreased in overweight (14.7±6.9kg/m^2) and obesity (12.5±6.6kg/m^2) categories. All average GWC z-scores were <1.0 after accounting for gestational duration, indicating lower relative GWC compared to the 1109 uncomplicated twin pregnancies used to develop this method.[12] GWC z-scores were lowest among those with prepregnancy healthy weight and highest for those with obesity. Of those with a BMI ≥18.5kg/m^2, only 35.9% (n=111) met the provisional IOM guidelines.

Incidence of Infant Outcomes

All BWZ were <0; mean BWZ was lowest for pregnancies with an underweight BMI (−0.62±1.03) and highest in the overweight and obesity groups (−0.42±0.90 and −0.42±0.93, respectively). Incidence of PTB <32wk was greatest with a healthy weight BMI (n=54, 38.0%) and increased from 20.8% for healthy weight to 22.5% within the obesity category. Incidence of SGA and LGA also varied by BMI: SGA incidence was greatest with a healthy BMI (21.5%) and lowest with obesity (11.8%), whereas LGA incidence was greatest with an underweight BMI (9.1%, n=2) followed by the obesity category (7.9%).

GWC Trajectories

Three distinct patterns of weight change from 0–32wk gestation were identified by the latent class trajectory models (Figure 2). Compared to one another, these classes exhibited low gain (Class1), moderate gain (Class2), or high gain (Class3). Class1 demonstrated low gain characterized by weight maintenance until ~15wk, then gradual GWC to a predicted gain of 6.6kg at 32wk (Table 2). Moderate gain Class2 exhibited steady gain starting at 4.6wk with a total gain of 13.5kg at 32wk. The class with the greatest GWC, Class3, exhibited rapid weight gain to 21.3kg at 32wk. Class2 had the greatest membership (n=195, 60.9%), a majority with a healthy weight BMI (47.2%), and largest proportion of those who met the IOM recommendations (n=78, 41.5%). Class3 had a majority of individuals with a healthy prepregnancy BMI (43.5%) and largest proportion with GWC above the IOM guidelines. The majority in Class1 had obesity (49.4%) and 84.4% experienced GWC below the recommendations.

GWC Trajectory Class and Infant Outcomes

Compared to low gain Class1 (referent), there were notable differences in adjusted regression models for risk of LGA, BWZ, and PTB among those with high GWC (Table 3). For Class3, risk for LGA was more than five times higher and BWZ was 0.63 units higher than the referent class. Risk for PTB was also elevated (IRR=2.44, 95% CI: 1.10, 5.41) with high GWC. For moderate gain Class2, BWZ (β=0.24, 95% CI: 0.00, 0.48; p=0.050) was also greater than referent Class1. No differences in risk for SGA or cesarean delivery were detected between classes of weight change compared to Class1.

Sensitivity Analyses

First, we examined pregnancies with ≥1 weight during the first half of pregnancy (<21.0wk, n=532). Outcomes associated with GWC trajectories in the primary analyses were maintained in the expanded sample, except risk for PTB <32wk was attenuated in

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Class3 (IRR=1.96, 95%CI 0.98, 3.94) (Supplemental Table 3). Second, we examined total GWC z-scores developed by Hutcheon et al.[12] for similar patterns of risk as the analytic and expanded samples for those with a BMI ≥18.5kg/m^2. No associations were detected in the analytic sample (Supplemental Table 4); however, in the expanded sample BWZ was elevated (β=0.26, 95%CI 0.00, 0.52, p=0.050) with a GWC z-score above the referent (>1.0), and decreased (β=−0.25, 95%CI −0.45, −0.05) with GWC z-score below the referent category (<−1.0) (Supplemental Table 5). Finally, using IPW to assess sampling bias, we detected similar findings compared to the primary analyses in terms of the direction and magnitude of effects (Supplemental Table 6), except between GWC and LGA in Class3 (IRR=5.03, 95%CI 0.21, 122.66). Associations between GWC and BWZ (Classes 2 and 3) and PTB (Class3) in the weighted sample were comparable to the analytic sample.

DISCUSSION

The IOM gestational weight gain guidelines for twin pregnancies remain provisional due to a lack of evidence to support total GWC ranges, timing, and pattern of weight change; however, these recommendations are widely used in clinical practice.[23] Our analyses indicate that risk for adverse infant outcomes differs by GWC pattern in high-risk pregnancies, especially with patterns of early, high weight gain. Classifying optimal GWC patterns and trajectories associated with infant risks may help determine important time periods for monitoring weight change in twin pregnancies. These novel analyses allow for practical and statistical characterization of how weight may change during twin pregnancies. Using our findings as reference, identifying an individual's pattern of GWC across pregnancy may aid identification of pregnancies that need, and allow implementation of, enhanced strategies with the potential to improve pregnancy outcomes.

Principal findings

Three latent GWC classes were identified. Low gain Class1 maintained weight then slowly gained to 6.6kg. Moderate gain Class2 exhibited steady gain to 13.5kg, and high gain Class3 exhibited rapid gain to 21.3kg. Those with prepregnancy obesity constituted the greatest portion (49.4%) of low GWC Class1, whereas those with a healthy BMI made up the greatest portion (47.2%) of moderate GWC Class2. Healthy weight (43.5%) and overweight prepregnancy BMI (39.1%) contributed comparably to high GWC Class3. Compared to Class1, a high GWC pattern was associated with increased LGA risk and, accordingly, a markedly increased BWZ. Moderate GWC Class2 was also associated with modestly increased BWZ, but not LGA. These results indicate that the direct association observed between total GWC and absolute birthweight in previous twin studies[39–41] is similarly observed when examining trajectories of moderate or high GWC relative to a low gain reference.

Relative to low gain, no associations were detected between any GWC class and cesarean delivery or SGA. Those with obesity had the lowest rate of SGA but comprised the highest portion of pregnancies with low GWC. This inverse relationship between excess adiposity and small infant size may have protected against SGA.[37,42,43] Likewise, the relationship between pattern and timing of GWC and risk for twin outcomes may be more nuanced at specific points during pregnancy[41] and is an important factor to consider for individualized clinical care.

Results in the context of what is known

We found that a pattern of high GWC was associated with increased risk for LGA and elevated BWZ. Considering most twins are born <2500 grams,[1] LGA has not been extensively studied in twin pregnancies, although the association between BMI, total GWC, and LGA is well documented in singletons.[44] Similar to our findings, in one cross-sectional examination of 54,836 twin birth records from Pennsylvania, Bodnar et al. observed that both increasing BMI and twin-specific GWC z-score[12] increased risk for twin-specific LGA,[10] noting a sharp increase in LGA risk with GWC above IOM guidelines regardless of BMI category.[37]

When comparing our results to investigations utilizing total GWC, higher total GWC and higher prepregnancy BMI have both, independently and jointly, been linked to greater unadjusted birthweight in twin infants.[39,45–47] In our results, unadjusted total GWC, GWC z-score, and BWZ decreased as BMI increased from underweight or healthy weight to the obesity BMI category. However, assessments of total GWC, rather than GWC timing, pattern, or adjustment for GA, have produced conflicting results. Generally, GWC within IOM recommendations is linked to greater absolute birthweight in twins[39,45–47] and reduced risk for LBW.[39,46] Likewise, a direct relationship between increasing GWC and birthweight has been demonstrated, although evidence by BMI category is conflicting.[45,47–49] Contrary to our methods, these studies relied on absolute birthweight/LBW or singleton standards to identify adverse size for GA outcomes in twins (i.e., SGA, LGA) and are difficult to compare to our findings since we examined GWC trajectories. Further work in large, population-based cohorts examining GWC patterns in relation to infant size outcomes would aid clarification of these inconsistencies.

Surprisingly, we did not detect associations between GWC pattern and SGA risk. The incidence of SGA in our sample was 16.4% compared to 12.3% of 54,836 births examined by Bodnar;[37] indeed, SGA incidence was elevated across GWC classes. The lack of association between GWC and SGA may be indicative of the high-risk nature of this cohort receiving early and consistent prenatal care, use of low gain Class1 as the referent, and small percentage with prepregnancy underweight, and a higher proportion with obesity in Class1. Previous observations of twin BWZ have demonstrated an inverse relationship between total GWC and SGA, i.e.., that as weight gain decreases, risk for SGA increases,[37,50,51] and prepregnancy obesity may reduce risk for SGA.[37,42,43] However, prior studies often used singleton SGA references or birthweight without correction for GA. Considering that growth trajectories of twin fetuses deviate from singletons by the 3rd trimester and that most deliveries occur earlier than singletons, these measures likely inflate the proportion of twin infants truly born SGA.[10,38,52]

We did not detect an association between GWC class and cesarean delivery, but we did observe increased risk for PTB <32wk in high gain Class3. Since cesarean delivery may be recommended to protect against potential birth pathology and is the delivery method for up to 75% of twin pregnancies,[53] the high rate in our sample (84.7%) is not surprising.[19]

However, the relationship between high GWC and a two-fold increased risk for PTB was unexpected, and conflicts with evidence for increased PTB risk with low GWC.[50,51,54] Our initial finding of this association is contrary to biological expectations and may reflect sampling bias. In sensitivity analyses, we compared those included versus excluded from the analytic sample and found a higher incidence of PTB <32wk in the analytic sample (Supplemental Table 2). We also examined whether inclusion of individuals with first visit before 21.0wk changed observed associations. Observations were similar between GWC class and outcomes, except for PTB, suggesting this may be a spurious finding. We also believe this PTB finding is due, in part, to earlier high-risk pregnancy referral to Austin Maternal-Fetal Medicine that resulted in bias.

We observed three distinct patterns of GWC. Similar to other investigations in twins and singletons, those with a higher BMI tended to gain less weight compared to lower BMI and higher weight gain. Many studies have excluded underweight BMI because no recommendation exists and/or have compared weekly averaged GWC to a linear average of the IOM ranges (e.g., total /GA), and selected a denominator of 37–38wk noting the guidelines were determined from healthy twin deliveries at 37–42wk. Thus, comparison to our nonlinear GWC characterization is difficult. Fox et al. identified weekly averaged GWC rates in the 2nd and 3rd trimesters in 297 individuals with a healthy weight BMI, finding increased birthweight and decreased risk for PTB <32wk for those within the IOM ranges. Similarly, in individuals with a BMI ≥18.5kg/m^2, Lutsiv and colleagues observed GWC below guidelines increased SGA risk (OR=1.44, 95%CI 1.01, 2.06), but above the guidelines did not decrease SGA risk (OR=0.92, 95%CI 0.62, 1.36). Our findings suggest a protective effect against decreased BWZ with higher GWC patterns, although no association with SGA was detected, potentially due to the high proportion (49.4%) of individuals with obesity in Class1.[37,42,43] Similar methodologically to Fox and Lutsiv, Liu et al. examined GWC adequacy at 0–16, 16–24, and ≥24wk gestation in 609 healthy-weight pregnancies.[41] An average gain ≥1lb/wk was associated with fetal growth and decreased PTB at 0–16wk or 6–24wk, but GWC <1lb/wk was associated with lower birthweight from 0–24wk and increased PTB risk >24wk. Although we did not examine specific periods, we also found a protective association between increased GWC patterns and BWZ.

To compare our findings to commonly utilized methods using GWC z-score references,[12] we did not find a relationship between GWC z-score and infant outcomes in the analytic sample. In those with first prenatal weight <21.0wk we detected a direct relationship between higher GWC z-score and BWZ, but no associations with SGA or LGA. These observations indicate that our trajectory analyses may be more sensitive to the nuances between GWC and perinatal outcomes.

After weighting the analytic sample with IPW, similar associations between GWC trajectory and BWZ (Classes 2 and 3) and PTB (Class3) were observed. But, unlike our primary model, we did not observe increased LGA risk for any GWC class. Despite different methodologies employed, the majority of studies have shown an increased SGA and PTB risk with lower weight gain, and greater birthweight with higher weight gain. However, infants from GWC Class3 were born the earliest and had the highest incidence of PTB that may explain this association. Those included in the analytic sample were referred for high-risk care earlier than those excluded, thus, we suspect we are observing a high-risk subpopulation of twins that deserve further study.

Strengths and limitations

This study has many strengths, including advanced methods to identify GWC patterns and associations with infant outcomes. This study also has limitations. Only 11 individuals with an underweight BMI (3.4%) met inclusion criteria for analysis, and we were underpowered to stratify by BMI category. Further, we lacked data related to chorionicity and zygosity, important factors when examining twin outcomes. Perhaps the greatest challenge was the use of high-risk pregnancies receiving care through Austin Maternal-Fetal Medicine that included a high rate of early PTB <34wk (n=262, 34.0%; data not shown) – a dramatic deviation from the 19.2% of US twins born <34wk in 2020.[1] Although sampling bias plays a role in those attending high-risk clinics, we believe these pregnancies had the advantage of regular care that likely aided GWC and outcomes, such as SGA. These findings signal the importance of studying higher-risk subpopulations of twin pregnancies to discern whether these trends are true in the population at-large, but should be interpreted cautiously.

CONCLUSION

In this study we present novel GWC latent class models across twin pregnancy, showing direct associations between 1) moderate or high GWC patterns with BWZ and 2) high GWC with LGA. Similar to other studies, we found considerable variation in GWC among twin pregnancies, suggesting an individualized approach is necessary to aid prenatal care. Those pregnant with twins may benefit from early, frequent prenatal visits, including regular consultations with a dietitian. This may be especially important at either end of the BMI spectrum, as status of particular nutrients may be of greater concern related to adverse perinatal outcomes (e.g., PTB). Providing twin-specific nutritional and weight change guidance is of the utmost importance to enhance early interventions for high-risk pregnancies.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Acronyms:

BWZ	Birthweight for Gestational Age Z-score
BMI	Body Mass Index
GA	Gestational Age
GWC	Gestational Weight Change
IOM	Institute of Medicine
LGA	Large for Gestational Age
LBW	Low birthweight
PTB	Preterm Birth
SGA	Small for Gestational Age

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KEY POINTS:

- Most gained below IOM twin weight gain recommendations.
- Three patterns of GWC across pregnancy were identified.
- Moderate and high GWC patterns associated with infant size.

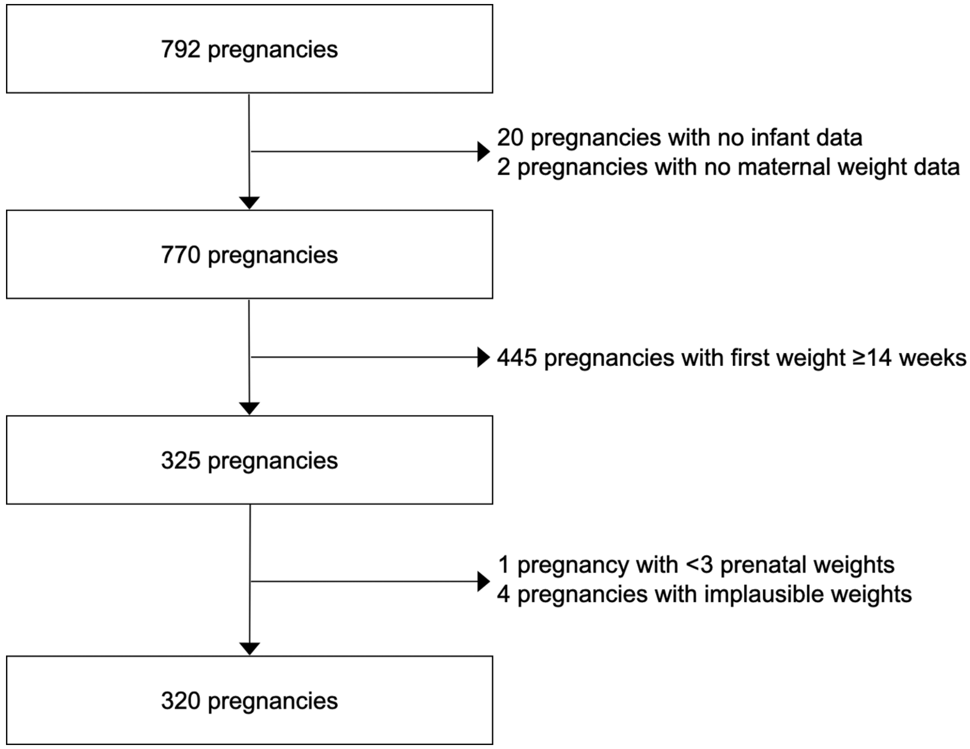

Figure 1.
Participant flow diagram.

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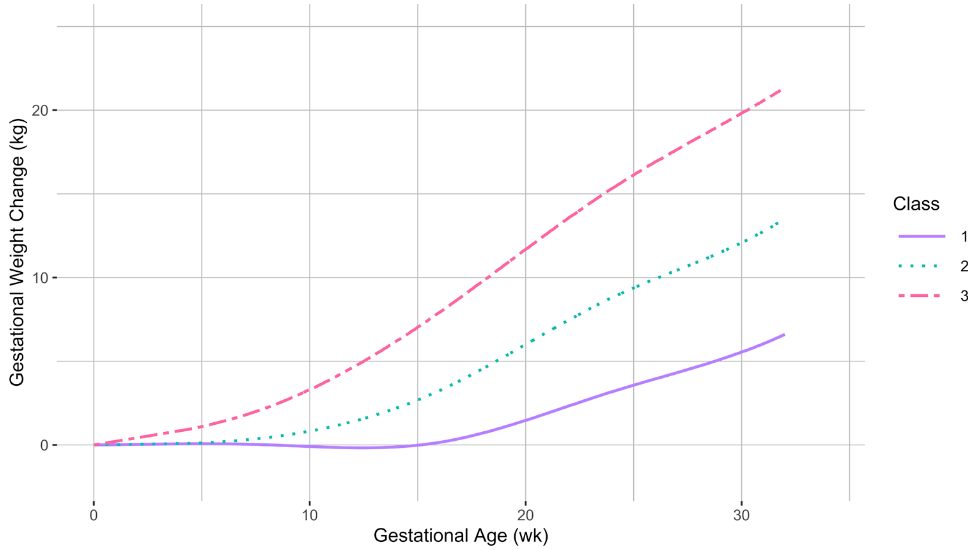

Figure 2.
Predicted gestational weight change from 0 to 32 weeks gestation among 320 twin pregnancies.

Table 1.

Sample characteristics by prepregnancy BMI category in twin pregnancies (n=320 pregnancies or 640 infants).

	Underweight	Healthy	Overweight	Obesity	Total
n (%)	11 (3.4)	130 (40.6)	90 (28.1)	89 (27.8)	320
Age, y	30.5 ± 4.1	31.9 ± 5.9	31.6 ± 4.9	32.3 ± 7.0	31.9 ± 5.9
Height, cm	173.9 ± 20.1	166.8 ± 10.1	162.7 ± 8.4	163.2 ± 8.7	164.9 ± 10.1
Gestational age,[a] wk	31.8 ± 4.6	33.9 ± 3.1	33.5 ± 3.2	33.7 ± 3.5	33.7 ± 3.3
BMI, kg/m^2	17.8 ± 0.8	22.0 ± 1.8	27.2 ± 1.5	36.0 ± 5.8	27.2 ± 6.9
Ethnicity					
White	6 (2.9)	92 (44.7)	54 (26.2)	54 (26.2)	206 (64.4)
Hispanic	1 (2.0)	19 (38.8)	14 (28.6)	15 (30.6)	49 (15.3)
Black	1 (3.0)	7 (21.2)	13 (39.4)	12 (36.4)	33 (10.3)
Asian	2 (16.7)	5 (41.7)	2 (16.7)	3 (25.0)	12 (3.8)
Multiracial/Other[b]	1 (5.0)	7 (35.0)	7 (35.0)	5 (25.0)	20 (6.3)
Total GWC,[c] kg	15.4 ± 6.3	15.4 ± 5.8	14.7 ± 6.9	12.5 ± 6.6	14.4 ± 6.4
GWC z-score	--	−0.41 ± 1.04	−0.29 ± 0.87	−0.15 ± 0.78	−0.30 ± 0.92
Adherence to IOM[d]					
Above IOM	--	8 (28.6)	7 (25.0)	13 (46.4)	28 (9.1)
Within IOM	--	40 (36.0)	34 (30.6)	37 (33.3)	111 (35.9)
Below IOM	--	82 (48.2)	49 (28.8)	39 (22.9)	170 (55.0)
Cesarean Delivery	9 (3.3)	112 (41.3)	77 (28.4)	73 (269)	271 (84.7)
Infant sex					
Female/Female	1 (0.8)	55 (43.7)	40 (31.8)	30 (23.8)	126 (39.4)
Female/Male	3 (4.6)	25 (38.5)	18 (27.7)	19 (29.2)	65 (20.3)
Male/Male	7 (5.4)	50 (38.8)	32 (24.8)	40 (31.0)	129 (40.3)
Birthweight, g	1638.2 ± 694.6	2023.5 ± 575.8	1966.9 ± 544.3	2026.3 ± 614.9	1995.1 ± 585.8
Birthweight z-score[e]	−0.62 ± 1.03	−0.57 ± 1.03	−0.42 ± 0.90	−0.42 ± 0.93	−0.49 ± 0.97
Low birthweight[f]	20 (3.7)	219 (40.7)	156 (29.0)	143 (26.6)	538 (84.1)
Preterm <34wk	12 (54.6)	82 (31.5)	80 (38.9)	76 (42.7)	240 (37.5)
Preterm <32wk	10 (7.0)	54 (38.0)	38 (26.8)	40 (28.2)	142 (22.2)

	Underweight	Healthy	Overweight	Obesity	Total
SGA[g]	3 (2.9)	56 (53.3)	25 (23.8)	21 (20.0)	105 (16.4)
LGA[h]	2 (4.4)	19 (42.2)	10 (22.2)	14 (31.1)	45 (7.0)

Values are n(%) or mean ± SD. Underweight BMI <18.5kg/m^2; healthy 18.5–24.9kg/m^2; overweight 25.0–29.9kg/m^2; obesity ≥30kg/m^2.

[a]Gestational age at delivery;

[b]Includes unknown/not reported;

[c]Gestational weight change;

[d]IOM provisional twin-specific guidelines, no recommendation for underweight BMI (n=309);

[e]Singleton reference (Aris et al. 2019.);

[f]Birthweight <2500g;

[g]Small for gestational age, birthweight <10th percentile and

[h]Large for gestational age, birthweight >90th percentile (Grantz et al. 2016.).

Table 2.

Gestational weight change latent class membership characteristics in twin pregnancies (n=320 pregnancies or 640 infants).

	Class 1	Class 2	Class 3	Total
n (%)	79 (24.7)	195 (60.9)	46 (14.4)	320 (100)
Prepregnancy BMI				
Underweight	2 (18.2)	7 (63.6)	2 (18.2)	11 (3.4)
Healthy weight	18 (13.9)	92 (70.8)	20 (15.4)	130 (40.6)
Overweight	20 (22.2)	52 (57.8)	18 (20.0)	90 (28.1)
Obesity	39 (43.8)	44 (49.4)	6 (6.7)	89 (27.8)
Predicted GWC[a] at 32wk, kg	6.6	13.5	21.3	-
Delivery characteristics				
Total GWC, kg	8.4 ± 4.6	14.8 ± 4.2	22.9 ± 6.6	14.4 ± 6.4
GWC range, kg	−0.4, 23.8	4.4, 25.6	13.2, 39.9	−0.4, 39.9
Gestational age, wk	33.7 ± 3.6	33.8 ± 3.2	33.0 ± 3.6	33.7 ± 3.3
GWC compared to IOM[b]				
Above	2 (7.1)	10 (35.7)	16 (57.1)	28 (9.1)
Within	10 (9.0)	78 (70.3)	23 (20.7)	111 (35.9)
Below	65 (38.2)	100 (58.8)	5 (2.9)	170 (55.0)
Cesarean delivery	66 (24.4)	164 (60.4)	41 (15.1)	271 (84.7)
Infant characteristics				
Preterm <32 weeks	26 (18.3)	86 (60.6)	30 (21.1)	142 (22.2)
SGA[c]	30 (28.6)	60 (57.1)	15 (14.3)	105 (16.4)
LGA[d]	5 (11.1)	26 (57.8)	14 (31.1)	45 (7.0)
Birthweight z-score[e]	−0.67 ± 0.96	−0.49 ± 0.96	−0.16 ± 0.93	−0.49 ± 0.97

Values are n(%) or mean ± SD. GWC classes, Class 1: low gain; Class 2: moderate gain; Class 3: high gain,

[a]Gestational weight change;

[b]Institute of Medicine, includes n=309 due to lack of recommendations for underweight BMI category.

[c]Twin-specific large for gestational age, birthweight >90th percentile, and

[d]Small for gestational age, birthweight <10th percentile (Grantz et al. 2016.);

[e]Singleton reference (Aris et al. 2019).

Table 3.

Adjusted associations between gestational weight change trajectory class and perinatal outcomes in twin pregnancies (n=320 triads or 640 infants).

	LGA[a] **IRR (95% CI)**	**SGA[b]** **IRR (95% CI)**	**Birthweight z-score[c]** ***β*** **(95% CI)**	**Preterm Birth Delivery <32wk IRR (95% CI)**	**Cesarean Delivery IRR (95% CI)**
Class 1			*Referent*		
Class 2	2.04 (0.60, 6.90)	0.74 (0.47, 1.18)	**0.24 (0.00, 0.48)** [d]	1.55 (0.81, 2.98)	1.01 (0.75, 1.37)
Class 3	**5.19 (1.47, 18.32)**	0.73 (0.37, 1.43)	**0.63 (0.31, 0.96)**	**2.44 (1.10, 5.41)**	1.11 (0.74, 1.67)

Values are estimated Incidence-Rate Ratios for multivariate Poisson regression or β-coefficients for multivariate linear regression models adjusted for maternal ethnicity, age, height (cm), BMI, and infant sex. Weight trajectories modeled to ≤32 weeks.

[a] Twin-specific large for gestational age, birthweight >90th percentile, and

[b] Small for gestational age, birthweight <10th percentile (Grantz et al. 2016.);

[c] Singleton reference (Aris et al. 2019);

[d] Birthweight z-score for Class 2, p=0.05.