ABSTRACT

Objective This retrospective cohort study analyzes risk factors for abnormal pre-pregnancy body mass index and abnormal gestational weight gain in twin pregnancies.

Methods Data from 10603/13682 twin pregnancies were analyzed using uni- and multivariable logistic regression models to determine risk factors for abnormal body mass index and weight gain in pregnancy.

Results Multiparity was associated with pre-existing obesity in twin pregnancies (aOR: 3.78, 95% CI: 2.71–5.27). Working in academic or leadership positions (aOR: 0.57, 95% CI: 0.45–0.72) and advanced maternal age (aOR: 0.96, 95% CI: 0.95–0.98) were negatively associated with maternal obesity. Advanced maternal age was associated with a lower risk for maternal underweight (aOR: 0.95, 95% CI: 0.92–0.99). Unexpectedly, advanced maternal age (aOR: 0.98, 95% CI: 0.96–0.99) and multiparity (aOR: 0.6, 95% CI: 0.41–0.88) were also associated with lower risks for high gestational weight gain. Pre-existing maternal underweight (aOR: 1.55, 95% CI: 1.07–2.24), overweight (aOR: 1.61, 95% CI: 1.39–1.86), obesity (aOR: 3.09, 95% CI: 2.62–3.65) and multiparity (aOR: 1.64, 95% CI: 1.23–2.18) were all associated with low weight gain. Women working as employees (aOR: 0.85, 95% CI: 0.73–0.98) or in academic or leadership positions were less likely to have a low gestational weight gain (aOR: 0.77, 95% CI: 0.64–0.93). 

Conclusion Risk factors for abnormal body mass index and gestational weight gain specified for twin pregnancies are relevant to identify pregnancies with increased risks for poor maternal or neonatal outcome and to improve their counseling. Only then, targeted interventional studies in twin pregnancies which are desperately needed can be performed.


Introduction

In 2016, the World Health Organization (WHO) reported that globally more than 1.9 billion individuals (39%) had an increased body mass index (BMI) > 25.0 kg/m², which means that these are globally more than 1.9 billion individuals (39%) had an increased In 2016, the World Health Organization (WHO) reported that overweight or obese [1]. In contrast, undernutrition, de-
twin pregnancies.

aim to identify risk factors of abnormal BMI and deviant GWG in weight gain (GWG) in twin pregnancies. Therefore, we hereby

know risk factors for abnormal BMI and inadequate gestational [12].

Moreover, epigenetic processes cause rising rates of non-commu-
tic diseases in the offspring [6].

Twin births had increased since the 1980s in most Western countries, mainly due to artificial reproductive techniques [7]. Accordingly, in Germany (Hessen), twin births increased between 2000 and 2015 from 1.5% to 1.9% [8]. Nevertheless, the rates of obesity in the whole population, among pregnant women with singletons and with twin pregnancies continue to increase [8, 9].

To date, studies only investigated the impact of a high BMI in twin pregnancies on pregnancy outcomes such as HDP or GDM [10, 11] or the impact of a low maternal BMI on preterm birth [12].

However, to improve preventive concepts, it is necessary to know risk factors for abnormal BMI and inadequate gestational weight gain (GWG) in twin pregnancies. Therefore, we hereby aim to identify risk factors of abnormal BMI and deviant GWG in twin pregnancies.

Materials and Methods

Study group

This is a retrospective population-based cohort study of twin pregnancies between 2000 and 2015 in the Federal state of Hes-

sen (Germany) with a population of 6.176 million inhabitants in 2015 [13]. The electronic medical records from all perinatal centers were anonymously stored by the Federal Office for Perinatal Quality Assurance ("Geschäftsstelle Qualitätssicherung Hessen"/ HEPE). All data retrieved for this study were extensively reviewed for plausibility and completeness by two reviewers (KN, NT). Since the original data set was organized and registered per twin and not per pregnancy, here, we only examined maternal characteristics from the data sets of first twins.

From the total data base of twin pregnancies (n = 13682) we excluded data sets with missing or incomplete maternal weight measurements (n = 656), missing height measurements or height < 120 cm (n = 562), first clinical examinations performed after 14 weeks (n = 1771), delivery before 24 gestational weeks (n = 89) and one case with unknown sex of the first twin.

BMI and GWG

The WHO definitions were applied to categorize the maternal BMI into four groups: underweight < 18.5 kg/m², normal weight 18.5–24.9 kg/m², overweight 25.0–29.9 kg/m² and obesity ≥ 30 kg/m². The database contained two weight measurements for each preg-
nancy: one from the first examination and a second one before birth. The mean maternal GWG per week was calculated by divid-
ing the total GWG in grams during pregnancy by the number of weeks between first examination and delivery assuming a linear weight gain throughout pregnancy. In absence of international or national guidelines for maternal GWG in twin pregnancies, we had classified the maternal GWG per week in quartiles (Q), with the medium quartiles (Q2 and Q3) representing normal GWG.
This resulted in cut-offs of GWG <419.4 g/week for low GWG (Q1), 419.4–692.3 g/week for normal GWG (Q2 and Q3) and >692.3 g/week for high GWG (Q4) [8].

Statistical analysis

Using uni- and multivariable logistic regression models, the following risk factors for low and high maternal BMI early in pregnancy ("pre-existing") and low and high GWG were identified: maternal age (continuous variable), nationality (German or other), parity (number of previous deliveries including stillbirths), marital status (mother with a partner, single parent), and maternal socio-economic status. For the latter, the work characteristics was used as a proxy and was classified in: housewife, in training, workers (untrained workers or temporary employees), employees, and women with academic or leadership positions. For GWG, maternal BMI was included in analyses as a confounder (Fig. 2).

Reference groups for all analyses were women with a normal BMI (18.5–24.9 kg/m²) and normal GWG (Q2–Q3). All p-values were two-sided with a significance level of 0.05.

Univariable analyses assessed the association between sociodemographic factors and BMI or GWG, respectively (Tables 2 and 3). In multivariable analyses, we assessed the maternal characteristics as risk factors for abnormal BMI and GWG. For all statistical analyses we used the programs R for Windows version 3.5.1, RStudio version 1.1.456 and Microsoft Excel 2013. 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].

Results

Characteristics of the study group

The final study cohort comprises 10603/13682 twin pregnancies between 2000 and 2015. Within this cohort, 324/10603 women (3.1%) were classified as underweight at their first examination, 6321/10603 women (59.6%) were normal weight, 2489/10603 women (23.5%) were overweight and 1469/10603 (13.9%) were obese. The mean maternal age was 32.1 years, 81.3% of mothers were of German nationality, almost 10% were a single parent, more than 50% were primiparous, 38% of the mothers were housewives, and >50% were either employees or working in an academic or leadership position (Table 1).

Risk factors for maternal BMI

The multivariable analysis found that advanced maternal age was negatively associated with maternal underweight (aOR: 0.89, 95% CI: 0.82–0.99, p < 0.01). None of the other variables assessed were associated with maternal underweight (Fig. 1a).

Multiparity with 3 or more previous deliveries was associated with overweight in twin mothers (aOR: 2.46, 95% CI: 1.82–3.33, p < 0.0001), whereas there was a significantly lower frequency of overweight in women with an academic or leadership position (aOR: 0.74, 95% CI: 0.62–0.89, p = 0.001) (Fig. 1b).

Mothers with a nationality other than German were significantly less obese as compared to German women with twins (aOR: 0.66, 95% CI: 0.54–0.8, p < 0.001). A parity ≥3 was associ-
### Fig. 1 Risk factors for low ("underweight") (a), increased ("overweight") (b) or high ("obesity") (c) maternal body mass index at the 1st examination. n = 10603 twin pregnancies, reference: normal BMI (≥ 18.5 and < 25.0 kg/m², n = 6321, 59.62%), multivariable analysis adjusted for all other risk factors.

| Risk factors | Odds ratio | p-value |
|--------------|------------|---------|
| Maternal age | 0.95 (0.92, 0.99) | 0.005 |
| Single parent | Yes | 1.06 (0.63, 1.70) | 0.812 |
| | No | Reference | |
| Origin | German | 1.36 (0.94, 1.95) | 0.097 |
| | Other | 1.36 (0.94, 1.95) | 0.097 |
| Previous pregnancies | 0 | Reference | |
| | 1 | 0.95 (0.66, 1.36) | 0.800 |
| | 2 | 1.01 (0.54, 1.79) | 0.963 |
| | 3 or more | 1.46 (0.59, 3.13) | 0.365 |
| Profession | Housewives | Reference | |
| | In training | 1.13 (0.42, 2.54) | 0.781 |
| | Worker | 0.49 (0.12, 1.35) | 0.237 |
| | Employee | 0.79 (0.54, 1.17) | 0.241 |
| | Academic position | 0.87 (0.54, 1.38) | 0.565 |

### a

| Risk factors | Odds ratio | p-value |
|--------------|------------|---------|
| Maternal age | 0.99 (0.98, 1.01) | 0.282 |
| Single parent | Yes | 0.83 (0.67, 1.02) | 0.082 |
| | No | Reference | |
| Origin | German | 0.99 (0.85, 1.15) | 0.887 |
| | Other | 0.99 (0.85, 1.15) | 0.887 |
| Previous pregnancies | 0 | Reference | |
| | 1 | 1.08 (0.94, 1.24) | 0.249 |
| | 2 | 1.70 (1.38, 2.08) | <0.001 |
| | 3 or more | 2.46 (1.82, 3.33) | <0.001 |
| Profession | Housewives | Reference | |
| | In training | 0.73 (0.45, 1.14) | 0.179 |
| | Worker | 0.99 (0.69, 1.39) | 0.937 |
| | Employee | 0.97 (0.84, 1.12) | 0.679 |
| | Academic position | 0.74 (0.62, 0.89) | 0.001 |

### b

| Risk factors | Odds ratio | p-value |
|--------------|------------|---------|
| Maternal age | 0.96 (0.95, 0.98) | <0.001 |
| Single parent | Yes | 0.81 (0.62, 1.04) | 0.104 |
| | No | Reference | |
| Origin | German | 0.66 (0.54, 0.80) | <0.001 |
| | Other | 0.66 (0.54, 0.80) | <0.001 |
| Previous pregnancies | 0 | Reference | |
| | 1 | 1.35 (1.14, 1.59) | <0.001 |
| | 2 | 1.79 (1.38, 2.30) | <0.001 |
| | 3 or more | 3.78 (2.71, 5.27) | <0.001 |
| Profession | Housewives | Reference | |
| | In training | 0.74 (0.42, 1.22) | 0.257 |
| | Worker | 1.21 (0.81, 1.77) | 0.346 |
| | Employee | 0.85 (0.71, 1.01) | 0.067 |
| | Academic position | 0.57 (0.45, 0.72) | <0.001 |

### c
Risk factors associated with increased risk for obesity (aOR: 3.78, 95% CI: 2.71–5.27, p < 0.001) working in an academic or leadership position (aOR: 0.57, 95% CI: 0.45–0.72, p < 0.001) and increasing maternal age were both negatively associated with maternal obesity in the multivariable model (aOR: 0.96, 95% CI: 0.95–0.98, p < 0.001) (Fig. 1c).

### Risk factors for maternal GWG

Advanced maternal age (aOR: 0.98, 95% CI: 0.96–0.99, p < 0.001) and parity ≥ 3 (aOR: 0.60, 95% CI: 0.41–0.88, p = 0.009) were associated with lower risks for high GWG (>75th centile, Q4) (Fig. 2a). High GWG was not significantly associated with the pre-existing BMI (Fig. 2a).

Accordingly, parity ≥ 3 (aOR: 1.64, 95% CI: 1.23–2.18, p < 0.001), maternal underweight (aOR: 1.55, 95% CI: 1.06–2.23,
high BMI or GWG are demonstrated in

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These findings are different from the singleton pregnancies of

- Maternal age
- Mothers’ nationality
- German
- Other
- Single parent
- No
- Yes
- Parity
- Professions
- In training
- Worker
- Employee
- Academic/leadership position

| Risk factors          | Underweight |             |                      | Overweight |             |                      | Obesity            |             |                      |
|-----------------------|-------------|-------------|----------------------|------------|-------------|----------------------|---------------------|-------------|----------------------|
|                       | OR (95% CI) | p-value     | Global p-value       | OR (95% CI)| p-value     | Global p-value       | OR (95% CI)        | p-value     | Global p-value       |
| Maternal age          | 0.95 (0.93–0.98) | <0.0001 |                      | 0.99 (0.98–1) | 0.0318 | 0.97 (0.96–0.98) | <0.0001 |
| Mothers’ nationality  |             | 0.0130      |                      |            |             | 0.0010               |                     |             | 0.2957               |
| German                |             |             |                      |            |             |                      |                     |             |                      |
| Other                 | 1.4 (1.07–1.82) | 1.21 (1.08–1.36) |                      | 0.92 (0.79–1.07) |             | 0.0472               |                     |             |                      |
| Single parent         |             | 0.6232      |                      |            | 0.3246      |                      |                     |             |                      |
| No                    |             |             |                      |            |             |                      |                     |             |                      |
| Yes                   | 1.11 (0.74–1.66) | 0.92 (0.77–1.09) |                      | 0.8 (0.64–1) |             | 0.001               |                     |             |                      |
| Parity                |             | 0.6069      | <0.0001              |            |             | <0.0001             | <0.0001            |             |                      |
| 0                     |             |             |                      |            |             |                      |                     |             |                      |
| 1                     | 0.88 (0.68–1.14) | 0.3420      |                      | 1.14 (1.03–1.27) | 0.0123 | 1.36 (1.19–1.54) | <0.0001            |             |                      |
| 2                     | 0.92 (0.58–1.44) | 0.7102      |                      | 1.83 (1.56–2.15) | <0.0001 | 1.96 (1.61–2.38) | <0.0001            |             |                      |
| ≥3                    | 1.29 (0.69–2.42) | 0.4207      |                      | 2.44 (1.92–3.09) | <0.0001 | 3.9 (3.03–5.02)  | <0.0001            |             |                      |
| Professions           |             | 0.02239     | <0.0001              |            |             | <0.0001             | <0.0001            |             |                      |
| Housewife             |             |             |                      |            |             |                      |                     |             |                      |
| In training           | 1.36 (0.64–2.88) | 0.4221      |                      | 0.63 (0.41–0.97) | 0.0364 | 0.71 (0.43–1.14) | 0.1578              |             |                      |
| Worker                | 0.75 (0.32–1.75) | 0.5103      |                      | 0.82 (0.59–1.15) | 0.2590 | 1.04 (0.72–1.5)  | 0.8280              |             |                      |
| Employee              | 0.61 (0.44–0.85) | 0.0035      |                      | 0.85 (0.75–0.96) | 0.0105 | 0.76 (0.66–0.89) | 0.0004              |             |                      |
| Academic/leadership   | 0.7 (0.49–1.01) | 0.0586      |                      | 0.65 (0.56–0.76) | <0.0001 | 0.49 (0.41–0.6)  | <0.0001             |             |                      |

Univariable analysis, n = 10603 twin pregnancies, reference: normal BMI (≥ 18.5 < 25.0 kg/m²), OR = odds ratio, 95% CI = 95% confidence interval, a n = 8767, b n = 10552, c n = 7471. Bold = p < 0.05

Discussion

The present study found that, in twin pregnancies, maternal age, multiparity, and mothers’ profession reflecting her socioeconomic status were risk factors associated with an abnormal maternal BMI and deviant GWG. Additionally, both a high and a low pre-existing BMI in early pregnancy were associated with low GWG. These findings are different from the singleton pregnancies of the German cohort, where high pre-pregnancy BMI is associated with excessive GWG [9]. In singleton pregnancies, it had been described that low GWG was positively associated with regular exercise in week 30, whereas being overweight before pregnancy was inversely associated with regular exercise in week 17, aOR = 0.8 (0.7–0.8) and 30, aOR = 0.7 (0.6–0.7). Since all women experiencing a multiple pregnancy were less likely to exercise regularly during pregnancy, the impact of lifestyle during pregnancy seems less pronounced [15].

We found a negative association between increasing maternal age and underweight in women with twin pregnancies, which had also been described in Asian and African women of reproductive age [16–18].

Not only in the whole population, but also in twin gestations a pre-existing BMI ≥ 30 kg/m² was more frequent in younger women. This can be explained by the increasing prevalence of obesity in Western countries [19]. It is worrisome that even the World Obesity Federation stated that, globally, the defined target of “no increase in obesity beyond the levels of 2010” cannot be realized [20].

The fact that a high parity was associated with increasing risks for maternal overweight and obesity had already been observed in women of childbearing age [18,21]. One of many causal factors is an excess postpartum weight retention occurring more fre-
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...in women with high parity, which had been observed in singleton pregnancies [23].

While the maternal BMI in early pregnancy was not associated with an increased risk for high GWG in this twin cohort, we observed a U-shaped association between maternal BMI and low GWG: women with a BMI ≥ 25 kg/m² demonstrated a significantly lower GWG as already described by Hutcheon et al. [29]. While Hutcheon et al. did not present results for underweight women, we found that a maternal BMI < 18.5 kg/m² was also significantly associated with low GWG. Since underweight and low GWG may simultaneously lead to increased risks for SGA infants and preterm birth [30] underweight women with twins need to be closely monitored for early diagnosis of fetal growth restriction. Overall, the effects of maternal BMI and GWG on the outcome of twin pregnancies require further evaluation. Previous studies found an association between a high maternal BMI and hypertensive disorders and gestational diabetes mellitus [10, 11] in twin pregnancies. Higher risks for hypertensive disorders [31, 32] and...

### Table 3  Association between sociodemographic and clinical characteristics and maternal GWG in twin pregnancies.

| Risk factors                  | Low maternal weight gain vs. normal weight gain | High maternal weight gain vs. normal weight gain |
|-------------------------------|-----------------------------------------------|-----------------------------------------------|
|                               | OR (95% CI)  | p-value | Global p-value | OR (95% CI)  | p-value | Global p-value |
| Maternal age                  | 0.99 (0.98–1) | 0.0299   | 0.97 (0.96–0.98) | <0.0001     |         |               |
| Mothers’ nationality          | reference    | 0.0391   | reference      | 0.7070      |         |               |
| • German                      | reference    |          |               | reference   |         |               |
| • Other                       | 1.13 (1.01–1.27) |          | 0.98 (0.87–1.1) |         | 0.0819 |               |
| Single parent*                | 0.3737       |          | 0.462         |            |         |               |
| • No                          | reference    |          | reference      |            |         |               |
| • Yes                         | 0.92 (0.77–1.1) |          | 1.18 (1–1.4)   |            |         |               |
| Parityb                       | <0.0001      |          | <0.0001        | <0.0001     |         |               |
| • 0                           | reference    |          | reference      |            |         |               |
| • 1                           | 1.16 (1.05–1.29) | 0.0049   | 0.74 (0.67–0.83) | <0.0001     |         |               |
| • 2                           | 1.32 (1.12–1.55) | 0.0007   | 0.64 (0.53–0.76) | <0.0001     |         |               |
| • ≥ 3                         | 2.17 (1.75–2.7) | <0.0001 | 0.68 (0.51–0.9)  | 0.0668      |         |               |
| Professionc                   | <0.0001      |          | 0.255         |             |         |               |
| • House wife                  | reference    |          | reference      |            |         |               |
| • In training                 | 0.75 (0.5–1.13) | 0.1672   | 0.99 (0.66–1.49) | 0.9780      |         |               |
| • Worker                      | 1.11 (0.8–1.54) | 0.5196   | 1.36 (0.97–1.9)  | 0.0718      |         |               |
| • Employee                    | 0.77 (0.67–0.87) | <0.0001 | 1.13 (0.99–1.29) | 0.0652      |         |               |
| • Academic/leadership position| 0.67 (0.57–0.78) | <0.0001 | 0.91 (0.78–1.06) | 0.2361      |         |               |
| BMI at 1st examination        | <0.0001      |          | 0.2849         |             |         |               |
| • Normal weight (BMI 18.5–24.9) | reference    |          | reference      |            |         |               |
| • Overweight (BMI ≥ 25–29.9)  | 1.63 (1.45–1.83) | <0.0001 | 1.07 (0.95–1.19) | 0.2709      |         |               |
| • Obese (BMI ≥ 30)            | 3.7 (3.25–4.23) | <0.0001 | 1.14 (0.97–1.33) | 0.1022      |         |               |
| • Underweight (BMI < 18.5)    | 1.43 (1.09–1.88) | 0.0090  | 0.93 (0.71–1.23) | 0.6294      |         |               |

Univariable analysis, n = 10 603 twin pregnancies, reference: quartiles Q2–Q3 (*normal weight gain*, 419.4–692.3 g/week) within the according population OR = odds ratio, 95% CI = 95% confidence interval, *n = 8767, ‡n = 10 552, §n = 7471. bold = p < 0.05
Cesarean deliveries [30] were also observed in women with high GWG. A low maternal pre-pregnancy BMI and low maternal GWG during twin pregnancies have been associated with adverse neonatal outcomes like preterm birth [12, 32, 33].

While the risk factors identified in this study can already be a useful tool to help identify women who need a more careful surveillance during twin pregnancy, we have also analyzed the impact of maternal BMI and weight gain on maternal and neonatal outcomes. This will be part of consecutive publications and debates.

The main strength of this study is that the analysis of risk factors for aberrant BMI and GWG might allow improving prevention and a closer surveillance of the twin pregnancies. The large cohort of twin pregnancies enabled us to perform multivariable analyses. Another strength is that we based the analysis in this study on previously defined cut-offs for GWG categories in twin gestations [8]. We are conscious of the fact that we could only show associations, but no causal relationships. A protocol of HEPE did allow neither to differentiate between mono- and dichorionic twins nor to analyse maternal weight continuously. Therefore, we could not specify the cut-off values for weekly maternal GWG for gestational age. Data on the socioeconomic status were not systematically documented causing missing values.

Conclusion

We identified multiparity and low socioeconomic status as risk factors for pre-existing maternal overweight or obesity in twin pregnancies. Young age and nulliparity were associated with high maternal GWG in twin gestations. Parity ≥ 3 and an abnormally high or low maternal BMI were all associated with increased risks for low GWG.

Our results should help to identify and counsel women pregnant of twins at risk for abnormal GWG, whereby high GWG is strongly associated with adverse maternal and low GWG with poor neonatal outcomes in twin gestations. This issue is part of still unpublished data from the same database investigating the impact of BMI and GWG on maternal and neonatal outcomes. Unfortunately, there are no controlled studies yet on interventions of abnormal GWG specified for twin pregnancies. Our paper might be a new stimulus for future studies to improve surveillance and to investigate which lifestyle interventions might be helpful in twin gestations to improve the outcome in mothers with abnormal BMI or weight gain.

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Conflict of Interest

The authors declare that they have no conflict of interest.

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