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Determinants of gestational weight gain with special respect to maternal stature height and its consequences for newborn vital parameters

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Abstract: An appropriate gestational weight gain is an essential factor of female reproductive success because gestational weight gain influences newborn size but also maternal and infant morbidity and mortality. This paper aims to analyze the impact of maternal somatic factors, first of all maternal stature height, on gestational weight gain. Additionally the effect of gestational weight gain and other maternal somatic factors on newborn size was tested. In the present study the data of 12,661 term birth which have taken place in Vienna, Austria were analyzed. Maternal and newborn somatometric features such as prepregnancy weight status, maternal stature height, birth weight, birth length and head circumference were included. Nearly 65% of the women gained appropriate weight during pregnancy. About 20% showed an excessive, less than 15% an inappropriate gestational weight gain. Gestational weight gain was influenced significantly by prepregnancy weight status, maternal stature height, maternal age, but also nicotine consumption during pregnancy. A significant association between gestational weight gain and newborn somatometrics could be stated. It could be shown that gestational weight gain is influenced by several maternal somatic but also behavioral factors. Newborn size is associated with gestational weight gain.

Key words: pregnancy weight gain, stature height, newborn somatometrics, pregnancy outcome

Introduction

Pregnancy is without any doubt a time for weight gain, which is essential for undisturbed fetal growth and development but also for maternal health. Consequently gestational weight gain is a major determinant of reproductive success and an important factor in human reproductive ecology. It is well known that inadequate weight gain as well as excessive weight during pregnancy has a profound negative impact on maternal and newborn health (Crane et al. 2009, Choi et al. 2011, Chung et al. 2013, Drehmer et al. 2013) and may reduce in this way

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female reproductive success dramatically. Inadequate gestational weight gain mainly results in small for gestational age newborns (Johansson et al. 2007, Kiel et al. 2007, Han et al. 2011, Jeric et al. 2013), and consequently with increased newborn morbidity and mortality (Savitz et al. 2011). Excessive gestational weight gain in contrast, has been associated with increased rates of pregnancy complications such as large for gestational age newborns, preeclampsia, gestational diabetes, gestational hypertension, increased rates of caesarean sections, but also long term effects such as increased rates of obesity among mothers and offspring (Rössner 1997, Gunderson & Abrams 2000, Kac et al. 2004, Cedergren 2006, Kabali & Werler 2007, Wrotinak et al. 2008, Chung et al. 2013, Hill et al. 2013). Although nobody denies the importance of an appropriate gestational weight gain for female reproductive success, the appropriate amount of gestational weight gain is still discussed controversial (Ronnberg & Nilson 2010,Zilko et al. 2010, Daemers et al. 2013). While recently published British guidelines does not recommend specific amounts of gestational weight gain (NICE 2010), The Institute of Medicine (IOM) provides strict guidelines for gestational weight gain which are based on optimizing short- and longterm maternal and child health outcomes (IOM 1990, Rasmussen & Yaktine 2009). These IOM recommendations have as their goal achieving an optimal newborn weight of between 3000 and 4000 grams, the birth weights in the United States associated with the lowest risk of mortality (Olson (2008). The new IOM guidelines published in 2009 considered not only the welfare of the infant but also the health of the mother. The recommendations for appropriate gestational weight gain are based on maternal prepregnancy weight status and include a specific narrow range of recommended gain for obese women (Rasmussen & Yaktine 2009). The optimal gestational weight gain for normal weight and overweight women was defined between 7 and 16 kg, while 12.5 to 18kg was recommend for low weight mothers. Obese mothers should no gain more than 9 kg during pregnancy (Rasmussen & Yaktine 2009). But which factors predict gestational weight gain? The total amount of gestational weight gain during pregnancy is determined by many different sociodemographic, genetic, physiological, endocrinological but also somatic factors, such as maternal stature height (Caulfield et al. 1996, Olson & Strawderman 2003, Brawarsky et al. 2005, Voigt et al. 2007, Straube et al. 2008, Abeysena & Jayawardana 2010, Adegboye et al. 2010). From a bioanthropological view point the impact of maternal somatic factors such as stature height and prepregnancy weight status are of special importance. While the problem of maternal prepregnancy obesity on gestational weight gain and consequently on pregnancy outcome was considered in numerous studies (Rössner 1997, Bianco et al. 1998, Cedergren 2006, Aliyu et al 2010, Rasmussen et al. 2010, Savitz et al. 2011, Kominiarek et al 2013) only few studies considered the impact of maternal height on gestational weight gain (Voigt et al 2007, Straube et al. 2008). The aim of the present paper was the analysis of the impact of maternal somatic factors, first of all maternal stature height, on gestational weight gain. Additionally the effect of gestational weight gain and other maternal somatic factors on newborn size was tested.

Materials and methods

Data set

In the present study included data of 12661 births which took place at the University Clinic for Gynaecology and Obstetrics in Vienna over a several year period (2000 to 2005). Strict inclusion and exclusion criteria were defined.

Inclusion criteria:

1. Births between the 38th and 41th week of gestation, because only term births should be included in analyses to make maternal pregnancy weight gain and newborn anthropometric data more comparable.
2. Only primiparae women ageing between 18 and 45 years were enrolled in the present study whose first prenatal check took place during the eighth week of gestation.
3. All prenatal check-ups of the mother-child passport were completed.
4. Delivery of a single infant without congenital malformations
5. No registered maternal diseases before and during pregnancy i.e. no hypertension (BP<150/90 mmHg), no protein or glucose in the urine, no pregnancy related immunization.

Exclusion criteria:

1. Teenage pregnancy i.e. maternal age below twenty years.
2. Coincident medical diseases such as diabetes mellitus or nephropathy.
3. Drug or alcohol abuse.
4. Twin birth or IVF.

Therefore only 12,661 births from 17,622 were included in the final analyses. Gestational age was calculated in terms of the number of weeks from the beginning of the last menstrual bleeding to the date of delivery (= duration of amenorrhoea) and by two consecutive ultrasound examinations performed before the 12th week of gestation. All subjects originated from Austria or central Europe. Nicotine consumption was recorded by mean of a questionnaire. The study was conducted in compliance with "Ethical principles for medical research involving human subjects" of Helsinki Declaration.

Anthropometric data

The following anthropometric data were determined according to the methods described in Knussmann (1988):

Maternal somatometrics

Stature, prepregnancy weight (PPW), weight at the end of pregnancy (EPW) and weight gain during pregnancy (PWG) were determined according to the methods described in Knussmann (1988). Stature was measured at the first prenatal visit. Prepregnancy weight was estimated by means of the retrospective method and the first weight determination, which was carried out at the first prenatal visit (8th week of gestation). During the first 13 weeks of gestation a weight gain of only 1.7% can be assumed (Gueri et al. 1982). Therefore the combination of retrospective method and weight determination at the 8th week of gestation seemed to be appropriate. In order to determine prepregnancy weight the mean value of the retrospective estimated weight and the weight at the 8th week of gestation was calculated. The weight gain during pregnancy was calculated by subtraction of prepregnancy weight from body weight at the end of pregnancy. Maternal weight status before pregnancy was described by means of the body mass index (BMI) (kg/m^2). Weight

status was classified according to the recommendations of the WHO (1995).
<18.50 = underweight
18.50–24.99 = normal weight
25.00–29.99 = overweight
30.00–39.99 = obese
>40.00 = morbid obese

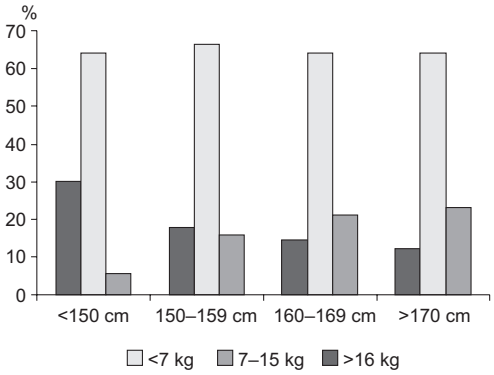
Stature was classified as very short, less than 150 cm, short 150–159 cm, average 160–169 cm and tall 170 cm and more.

Newborn anthropometrics

The following somatometric parameters were taken directly from the newborn, immediately after birth: birth weight, birth length and head circumfer-

Table 1. Sample description

Maternal characteristics (n=12,661)	Mean, SDs	%
Chronological age (years)	26.2 ±5.4	
Stature height (cm)	164.6 ± 6.8	
<150		2.2
150–159		18.8
160–169		53.8
≥170		25.2
Prepregnancy body weight (kg)	62.3 ± 11.9	
End of pregnancy body weight (kg)	76.7 ± 13.3	
Pregnancy weight gain (kg)	12.7 ± 5.1	
≤7		14.7
7–15		64.5
≥16		20.8
Pregnancy BMI (kg/m^2)	22.88 ± 3.89	
≤18.49 (underweight)		7.1
18.50–24.99 (normal weight)		70.1
25.00–29.99 (overweight)		17.2
≥30.00 (obese)		5.7
Nicotine consumption (number of daily smoked cigarettes)	5.1 ± 8.9	
None		68.2
1 to 10		13.6
11 to 20		13.4
>20		4.8
Newborn characteristics (n=12,661)		
Sex		
Male		50.7
Female		49.3
Birth weight (g)	3418.8 ± 453.8	
<2500		1.6
2500–4000		87.9
>4000		10.5
Birth lenght	50.7 ± 2.5	
Head circumferences	34.6 ± 1.5	



ence. A low birth weight was defined as <2500 g, a high birth weight (macrosomia) as >4000 g.

Statistical analyses

Statistical calculations were performed by using SPSS for Windows Program Version 18.0 (Microsoft corp.). Data of all 12661 births were included in all statistical analyses. After calculation of Kolmogoroff-Smirnov tests, descriptive statistics (means, SDs), the χ^2-test and the Duncan-test were used to analyze group differences with respect to their statistical significance. Pearson correlations have been carried out to determine the relationship between maternal stature height, body weight as well as prepregnancy body mass index and gestational weight gain. Additionally Pearson correlations between maternal and newborn somatometric characteristics have been performed. To test whether the relationship between gestational weight gain and stature height is independent of age and prepregnancy weight status (BMI) and nicotine consumption, multiple regression analyses were developed with gestational weight gain as dependent variable. The impact of maternal somatometric parameters as well as nicotine consumption on newborn somatometrics was evaluated by means of multiple regression analyses. A probability P value of less than 0.05 was considered significant.

Results

Sample description

A detailed description of maternal and newborn characteristics is presented in table 1. The majority of mothers (70.1%) were normal weight before pregnancy. 17.2% were classified as overweight and 5.7% of the mothers corresponded to the definitions of obesity. Only 2.2% were short statured indicated by a stature height below 150 cm. The body height of more than 50% of the mothers was between 160 and 169 cm. 25.2% of the mothers were classified as tall, indicated by a stature height above 170 cm. Among nearly 65% of the mothers a pregnancy weight between 7 and 15 kg could be observed. Less than 15% gained less weight during pregnancy, about 20% of the women exhibited a pregnancy weight gain above 15 kg. The majority of mothers (68.2%) were none smokers during pregnancy. 4.8% of the mothers however, reported the consumption of more than 20 cigarettes per day, even during pregnancy. Regarding newborn characteristics it turned out that nearly 90% of the newborns were normal weight at the time of birth, while only less than 2% were classified as low weight (<2500 g). 10.5% of the newborns corresponded to the definitions of marcosomia (>4000 g).

Factors associated with gestational weight gain

Pregnancy weight gain was associated with various maternal parameters, first

of all age, stature height and prepregnancy weight status. While maternal stature height as well as cigarette consumption correlated significantly positively with gestational weight gain, a significantly negative correlation could be observed between gestational weight gain and prepregnancy weight status (see Table 2). Women experiencing the highest pregnancy weight gain (above 15 kg) were significantly younger and taller, but lighter than women experiencing a moderate

Table 2. Gestational weight gain and maternal as well as newborn parameters. Pearson correlations

	Maternal age	Stature height	Prepregnancy body weight	Prepregnancy BMI	Nicotine consumption	Birth weight	Stature length	Head circumference
Pregnancy weight gain	–0.09***	0.09***	–0.11***	–0.17***	0.08***	0.18***	0.08***	0.09***
Maternal age		0.08***	0.21***	0.19***	–0.13***	0.11***	0.19***	0.14***
Stature height			0.45***	0.02	–0.02**	0.25***	0.35***	0.23***
Prepregnancy body weight				0.89***	–0.09***	0.29***	0.36***	0.27***
Prepregnancy BMI					–0.08***	0.21***	0.23***	0.19***
Nicotine consumption						–0.15***	–0.23***	–0.15***
Birth weight							0.72***	0.66***
Birth length								0.58***

Table 3. Pregnancy weight gain and maternal characteristics

	<7 kg	7–15 kg	≥16 kg	*p*-value
	x (SD) n=1,861	x (SD) n=8,166	x (SD) n=2,634	
Maternal characteristics				
Maternal age (years)	27.1 ± 5.5	26.9 ± 5.2	25.9 ± 5.1	0.0001
Stature height (cm)	164.5 ± 6.9	165.7 ± 6.9	166.6 ± 6.5	0.0001
Prepregnancy BMI (kg/m^2)	25.39 ± 5.25	22.96 ± 3.87	22.83 ± 3.61	0.0001
Cigarettes per day	3.7 ± 7.6	3.7 ± 7.7	5.4 ± 9.1	0.0001
Newborn characteristics				
Birth weight (g)	3329.1 ± 465.2	3449.5 ± 458.2	3583.1 ± 458.9	0.0001
Birth length (cm)	50.8 ± 2.8	51.3 ± 2.7	51.5 ± 2.6	0.0001
Head circumference (cm)	34.6 ± 1.5	34.8 ± 1.5	35.1 ± 1.4	0.0001

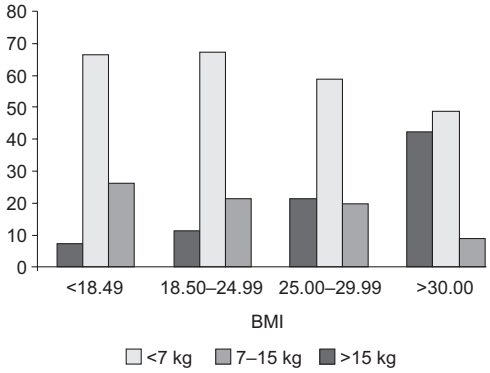


Fig. 2. Pregnancy weight gain according to pregnancy BMI

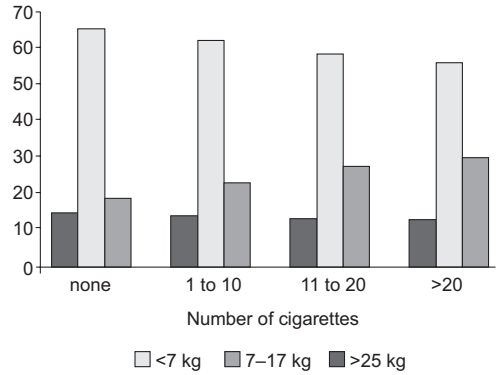


Fig. 3. Pregnancy weight gain according to daily nicotine consumption

or low weight gain during pregnancy (see Table 3). In detail, as demonstrated in figure 1 that the percentage of women experiencing a high pregnancy weight gain, i.e. above 15 kg increased significantly with increasing stature. While less than 6% of short statured women (<150 cm) gained more than 15kg during pregnancy this was true of more the 23% of tall women (>170 cm). Concerning the association between prepregnancy weight status and gestational weight gain it turned out that with increasing prepregnancy BMI, gestational weight gain decreased dramatically (see Fig. 2). While more than 25% of low weight mothers experienced a gestational weight gain of more than 15 kg, this was only true of about 8% of obese mothers (see Fig. 2). Regarding the association between nicotine consumption and pregnancy weight gain it could be shown that smokers and especially heavy smokers showed a significantly higher pregnancy weight gain than non smokers (see Fig. 3).

These findings were corroborated by the results of the multiple regression analyses. Pregnancy weight gain was significantly positively related with stature height and cigarettes per day, but significantly negatively related with maternal age and prepregnancy BMI (see Table 4).

Table 4. Impact of maternal parameters on pregnancy weight gain. Multiple Regression analyses

	Multiple R	Regression coefficient B	Significance	95% confidence interval
		Dependent variable: Pregnancy weight gain (n=12,661)		
Constant	0.22	4.54	<0.002	1.74–7.34
Age		–0.06	<0.000	–0.08– –0.04
Stature height		0.09	<0.000	0.07–0.11
BMI		–0.21	<0.000	–0.23– –0.17
Cigarettes per day		0.05	<0.000	0.03–0.06

Gestational weight gain and newborn somatic parameters

Birth weight, birth length and newborn head circumference were statistically significantly related to various maternal parameters. Positive associations were found between newborn somatic parameters and maternal age, maternal stature height, prepregnancy weight status and gestational weight gain (see Table 2). Nicotine consumption was significantly negatively related with birth weight, birth length and newborn head circumference (see Table 5). Interestingly maternal factors explained birth length to a higher degree (51%) than birth weight (42%). The impact of maternal parameters was lowest on head circumference (38%). Consequently maternal factors has a higher impact on linear growth than on intrauterine weight gain. As to be seen in figure 4 with increasing gestational weight gain the amount of low

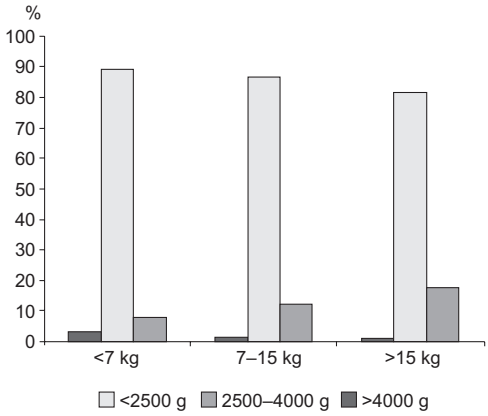


Fig. 4. Gestational weight gain and newborn weight status

Table 5. Impact of maternal characteristics on newborn somatometrics. Multiple Regression analyses

	Multiple R	Regression coefficient B	Significance	95% confidence interval
Dependent variable: birth weight (n=12,661)				
Constant	0.42	5.28	NS	–231.04–241.60
Maternal age		6.42	<0.0001	4.52–8.29
Maternal stature height		15.05	<0.0001	13.65–16.46
Pregnancy weight gain		19.26	<0.0001	17.36–21.16
Pregnancy BMI		24.75	<0.0001	22.37–27.12
Nicotine consumption		-7.96	<0.0001	-9.17– –6.75
Dependent variable: birth length (n=12,661)				
Constant	0.51	25.01	<0.0001	23.71–26.31
Maternal age		0.07	<0.0001	0.06–0.08
Maternal stature height		0.13	<0.0001	0.12–0.13
Pregnancy weight gain		0.06	<0.0001	0.05–0.07
Pregnancy BMI		0.13	<0.0001	0.12–0.14
Nicotine consumption		–0.07	<0.0001	–0.08– –0.06
Dependent variable: head circumferences (n=12,661)				
Constant	0.38	24.49	<0.0001	23.72–25.28
Maternal age		0.03	<0.0001	0.02–0.03
Maternal stature height		0.05	<0.0001	0.04–0.05
Pregnancy weight gain		0.04	<0.0001	0.03–0.04
Pregnancy BMI		0.07	<0.0001	0.06–0.08
Nicotine consumption		–0.03	<0.0001	–0.03– –0.02

weight newborns decreased, while the amount of macrosome newborns increased significantly ($p<0.0001$).

Discussion

Gestational weight gain is a major determinant of the individual reproductive success of human females. Inappropriate weight gain (below 7 kg) but also excessive weight gain of more than 15 kg may result in increased maternal and infant morbidity and mortality (Chung et al. 2013, Drehmer et al. 2013). Therefore strict recommendations for appropriate gestational weight gain have been developed (IOM 1990, Rasmussen & Yaktine 2009), although these recommendations are still discussed controversial (Zilko et al. 2010, Daemers et al. 2013). Some authors reported that gestational weight gain of the majority of women does not correspond to the recommendations of the Institute of Medicine. Daemers et al (2013) reported that 60% of their study population did not meet the IOM recommendations. According to Brawarsky et al. (2005) 14% of their sample corresponded to the definitions of inadequate weight gain and 53% of the women experienced an excessive weight gain of more than 16 kg. These findings could not be confirmed by results of the present study. While about 14% of the mothers experienced an inadequate weight gain, an excessive weight of more than 16 kg could be found among 20% of the mothers only. Two third of the women exhibited an appropriate weight gain during pregnancy. This may be mainly to the fact that only about 7% of our study population corresponded to the WHO definitions of underweight and only 5.7% of our study population was classified as obsess according to WHO definitions. Nevertheless underweight women defined by a prepregnancy body mass index below 18.50 kg/m^2 showed the highest amount of high gestational weight gain, while obese women, defined by a prepregnancy body mass index above 30.00 kg/m^2 exhibited the lowest amount of high gestational weight gain. These associations high prepregnancy weight status – low gestational weight gain and low prepregnancy weight gain – high gestational weight gain correspond to the recommendation of the Institute of Medicine. The association high gestational weight gain with low prepregnancy weight status was observed by Laraia et al. (2013) too and explained as a reaction of food insecurity with past experience of restrained eating to insure reproductive success. The aim of the present paper however was not only the evaluation of gestational weight gain recommendations, but also the analysis of maternal somatic factors influencing gestational weight gain. In the present study a highly significantly association between prepregnancy weight status and gestational weight gain could be documented. The higher the prepregnancy weight status, the lower was the gestational weight gain. These findings corresponded not only to the recommendations of the Institute of Medicine (IOM 1990, Rasmussen & Yaktine 2009) but also to the results of previous studies (Brawarsky et al. 2005,Voigt et al. 2007a, b, 2008, Straube et al. 2008) but also to the recommendations of IOM (1990 and 2009). Furthermore the present study could confirm the independent impact of maternal stature on gestational weight gain. This associations was previously described by only few authors (Voigt et al. 2007a, b, Straube et al. 2008). The taller the woman the higher the gestational weight gain. In contrast the higher

the prepregnancy weight status the lower the gestational weight gain. An increased gestational weight gain was also observed among smokers. Although the majority of women enrolled in the present study were non smokers more than 30% continued smoking during pregnancy. About 5% reported to smoke more than 20 cigarettes per day. Among these heavy smokers more than 30% gained excessive weight during pregnancy. This may be due to a general low health conscious behavior.

The second part of the present study analyzed the impact of gestational weight gain on pregnancy outcome in particular newborn size. Nearly 90% of the newborns corresponded to the definitions of normal birth weight between 2500 and 4000 g. The majority achieved a birth weight between 3000 and 4000 grams, the birth weight associated with the lowest risk of mortality in Industrialized countries (Olson 2008). Macrosmomia i.e. a birth weight above 4000 grams was most frequently found among women showing excessive weight gain. In general new born size increased with increasing gestational weight gain independent of maternal age, prepregnancy weight status and maternal stature. This finding corresponded to results of various other studies, which demonstrated a significant relationship between gestational weight gain and newborn size. Low gestational weight gain was strongly associated with small for gestational age infants and preterm birth (Han et al. 2011, Chung et al. 2013). Maternal stature height was independently positively associated with newborn size. This result is in accordance with the observation of Pickett et al. (2000) who reported that increasing maternal stature height was associated with increasing newborn weight.

From the results of the present study we can conclude that gestational weight gain is influenced by several maternal somatic factors. Taller mothers experienced a significantly higher weight gain during pregnancy than shorter women. Prepregnancy weight status however is negatively associated with pregnancy weight gain. Concerning the impact of maternal somatic parameters it turned out the length growth was influenced by a higher degree than intrauterine weight gain. The definition of cut points of ideal gestational weight gain is difficult, the results of the present study however support the cut points recommended by IOM.

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Author contribution

SK – concept, study protocol, data analysis, interpretation of results; BH – study protocol, data collection, interpretation of results

Conflict of interest

The Authors declare there is no conflict of interests.

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