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Review article

Weight gain and dietary intake during pregnancy in industrialized countries – a systematic review of observational studies

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Abstract

Background: Gestational weight gain (GWG) above the recently recommended ranges is likely to be related to adverse pregnancy outcomes and therefore a challenge in industrialized countries.

Aims: We conducted a systematic review on observational studies in order to gain more evidence on whether diets with lower caloric/protein content or other diets might be associated with lower GWG.

Methods: We searched in MEDLINE and EMBASE for observational studies written in English or German reporting associations between diet and GWG in singleton pregnancies of healthy women in industrialized countries.

Results: We identified 12 studies which met the inclusion criteria. Five studies suggested significant positive associations between energy intake and GWG, whereas three found no significant association. Further significant positive associations of GWG were reported with respect to protein intake, animal lipids, energy density and a number of different food servings per day, whereas intake of carbohydrates and vegetarian diet were associated with less GWG.

Conclusions: We suggest that GWG might be reduced by lower energy intake in pregnancy.

Keywords: Energy intake; gestational weight gain; nutrition; pregnancy.

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Introduction

Gestational weight gain (GWG) results from complex physiological interactions between growth and development of the fetus and changes in maternal physiology and metabolism as well as in placental metabolism [19: 3-1]. Recently, the Institute of Medicine (IOM) published recommendations for GWG, which depend on maternal pre-pregnancy body mass index (BMI) [19: S2]. Gaining more weight than the recommended ranges (frequently called ''excessive'' GWG) may cause adverse short- and long-term pregnancy outcomes, such as maternal and offspring obesity, gestational diabetes mellitus, pregnancy-related hypertension, complications through labor and delivery and macrosomia [6, 10, 14, 15, 17, 19: 5-1, 6-7, 20, 25, 26, 28, 30–32, 48, 49]. Therefore, GWG is of interest as a potentially modifiable prenatal risk factor. GWG, however, is determined by a number of factors which cannot be modified, such as maternal age, height, parity, duration of gestation or gender of the baby [19 (4), 47]. Interventions to modify pre-pregnancy BMI might be most promising but may be difficult because a large proportion of pregnancies are unplanned (in Germany, e.g., half of them [21]). General population interventions in young women have to be balanced against risks for eating disorders which are common in this age group [27, 41, 46]. A focus on potential dietary modifications has the advantage of better targeting.

GWG has increased in the last years in industrialized countries [4, 19: 2-1 to 2-3, 38] and it is a challenge to limit this trend. A number of interventional studies assessing the effects of energy or protein intake on perinatal outcomes including GWG has been summarized in a systematic review updated in 2009 [22].

The review concluded that GWG was significantly decreased by energy/protein restriction [22] based on only two studies [8, 9] comprising 253 women in total. The quality of both studies was poor due to inadequate allocation concealment, however. Furthermore, the studies were conducted in 1975 [9] and 1983 [8] and included only primiparous women from Scotland with either high GWG [9] or obesity [8], limiting the external validity of these findings.

Since the number of interventional studies addressing diet and GWG in the general population is limited [16], we performed a systematic review to assess whether observational studies reporting associations between maternal diet and GWG allow for further insight. We were specifically interested in whether diets with lower caloric/protein content or other diets might be associated with lower GWG.

Material and methods

The databases MEDLINE (1950–2009) and EMBASE (1974–2009) were used to identify relevant articles on dietary determinants of GWG in healthy women. The systematic computerized literature search of published studies was carried out in November 2009 using the following search terms: (''weight gain pregnancy'' OR ''maternal weight gain'' OR ''gestational weight gain'') AND (''nutrition'' OR ''diet'' OR ''energy intake'' OR ''protein intake'' OR ''dietary protein'' OR ''nutrition physiology''). After the search of the databases was finished, we searched manually the already identified articles and in the IOM guidelines [18, 19: S2] for further relevant articles.

We included only observational studies meeting the following criteria: written in English or German, dealing with healthy women having singleton pregnancies, published in population-based or hospital-based cohort studies in industrialized countries, without repeated pregnancies.

Not all studies explicitly mentioned whether they comprised only healthy women with singleton pregnancies; for example, only one study mentioned exclusion of women with gestational diabetes [23]. However, we assumed this if there was no indication (e.g., by adjustment) that women with severe diseases or multiple pregnancies were analyzed. We did not include studies which reported assessment of nutritional intake and GWG, but did not quantify associations between both.

Results

The literature search revealed n = 1917 results. From these, 1722 studies were excluded because their study topic was different from our research question: most of the studies were excluded because either dietary intake or GWG was not recorded. One study [3] analyzed repeated pregnancies in the same mothers, i.e., 95 pregnancies in 54 women. As shown in Figure 1, 11 observational studies [1, 2, 5, 12, 23, 24, 33, 35, 40, 42, 43, 45] on the impact of dietary intake on GWG of healthy singleton pregnant women were finally identified as eligible for the systematic review. We detected one additional article [42] by a hand search.

Table 1 summarizes the setting of the 12 selected studies. Nine studies were performed in the USA and three in Europe. The sample sizes varied widely (50–2087 pregnant women). Two studies followed exclusively low-income pregnant teenagers [40, 43], whereas the other studies focused predominantly on adult pregnant women. Also, other inclusion and exclusion criteria of study participants, such as gestational age at entry or parity, varied considerably.

To assess nutritional intake, different dietary assessment measures were used (Table 2). Four studies assessed dietary habits by semi-quantitative food frequency questionnaires (FFQ), also asking for information on portion size [12, 23, 33, 45], two used food records [5, 24], and five relied on recall methods [1, 2, 35, 40, 42]. One study used dietary records and recall methods [43]. Nutritional intake was assessed at least once or repeatedly at different points in time and assessed food intake over time periods of different length. Two studies, for example, assessed dietary habits during the last three months by an FFQ, implemented around the end of the second trimester [12] or in the first and in the third trimester [33]. With these instruments different nutritional aspects were considered. Some studies assessed intake of specific nutrients, e.g., protein, fat and carbohydrates or the intake of individual foods or food groups [23, 33, 40, 43]. Except for two studies [1, 42], food consumption was directly converted into some measure of energy intake. The study of Aaronson and Macnee [1] used a nutrition score to evaluate nutritional intake, in the study of Sloan et al. protein intake was recorded, which showed a significant correlation ($r = 0.81$, $P < 0.001$) with caloric intake [42].

GWG was defined in different ways in the studies examined. The majority of studies [1, 2, 12, 24, 35, 43, 45] defined GWG as the difference between the maternal weight at her last visit to the prenatal care centre and (mostly self-

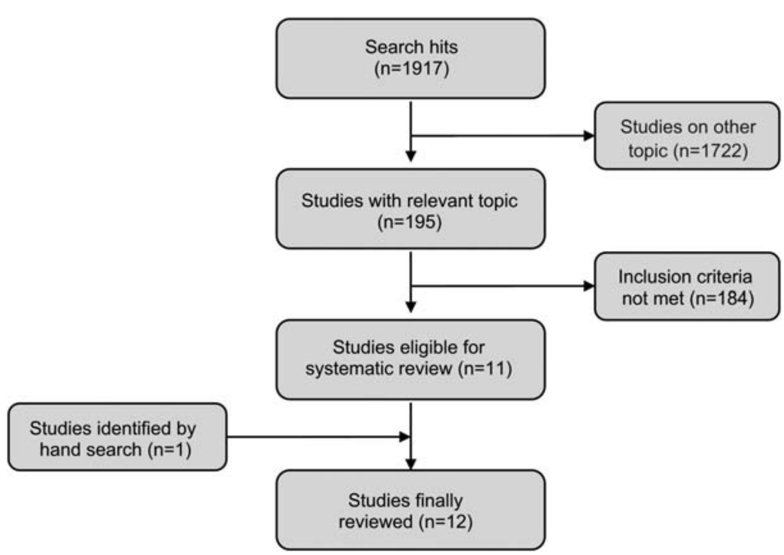

Figure 1 Identification and evaluation of the studies for the systematic review.

Table 1 Characteristics of the studies that met the inclusion criteria for the systematic review.

Study	Country, time	n[a]	Maternal age (years)	Inclusion criteria[b]	Exclusion criteria
Ancri et al., 1977 [2]	USA 1969	98	12–32	Healthy Multiparous First visit before W20 Caucasian	None reported
Picone et al., 1982 [35]	USA	60	Mean: 23	Healthy Multiparous First visit before W20 Uncomplicated pregnancy Average height and weight-for-height No drug use No college education	Infection or illness (except for common cold for <5 days) Cesarean delivery Labor and delivery medication (other than 100 ml vistaril or demerol)
Langhoff-Roos et al., 1987 [24]	Sweden	50	Not reported	Healthy Second pregnancy Delivery at term	None reported
Aaronson and Macnee 1989 [1]	USA 1982	510	18–41	None reported	None reported
Scholl et al., 1991 [40]	USA	365	≤ 18	Singleton pregnancy Low-income pregnant teenagers ≤ 19 years	Failed to return to the clinic before delivery Pregnancy loss Asian ancestry
Stevens-Simon and McAnarney 1992 [43]	USA	141	12–19	Singleton pregnancy Low-income pregnant teenagers First visit before W22	Chronic diseases (e.g., diabetes, asthma) Stillbirth Children with congenital anomalies
Bergmann et al., 1997 [5]	Germany 1986–1987	156	≤ 21 to ≥ 27	Healthy Singleton pregnancy First visit before W12	Missing data
Sloan et al., 2001 [42]	USA 1983	2087	Mean: 22	Singleton births First visit before W28 Annual income $<18,000$ \$ Delivery before 2nd interview (W32–W37)	Chronic diseases (e.g., heart disease, toxaemia, diabetes) Drug abuse Congenital anomalies Stillbirth Mean protein intake <25 g/day or >150 g/day
Lagiou et al., 2004 [23]	USA 1994–1995	207	18–35	Singleton births Parity ≤ 2 Delivery at W37–W42 Maternal age <40 years Caucasian origin	Preeclampsia Diabetes or thyroid disease Hormonal medication during pregnancy Fetus with a known major anomaly

(Table 1 continued)

Study	Country, time	n[a]	Maternal age (years)	Inclusion criteria[b]	Exclusion criteria
Olafsdottir et al., 2006 [33]	Iceland 1999–2001	406	Mean: 28	Healthy Singleton pregnancy Delivery at term Caucasian	Miscarriage Stillbirth Loss to follow-up or missing variables
Deierlein et al., 2008 [12]	USA 2001–2005	1231	16–47	Singleton pregnancy Maternal age >16 years Entry before W20	Stillbirth Missing or implausible dietary information
Stuebe et al., 2009 [45]	USA 1999–2002	1338	<25 to ≥ 35	Singleton pregnancy Entry before W22 Delivery after W34 Fluent in English	Missing information on diet, GWG or covariates

[a]Number of women included in the final model.
[b]WX: gestational week X.

reported) pre-pregnancy weight. Others assessed GWG in different time frames during pregnancy [23, 33, 40]. Bergmann et al. [5] analyzed their data defining GWG as net GWG, subtracting offspring birth weight and weight of the placenta from weight gain between first and third trimester. No definition of GWG was given in the study of Sloan et al. [42].

Six studies [5, 12, 23, 24, 40, 45] adjusted for confounders, whereas the other six [1, 2, 33, 35, 42, 43] did not. Significantly ($P<0.05$) positive associations between energy intake and GWG were reported in five studies [5, 23, 33, 35, 40], three of them adjusted for confounders, whereas in three others (two adjusted) no significant association was found [24, 43, 45]. All three studies which assessed protein intake reported positive associations with GWG [2, 23, 42] – in two of them (one with adjustment), these associations were significant [2, 23]. Further significant associations of GWG were reported with respect to animal lipids [23], energy density [12], number of different food servings per day [1] – all of them associated with higher GWG; carbohydrates [23] and vegetarian diet [45] – both associated with lower GWG; with all but one [1] of these studies having adjusted for confounders.

Discussion

A systematic review applying a broad search strategy revealed 12 studies addressing the association between dietary intake in pregnancy and GWG. A number of studies – partly adjusted for confounding factors-suggested positive associations between energy/protein intake and GWG.

These findings indicate that restrictions in energy intake during pregnancy might be a potential intervention strategy to avoid GWG above the IOM recommendations. Additionally, a diet with less intake of protein, but higher intake of carbohydrates, e.g., by reducing the amount of meat in the diet appeared to be associated with lower GWG although caution should be made to account for the well-known increased protein requirements in pregnancy [13, 34]. Whereas the increased iron requirement during pregnancy can be met by iron supplementation, careful balancing is needed in order to meet the micronutrients requirements regarding vitamin B12 and possibly iodine and zinc [13]. The most effective intervention, however, might be a combination of a healthy diet and moderate physical activity as suggested by Stuebe et al. [45].

Unfortunately, the studies identified varied considerably with respect to dietary assessment and definition of GWG, so that we were unable to provide a summary effect estimate. We were also unable to assess publication bias, since conventional approaches like funnel plots require comparable measures for the strength of the association [7].

It is likely that the strength of the relationship between nutrition and GWG has been confounded by other factors if no adequate adjustment was performed. For example, in the study of Sloan et al. the amount of protein intake in pregnancy was negatively associated with maternal age, maternal

Table 2 Results of the studies identified in the systematic review. Effects written in bold, if significant ($P<0.05$).

Study	Nutritional assessment	Nutritional aspects	Assessment of GWG	Effects	Adjusted for confounders
Ancri et al., 1977 [2]	24-h recall (3T)	Protein intake	LW – PPW	Correlation between protein intake and GWG in 25–32-year-old women: **r = 0.47**	No
Picone et al., 1982 [35]	24-h recall (2T, 3T)	EI	LW – PPW	Correlation of EI and GWG in non-smokers: **r = 0.44**	No
Langhoff-Roos et al., 1987 [24]	3-day record (2T, 3T)	EI	LW – PPW	EI (MJ/day): β(SE) = –0.30 (0.50)	Yes
Aaronson and Macnee 1989 [1]	48-h recall (date unclear)	Nutrition score (number of different food servings/day)	LW – PPW	Correlation of nutrition score and GWG: β = 0.06	Yes
Scholl et al., 1991 [40]	24-h recall (2T)	EI (reported in kcal; 1000 kcal = 4.184 MJ)	W(36) – PPW	Inadequate GWG: **mean EI = 7.86 MJ/day** Adequate GWG: **mean EI = 9.34 MJ/day**	Yes
Stevens-Simon and McAnarney 1992 [43]	Interview, dietary records, 24-h recall, FFQ (dates unclear)	EI	LW – PPW	Correlation of EI and GWG: r = 0.09	No
Bergmann et al., 1997 [5]	Weighed 7 d food record (1T, 2T, 3T)	EI: < 2000 kcal/day (low), 2000–2400 kcal/day (medium), > 2400 kcal/day (high)	W(3T) – W(1T) – BW – PW	**Low EI: mean net GWG = 4.6 kg** Medium EI: mean net GWG = 5.9 kg High EI: mean net GWG = 5.7 kg	Yes
Sloan et al., 2001 [42]	24-h recalls (2T, 3T)	Protein intake < 50 g/day (low), 50–84.9 g/day (medium), ≥ 85 g/day (high)	Not reported	Low protein intake: mean GWG (SD) = 10.27 (5.51) kg Medium protein intake: mean GWG (SD) = 10.95 (5.00) kg High protein intake: mean GWG (SD) = 10.96 (5.06) kg	No
Lagiou et al., 2004 [23]	Semiquantitative FFQ (2T)	EI, animal lipids, vegetable lipids, carbohydrates, protein	W(27) – PPW	EI (MJ/day): **β(SE) = 0.27 (0.10)** Animal lipids (g/day): **β(SE) = 0.13 (0.02)** Vegetable lipids (g/day): β(SE) = 0.08 (0.04) Carbohydrates (g/day): **β(SE) = –0.04 (0.01)** Protein (g/day): **β(SE) = 0.08 (0.02)**	Yes
Olafsdottir et al., 2006 [33]	Semiquantitative FFQ (1T, 3T)	EI	LW – W (11–15)	Normal-weight women: ''no significant difference'' **Overweight women:** **Suboptimal GWG: mean EI (SD) = 6.74 (2.28) MJ** **Optimal GWG: mean EI (SD) = 7.74 (2.61) MJ** **Excessive GWG: mean EI (SD) = 9.14 (4.32) MJ**	No
Deierlein et al., 2008 [12]	Self-administered FFQ (3T)	Quartiles of energy density: Q1 (0.43–0.80 kcal/g), Q2 (0.80–0.92 kcal/g), Q3 (0.92–1.05 kcal/g), Q4 (1.05–1.92 kcal/g)	LW – PPW	Q1: Reference Q2: β(SE) = 0.49 (0.44) Q3: **β(SE) = 1.13 (0.39)** Q4: **β(SE) = 1.08 (0.44)**	Yes
Stuebe et al., 2009 [45]	Semiquantitative FFQ (1T, 2T)	EI, dairy food, fried food, first trimester vegetarian diet	LW – PPW	EI (500 kcal/day): OR (95% CI) = 1.10 (1.00, 1.22) Dairy food (serving/day): OR (95% CI) = 1.08 (1.00, 1.17) Fried food (serving/day): OR (95% CI) = 3.47 (0.91, 13.24) Vegetarian diet: **OR (95% CI) = 0.46 (0.28, 0.78)**	Yes

1T/2T/3T = first/second/third trimester, β = regression coefficient, BW = birth weight (offspring), CI = confidence interval, EI = energy intake, +GWG = positive effect on GWG, –GWG = negative effect on GWG, LW = last measured weight before pregnancy, OR = odds ratio for excessive GWG according to IOM guidelines, PPW = weight before pregnancy (self-reported, if not stated otherwise), PW = placental weight, SE = standard error, W (XT) = measured weight in X trimester, W (XX) = measured weight at week XX of gestation.

BMI and smoking status, but positively with GWG [42]. Maternal age is an important confounding factor. The significance of maternal growth of adolescents during pregnancy and its implications for GWG are still controversial [39, 44]. Additionally, given the trend towards delayed childbearing age, one should focus on GWG of pregnant women older than 35 years. Older women showed significantly lower mean GWG than younger women [36]. Pre-pregnancy BMI is known to be an important effect modifier of GWG: total GWG has been reported to be lower on average in women with high BMI [11, 28]. However, since maternal BMI also has an impact on various short- and long-term outcomes, such as preeclampsia or offspring overweight, it seems necessary to perform analyses with stratification for maternal BMI [6, 10, 28, 30]. There is also evidence that cigarette smoking is inversely associated with GWG [37]. Parity is also known to have a significant impact on GWG [6, 29]. Bergmann et al. [5] showed that multigravid women with high BMI gained less weight than primigravid women with a high BMI, whereas primigravid women with a high BMI gained much more weight than primi- and multigravid women with medium or low BMI.

Although the data identified in our systematic review of observational studies do not allow quantifying the potential effect of modifications of maternal diet in pregnancy on GWG, it appears to suggest that reducing energy intake might contribute to reducing GWG above the recommendations.

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