Does Dietitian Involvement During Pregnancy Improve Birth Outcomes? A Systematic Review

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ABSTRACT

Maternal diet during pregnancy can have a significant impact on maternal and offspring health. As nutrition counselling is an important component of prenatal care, registered dietitians (RDs) are uniquely trained professionals who can provide personalized nutrition counselling customized to an individual's sociocultural needs. The objective of this systematic review was to determine if RD involvement during pregnancy is associated with a lower prevalence of adverse birth outcomes in the United States and Canada. The review was conducted through a search of four databases: PubMed, CINAHL, Embase, and Web of Science. A total of 14 studies were identified. Women had a lower prevalence of low birth weight and preterm infants when RDs were involved during prenatal care. While RD involvement during pregnancy was not associated with macrosomia, more research is needed to assess its relationship with small for gestational age, large for gestational age, and infant mortality. Future research should also investigate the specific dietary advice provided by RDs and the extent and timing of their involvement throughout pregnancy to better understand the mechanisms surrounding nutrition counselling, in utero development, and health outcomes.

Key words: dietitian, pregnancy, low birth weight, premature birth, stillbirth, infant, fetal macrosomia, dietician, nutrition.

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RÉSUMÉ

L'alimentation de la mère pendant la grossesse peut avoir un impact important sur la santé de la mère et de l'enfant. Le counseling nutritionnel étant une composante importante des soins prénatals, les diététistes (RD), des professionnels possédant une formation unique, peuvent fournir des conseils nutritionnels personnalisés et adaptés aux besoins socioculturels de la personne. L'objectif de cette revue systématique était de déterminer si l'implication des RD pendant la grossesse est associée à une prévalence plus faible d'issues défavorables de la grossesse aux États-Unis et au Canada. La revue a été réalisée au moyen de recherches dans quatre bases de données : PubMed, CINAHL, Embase et Web of Science. Au total, 14 études canadiennes ont été ciblées. La prévalence de faible poids à la naissance et de prématurité était plus faible lorsque des RD s'étaient impliquées dans les soins prénatals. Bien que l'implication des RD pendant la grossesse n'ait pas été associée à la macrosomie, des recherches supplémentaires sont nécessaires pour évaluer sa relation avec un bébé petit par rapport à l'âge gestationnel, un bébé gros par rapport à l'âge gestationnel et la mortalité infantile. Les recherches futures devraient également porter sur les conseils nutritionnels fournis par les RD et sur l'étendue et le moment de leur implication pendant la grossesse afin de mieux comprendre les mécanismes entourant le counseling nutritionnel, le développement in utero et les résultats en matière de santé.

Mots-clés : diététiste, grossesse, faible poids à la naissance, naissance prématurée, mortinatalité, nourrisson, macrosomie fœtale, nutritionniste, nutrition.

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INTRODUCTION

Maternal diet during pregnancy can have a significant impact on maternal and offspring health [1]. While pregnancy outcomes can be affected by environmental, demographic, medical, behavioural, and socioeconomic factors [2], the importance of adequate weight gain, balanced meals, vitamin and mineral supplementation, alcohol and drug avoidance, and food safety cannot be overemphasized, as they are key factors associated with healthy pregnancies. As nutrition counselling is an important component of prenatal care, registered dietitians (RDs) are uniquely trained professionals who can provide nutrition counselling customized to an individual's sociocultural needs.

In 2009, the Institute of Medicine (IOM) modified its 1990 guidelines for gestational weight gain, which considers prepregnancy body mass index (BMI) as an important predictor of birth weight [3]. Gestational weight gain below the recommended range for prepregnancy BMI increases the likelihood of having a low birth weight infant, whereas excessive gestational weight gain is associated with a higher risk for fetal macrosomia [4, 5]. Although RDs are not required members of prenatal health care teams in Canada and the United States, and studies supporting RDs' roles have not been comprehensively evaluated [6], referrals to RDs are common for high-risk pregnancies, whereas resources remain limited for low-risk pregnancies [7]. Yet, randomized controlled trials (RCTs) have shown that RD involvement during pregnancy is associated with improved dietary intake and adherence to gestational weight guidelines for both low-risk and high-risk pregnancies [8–11].

Given that prenatal diets are a modifiable risk factor for gestational weight gain and adverse birth outcomes, dietetic counselling may correlate with more optimal birth outcomes. However, existing studies on the association between RD involvement and birth outcomes have been inconsistent, with some studies showing positive effects and others having null findings. Vesco et al. found that an intensive dietary intervention initiated by RDs is associated with a lower prevalence of large-for-gestational-age infants (9%) compared to groups receiving only one-time dietary advice (26%) [12]. Crowther et al. found a significantly lower incidence of large for gestational age (13%) and macrosomia (10%) as a result of RD involvement compared to a control group (22% and 21%) [13]. Other studies have found no effect of RD involvement during pregnancy on infant outcomes [14, 15]. Low birth weight (LBW), preterm birth (PTB), small for gestational age (SGA), and mortality are the most common outcomes evaluated in the literature, and there have been recommendations for more research on large for gestational age (LGA) and macrosomia [16].

The objective of this systematic review was to determine if RD involvement during pregnancy is associated with a lower prevalence of LBW, PTB, SGA, LGA, macrosomia, and infant mortality. This is the first systematic review to assess these relationships.

METHODS

This systematic review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [17]. A protocol was registered with The Open Science Framework (https://osf.io/k5nup) on February 16 2022. The PICOS framework guided the search strategy: Population (pregnant individuals); Intervention/Exposure (direct involvement by an RD or as part of a multidisciplinary team during pregnancy); Comparator (no RD involvement during pregnancy or standard care by an RD); Outcomes (LBW, SGA, LGA, macrosomia, PTB, infant mortality); Study Design (observational and experimental studies). Using a narrative analysis, the association between RD involvement during pregnancy and birth outcomes was assessed, summarized, and synthesized for all eligible studies.

Search strategy

Comprehensive literature searches of PubMed (1966–2021), CINAHL (1937–2021), Embase (1947–2021), and Web of Science (1970–2021) were conducted independently on December 18 2021 by two authors (WL and MH). A search strategy was developed using the key search terms in Supplementary File A[1]. Search string, MeSH terms, and subject headings were then created for each database. The search strategy was developed by the authors and a health sciences librarian at Brescia University College. Search results from the four databases were imported into Covidence (Covidence systematic review software, Veritas Health Innovation, Melbourne, Australia. 2022), and duplicates were removed. Covidence was used to screen titles, abstracts, and full texts. Reference lists of retrieved articles were assessed to identify additional studies not obtained in the original search.

Study eligibility criteria

Studies needed to be original research, written in English, conducted in Canada and (or) the United States, and include pregnant individuals. The search was limited to the two countries to ensure consistency in the legal practice of RDs. Each study should have observed at least one of the six birth outcomes: LBW (<2500g), SGA (birth weight <10th percentile for gestational age or infants smaller in size than normal for their gestational age) [18, 19], LGA (a birth weight >90th percentile) [20], macrosomia (birth weight >4000g) [21], PTB (<37 weeks' gestation), and infant mortality (death of the fetus or infant death following a live birth; i.e., stillbirth, neonatal death, and perinatal death). Eligible studies must have had direct involvement from an RD or those with equivalent legal titles (Supplementary File B[1]). Direct involvement was defined as nutrition practice (i.e., nutrition interventions, dietary changes/plan, nutrition counselling, or medical nutrition therapy) by an RD alone or as a part of a multidisciplinary team. Reviews, editorials, letters, and grey literature were excluded. There were no restrictions on study design or publication dates.

Title, abstract, and full-text screening were conducted independently by two authors (WL and MH), with conflicts resolved by consensus or adjudication with the senior author (JAS).

Data extraction

A standardized coding guide was developed using Microsoft Excel (Microsoft Corporation, Redmond, Washington, USA, 2019). Information included were publication year, author name(s), objectives, sample characteristics (e.g., health status, maternal age, race/ethnicity, socioeconomic status), geographic location, sample size, study design, types of RD involvement, key findings, and study limitations. Two authors (WL and MH) independently extracted data and collectively resolved discrepancies. The senior author (JAS) adjudicated any unresolved discrepancies.

Study quality assessment

The methodological quality of studies was assessed by two independent authors (WL and MH) using the JBI critical appraisal tool [22, 23]. This tool determined the risk of bias through a customized checklist created for each study. A specific JBI checklist was used for cross-sectional studies, case-control studies, cohort

[1]Supplementary data are available with the article at https://dcjournal.ca/doi/suppl/10.3148/cjdpr-2023-014.

studies, and RCTs [22, 23]. The checklist consisted of four possible answers: "yes," "no," "unclear," and "not applicable." Answers that were "not applicable" were excluded from the final count towards determining the overall quality rating of each paper. The quality rating of each study was determined using a three-range scale (≥ 80% "yes" is good; 60-79% "yes" is fair; ≤ 59% "yes" is poor). The three-range scale and its ratings closely align with other studies using the JBI [24, 25]. Checklist questions and a summary of the assessment can be found in Supplementary Tables 1–4[1].

RESULTS

Description of studies

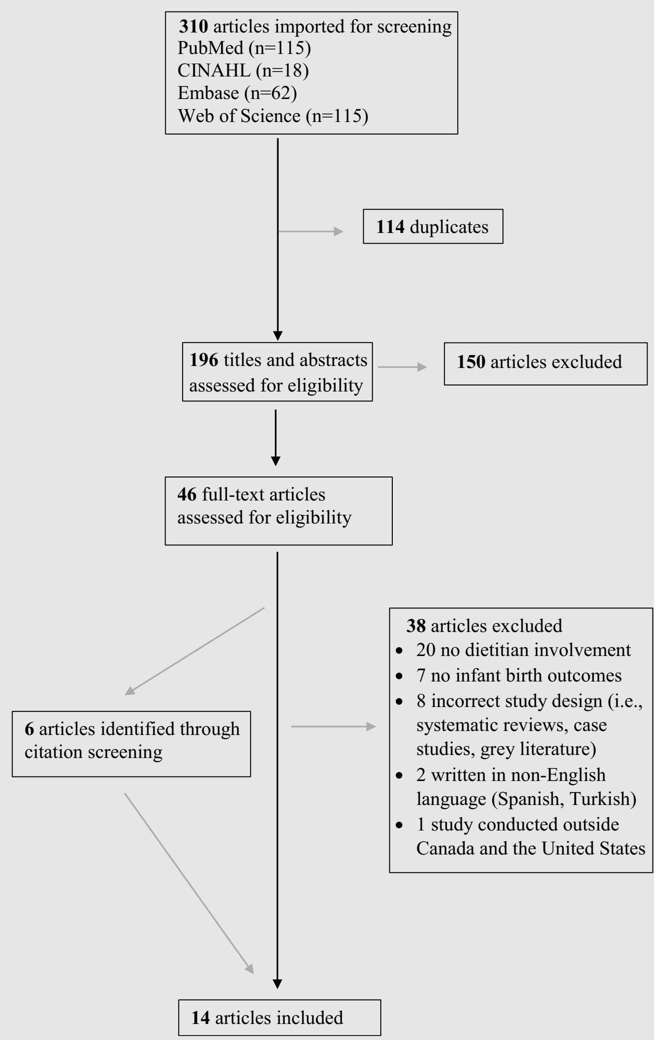
The search strategy identified 310 studies, 114 were removed as duplicates, and 196 required screening. From the 196 articles, 188 did not meet inclusion criteria. Six additional articles were retrieved from reference lists screened. Therefore, 14 studies were included in this systematic review (Figure 1).

Thirteen studies were conducted in the United States, and 1 study was from Canada. The publication years ranged from 1989 to 2018. Study designs consisted of 2 cross-sectional studies, 2 case-control studies, 3 retrospective cohort studies, 5 RCTs, 1 implementation trial, and 1 pilot study. Low birth weight was examined in 7 studies, SGA in 3 studies, LGA in 4 studies, macrosomia in 6 studies, PTB in 9 studies, and infant mortality in 2 studies. The average age of pregnant women was 29.3 years among 9 studies, with 1 study specifying the common age as 20 to 24 years [26] and another study specifying the median age as 26.8 years in its study group and 37.3 years in its control group [27]. Three studies did not report maternal age [28–30]. Seven studies described participants' gestational age. Most women entered the studies before the 28th week of gestation, although participants in 3 studies joined before 16 weeks of gestation [12, 28, 31]. Sample sizes ranged from 87 to 2,377 participants. Eleven of the 14 studies included diverse ethnic groups. Registered dietitian involvement during pregnancy included nutrition care, education, and counselling. A description of the studies (e.g., study design, sample characteristics, type of RD involvement) can be found in Table 1.

Low birth weight

Four of the 5 studies that compared RD involvement to no RD involvement found a lower prevalence of LBW in groups with RD involvement [26, 31–33]. When comparing standard RD care to advanced RD care, an RCT [34] found no difference between groups receiving standard nutrition counselling (control) compared to advanced nutrition care (intervention), although very few patients had LBW overall. For example, among women identified as normal weight at the first prenatal visit, 5/92 women had a LBW infant in the control group versus 4/90 in the intervention group. Similarly, only 4/86 overweight women had a LBW infant

Figure 1. Flow diagram following the search process based on Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA).



in the control group compared to 5/81 in the intervention group. One study found that 9.7% of all participants had a LBW infant, although LBW was reduced to 6.7% among women with adequate gestational weight gain, compared to 17.2% among those with inadequate weight gain ($p < 0.001$) [30]. In an implementation trial for clinical practice guidelines [35], both the intervention and control groups included RDs. Registered dietitians in the intervention group (n = 130) provided prenatal care as described in nutrition practice guidelines for gestational diabetes mellitus (GDM), whereas RDs in the control group (n = 85) provided usual prenatal care. No statistically significant difference in LBW was found between the nutrition practice guidelines group and the usual care group (2.4% vs. 8.4%, respectively, $p = 0.27$) [35].

Table 1. Summary of all included studies assessing the relationship between registered dietitian involvement during pregnancy and infant birth outcomes (n = 14).

Authors, Year, Reference	Study Objective	Location	Study Design	Sample Characteristics	RD Involvement/ Intervention group	Key Findings	Limitations
Bahry et al., 1989 [27]	To discuss the effectiveness of a perinatal care system which was developed to improve access and availability of obstetrical health services to a rural, mainly Hispanic, and socioeconomically disadvantaged population	United States	Cross-sectional study	n = 230; age: 20–24 y (most common) 77 (33.5%) at first trimester (0–16 weeks); 104 (45.2%) at second trimester (16–28 weeks); 49 (21.3%) at third trimester (28 weeks – delivery) 147 (62.9%) Hispanic; 83 (36.1%) non-Hispanic	Control groups: San Diego Country, California, US data (1985) Rural Comprehensive Perinatal Program (CPP) group: bilingual nutrition assessment and guidance Received nutrition assessment at 1st prenatal visit; reassessment in 2nd trimester and PRN	LBW: rural CPP group 5.2% versus San Diego County 5.7%, California 6.0%, United States 6.8% Perinatal death (per 1,000 live births): rural CPP group 8.7 versus San Diego County 13.2, California 12.7, United States 14.9 PTB: rural CPP group 6.5% versus United States 10.0%	Small sample size
Fassett et al., 2007 [38]	To determine whether medical nutrition therapy and home glucose monitoring can reduce complications in pregnancies with 1 elevated oral glucose tolerance test value	United States	Retrospective case-control study with historical controls	n = 126; age: untreated group: 29.2 ± 5.0 y, treated group: 28.5 ± 5.8 y Women with single-elevated glucose tolerance test value Prepregnancy weight: untreated group: 160.1 lbs, treated group: 178.8 lbs Total weight gain: untreated group: 23 lbs, treated group: 22.8 lbs 37 White; 74 Hispanic; 3 African American; 5 South Asian; 6 Asian; 1 other	Untreated group: No nutrition therapy Treated group: Routine medical nutrition therapy with minimum of 1 dietitian follow-up visit Received meal plans: 20–35 kcal/kg of pregnancy body weight (min. 1800 kcal, max. 2200 kcal), ~40% carbs, 30% protein, 30% fat	Macrosomia: treated group versus untreated groups (14% vs. 14%; $p = 0.94$) LGA: treated group versus untreated groups (14% vs. 14%; $p = 0.94$)	Small sample size Physicians caring for both treated and untreated groups changed during the study period
Gandhi et al., 2018 [39]	To determine whether a dietitian consult leads to a more favourable weight gain pattern, associated with prenatal outcomes, according to Institute of Medicine (IOM) guidelines in twin gestations	United States	Retrospective cohort study	n = 287; age: dietitian consult group: 31.4 ± 5.3 y, control group: 31.7 ± 5.8 y Prepregnancy BMI: dietitian consult group: 25.4 kg/m^2, control group: 25.5 kg/m^2 Twin pregnancy Prior to 20 weeks' gestation (first or early second trimester) 65 (35%) Hispanic	Control group: Not receiving personalized dietary consultation Dietitian consult group: Personalized dietary consultation (single, 60-min, targeted personalized dietitian consult in the first or early second trimester)	PTB (‹ 37 wks): dietitian consult group versus control group (71% vs. 67%; $p = 0.41$) PTB (‹ 32 wks): dietitian consult group versus control group (21% vs. 17%; $p = 0.30$)	Participants were nonrandomized, and thus, could not represent the entire population of twin pregnancies Confounding factors (socioeconomic status, motivation)

(*continued*)

Table 1. (Continued).

Authors, Year, Reference	Study Objective	Location	Study Design	Sample Characteristics	RD Involvement/ Intervention group	Key Findings	Limitations
Morris et al., 1993 [33]	To determine whether a difference exists in pregnancy characteristics, pregnancy course, and immediate outcomes of pregnant adolescents based on source of prenatal care	United States	Retrospective cohort study	n = 1080; overall age: 15.8 y Mean weight of participants: teen clinic: 122.9 lbs, traditional clinic: 125.1 lbs Mean weight gain: teen clinic: 31.5 lbs, traditional clinic: 31.1 lbs Teen pregnancy In teen clinic, 298 at the first trimester; 281 at the second trimester; 81 at the third trimester In traditional clinic, 54 at first trimester; 158 at second trimester; 65 at third trimester 23.5% Hispanic; 30.5% African American; 46% Anglo	No care group: Not receiving nutrition care Traditional clinic group: Limited access to nutrition support Teen clinic group: Full nutrition support Nutrition support included: nutrition counselling	LBW (≤ 1500g): teen clinic group 1.8%, traditional clinic group 0.4% versus no care group 9.8% LBW (≤ 2500g): teen clinic group 9.0%, traditional clinic group 8.6% versus no care group 30.8% Stillbirth: teen clinic group 0.8%, traditional clinic group 0.4% versus no care group 2.8% PTB: teen clinic group 10.5%, traditional clinic group 8.7% versus no care group 35% ($p = 0.0001$)	Lack of compliance rate Incomplete data in no care group
Peccei et al., 2017 [29]	To assess the effect of a culturally appropriate nutritional intervention delivered to overweight and obese patients in a community health setting on gestational weight gain and postpartum weight retention	United States	Randomized controlled trial	n = 272 Overweight and obese ‹16 weeks of gestation Final weight: control: 202.9 lbs, intervention: 201.1 lbs Final weight gain: control: 26.9 lbs, intervention: 24.7 lbs 107 White (non-Hispanic); 17 Black (non-Hispanic); 128 Hispanic; 20 other (non-Hispanic)	Control group: Nutrition counselling* Intervention group: Nutrition counselling*, individualized counselling sessions** Both groups received counselling by RD at the initial study visit (60–90 minutes on average). Intervention group received individualized counselling sessions (10–30 minutes) twice a month; received individualized meal plans (~1800–2400 kcals) and adjusted at every visit; reviewed weight gain trajectory and exercise level; food literacy (label reading; shopping on a budget; calories comparisons; fibre, vitamin, and mineral recommendations; benefits of breastfeeding)	LGA: intervention group versus control group (6.1% vs. 13%; odds ratio = 0.4, 95% CI [0.2–1.0]; $p = 0.058$) LGA among obese participants: intervention group versus control group (6.7% vs. 17.3%; odds ratio = 0.3, 95% CI [0.1–0.99]; $p = 0.048$) SGA: intervention group versus control group (6.1% vs. 3.3%; odds ratio = 1.9, 95% CI [0.5–7.1])	Small sample size The control group received significant counselling by the RD at the initial visit and was referred to a nonstudy RD when appropriate, which may have diluted the intervention effects

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Table 1. (Continued).

Authors, Year, Reference	Study Objective	Location	Study Design	Sample Characteristics	RD Involvement/ Intervention group	Key Findings	Limitations
Reader et al., 2006 [36]	To determine if nutrition care delivered by RDs using nutrition practice guidelines for gestational diabetes results in different care and better pregnancy outcomes compared with usual nutrition care provided by RDs	United States	Implementation trial for clinical practice guidelines	n = 215; age: usual care group: 30.7 ± 5.8 y, nutrition practice guidelines group: 31.8 ± 5.6 y GDM pregnancy Average 28.0 weeks of gestation at GDM diagnosis; average 29.5 weeks of gestation at the first nutrition visit 131 White; 22 African American; 28 Hispanic; 12 other	Control groups: US birth 2002 and GDM births 1995 Usual care group: Prenatal nutrition care according to usual practice Received at least five referrals for GDM in the following 6 months Practice guidelines nutrition care group: Prenatal nutrition care according to Nutrition Practice Guidelines for Gestational Diabetes Provided education on starting insulin, self-monitoring blood glucose, and kept blood glucose records following a food plan and completing food records; reviewed lab values (urine ketones); at least three nutrition visits.	PTB: usual care group versus practice guidelines nutrition care group (4.6% vs. 10.6%; p = 0.25) LBW: usual care group versus practice guidelines nutrition care group (2.4% vs. 8.4%; *p* = 0.27) Macrosomia: usual care group versus practice guidelines nutrition care group (13.3% vs. 13.4%; *p* = 0.98)	Small sample size Interventions could be provided similarly in the two groups
Ricketts et al., 2005 [31]	To examine rates of LBW among participants in Colorado's Prenatal Plus program by prenatal risk factors and the effect of successful resolution of these risks during pregnancy	United States	Cross-sectional study	n = 2377; 31% of participants aged ≤19 y At risk of delivering LBW infant, before 28 weeks of gestation 1032 (43%) White non-Hispanic; 1091 (46%) Hispanic; 165 (7%) Black; 89 (4%) Other/unknown	Prenatal Plus program group***: Nutrition counselling A minimum of 10 visits	LBW: overall 9.7% Prenatal Plus program group. LBW was reduced to 6.7% among women with adequate gestational weight gain, compared to 17.2% among those with inadequate weight gain ($p < 0.001$).	Increased risks of underreporting due to self-reported information Attrition might influence the effectiveness of the program

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Table 1. (Continued).

Authors, Year, Reference	Study Objective	Location	Study Design	Sample Characteristics	RD Involvement/ Intervention group	Key Findings	Limitations
Weiderman et al., 1996 [30]	• To develop a protocol for surveillance, diagnosis, and management of diet-controlled gestational diabetes for rural care providers • To establish a method of delivering specialized perinatal care to Medical-eligible women with GDM in a rural clinic setting according to streamlined CDAPP protocols without the multidisciplinary approach	United States	Pilot study	n = 87 Gestational Diabetes ‹ 20 weeks of gestation (least participants); 21–30 weeks of gestation (most participants); 31–40 weeks of gestation (second most participants) White; African American; American Indian; Asian; Other	Pilot group: Trained by RDs, nutritional education by the pilot guidelines and protocols Affiliate group: Direct diabetes and nutritional education from RDs Patients were followed up on a weekly or biweekly basis.	Macrosomia: pilot group versus affiliate group (3 vs. 1 cases; $p = 0.4$)	The multidisciplinary requirement of the program was difficult for most providers to participate as affiliates Small sample size, especially Asian patients Sample was not representative of Native American patients
Vesco et al., 2014 [12]	To test the efficacy of a group-based weight management intervention for limiting GWG among obese women	United States	RCT	n = 114; overall age: 31.8 ± 4.8 y Weight at randomization: control group: 100.5 kg, intervention group: 98.8 kg BMI at randomization: control group: 36.8 kg/m^2, intervention group: 36.7 Obese Gestational age: 14.9 ± 2.6 weeks at randomization 98% White	Intervention group: received individual counselling on tailored diet (based on DASH) and exercise guideline [intervention goal is to help participants maintain their weight during pregnancy to within 3% change] Started with two individual counselling sessions, followed by weekly group sessions throughout their pregnancy. Control group: received one-time dietary advice	LGA: intervention group versus control group (9% vs. 26%; odds ratio = 0.28, 95% CI [0.09, 0.84]; $p = 0.02$) Macrosomia: intervention group versus control group (11% vs 22%; odds ratio = 0.42, 95% CI [0.14, 1.18]; $p = 0.09$) SGA: intervention group versus control group (5% vs. 7%; odds ratio = 0.76, 95% CI [0.11, 4.76]; $p = 1.00$) PTB (‹37 weeks): intervention group versus control group (7% vs 2%; odds ratio = 4.38, 95% CI [0.41, 219.64]; $p = 0.13$) PTB (‹34 weeks): intervention group versus control group (0% vs 2%; $p = 0.09$)	Small sample size Minimal racial and ethnic diversity Included only insured women with access to routine prenatal care

(*continued*)

Table 1. (Continued).

Authors, Year, Reference	Study Objective	Location	Study Design	Sample Characteristics	RD Involvement/ Intervention group	Key Findings	Limitations
Luke et al., 2003 [32]	To evaluate the effect of a prenatal nutrition and education program on twin pregnancy, neonatal, and early childhood outcomes	United States	Retrospective cohort study	n = 529; age: program group: 31.5 ± 0.4 y, nonprogram group: 29.7 ± 0.3 y Twin births Gestation age: first program visit: 16 ± 0.4 weeks 86% White, 9% African American, 2.5% Asian, 2.5% Other	Program group: receiving twice-monthly visit by RD on team, including dietary assessment, dietary prescription of 3000–4000 kcals per day, and multimineral supplementation Nonprogram group: Not receiving any service	PTB: program group versus nonprogram group (23% vs. 42%; adjusted odds ratio = 0.45, 95% CI [0.30–0.68]; $p < 0.0001$) Delivery < 36 wk: program group versus nonprogram group (41% vs. 53%; adjusted odds ratio = 0.62, 95% CI [0.43–0.89]; $p = 0.01$) Delivery < 32 wk: program group versus nonprogram group (41% vs. 53%; AOR = 0.62, 95% CI [0.43–0.89]; $p = 0.01$) Delivery < 30 wk: program group versus nonprogram group (3% vs. 9%; AOR = 0.29, 95% CI [0.11–0.76]; $p = 0.01$) LBW: program group versus nonprogram group (41% vs. 64%; AOR = 0.42, 95% CI [0.29–0.61]; $p < 0.0001$)	Nonrandomized group Confounding factors (difficulty in separating out different effects)
Phelan et al., 2011 [35]	To examine whether a behavioural intervention during pregnancy could decrease the proportion of women who exceeded the 1990 Institute of Medicine recommendations for gestational weight gains and increase the proportion of women who returned to pregravid weights by 6 months postpartum	United States	RCT	n = 401; overall age: 28.8 y BMI at baseline: standard care: 26.48 kg/m^2, intervention: 26.32 kg/m^2 Gestational age: 13.5 wks 68.1% Non-Hispanic White, 19.6% Latina and Hispanic, 8.35% Non-Hispanic African American, 3.95% Other	Standard care group: Received standard nutrition counselling Intervention group: intensive nutrition care including weight gain discussions, food patterns, self-monitoring, supportive phone calls from dietitians; one face-to-face visit at the onset of treatment Monthly visits until 28 wk gestation, biweekly for 28–36 wk gestation.	No difference in LBW between standard care and intervention groups Macrosomia: standard care group versus intervention group (17 vs. 20 cases) Preterm delivery (<36 weeks): standard care group versus intervention group (20 vs. 16 cases)	Reporting bias/ underreporting (self-reported pregnancy weight)

(*continued*)

Table 1. (Continued).

Authors, Year, Reference	Study Objective	Location	Study Design	Sample Characteristics	RD Involvement/ Intervention group	Key Findings	Limitations
Dubois et al., 1991 [34]	To evaluate the impact of the Higgins Nutrition Intervention Program on twin-pregnancy	Canada	Retrospective case-control study	n = 520; overall age: 28 y Twin birth Intervention group: 50% Non-White, Nonintervention group: 13%	Intervention group: Received Higgins Nutrition Intervention Program from registered dietitians Nonintervention group: Not receiving any service	LBW: intervention group versus nonintervention group (47% vs. 55%; odds ratio = 0.73, 95% CI [0.54–0.99]) PTB: intervention group versus nonintervention group (40% vs. 47%; odds ratio = 0.68, 95% CI [0.51–0.92])	Did not report adherence rate? Large sample size difference between intervention and nonintervention Higher proportion of intervention group was non-White and had social assistance indicated as a source of income. Confounding factors (lower proportion of smokers in intervention group)
Artal et al., 2007 [37]	To assess whether a weight-gain restriction regimen, with or without exercise, would impact glycemic control, pregnancy outcomes, and total pregnancy weight gain in obese subjects with gestational diabetes mellitus	United States	RCT	n = 96; age: exercise and diet intervention group: 32.4 ± 5.3 y, diet intervention group: 30.6 ± 5.5 y BMI: exercise and diet intervention group: 35.2 kg/m^2, diet intervention group: 33.5 kg/m^2 Maternal weight: exercise and diet intervention group: 95 kg, diet intervention group: 92.3 kg GDM & obese Gestational age at study entry: exercise and diet intervention group: 29.4 ± 4.9 weeks, diet intervention group: 28.0 ± 5.1 weeks 58.3% Caucasian, 29.2% African-American, 3.1% Hispanic, Other 9.4%	Exercise and diet intervention group: Received medical nutrition therapy and maintained a moderate exercise routine Diet intervention group: Received medical nutrition therapy	LGA (>4000 g): exercise and diet intervention group versus diet intervention group (11.8% vs. 15.2%; $p = 0.64$) SGA (<2500 g): exercise and diet intervention group versus diet intervention group (5.9% vs. 2.2%)	Lack of randomization Confounding factors (insulin therapy) Small sample size

(*continued*)

Table 1. (Continued).

Authors, Year, Reference	Study Objective	Location	Study Design	Sample Characteristics	RD Involvement/ Intervention group	Key Findings	Limitations
Thornton et al., 2009 [28]	To compare perinatal outcomes of obese pregnant women treated in the conventional manner (control group) to outcomes of nutritionally monitored obese pregnant women (study group)	United States	RCT	n = 232; median age: control group: 37.3 y, study group: 26.8 y Baseline pregnancy weight: control group: 214.20 lbs, study group: 204.11 lbs BMI: control group: 38.22 kg/m^2, study group: 37.41 kg/m^2 40.9% African American, 22.4% Caucasian, 23.3% Latina, 13.3%Indian	Control group: Received at least one nutrition consultation Study group: Received nutrition consultations and dietary intake protocol (followed dietary guidelines similar to guidelines for GDM: 18–24 kcal/kg body weight); recorded food diary	PTB (<37 wks): control group versus study group (4.3% vs. 2.6%, p = 0.472) Macrosomia (>4500 g): control group versus study group (3.4% vs. 7.8%, p = 0.153)	Reporting bias (self-reported nutritional regimen) Low samples size in fetal macrosomia adherence versus nonadherence groups

Note: a Mean age at the onset of pregnancy for the sample, similar age distribution in all three groups. N.B.: CDAPP = California Diabetes and Pregnancy Program; DASH = Dietary Approaches to Stopping Hypertension; GDM = Gestational Diabetes Mellitus; GWG = gestational weight gain; LGA = large for gestational age; LBW = low birth weight; PTB = preterm birth; PRN = "pro re nata"/as needed; RD = registered dietitians; RCTs = randomized controlled trials; SGA = small for gestational age; IOM = Institute of Medicine; US = United States.

*Included pregnancy-related risks of being overweight or obese, a review of the IOM gestational weight gain recommendation based on participants' BMIs, information on basic nutritional needs, healthy eating, and safe exercise during pregnancy. **Included dietary assessment, individualized meal plans, and additional counselling topics; twice a month throughout pregnancy. ***Total participants.

Small for gestational age

In an RCT by Peccei et al. assessing the effect of a culturally appropriate nutritional intervention delivered to overweight and obese patients in a community health setting, there was no significant difference in SGA prevalence between the RD involvement intervention group and the control group (6.1% vs. 3.3%; odds ratio [OR] = 1.9, 95% confidence interval [CI]: 0.5–7.1) [28]. In the RCT by Vesco et al., where the intervention group received individualized nutrition counselling and the control group received one-time dietary advice, no significant difference in SGA was found between the intervention and control group (5% vs. 7%; OR = 0.76, 95% CI: 0.11–4.76) [12]. In Artal et al.'s RCT, both groups received medical nutrition therapy (MNT) administrated by RDs, and there was no difference in the rate of SGA in the group receiving MNT and exercise (2/39; 5.9%) to those receiving the diet intervention alone (1/57; 2.2%) [36].

Large for gestational age

Fassett et al. found no significant difference in LGA between the RD involvement group and the non-RD involvement group (14% vs. 14%; $p = 0.94$) [37]. Peccei et al. examined LGA among all participants and separately among obese participants [28]. The intervention group, which involved intensive prenatal nutrition counselling by an RD, was not significantly different from the control group (6% vs. 13%; OR = 0.4, 95% CI: 0.2-1.0; $p = 0.058$) for LGA. Among obese participants however, those in the intervention group had 70% lower odds of LGA infants than in the control group, and the difference was statistically significant (7% vs. 17%; OR = 0.3, 95% CI: 0.1–0.99; $p = 0.048$) [28]. An RCT by Vesco et al. also found a significantly lower prevalence of LGA in the intervention group than the control group (9% vs. 26%; OR = 0.28, 95% CI: 0.09–0.84) [12]. In the Artal et al. RCT, both groups received a diet intervention, but there was no significant different in LGA between the group receiving MNT alone (7/57) and the group receiving an additional exercise intervention (4/39) ($p = 0.64$) [36].

Macrosomia

The retrospective case-control study by Fassett et al. revealed no difference in macrosomia between the RD involvement group and the non-RD involvement comparator (14% vs. 14%; $p = 0.94$) [37]. The pilot study by Weiderman et al. also found no significant difference between groups with and without RD involvement ($p = 0.40$) [29]. Phelan et al. found that, among those with a prepregnancy BMI indicating normal weight, 3/92 birthed children with fetal macrosomia in the standard nutrition care group compared to 6/90 in the intensive nutrition care group [34]. For women with a prepregnancy BMI indicating overweight, the rates of macrosomia were 14/86 (16.3%) and 14/81 (17.3%) for the standard and intensive nutrition care groups, respectively. In studies by

Reader et al. [35], Vesco et al. [12], and Thornton et al. [27], there were no statistically significant differences in macrosomia in the control groups receiving basic nutrition care (i.e., nutrition counselling) and the groups receiving extensive nutrition care (i.e., dietary advice, weight gain discussions, dietitian follow-ups).

Preterm birth

Among 5 studies examining PTB that compared groups with RD involvement to those without RD involvement, 4 studies found a lower prevalence of PTB in groups with RD involvement [26, 31–33], with 2 studies indicating a significant difference [31, 32]. One study found no significant difference between groups [38]. Among the remaining 4 studies, all participants received nutrition care by RDs, with 1 study indicating a lower prevalence of PTB in groups receiving extensive nutrition care [34], and 3 studies finding no significant differences in PTB between groups receiving standard and in-depth nutrition care [12, 27, 35].

Infant mortality

Perinatal death and stillbirth were reported as infant mortality in 2 studies [26, 32]. Both found a lower prevalence of infant mortality with RD involvement compared to no RD involvement.

DISCUSSION

Main findings

This systematic review demonstrates that pregnant individuals have a lower prevalence of LBW infants when RDs are involved during prenatal care. This is an important finding because LBW increases the risk for infant mortality, poor cognitive development, respiratory distress, and asthma during childhood, and cardiovascular disease, type 2 diabetes, and hypertension during adulthood [2]. While the etiology of LBW is multifactorial [39, 40], poor maternal nutrition is a major contributing factor [41, 42]. Two of the 4 studies which found a lower prevalence of LBW with RD involvement compared to no involvement were of good quality, 1 was fair quality, and 1 was poor quality. RD involvement was also associated with a lower prevalence of PTB, particularly when RD involvement was compared to no involvement (4/5 studies). Furthermore, while RD involvement during pregnancy was not associated with macrosomia, more research is needed to elucidate its correlation with SGA, LGA, and infant mortality. All 3 studies that assessed SGA as an outcome were not of good methodological quality. Additionally, 2/4 studies found a reduction in LGA infants with RD involvement compared to no involvement, and only 2 studies assessed infant mortality, both of which found a lower rate of mortality with RD involvement.

Interpretation

Although this systematic review investigates the association between RD involvement during pregnancy and birth outcomes in Canada and the United States, our findings are fairly consistent with studies from other countries. In a quasi-experimental design from Mexico City, Perichart-Perera et al. [43] examined the relationship between dietitian-initiated MNT (i.e., counselling, education, and capillary glucose monitoring) and birth outcomes. Among women with GDM, the MNT group were significantly less likely to have a LBW infant than the control group (5.1 % vs 20.5%, $p = 0.03$), although there were no differences in LBW between groups among women with type 2 diabetes. The study found no significant differences in rates of prematurity and macrosomia between the two groups. In an RCT from Australia examining whether treatment of women with GDM reduced the risk of perinatal complications, Crowther et al. [13] found that the intervention group (n = 506, receiving dietary advice from an RD, blood glucose monitoring, insulin therapy) was significantly less likely than the routine-care group (n = 524) to have an LGA (13% vs. 22%, $p < 0.001$) or fetal macrosomia (10% vs 21%, $p < 0.001$) outcome, although SGA was similar between the two groups. Noteworthy is that the current review includes various population types, such as twin pregnancies, adolescent pregnancies, obese pregnant women, and women diagnosed with GDM, all of which increase the risk for adverse birth outcomes [44–47]. It is plausible that pregnant individuals may have received different nutrition care from RDs depending on their health concerns and conditions, adding to greater heterogeneity in the exposure.

Strengths and limitations

This systematic review provides a comprehensive assessment of the association between RD involvement during pregnancy and birth outcomes in Canada and the United States. Given that many prenatal health care providers report insufficient education and training in nutrition [48, 49], and that dietitians are regulated health professionals who undergo rigorous training, RD advice to pregnant individuals (e.g., recommended foods and those to avoid) may enhance maternal health and fetal development, if the advice is followed. However, there are some limitations to consider when interpreting these findings. First, there was limited sociodemographic information reported in most studies with respect to race, ethnicity, and socioeconomic status. This is unfortunate because research shows that pregnant women who are non-Hispanic Black, Hispanic, and those with low educational attainment have poorer diet quality than those who are non-Hispanic Whites [50]. Future research should address the extent to which RD involvement during pregnancy can attenuate disparities in birth outcomes by factors such as socioeconomic status, race, and ethnicity. Second, several studies had inadequate statistical power to detect clinically meaningful results in birth outcomes. Underpowered studies are problematic because they increase the risk of a type II error/false negative [51]. While underpowered studies can sometimes be mitigated by pooling the data when conducting a meta-analysis, the heterogeneity would have been very large between the included studies since the definition of RD involvement varied considerably. Future interventions that involve RDs during pregnancy need to accurately specify the content and frequency of their involvement.

RELEVANCE TO PRACTICE

Although more research is warranted on the relationship between RD involvement and adverse birth outcomes, our systematic review suggests that RD involvement during prenatal care is associated with a lower prevalence of LBW and PTB, both of which increase the risk for infant morbidity and mortality, and the development of chronic health conditions in adulthood. These findings are important and indicate a need for greater advocacy from other health care professionals with regard to the importance of dietitian services during pregnancy. Future research should investigate the specific dietary advice provided by RDs and the extent and timing of their involvement throughout pregnancy.

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