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Risk Factors for Maternal Body Mass Index and Gestational Weight Gain in Twin Pregnancies

Risikofaktoren für den mütterlichen Body-Mass-Index und die Gewichtszunahme in der Schwangerschaft bei Zwillingsschwangerschaften

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Key words

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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 10 603/13 682 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 counselling. Only then, targeted interventional studies in twin pregnancies which are desperately needed can be performed.

ZUSAMMENFASSUNG

Ziel Diese retrospektive Kohortenstudie analysiert die Risikofaktoren für einen abnormalen Body-Mass-Index vor der Schwangerschaft und eine abnormale Gewichtszunahme während der Schwangerschaft bei Zwillingsschwangerschaften.

Methoden Daten aus 10 603/13 682 Zwillingsschwangerschaften wurden mithilfe von univariablen und multivariablen logistischen Regressionsmodellen analysiert, um die Risikofaktoren für einen abnormalen Body-Mass-Index und eine abnormale Gewichtszunahme in der Schwangerschaft zu bestimmen.

Ergebnisse Multiparität war mit vorbestehender Adipositas bei Zwillingsschwangerschaften assoziiert (aOR 3,78; 95%-KI 2,71–5,27). Eine akademische Anstellung bzw. eine Führungsposition (aOR 0,57; 95%-KI 0,45–0,72) sowie fortgeschrittenes mütterliches Alter (aOR: 0,96, 95%-KI 0,95–0,98) waren negativ mit mütterlichem Adipositas assoziiert. Fortgeschrittenes mütterliches Alter war mit einem niedrigeren Risiko für mütterliches Untergewicht assoziiert (aOR 0,95; 95%-KI 0,92–0,99). Unerwarteterweise waren fortgeschrittenes mütterliches Alter (aOR 0,98; 95%-KI 0,96–0,99) sowie Multiparität (aOR 0,6; 95%-KI 0,41–0,88) auch mit einem niedrigeren Risiko für eine starke Gewichtszunahme in der Schwangerschaft assoziiert. Vorbestehendes mütterliches Untergewicht (aOR 1,55; 95%-KI 1,07–2,24), Übergewicht (aOR 1,61; 95%-KI 1,39–1,86), Adipositas (aOR 3,09; 95%-KI 2,62–3,65) und Multiparität (aOR 1,64; 95%-KI 1,23–2,18) waren alle mit einer niedrigeren Gewichtszunahme assoziiert. Die Wahrscheinlichkeit, dass Frauen, die als Angestellte (aOR 0,85; 95%-KI 0,73–0,98) oder in akademischen Stellungen arbeiteten oder Führungspositionen innehaben, in der Schwangerschaft nur wenig an Gewicht zulegen, war geringer (aOR 0,77; 95%-KI 0,64–0,93).

Schlussfolgerung Das Wissen um die Risikofaktoren für einen abnormalen Body-Mass-Index und eine abnormale Gewichtszunahme in der Schwangerschaft bei Zwillingsschwangerschaften ist wichtig, damit Schwangerschaften mit einem erhöhten Risiko eines schlechten mütterlichen oder kindlichen Outcomes frühzeitig identifiziert werden können und die Beratung dieser schwangeren Frauen dementsprechend verbessert werden kann. Nur dann können dringend benötigte gezielte Interventionsstudien bei Zwillingsschwangerschaften durchgeführt werden.

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/m^2, which means that these are either overweight or obese [1]. In contrast, undernutrition, defined as a BMI < 18.5 kg/m^2, affected “only” 462 million adults in the same year [2]. Meanwhile, overweight and obesity have exceeded undernutrition as global public health concern.

It has been demonstrated that, in singleton pregnancies, an abnormal maternal body mass index is associated with pre-, peri- and postnatal risks such as stillbirth [3], gestational diabetes (GDM) [4], hypertensive disorders in pregnancy (HDP) [5], preterm birth [5] or increased rates of cesarean deliveries [4]. Furthermore, epigenetic processes cause rising rates of non-communicable 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 Hessen (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 = 13 682) 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/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 database contained two weight measurements for each pregnancy: one from the first examination and a second one before birth. The mean maternal GWG per week was calculated by dividing 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.

▶ **Table 1** Sociodemographic and clinical characteristics of the study population.

	Underweight (n = 324, 3.06 %)	Normal weight (n = 6321, 59.62 %)	Overweight (n = 2489, 23.47 %)	Obesity (n = 1469, 13.85 %)	Total (n = 10 603)	Overall p-value
Mean maternal age (SD)	31.1 (5.80)	32.3 (5.08)	32.1 (5.02)	31.5 (5.03)	32.1 (5.09)	**< 0.001**
Mothers' nationality						**< 0.001**
▪ German	248 (76.5 %)	5185 (82.0 %)	1966 (79.0 %)	1222 (83.2 %)	8621 (81.3 %)	
▪ Other	76 (23.5 %)	1136 (18.0 %)	523 (21.0 %)	247 (16.8 %)	1982 (18.7 %)	
Single parent[a]						0.185
▪ No	219 (88.7 %)	4647 (89.6 %)	1886 (90.4 %)	1144 (91.3 %)	7896 (90.1 %)	
▪ Yes	28 (11.3 %)	537 (10.4 %)	200 (9.6 %)	106 (8.5 %)	871 (9.9 %)	
Parity[b]						**< 0.001**
▪ 0	201 (62.2 %)	3783 (60.1 %)	1308 (52.8 %)	703 (48.1 %)	5995 (56.8 %)	
▪ 1	89 (27.6 %)	1896 (30.1 %)	750 (30.3 %)	478 (32.7 %)	3213 (30.4 %)	
▪ 2	22 (6.8 %)	451 (7.2 %)	285 (11.5 %)	164 (11.2 %)	922 (8.7 %)	
▪ ≥ 3	11 (3.4 %)	160 (2.5 %)	135 (5.5 %)	116 (7.9 %)	422 (4.0 %)	
Profession[c]						**< 0.001**
▪ Housewife	96 (44.2 %)	1518 (35.0 %)	746 (41.1 %)	486 (44.3 %)	2846 (38.1 %)	
▪ In training	8 (3.7 %)	93 (2.1 %)	29 (1.6 %)	21 (1.9 %)	151 (2.0 %)	
▪ Worker	6 (2.8 %)	126 (2.9 %)	51 (2.8 %)	42 (3.8 %)	225 (3.0 %)	
▪ Employee	62 (28.6 %)	1595 (36.7 %)	665 (36.7 %)	389 (35.4 %)	2711 (36.3 %)	
▪ Academic/leadership position	45 (20.7 %)	1010 (23.3 %)	323 (17.8 %)	160 (14.6 %)	1538 (20.6 %)	

n = 10 603 twin pregnancies, SD = standard deviation, [a] n = 8767, [b] n = 10 552, [c] n = 7471. bold = p < 0.05

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 socioeconomic 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/m^2) 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

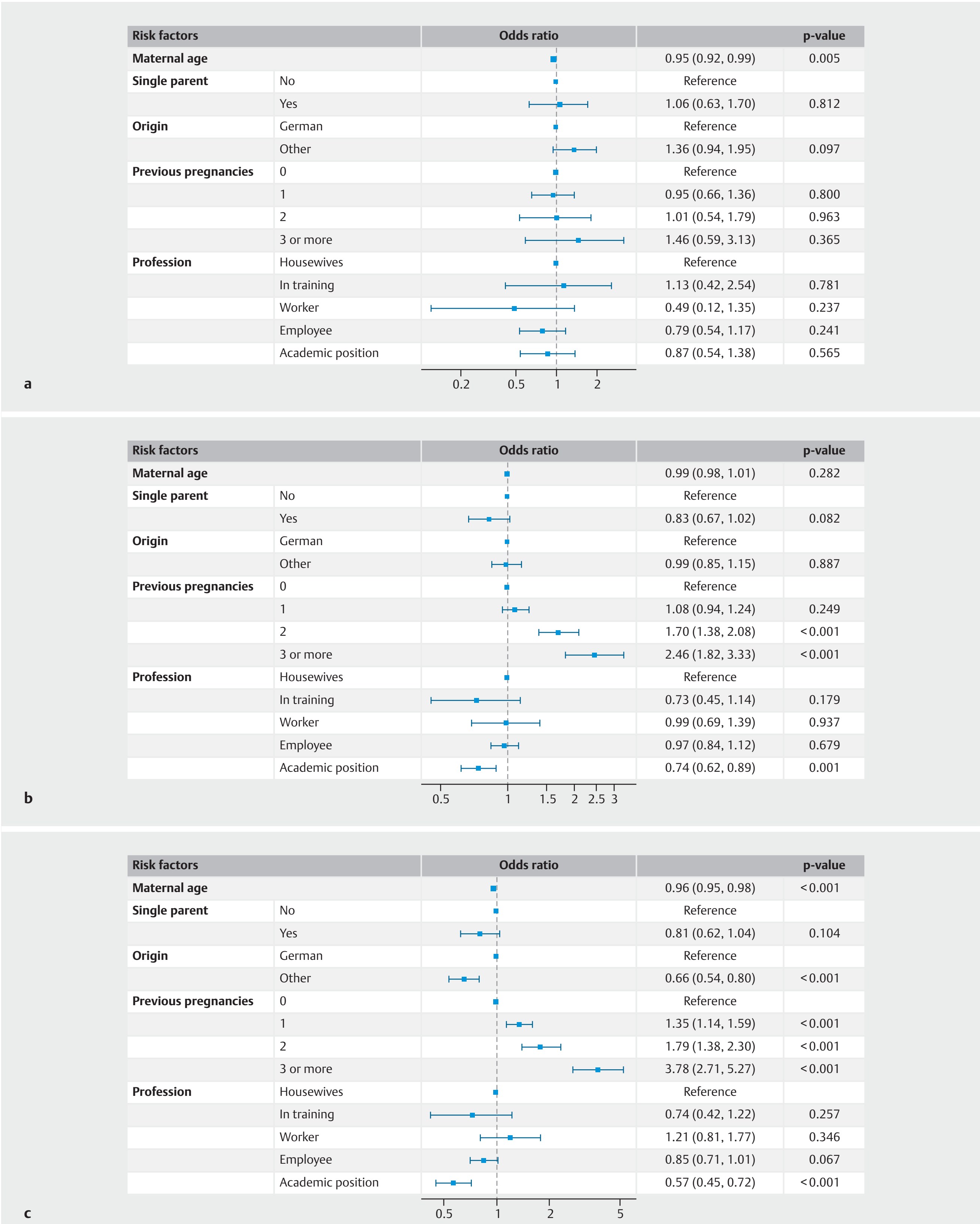
The final study cohort comprises 10 603/13 682 twin pregnancies between 2000 and 2015. Within this cohort, 324/10 603 women (3.1 %) were classified as underweight at their first examination, 6321/10 603 women (59.6 %) were normal weight, 2489/10 603 women (23.5 %) were overweight and 1469/10 603 (13.9 %) 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: 0.95, 95 % CI: 0.92–0.99, p < 0.01). None of the other variables assessed were associated with maternal underweight (▶ **Fig. 1 a**).

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. 1 b**).

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-



a

Risk factors		Odds ratio		p-value
Maternal age			0.95 (0.92, 0.99)	0.005
Single parent	No		Reference	
	Yes		1.06 (0.63, 1.70)	0.812
Origin	German		Reference	
	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

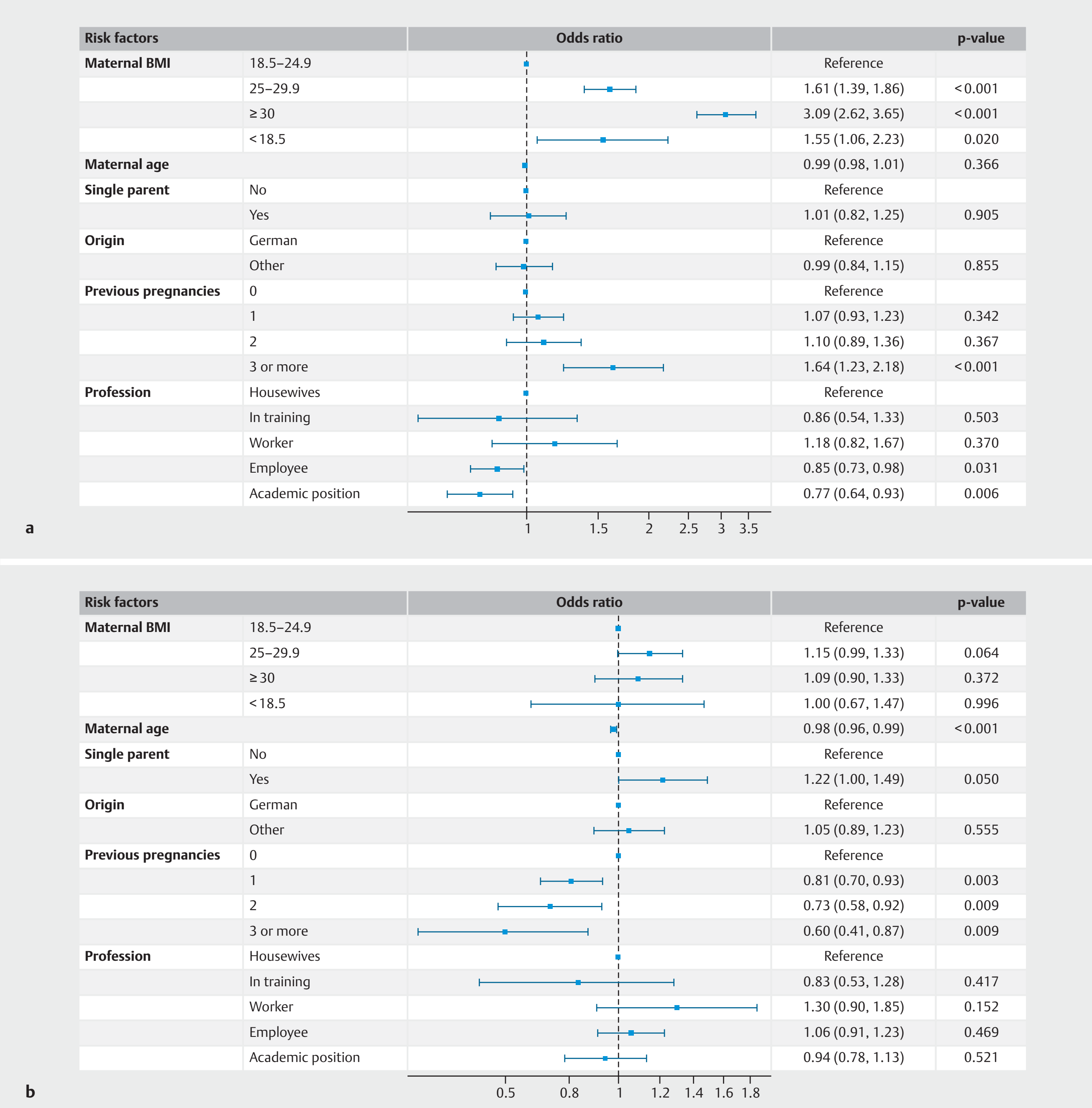
b

Risk factors		Odds ratio		p-value
Maternal age			0.99 (0.98, 1.01)	0.282
Single parent	No		Reference	
	Yes		0.83 (0.67, 1.02)	0.082
Origin	German		Reference	
	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

c

Risk factors		Odds ratio		p-value
Maternal age			0.96 (0.95, 0.98)	< 0.001
Single parent	No		Reference	
	Yes		0.81 (0.62, 1.04)	0.104
Origin	German		Reference	
	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

▶ **Fig. 1** Risk factors for low (“underweight”) (**a**), increased (“overweight”) (**b**) or high (“obesity”) (**c**) maternal body mass index at the 1st examination. n = 10 603 twin pregnancies, reference: normal BMI (≥ 18.5 and < 25.0 kg/m^2, n = 6321, 59.62 %), multivariable analysis adjusted for all other risk factors.



Risk factors		Odds ratio		p-value
Maternal BMI	18.5–24.9		Reference	
	25–29.9		1.61 (1.39, 1.86)	< 0.001
	≥ 30		3.09 (2.62, 3.65)	< 0.001
	< 18.5		1.55 (1.06, 2.23)	0.020
Maternal age			0.99 (0.98, 1.01)	0.366
Single parent	No		Reference	
	Yes		1.01 (0.82, 1.25)	0.905
Origin	German		Reference	
	Other		0.99 (0.84, 1.15)	0.855
Previous pregnancies	0		Reference	
	1		1.07 (0.93, 1.23)	0.342
	2		1.10 (0.89, 1.36)	0.367
	3 or more		1.64 (1.23, 2.18)	< 0.001
Profession	Housewives		Reference	
	In training		0.86 (0.54, 1.33)	0.503
	Worker		1.18 (0.82, 1.67)	0.370
	Employee		0.85 (0.73, 0.98)	0.031
	Academic position		0.77 (0.64, 0.93)	0.006

Risk factors		Odds ratio		p-value
Maternal BMI	18.5–24.9		Reference	
	25–29.9		1.15 (0.99, 1.33)	0.064
	≥ 30		1.09 (0.90, 1.33)	0.372
	< 18.5		1.00 (0.67, 1.47)	0.996
Maternal age			0.98 (0.96, 0.99)	< 0.001
Single parent	No		Reference	
	Yes		1.22 (1.00, 1.49)	0.050
Origin	German		Reference	
	Other		1.05 (0.89, 1.23)	0.555
Previous pregnancies	0		Reference	
	1		0.81 (0.70, 0.93)	0.003
	2		0.73 (0.58, 0.92)	0.009
	3 or more		0.60 (0.41, 0.87)	0.009
Profession	Housewives		Reference	
	In training		0.83 (0.53, 1.28)	0.417
	Worker		1.30 (0.90, 1.85)	0.152
	Employee		1.06 (0.91, 1.23)	0.469
	Academic position		0.94 (0.78, 1.13)	0.521

▶ **Fig. 2** Risk factors for low (within the lowest quartile Q1: < 419.4 g/week) (**a**) or high (within the highest quartile Q4: > 692.3 g/week) (**b**) maternal weight gain during twin pregnancy. n = 10 603 twin pregnancies, Reference: quartiles Q2–Q3 ("normal weight gain", 419.4–692.3 g/week) within the according population, multivariable analysis adjusted for all other risk factors.

ated 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. 1 c**).

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. 2 a**). High GWG was not significantly associated with the pre-existing BMI (▶ **Fig. 2 a**).

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,

▶ **Table 2** Association between sociodemographic and clinical characteristics and maternal BMI in twin pregnancies.

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	reference			reference			reference		
▪ Other	1.4 (1.07–1.82)			1.21 (1.08–1.36)			0.92 (0.79–1.07)		
Single parent[a]			0.6232			0.3246			**0.0472**
▪ No	reference			reference			reference		
▪ Yes	1.11 (0.74–1.66)			0.92 (0.77–1.09)			0.8 (0.64–1)		
Parity[b]			0.6069			**< 0.0001**			**< 0.0001**
▪ 0	reference			reference			reference		
▪ 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**	
Profession[c]			**0.02239**			**< 0.0001**			**< 0.0001**
▪ Housewife	reference			reference			reference		
▪ 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 position	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 = 10 603 twin pregnancies, reference: normal BMI (≥ 18.5 < 25.0 kg/m²), OR = odds ratio, 95% CI = 95% confidence interval, [a] n = 8767, [b] n = 10 552, [c] n = 7471. bold = p < 0.05

p = 0.02), overweight (aOR: 1.61, 95% CI: 1.39–1.86, p < 0.0001) and obesity (aOR: 3.09, 95% CI: 2.62–3.65, p < 0.0001) were all associated with a low GWG (< 25th centile, Q1). As compared to housewives working as employee (aOR: 0.85, 95% CI: 0.73–0.98, p = 0.03) or in an academic or leadership position (aOR: 0.77, 95% CI: 0.64–0.93, p < 0.01) was negatively associated with low GWG (▶ **Fig. 2 b**).

The results of the univariable analysis of risk factors for low or high BMI or GWG are demonstrated in ▶ **Tables 2** and **3**. After controlling for confounders, the results were similar in the multivariable model. However, within the univariable model working as an employee was significantly associated a lower risk for underweight (OR: 0.61, 95% CI: 0.44–0.85, p = 0.0035), overweight (OR: 0.85, 95% CI: 0.75–0.96, p = 0.0105) and obesity (OR: 0.76, 95% CI: 0.66–0.89, p = 0.0004).

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-

▶ 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			**0.0391**			0.7070
▪ German	reference			reference		
▪ Other	1.13 (1.01–1.27)			0.98 (0.87–1.1)		
Single parent[a]			0.3737			**0.0462**
▪ No	reference			reference		
▪ Yes	0.92 (0.77–1.1)			1.18 (1–1.4)		
Parity[b]			**< 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)	**0.0068**	
Profession[c]			**< 0.0001**			**0.0255**
▪ 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, [a] n = 8767, [b] n = 10 552, [c] n = 7471. bold = p < 0.05

quently in women with excessive GWG [22]. While pre-pregnancy BMI was increased in multiparous women, the risk for high GWG was significantly lower in women with a high parity, which had already been observed in singleton pregnancies [23–25]. While the lower frequency of high GWG we observed among multiparous women is in accordance with recommendations for women with a high BMI [26] to prevent pregnancy and birth complications in singleton pregnancies, their effects differ in twin pregnancies: Even though an association between high maternal BMI and adverse maternal pregnancy such as preeclampsia or gestational diabetes was found in twin pregnancies, the relationship is not as strong as in singletons [12]. In addition, one study even stated that low GWG of overweight women with twin pregnancies does not reduce the risk for maternal complications but causes increased rates of preterm birth [27]. This association still needs further research but we can already conclude that multiparous women should be monitored especially close.

A multivariable analysis of almost 7000 singleton pregnancies had found that a low maternal educational level was associated with increased risks of maternal overweight and obesity [25]. Hughes et al. analyzed the relationship between unemployment and BMI among adults in the UK and similarly observed an association between unemployment and obesity among non-smokers [28].

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/m^2 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/m^2 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

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 weakness is that the 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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