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ORIGINAL RESEARCH ARTICLE

Impact of maternal body mass index and gestational weight gain on maternal and neonatal outcomes in twin pregnancies

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Abstract

Introduction: To date, there have only been provisional recommendations about the appropriate gestational weight gain in twin pregnancies. This study aimed to contribute evidence to this gap of knowledge.

Material and methods: Using a cohort of 10 603 twin pregnancies delivered between 2000 and 2015 in the state of Hessen, Germany, the individual and combined impact of maternal body mass index and gestational weight gain on maternal and neonatal outcomes was analyzed using uni- and multivariable logistic regression models. The analysis used newly defined population-based quartiles of gestational weight gain in women carrying twin pregnancies (Q1: <419.4 g/week [low weight gain], Q2–Q3: 419.4–692.3 g/week [optimal weight gain], Q4: >692.3 g/week [high weight gain]) and the World Health Organization body mass index classification.

Results: Pre-pregnancy body mass index ≥25 kg/m^2 was associated with significantly increased rates of cesarean deliveries (aOR1.2, 95% CI: 1.01–1.41) and pregnancy-induced hypertensive disorders (aOR 1.53, 95% CI: 1.11–2.1) but not with any adverse neonatal outcome.

Perinatal mortality (aOR 2.23, 95% CI: 1.38–3.6), preterm birth (aOR 1.88, 95% CI: 1.58–2.25), APGAR′5 < 7 (aOR 1.61, 95% CI: 1.19–2.17) and admissions to the neonatal intensive care unit (aOR 1.6, CI: 1.38–1.85) were increased among women with low gestational weight gain. Rates of cesarean deliveries were high in both women with low (aOR 1.25, 95% CI: 1.05–1.48) and high gestational weight gain (aOR 1.17, 95% CI: 1.01–1.35). A high gestational weight gain was also associated with higher rates of hypertensive disorders in pregnancy (aOR 2.32, 95% CI: 1.79–3.02) and postpartum hemorrhage (aOR 1.72, 95%CI: 1.12–2.63). The risk of preterm birth, low Apgar scores and NICU admissions showed a converse linear relation with pre-pregnancy body mass index in women with low gestational weight gain.

Conclusions: In twin pregnancies, nonoptimal weekly maternal weight gain seems to be strongly associated with maternal and neonatal adverse outcomes. Since

Abbreviations: BMI, body mass index; GWG, gestational weight gain; HDP, hypertensive disorders in pregnancy; NICU, neonatal intensive care unit; PPH, postpartum hemorrhage.

gestational weight gain is a modifiable risk factor, health care providers have the opportunity to counsel pregnant women with twins and target their care accordingly. Additional research to confirm the validity and generalizability of our findings in different populations is warranted.

KEYWORDS
gestational weight gain, obesity, overweight, twin pregnancy, underweight

1 | INTRODUCTION

Optimal gestational weight gain (GWG) was defined for singleton pregnancies with evidence-based ranges of weekly changes specified for each pre-pregnancy body mass index (BMI) category.[1] For twin pregnancies, such weekly recommendations for weight gain are not yet established. Thus far, the range for total GWG, for normal weight, overweight and obese women has been defined, but not for underweight women.[1] Several years ago, a systematic review stated that weight gain in twin pregnancies is "a neglected area of research".[2] There are still no official guidelines about weekly GWG specific for twin pregnancies. The findings from singletons cannot be extended for the management of twin pregnancies due to physiological differences in plasma volume, placental implantation and nutritional requirements of twins compared to singletons pregnancies.[3]

Some authors found an association between low pre-pregnancy BMI, the risk of preterm birth and admissions to neonatal intensive care units (NICU) of twins.[4] An association between high BMI and cesarean deliveries, hypertensive disorders in pregnancy (HDP) and gestational diabetes mellitus has also been reported for twin pregnancies.[4,5] Earlier attempts to retrospectively analyze GWG in twin pregnancies suggested that low GWG causes an increase in preterm deliveries,[6,7] NICU admissions[7] and inter-twin weight discordance[8] while high GWG was associated with HDP.[6,9] Other recent studies while confirming the association between inadequate GWG and adverse pregnancy outcomes,[10,11] either did not consider any maternal outcomes[10] or did not analyze the outcomes for underweight women.[11]

In order to provide additional evidence in counseling and surveillance of pregnant mothers with twins, we planned this study in which we evaluated the individual and combined impact of low and high BMI and low and high GWG on maternal and neonatal outcomes in twin pregnancies.

Key message

In twin pregnancies, maternal gestational weight gain is associated with adverse maternal and neonatal outcomes. High gestational weight gain increased the risk of hypertensive disorders and cesarean deliveries, low gestational weight gain increased the risks of perinatal mortality, preterm birth and cesarean deliveries.

2 | MATERIAL AND METHODS

This study is based on a historical cohort of all twins delivered between 2000 and 2015 at a hospital in the federal state of Hessen (Germany). The federal office for quality management collects and stores electronic medical records from all perinatal centers in the state. The data were anonymized before collection and storage. Two reviewers (KN, NT) extensively reviewed the dataset retrieved from the federal office for plausibility and completeness. Incomplete and non-plausible records were not considered for the final analysis. Required inclusion criteria were availability of maternal weight and height measurements at the first examination and before delivery, maternal height ≥ 120 cm, a clinical examination performed before 14 weeks, gestational age ≥ 24 weeks at delivery, and data available on both twin newborns. One pair of twins with unknown sex was excluded (Figure 1).

The maternal BMI in early pregnancy was categorized according to the WHO definitions: underweight <18.5 kg/m^2, normal weight 18.5–24.9 kg/m^2, overweight 25.0–29.9 kg/m^2 and obesity ≥30 kg/m^2. The registry documented two weight measurements for each woman. The mean maternal GWG per week was calculated by dividing the total weight gain (grams [g]) between the first examination and the delivery by the number of weeks between those two dates, making it independent of the pregnancy duration. The weekly maternal GWG was classified into three groups with the following cut-offs: within the first quartile (Q1: <419.4 g/week), between the second and third quartile (Q2–Q3: 419.4–692.3 g/week) and within the fourth quartile (Q4: >692.3 g/week).

2.1 | Statistical analyses

The impact of maternal BMI and GWG on maternal and neonatal outcomes was examined by uni- and multivariable logistic regression models (Table 3 and Table S1): the rates of HDP (indirectly calculated from clinical findings), cesarean deliveries, postpartum hemorrhage (PPH), stillbirth, perinatal mortality (death at birth or within 7 days after delivery), preterm birth <34 gestational weeks (which has more severe effects on the newborns than a delivery <37 gestational weeks[12]), APGAR score <7 at 5 minutes, and NICU admissions. Maternal age, the year of delivery and smoking during pregnancy were added as possible confounders to the models. Unfortunately, the diagnosis of gestational diabetes mellitus was not sufficiently

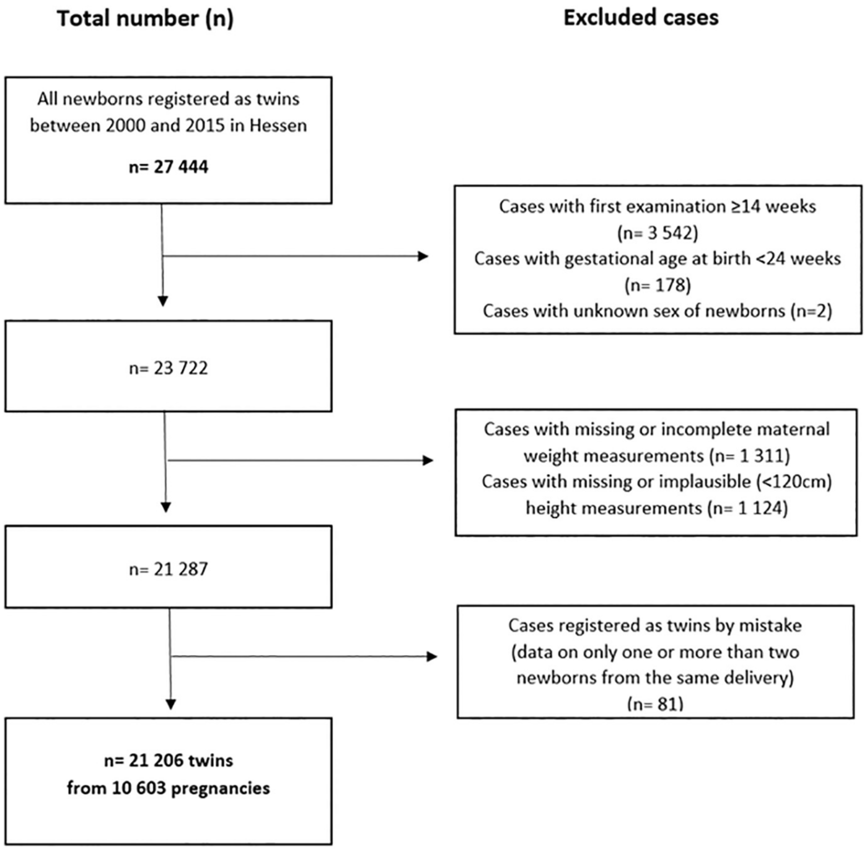

FIGURE 1 Flowchart of the study population. After inclusion and exclusion criteria were applied, a total of 10 603 twin pregnancies registered in the Hessen perinatal database between 2000 and 2015 were included for the final analyses.

standardized and thus unreliable within the observation period of our database deriving from centers with different diagnostic policies. Therefore, we decided not to consider gestational diabetes mellitus as a maternal outcome variable neither within the uni- nor within the multivariable models.

The impact of BMI and GWG on neonatal outcomes of each twin pregnancy was analyzed when at least one twin was characterized by the specified outcome. Reference groups for all analyses were women with a normal BMI (18.5–24.9 kg/m^2) and normal GWG (Q2–3). In the main study we demonstrate the results of the multivariable analyses (Table 3) but add the findings from univariable models in the supporting information (Table S1). Within the multivariable logistic regression models pairwise comparisons of least-squares means were used for low (<25th centile/ Q1) and high (≥75th centile/ Q4) GWG as compared to normal GWG in order to identify the impact of GWG on maternal and neonatal outcomes separately within each BMI group (Figure 2).

All *p*-values were two-sided with a significance level of 0.05. The programs R for Windows version 3.5.1 with the package lsmeans,[13] RStudio version 1.1.456 and Microsoft Excel 2013 were used to perform the statistical analyses.

2.2 | Ethics statement

In accordance with the guidelines of the working group for the survey and utilization of secondary data (AGENS), no ethical approval was required for this study.[14]

3 | RESULTS

After applying all inclusion and exclusion criteria, 10 603 twin pregnancies remained for the final analyses (Figure 1).

The sociodemographic characteristics of the study population are presented in Table 1. The mean maternal age was 32.1 years, more than half of the women were primiparous and while only 3% were underweight at the beginning of the pregnancy, more than 37% were overweight or obese (Table 1).

The overall incidences of all examined maternal and neonatal outcomes are demonstrated in Table 2. The incidences of HDP and cesarean deliveries within the study group were 7.0 and 73.7%, respectively, with increasing rates in higher BMI groups. Less common outcomes were stillbirth (1.3%), perinatal death (1.9%) and PPH (2.2%) while 18.0% of the twin deliveries were preterm <34 gestational weeks and in almost half the cases (48.3%) at least one twin was admitted to NICU (Table 2).

Pre-existing maternal underweight alone was not associated with any of the pathological maternal or neonatal outcomes studied (Table 3). Pre-existing high BMIs were associated with increased risks for HDP (overweight: aOR: 1.53, 95% CI: 1.11–2.1, $p = 0.009$; obesity: aOR: 2.85, 95% CI: 1.98–4.09, $p < 0.001$) and cesarean delivery (overweight: aOR: 1.2, 95% CI: 1.01–1.41, $p = 0.036$; obesity: aOR: 1.9, 95% CI: 1.45–2.49, $p < 0.001$), but had no significant association with neonatal outcome (Table 3).

In contrast, low GWG (<419.4 g/week) was associated with significantly increased risks for cesarean deliveries (aOR: 1.25,

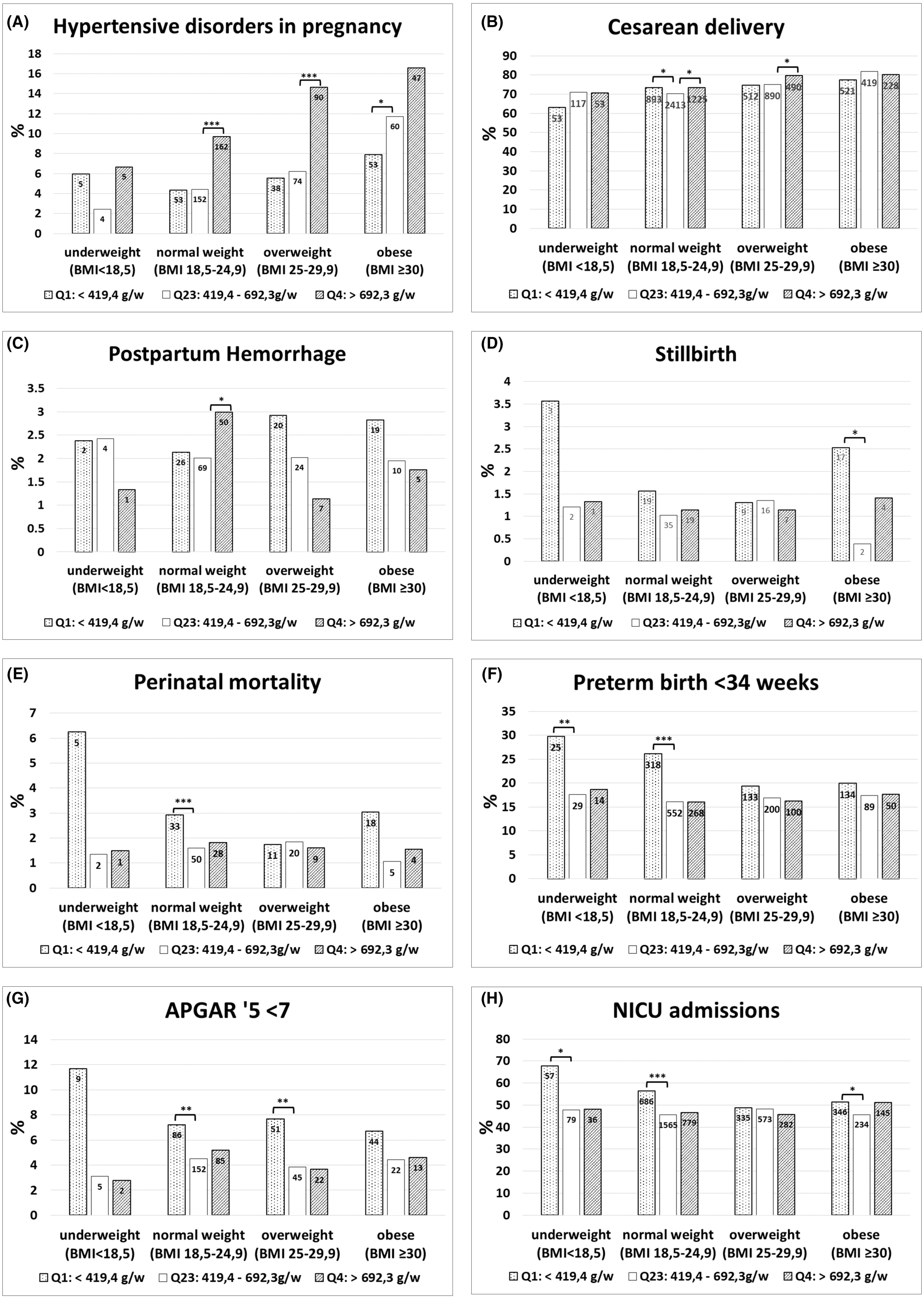

FIGURE 2 A–H Combined effects of maternal body mass index (BMI) and gestational weight gain (GWG) on pregnancy and neonatal outcomes in twin pregnancies. Rates (%) of hypertensive disorders in pregnancy (A), cesarean delivery (B), postpartum hemorrhage (C), stillbirth (D), perinatal mortality (E), preterm birth <34 weeks (F), APGAR score values <7 at 5 minutes (G) and NICU admissions (H) stratified by maternal BMI and gestational weight gain (Q1, Q2–3, Q4), $n = 10603$ twin pregnancies, absolute numbers of cases given within the column, significant results are marked with asterisks: $^{*}p < 0.05$, $^{**}p \le 0.01$, $^{***}p \le 0.001$.

TABLE 1 Sociodemographic characteristics of the study population stratified by gestational weight gain

	Low GWG <4194 g/week $n = 2661$	Normal GWG 4194–6923 g/week $n = 5296$	High GWG >6923 g/week $n = 2646$	Total group $n = 10\,603$	p-value
Mean maternal age (SD)	32.1 (5.33)	32.4 (5.00)	31.6 (5.01)	32.1 (5.09)	**<0.001**
Mothers' nationality					0.062
German	2123 (79.8%)	4327 (81.7%)	2171 (82.0%)	8621 (81.3%)	
Other	538 (20.2%)	969 (18.3%)	475 (18.0%)	1982 (18.7%)	
Parity					**<0.001**
0	1329 (50.3%)	2971 (56.3%)	1695 (64.3%)	5995 (56.8%)	
1	859 (32.5%)	1652 (31.3%)	702 (26.6%)	3213 (30.4%)	
2	279 (10.6%)	472 (8.95%)	171 (6.48%)	922 (8.74%)	
≥3	174 (6.59%)	179 (3.39%)	69 (2.62%)	422 (4.00%)	
Profession					**<0.001**
Housewife	835 (43.6%)	1379 (36.6%)	632 (35.3%)	2846 (38.1%)	
Still in education	36 (1.88%)	79 (2.10%)	36 (2.01%)	151 (2.02%)	
Worker	66 (3.45%)	98 (2.60%)	61 (3.41%)	225 (3.01%)	
Employee	634 (33.1%)	1368 (36.3%)	709 (39.6%)	2711 (36.3%)	
Executive position	342 (17.9%)	844 (22.4%)	352 (19.7%)	1538 (20.6%)	
Maternal BMI					**<0.001**
Underweight (BMI <18.5)	84 (3.16%)	165 (3.12%)	75 (2.83%)	324 (3.06%)	
Normal weight (BMI 18.5-24.9)	1218 (45.8%)	3432 (64.8%)	1671 (63.2%)	6321 (59.6%)	
Overweight (BMI 25–29.9)	686 (25.8%)	1187 (22.4%)	616 (23.3%)	2489 (23.5%)	
Obesity (BMI ≥30)	673 (25.3%)	512 (9.67%)	284 (10.7%)	1469 (13.9%)	

Abbreviations: BMI, body mass index; n, absolute numbers; GWG, gestational weight gain; SD, standard deviation.

TABLE 2 Frequencies of maternal and neonatal complications in twin pregnancies, stratified by maternal pre-pregnancy body mass index

Pregnancy outcomes	Underweight ($n = 324$, 3.1%)	Normal weight ($n = 6321$, 59.6%)	Overweight ($n = 2489$, 23.5%)	Obesity ($n = 1469$, 13.9%)	Total ($n = 10\,603$)	Overall p-value
Maternal						
Hypertensive disorders	14 (4.3%)	367 (5.8%)	202 (8.1%)	160 (10.9%)	743 (7.0%)	**<0.001**
Cesareans	223 (68.8%)	4531 (71.7%)	1892 (76.0%)	1168 (79.5%)	7814 (73.7%)	**<0.001**
Postpartum Hemorrhage	7 (2.2%)	145 (2.3%)	51 (2.1%)	34 (2.3%)	237 (2.2%)	0.909
Neonatal						
Stillbirth	6 (1.9%)	73 (1.2%)	32 (1.3%)	23 (1.6%)	134 (1.3%)	0.387
Perinatal Mortality	8 (2.7%)	111 (1.9%)	40 (1.8%)	27 (2.1%)	186 (1.9%)	0.697
Preterm birth <34 weeks	68 (21.0%)	1138 (18.0%)	433 (17.4%)	273 (18.6%)	1912 (18.0%)	0.407
APGAR′5 < 7	294 (5.2%)	323 (5.2%)	118 (4.9%)	79 (5.5%)	536 (5.2%)	0.842
NICU admissions	172 (53.1%)	3030 (47.9%)	1190 (47.8%)	725 (49.4%)	5117 (48.3%)	0.241

Abbreviation: n, absolute numbers.

95% CI: 1.05–1.48, $p = 0.01$), perinatal mortality (aOR: 2.23, 95% CI: 1.38–3.6, $p = 0.001$), preterm birth (aOR: 1.88, 95% CI: 1.58–2.25, $p < 0.001$), low APGAR scores (aOR: 1.61, 95% CI: 1.19–2.17, $p = 0.002$) and NICU admissions (aOR: 1.6, 95% CI: 1.38–1.85, $p < 0.001$) (Table 3).

High GWG (>692.3 g/week) was associated with increased rates of HDP (aOR: 2.32, 95% CI: 1.79–3.02, $p < 0.001$), cesarean deliveries (aOR: 1.17, 95% CI: 1.01–1.35, $p = 0.043$) and PPH (aOR: 1.72, 95% CI: 1.12–2.63, $p = 0.013$) (Table 3).

The results of the univariable analysis for the impact of early-pregnancy BMI and GWG on the maternal and neonatal outcome of twin pregnancies are shown in the Supporting information (Table S1). Most findings from the univariable analyses were maintained after controlling for confounding variables in the multivariable regression models,

TABLE 3 Individual effects of maternal body mass index and gestational weight gain on maternal and neonatal outcomes in twin pregnancies

Covariates	Hypertensive disorders aOR (95%CI)	*p*-value	Global *p*-value	Cesarean delivery aOR (95%CI)	*p*-value	Global *p*-value	Postpartum hemorrhage aOR (95%CI)	*p*-value	Global *p*-value	Stillbirth aOR (95%CI)	*p*-value	Global *p*-value
Maternal BMI			**<0.0001**			**<0.0001**			0.9439			0.4362
BMI <18.5	0.52 (0.16–1.66)	0.2677		0.99 (0.67–1.45)	0.9449		1.3 (0.4–4.23)	0.6626		0.74 (0.1–5.45)	0.7639	
BMI 18.5-24.9	reference			reference			reference			reference		
BMI 25–29.9	1.53 (1.11–2.1)	**0.0089**		1.2 (1.01–1.41)	**0.0357**		1.13 (0.66–1.93)	0.6636		1.42 (0.74–2.71)	0.2885	
BMI ≥30	2.85 (1.98–4.09)	**<0.0001**		1.9 (1.45–2.49)	**<0.0001**		0.96 (0.43–2.14)	0.9174		0.47 (0.11–1.97)	0.3013	
Weight gain Quartiles			**<0.0001**			**0.0143**			**0.0390**			0.1261
Q1 (low GWG)	0.87 (0.59–1.27)	0.4721		1.25 (1.05–1.48)	**0.0101**		1.12 (0.65–1.91)	0.6862		1.72 (0.94–3.15)	0.0806	
Q2–3 (normal GWG)	reference			reference			reference			reference		
Q4 (high GWG)	2.32 (1.79–3.02)	**<0.0001**		1.17 (1.01–1.35)	**0.0426**		1.72 (1.12–2.63)	**0.0127**		0.87 (0.44–1.72)	0.6938	
Year of delivery	0.98 (0.97–1)		0.0859	1.03 (1.02–1.04)		**<0.0001**	1.02 (0.99–1.05)		0.2677	1 (0.96–1.04)		0.8762
Maternal age	1.02 (1.01–1.04)		**0.0058**	1.02 (1.01–1.03)		**0.0003**	1.01 (0.98–1.04)		0.3548	1 (0.96–1.04)		0.9727
Smoking			**0.0125**			0.7527			0.5562			0.5018
No	reference			reference			reference			reference		
Yes	0.55 (0.34–0.88)			1.03 (0.84–1.28)			1.2 (0.66–2.18)			1.29 (0.62–2.68)		
	Perinatal mortality			**Preterm birth < 34 weeks**			**APGAR'5 < 7**			**NICU admissions**		
Maternal BMI			0.7401			0.7520			0.5937			0.6587
BMI <18.5	0.52 (0.07–3.84)	0.5244		0.97 (0.6–1.57)	0.9155		0.64 (0.23–1.75)	0.3823		1.11 (0.79–1.57)	0.5452	
BMI 18.5-24.9	reference			reference			reference			reference		
BMI 25–29.9	1.24 (0.7–2.2)	0.4673		1.08 (0.89–1.31)	0.4434		0.81 (0.55–1.17)	0.2585		1.04 (0.9–1.21)	0.5764	
BMI ≥30	0.84 (0.33–2.15)	0.7165		1.13 (0.86–1.48)	0.3762		0.92 (0.55–1.52)	0.7389		0.91 (0.74–1.13)	0.3999	
Weight gain Quartiles			**0.0020**			**<0.0001**			**0.0062**			**<0.0001**
Q1 (low GWG)	2.23 (1.38–3.6)	**0.0010**		1.88 (1.58–2.25)	**<0.0001**		1.61 (1.19–2.17)	**0.0019**		1.6 (1.38–1.85)	**<0.0001**	
Q2–3 (normal GWG)	reference			reference			reference			reference		
Q4 (high GWG)	1.02 (0.59–1.76)	0.9398		0.94 (0.78–1.12)	0.4704		1.06 (0.78–1.44)	0.7067		1 (0.87–1.14)	0.9568	
Year of delivery	1.01 (0.97–1.04)		0.6575	1.02 (1.01–1.03)		**0.0004**	1 (0.98–1.02)		0.8762	1.01 (1–1.02)		**0.0463**
Maternal age	0.98 (0.95–1.02)		0.3320	0.98 (0.97–0.99)		**0.0001**	0.98 (0.97–1)		0.1032	0.98 (0.97–0.98)		**<0.0001**
Smoking			0.2567			0.7856			**0.0482**			0.2187
No	reference			reference			reference			reference		
Yes	1.42 (0.77–2.61)			0.97 (0.76–1.23)			1.44 (1–2.06)			1.12 (0.93–1.35)		

Note: Rates of hypertensive disorders in pregnancy, cesarean delivery, postpartum hemorrhage, stillbirth, perinatal mortality, preterm birth <34 gestational weeks, APGAR values <7 after 5 min and NICU admissions within a cohort of 10 603 twin pregnancies, multivariable analysis adjusted for maternal age, maternal smoking and year of delivery.

Abbreviations: aOR, adjusted odds ratio; 95% CI, confidence interval.

with one exception. Only the univariable model showed low GWG significantly associated with stillbirth (OR: 1.75, 95% CI:1.19–2.59, $p = 0.005$); the association was not present after controlling for confounding factors (aOR: 1.72, 95% CI: 0.94–3.15, $p = 0.08$).

Figure 2 illustrates the combined effects of maternal GWG and BMI on maternal and neonatal outcomes. An increased risk for HDP was observed in normal weight (aOR: 2.32, 95% CI: 1.79–3.02, $p < 0.001$) and overweight women with GWG in the highest quartile (aOR: 2.64, 95% CI: 1.85–3.76, $p < 0.001$). The risk for HDP was lower in obese women with GWG in the lowest quartile (aOR: 0.62, 95% CI: 0.39–0.97, $p = 0.036$) (Figure 2A).

Cesarean deliveries were more frequent in normal weight (aOR: 1.17, 95% CI: 1.01–1.35, $p = 0.043$) and overweight mothers (aOR: 1.38, 95% CI: 1.06–1.79, $p = 0.017$) with high GWG but also in normal weight women with low GWG (aOR: 1.25, 95% CI: 1.05–1.48, $p = 0.01$) (Figure 2B). The rate of PPH was increased in women with a normal BMI whose GWG was >692.3 g/week. (aOR: 1.72, 95% CI: 1.12–2.63, $p = 0.013$) (Figure 2C).

The risk for stillbirth was significantly increased in obese women with low GWG (aOR: 5.70, 95% CI: 1.30–25.03, $p = 0.021$) (Figure 2D). Perinatal mortality was also increased among normal weight women with low GWG (aOR: 2.23, 95% CI: 1.38–3.60, $p = 0.001$) (Figure 2E). In addition, preterm births <34 gestational weeks were significantly more frequent in underweight (aOR: 2.53, 95% CI: 1.28–4.99, $p = 0.007$) and normal weight mothers (aOR: 1.88, 95% CI: 1.58–2.25, $p < 0.001$) with low GWG (Figure 2F).

Similarly, an APGAR score <7 at 5 minutes occurred more frequently in normal weight (aOR: 1.61, 95% CI: 1.19–2.17, $p = 0.002$) or overweight women with low GWG (aOR: 2.08, 95% CI: 1.32–3.28, $p = 0.002$) (Figure 2G). Low GWG was also associated with increased rates of NICU admissions in underweight (aOR: 2.12, 95% CI: 1.17–3.84, $p = 0.013$), normal weight (aOR: 1.60, 95% CI: 1.38–1.85, $p < 0.001$) and obese women (aOR: 1.34, 95% CI: 1.04–1.73, $p = 0.025$) (Figure 2H).

4 | DISCUSSION

Our study assessed the effects of BMI and GWG in twin pregnancy individually and together. In this twin cohort, overweight and obesity were associated with increased rates of HDP and cesarean deliveries, but neither low nor high BMI alone had any association with poor neonatal outcomes of twins. However, high GWG was associated with an increased risk for maternal HDP, cesarean delivery and additionally for PPH. In contrast, women with low GWG had significantly increased rates of perinatal mortality, preterm birth, cesarean deliveries, APGAR score <7 at 5 minutes and NICU admissions, regardless of the pre-existing BMI. This association was strongest in underweight women with low GWG.

A large Canadian twin study demonstrated increased rates of cesarean deliveries in overweight and obese women.[4] Similarly, the rate of cesarean deliveries significantly increased in women with a high BMI in our twin cohort, but also in women with both low and high GWG. While underweight alone was not a risk factor for any examined maternal or neonatal complications in our study, underweight and normal weight mothers with a low GWG had a significantly increased risk of preterm birth. Hence, it seems that GWG has stronger impact on the outcome of twin pregnancies than the pre-pregnancy BMI. Since GWG might be easier modifiable, pregnant women could benefit from information, counseling, and interventions to help them maintaining GWG within the normal range.

Several groups had already described an association between low GWG and preterm twin birth.[6,7,15,16] Bodnar et al. reported a U-shaped relation between preterm birth and low or excessive GWG in the analysis of a cohort of over 27000 twin pregnancies.[10] Findings from other publications on the effect of high GWG on cesarean deliveries in twin pregnancies are controversial, from no effects[17] to an increased risk.[10] In the present study, we found that a high GWG additionally increased HDP in twin pregnancies in agreement with previous findings by others.[6,7] Maeda et al. recently confirmed this association even in underweight women.[18] Since we divided our study cohort into three groups of GWG using the same range for all BMI groups, our cut-off for low GWG in obese women was higher than suggested by Lipworth et al.[11] But even using this cut-off, low GWG was significantly associated with increased risks for stillbirth and NICU admissions in obese women. We were able to assess the outcomes for underweight women and for rare outcomes such as stillbirth and perinatal mortality due to our larger cohort. However, given the relatively small subgroup analyses we interpret these results with caution.

In our cohort, an average maternal GWG between 419.4 and 692.3 g/week was associated with optimal pregnancy outcome for both, mothers and offspring. These cut-off values are similar with the provisional recommendations by the Institute of Medicine (IOM, now National Academy of Medicine) which suggested a total weight gain between 17–25 kg for normal weight women and 11–19 kg for obese women with twin pregnancies.[1] The quartiles of GWG in twin pregnancies are an average value whereby the weekly definitions make them independent of the gestational age at delivery. Although our cohort was sizable, our results do not allow us to define with certainty the cut-off values of GWG stratified by the pre-existing BMI for women with twin pregnancies. Our results do inform, however, on the need of increased awareness on the significance of the effect of low or high maternal GWG on pregnancy outcomes and the importance of patient counseling on nutrition in pregnancy. Identifying the risk factors for abnormal BMI and GWG in twin pregnancies can help target the counseling concerning nutrition and physical activity for women who will most benefit.[19]

In 2016, Whitaker et al. found that only 52% of women with singleton pregnancies received advice on optimal GWG.[20] Women pregnant with twins were only counseled with respect to physical activity in 74.5% and to nutrition in 62.7%.[21] Vinturache et al. showed that pre-pregnancy BMI had no impact on the recall of prenatal counseling in community health care.[22] While the evidence for singleton pregnancy started to accumulate, the epigenetic harm of low or high GWG has not yet been evaluated for twin pregnancies. Since women play an active role in achieving appropriate GWG, their health literacy should be improved, interventions implemented and the outcomes of interventions should be evaluated.[23]

Policy makers and health care providers should be aware of the short and long-term effects of the pathways and aberrant processes initiated in utero in both singleton and multiple pregnancies.[24] Thereby, not only GWG by its own, but also its consequences, such as preterm birth contribute to the prevalence of later noncommunicable diseases in survivors, which have high and diverse individual and societal impact.[25] Thus, development of professional guidelines and public awareness materials should promote the importance of lifestyle and nutrition in pregnancy and their impact on the health of women and their offspring more assiduously.[26]

A strength of this study is the generous sample size. Even after performing an extensive plausibility control with exclusion of incomplete and improbable data, the size of the twin cohort was large enough to perform multivariable analyses with significant results even for less common adverse maternal and neonatal outcomes. The large sample size also allowed us to include an array of potential confounders in the multivariable models. This is a population-based study, representative for the current German population, with data collected not only from specialized maternity centers but from all perinatal clinics within the region. Since we defined quartiles of weekly GWG, the analyses were independent of the gestational age and enabled us to assess the outcomes based on these quartiles, thus giving to the clinician a clinically applicable tool for assessment and management of women with twin pregnancies. The GWG cut-offs were based on a large, diverse and representative population, potentially generalizable to the German but also central a European population. Another strength was that we were able to assess both, maternal and neonatal outcomes for all BMI groups, while previous studies either did not consider any maternal outcomes or did not analyze any results for underweight women.

Our study also has limitations. The study is based on secondary data collected over several years, carrying risks of included errors.[27] We overcame this drawback through a thorough plausibility control. Additionally, the available information was restricted by the protocol of the population-based perinatal registry, which does not distinguish between mono- and dichorionic twins and did not allow evaluating the incidence of gestational diabetes mellitus. The data set documented the maternal weight at the first prenatal appointment but not prior to pregnancy. By using a weight measured in early pregnancy we were not able to evaluate any possible effects of weight gain during early pregnancy. Although there is substantial evidence to demonstrate that measured weight in early pregnancy is a valid method for estimating pre-pregnancy weight[28] weight gain in the first trimester is minimal and women may also be losing weight.[28] Therefore calculating weekly GWG does not guarantee the correlation with the entire pregnancy duration because GWG is not linear. Different approaches like using z-scores may be more robust. In the uni- and multivariable analyses, we could not distinguish if only one or both twins were affected by a certain neonatal outcome. Up to now, we could not yet apply the new cut-off values for weekly maternal GWG during different pregnancy periods. Moreover, it remains a challenge to find out whether counseling mothers-to-be with our results would make a difference in outcomes of twin pregnancies.

After the completion of our data analysis, several studies have been published focusing on the impact of BMI and GWG on the outcomes of twin gestations. Similar to our results, the impact of deviant GWG in twin pregnancies has been analyzed by Zhao et al. These authors found an increased risk for HDP among overweight and obese women and in women with high GWG during twin pregnancy.[29] Similarly, an association between high GWG and preeclampsia and between low GWG and an increased risk for preterm birth was described in a recent meta-analysis.[30] The authors concluded that inappropriate GWG affects more than 50% of twin pregnancies and that it may be a potentially modifiable risk factor for preterm birth and pre-eclampsia. However, another recent systematic review stated that up to now, no studies examined the associations of GWG and outcomes beyond birth and that additional methodologically rigorous studies are needed to better inform about evidence-based guidelines.[31]

5 | CONCLUSION

High and low GWG are strongly associated with adverse maternal and neonatal outcomes in twin pregnancies. In general, high GWG (in our cohort of >692.3 g/week) led to increased rates of HDP, cesarean deliveries, and PPH, low GWG (in our cohort of <419.4 g/week) was associated with increased rates of perinatal mortality, preterm birth, cesarean deliveries, low APGAR scores, and NICU admissions of twins. For the present time, our findings may be a pragmatic support for health care providers and mothers of twins contributing to improve awareness of risks for short- and long-term outcomes. Nevertheless, more research should be designed to further refine the present findings and to determine the GWG criteria in women with twin pregnancies, based on BMI categories, similar as they are defined for singleton pregnancies. In addition, we look forward to interventions to optimize GWG specified for maternal pre-pregnancy weight and respective gestational age in twin pregnancies.

AUTHOR CONTRIBUTIONS

JS arranged the twin data of the results section and contributed to their interpretation within the manuscript. NT assisted the team by her expertise in statistical methodology. KN and NT were responsible for data curation and cleaning. SB contributed to literature search and discussion. AV assisted with writing the final manuscript. BA designed the concept, assisted with data interpretation and mentored JS throughout the project.

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CONFLICT OF INTEREST

The authors do not have any competing interests.

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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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