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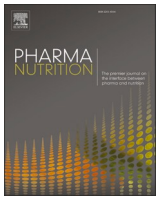

Probiotics in pregnancy: Inequities in knowledge exchange, attitudes, and use of probiotics in a socio-demographically diverse, cross-sectional survey sample of pregnant Canadians

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ABSTRACT

Background: Pregnancy interventions, potentially including consumption of nutraceuticals like probiotics, represent possible avenues for preventing non-communicable diseases. However, evidence syntheses indicate that probiotic interventions, while effective in managing some pregnancy complications (e.g., gestational diabetes), do not confer health benefits to uncomplicated pregnancies. Messaging around probiotics in pregnancy is mixed, such that people with low-risk pregnancies may nevertheless feel pressure to spend limited resources on (costly) probiotics. To tailor knowledge exchange and support safe, equitable access to pregnancy probiotics when their prescription may be warranted, we need to understand who takes probiotics during pregnancy and under what conditions.

Methods: We used chi-square and logistic regression analyses of anonymous, cross-sectional survey data from 341 pregnant Canadians of diverse socio-demographic backgrounds to assess which respondents, by socio-demographic characteristics and pre-pregnancy/pregnancy health indicators, were relatively likely to: perceive probiotics as beneficial to pregnancy health and/or report taking probiotics during pregnancy.

Results: Forty-seven percent of respondents perceived probiotics as beneficial to pregnancy health; 51 % reported consuming them. Probiotic attitudes and consumption were socio-demographically-patterned: higher-income, post-secondary-educated respondents disproportionately perceived probiotics as healthy and consumed them. There was no evidence of variation in probiotics attitudes or use by pregnancy health indicators.

Conclusion: Socio-economic factors may be more important determinants of pregnancy probiotic use in this sample than indications for pregnancy complications. Clear guidelines on pregnancy probiotics that reflect current evidence are needed. Equitable access to probiotics should be facilitated for pregnant people likely to benefit from interventions (i.e., those with certain complications), supporting long-term health equity.

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1. Introduction

Globally, non-communicable diseases (NCDs) represent leading causes of illness and death, and are leading drivers of health inequities [1]. Overwhelming evidence indicates that the metabolic health of parents at the earliest stages of their children's lives, from just prior to conception through pregnancy, has outsized impacts on their children's long-term risk of developing NCDs [2]. As such, improving metabolic health and nutrition during the peri-conceptional and pregnancy periods constitutes a key intervention target for reducing the NCD burden and NCD-related health inequities in the next generation [2]. To date, however, traditional health interventions targeting the knowledge or behaviours of pregnant people are of low efficacy, so novel strategies are needed to improve the metabolic health of pregnant women and other pregnant people and their children, particularly those facing structural barriers like poverty and lack of education [3,4].

One potential avenue for interventions that could improve metabolic health in pregnancy concerns the maternal gut microbiome [5]. The gut microbiome comprises the community of microbes (i.e., bacteria, fungi, and viruses) and the environment they inhabit in our intestines. Gut microbiome composition plays a critical role in nutrient absorption and allocation [6], and is associated with variation in numerous metabolic and inflammatory indicators [7–10]. These general patterns hold during pregnancy, and the gut microbiomes of people who are healthy through pregnancy appear also to be associated with relatively better health outcomes for themselves and their offspring [11,12].

Given the role of the gut microbiome in metabolism, a growing number of public health interventions are focusing on modifying the microbial communities of pregnant people at elevated risk for metabolic complications [7,13]. Most of these interventions involve administering functional foods or nutraceuticals containing commensal live bacteria (probiotics) to pregnant people, and then comparing pregnancy and/or maternal and infant/child health indicators to matched controls [14,15].

So far, the efficacy of such interventions remains uncertain [10,14,16]. Three recent meta-analyses found modest or no effects of probiotic administration during pregnancy on most pregnancy outcomes, and one even suggests that probiotic administration may increase risks of hypertensive disorders in pregnancy [14,16,17]. This mixed picture may be due to considerable heterogeneity in the timing and duration of administration, in the types of probiotics administered, and in the socio-demographic and health characteristics of the participants in the reviewed studies. Another challenge to interpreting the current body of evidence is that evidence synthesizers sometimes conceptually or even analytically pool results of preventative interventions with those of treatment interventions. Such pooling is problematic because it appears that treatment-based probiotic interventions during pregnancy may be more efficacious than preventative ones. That is, evidence supports the use of probiotics during pregnancy following diagnosis of metabolic pregnancy complications, and particularly following diagnosis with gestational diabetes mellitus (GDM) [13,18–21]. However, as it stands, the idea that metabolically-healthy pregnant people should take probiotics–at considerable personal expense and with potential health risks for some individuals–[16] is not yet ready for widespread public endorsement as a strategy to improve metabolic health in pregnancy (but see [15,22]).

Despite the lack of evidence-based recommendations, probiotics have made it into the public consciousness in many high-income countries. In particular, probiotic interventions for pregnancy and for metabolic health more generally have become a popular science media darling, beginning in the late 2000s/early 2010s [23,24]. This raises several questions related to public health and public health knowledge exchange regarding probiotics and functional foods and supplements more generally, with possible implications for equity, in supporting metabolic health in pregnancy and early life (i.e., infancy and childhood) [25,26]. Chief among these are: "Who, in terms of socio-demographic profile, is taking probiotics during pregnancy?", "Are there socio-demographic inequities in who is exposed to and internalizing the (unsupported) idea that probiotics are healthy for all pregnancies?", "From what kinds of sources might pregnant people be getting information about probiotics in pregnancy, and are these areas of knowledge exchange likely to be equitable?", and "Are people who are at elevated risk for metabolic complications of pregnancy more likely than others to seek out novel/popular treatments of unknown efficacy like probiotics?"

With these gaps in our understanding regarding public knowledge translation of the cost-benefits of probiotics in pregnancy in mind, we report a study aimed at assessing whether pregnant people from diverse socio-demographic backgrounds in a high-income country (Canada) perceive probiotics as beneficial to pregnancy health, and whether they actually take probiotics. We investigated the extent to which perceptions and use of probiotics vary with socio-demographic and pregnancy health indicators, focusing on candidate fundamental structural drivers and constraints on probiotics use and attitudes (e.g., income, education, and rural-urban geography) as well as on whether pregnant people are following the evidence and investing in probiotics if and only if they are at elevated risk of metabolic complications of pregnancy. We also conducted supplementary analyses aimed at shedding light on possible informational and behavioural mechanisms that could link likehihood of probiotic-taking with socio-demographic/ structural factors.

2. Methods

2.1. Study design, setting and participants

The data used in the present study come from respondents to an anonymous questionnaire, administered to pregnant women and other pregnant people as part of the Mothers to Babies (M2B) Study. M2B is a community pregnancy health project based in Hamilton, Ontario, Canada. It focuses on a combination of community-engaged formative research and Knowledge Exchange (KE) as well as local stakeholder-driven health intervention development, aimed at promoting healthy pregnancy and reducing pregnancy health inequities in the city [4,27].

Hamilton, a city of ~750,000 [28], provides a socio-demographically diverse study setting, characterized by relatively high rates of poverty and by relatively extreme socio-economic inequity for a Canadian city of its size. Furthermore, it has a persistent, high, and inequitable chronic disease burden [29], which likely contributes to the periconceptional and pregnancy health environments of pregnant Hamiltonians [27].

We promoted the M2B questionnaire in partnership with local public health professionals. To ensure responses from pregnant people across socio-demographic spectrums, we promoted M2B at community and midwifery centres that disproportionately serve pregnant people and new mothers and other birthing parents living with poverty, linguistic and cultural barriers, and/or related challenges. Promotion at such sites combined short talks with strategic placement of study flyers/posters, and circulation of print copies of the questionnaire, which could be mailed to the lead author, handed to a health care provider, or dropped in a secured drop-box or envelope. To reach other demographic segments of Hamilton's population, we also distributed flyers and hung posters in four major pregnancy health service locations around the city and at dozens of community centres and local businesses. We and our public health partners also advertised the study on multiple social media channels.

Participation in this study was limited to people who self-identified as pregnant and who reported living in a recognized Hamilton postal code at the time of their questionnaire submission. Respondents were not individually compensated, although they were eligible to enter a draw for one of three chances to win a $100 visa gift card. The protocol was approved by the Hamilton Integrated Research Ethics Board (HIREB), approval #0570.

2.2. Study instrument

We developed online (LimeSurvey©) and print versions of our 140-item M2B questionnaire in English. The questionnaire was piloted with 78 respondents between December 2015 and April 2016 to assess reliability of items. Following piloting, it was slightly modified (including the addition of three questions about attitudes towards probiotics), then re-launched and re-run between June 2017 and September 2018. Following the re-launch, a print version was also translated and made available in Arabic, the most spoken language at a core study promotion location. The questionnaire included questions on a range of domains related to pregnancy health and nutrition, three of which are central to the present study and the fourth and fifth which may hint at possible mediators between probiotic use during pregnancy and structural inequities. These first three domains are: 1) respondents' perceptions of and use of probiotics and other functional foods or nutraceuticals during pregnancy, 2) socio-demographic characteristics of respondents, and 3) pre-pregnancy and pregnancy health status indicators of respondents. The fourth and fifth domains, for which measures, analyses, and preliminary findings are only reported in the supplementary materials, concern the numbers and kinds of sources from which respondents report getting information about pregnancy health and nutrition, and also about their capacity to martial informational and other resources into action or behaviour (a validated general self-efficacy measure).

2.3. Measures

To assess respondents' *perceptions of and use of probiotics*, for the primary analyses reported here, we asked three simple questions; The first was based on a yes or no question: "Probiotics are live bacteria, sometimes called 'good' bacteria, that keep your digestive system (e.g., intestine) healthy. Do you take or eat probiotics (in pills, yogurts with a probiotic label, or other forms)?". "Yes" responses were given a score of 1 and "no" responses were given a score of 0. The second was an open-ended question regarding the form of probiotics taken: "If you are taking probiotics, what types of probiotics do you take or eat (such as pills or yogurts with a probiotic label)?". These responses were lumped categorically into "pills and/or powder", "probiotic yogurt, kefir, or other fermented dairy products", and "other fermented food and/or drink". Lastly, we asked "Do you think that pregnant women should take or eat probiotics to be healthy?", with the check-box response options being "yes", "no", or "not sure". In preparation for analyses, these responses were rescored as dummy variables in which all "yes" responses were given a score of 1 and all "no" and "not sure" responses were given a score of 0.

We asked respondents to report their *socio-demographic characteristics*: current age, the age of their oldest child (used to calculate age at first birth); whether their household income derived predominantly from waged or salaried employment versus from government cash transfers; their household income bracket (<$20,000; $20,000 to $39,999; $40,000 to 79,999; or $80,000+); their highest completed educational attainment bracket (<10th grade; <high school; high school; some college or university; completed college or university degree; any graduate or post-degree education in progress or complete); how they identified their cultural and/or racial background (16 check-box options or "other", multiple selections allowed); whether or not they had immigrated to Canada within the last five years; the number of dependents living in their households; and the first three digits of their postal codes, which were binned into "urban" and "rural", depending on whether their postal code prefix fell within the boundaries of geo-political wards 1-9 (relatively dense, urban) or 11-15 (relatively sparse, ex-urban/rural). These socio-demographic indicators were converted to dummy variables (e.g., "household annual income below $19,999=1, household annual income $20,000+=0"), so that we could directly compare our analyses to those of the only previous study on this topic that used these binary measures, which are indicative of structural divides between segments of the population living with or without poverty and with or without the health and science literacy skills and social advantages enabled through completing post-secondary education [32]. This approach (dummy coding) also simplifies the interpretation of our regression model, for which the error is likely mis-specified when the socio-demographic items are expressed as counts. We note that, in addition to the three main questions just described, we also asked three further questions pertinent to measuring attitudes towards and use of supplements and functional foods more broadly in this sample (these additional questions, how item responses were scored, and sensitivity analyses that used these scores are available in the supplementary materials).

We asked respondents to report their gestational age in weeks as well as pre-pregnancy and pregnancy health indicators: self-reported overall health prior to pregnancy, measured on a five-point scale; self-reported overall health at time of response (i.e., during pregnancy), measured on a five-point scale; current height and recalled periconceptional weight, to calculate approximate pre-pregnancy body mass index (BMI; weight kg/height m^2) and to identify pre-pregnancy overweight ($25.0 \geq BMI \leq 29.9$) or obesity ($BMI \geq 30.0$); weight at the time of response, to assess whether pregnancy weight gain trajectory was in line with the Public Health Agency of Canada (PHAC) recommendations, given pre-pregnancy BMI and gestational age; and report of diagnosis with GDM. All respondents who checked off that they had received a GDM diagnosis were given a score of 1 and all other responses were given a score of 0. Any absence of diagnosis cases were excluded in the GDM-specific analyses if respondents reported fetal gestational ages younger than 24 weeks, since GDM screening in Canada usually occurs beyond 24 weeks gestation.

2.4. Statistical analyses

Frequency statistics and contingency tables were used to characterize the sample socio-demographically, as well as to describe general patterns regarding attitudes towards and consumption of probiotics. Chi-square tests were used to assess whether probiotic attitudes and use differed among various socio-demographic groups, between groups of pregnant people at elevated GDM risk (i.e., respondents with pre-pregnancy overall health reported to be less than "very good", possibly indicating pre-existing metabolic issues; respondents with pre-pregnancy BMIs over 24.9; and respondents gaining gestational weight at higher than recommended rates), and between those diagnosed with GDM and those not. Finally, we fit a multiple logistic regression model with reported probiotic use as the dependent variable. The independent variables were belief that probiotics are healthy and any socio-demographic factors suggested by the chi-square tests to contribute to variation in responses. The model also adjusted for gestational week. A sensitivity analysis was conducted and reported in the supplementary materials, in which the socio-demographic variables measuring income and education level were combined and expressed as a discrete socio-economic position variable. All statistical analyses and all plots were conducted using the "stat" [30] and "MASS" [31] packages in the statistical environment R.

3. Results

In total, we received 350 responses to the post-pilot version of the questionnaire. Nine cases were removed because they were less than 20 % complete, leaving a maximum sample size of 341. Missing case data for any particular analysis were omitted.

Respondents ranged in age from 17 to 47 years, with a mean (s.d.) of 30.4 (±5.7) years (n=339). They had between zero and six dependent children living in their houses, with a mean of 0.8 (±1.1; n=340), and had given birth previously between zero and seven times (mean=0.9 ±1.2; n=321), with a mean age at first birth of 27.9 (±5.6) years

(n=339). Gestation week ranged from one self-reported zero (clinically, ~2 weeks) to 40 weeks, with a mean of 22.9 (±10.2; n=339). Additional sample socio-demographic and health characteristics included in main study analyses are presented in Table 1.

Three hundred nineteen respondents answered the question "Do you think that pregnant women should take or eat probiotics to be healthy?". Of these, 149 (47 %) answered "yes", 157 (49 %) answered "not sure", and 13 (4 %) answered "no". Three hundred and six respondents answered the question "Do you take or eat probiotics?", with 155 (51 %) answering "yes" and 151 (49 %) answering "no". One hundred sixty-three of these respondents, including 11 who did not identify as probiotics takers, detailed their main sources of probiotics, with 122 (75 %) answering probiotic yogurt, kefir or other fermented dairy products, 30 (19 %) answering probiotic pills and/or powder, and eight (5 %) answering other fermented foods and/or drinks (most of these were home-made kombucha brews). Notably, most (116; 82 %) but not all of 142 respondents who answered "yes" to the question about whether they thought taking probiotics was healthy for pregnant people and who also answered the question about taking probiotics, then reported actually taking probiotics. Most (111; 74 %) of those who responded "not sure" did not take probiotics; only one person of the 15 (i.e., 7 %) who responded that they didn't think probiotics were healthy for pregnancy reported that they took or ate probiotics despite their beliefs. There are no obvious socio-demographic features in common among the sub-group who reported agreeing that probiotics are healthy during pregnancy but who did not report taking them. The sub-group which reported being unsure about whether probiotics were healthy during pregnancy but took them regardless had, overwhelmingly (72 %), completed at least one post-secondary degree.

Frequencies of positive (i.e., "yes") responses to the questions "Do you take or eat probiotics?" and "Do you think pregnant women should take or eat probiotics to be healthy" by socio-demographic and health indicators, as well as chi-square statistics, are presented in Table 2. Generally, respondents with incomes from employment wages/salaries, with above-poverty-level household incomes, and with completed post-secondary education were relatively likely both to agree that probiotic consumption was healthy during pregnancy, and to actually take probiotics. There was no evidence that maternal age, self-identifying as non-white/non-European, status as a newcomer to Canada, or urban versus rural living, was associated with likelihood of taking and/or believing in the efficacy of probiotics during pregnancy. There was also no evidence that having any indicators of poorer metabolic health prior to or during pregnancy increased the likelihood that respondents reported believing in the benefits of and/or taking probiotics. Our supplementary analyses concerning attitudes towards supplements and functional foods during pregnancy more broadly align with these observed patterns (that is, there were differences only with respect to sources of household income, whether or not annual household earnings were below $20,000, and whether or not the respondent had completed a university degree; there were no differences by maternal age group, self-identification as non-white/non-European, newcomer status, rural living status, or by pregnancy health indicators or risk factors; see S Text 1 and S Table 1.1).

The results of the full logistic regression model predicting log-odds of taking probiotics are presented in Table 3. Agreeing that probiotics are healthy during pregnancy and holding a college or university degree were the only significant predictors of increased log-likelihood of taking probiotics when adjusting for other candidate predictors and for gestational age. A supplemental analysis modeled score on general attitudes to nutraceuticals during pregnancy as a function of any socio-demographic and/or pregnancy health indicators suggested by chi-square tests to be candidate predictors of such attitudes. This analysis recapitulates the main findings in the "takes probiotics" model (see S Text 1 and S Table 1.2). A sensitivity analysis in which income and education were combined and treated as a discrete socio-economic position variable rather than two dummy variables also generally recapitulates these core findings (see S Text 2 and S Table 2.1).

Our primary aims here were to investigate: the extent to which pregnant Canadians were taking probiotics and/or thought that taking them was beneficial to pregnancy health; whether, in keeping with the current state of evidence, people diagnosed with or at elevated risk of GDM were taking them; and whether there were structural inequities (e.g. poverty- or education- related barriers to access) in who was taking probiotics in pregnancy. Nevertheless, we also carried out three supplementary analyses that may hint at mechanisms through which pregnancy probiotics knowledge and attitudes are transmitted and/or translated into behaviour. These analyses show weak evidence (we cannot, however, confidently reject null hypotheses of no effects) that log-likelihood of taking probiotics increases when a respondent's number of total sources of information about pregnancy health and nutrition increases, and when their general self-efficacy (a measure of how much control they think they have over their lives and behaviour) increases. These analyses, which adjusted for socio-economic factors as well as gestation week, are reported and briefly discussed in the supplementary materials (see S Text 3, and S Table 3.1).

Table 1
Socio-demographic characteristics of respondents to the Mothers to Babies (M2B) survey (n=341).

Variable	n	Frequency (%)
Total respondents eligible for inclusion in any analysis	341	NA
Respondent's age over 35	339	58 (17 %)
Household income mainly from government cash transfers	339	55 (16 %)
Household income below $20,000 per annum	320	68 (21 %)
Respondent's educational attainment at or beyond completed college or university degree level	335	238 (71 %)
Identifies ethnically or racially with one or more non-White and/or non-European populations	340	96 (28 %)
Has lived in Canada for less than 5 years	340	34 (10 %)
Lives in a rural or ex-urban postal code	339	72 (21 %)
Pre-pregnancy overall health score very good (4) or excellent (5)	340	213 (63 %)
Pregnancy overall health score very good (4) or excellent (5)	340	169 (50 %)
Pre-pregnancy overweight or obesity	310	141 (45 %)
Pregnancy weight gain trajectory in excess of recommendations	302	124 (41 %)
Diagnosis with GDM, for respondents past 24 wks of gestation at time of response	155	19 (12 %)

4. Discussion

Our analyses indicate that nearly half (47 %) of pregnant respondents to the M2B survey perceive probiotic use to be beneficial to health during pregnancy, and slightly over half (51 %) of respondents reported taking or eating probiotics during their pregnancies. Attitudes towards and reported consumption of probiotics during pregnancy were strongly socio-demographically patterned in this sample. Specifically, respondents from higher income (generally waged/salaried employment income) households and respondents with completed post-secondary education were more likely to perceive probiotics as healthy for pregnant people and to report taking probiotics during pregnancy. Further, the data suggest that education rather than income may represent the most important socio-demographic factor predicting consumption of probiotics during pregnancy in this sample. The belief that probiotics might be beneficial for pregnancy metabolic health and the taking of probiotics appears to be independent of pre-pregnancy or pregnancy health indicators like obesity or excess gestational weight gain or diagnosis with GDM, possibly suggesting that probiotics are not being used to attenuate pregnancy health risks or metabolism-related pregnancy complications, as might have been predicted by the current evidence, which only supports the taking of probiotics during pregnancy as a treatment for metabolic complications (mainly GDM). Rather, the

Table 2
Comparisons (using chi-squared) across binary socio-demographic or health indicator categories of respondents' likelihoods of agreeing with the statement that probiotics are healthy during pregnancy and of reporting taking probiotics during pregnancy.

Socio-demographic or health variable		Probiotic Use				Agrees Probiotics Healthy during Pregnancy			
		Yes	No	χ2	p	Yes	No/Not sure	χ2	p
Respondent's age	≤ 35 yrs	128	127	0.22	0.636	124	129	0.05	0.831
	36+ yrs	27	22			24	30		
Main household income source	Waged or salaried employment	136	117	3.99	0.046*	136	130	12.011	0.001**
	Government cash transfers	19	32			12	39		
Household income per annum	≤ $19,999	22	42	8.16	0.004**	17	46	10.65	0.001**
	$20,000+	98	123			120	115		
Respondent's education	Holds college or university degree	124	87	14.75	0.000***	118	103	10.44	0.001**
	Does not hold degree	30	59			30	62		
Ethnic or racial identity	Identifies as racialized/ minority	44	42	0.06	0.814	35	53	2.07	0.149
	Identifies as White and/or European	112	107			114	116		
Newcomer status	Immigrated to Canada within last 5 years	14	18	0.43	0.510	11	21	1.70	0.192
	Resident of Canada for 5+ years	141	132			138	148		
Postal code urban/sub-urban versus rural/ ex-urban	Urban/sub-urban	116	112	1.23	0.258	113	135	0.39	0.533
	Rural/ex-urban	38	28			35	34		
Pre-pregnancy overall health status	Excellent or very good	106	90	1.98	0.159	103	100	3.52	0.061
	Good, fair, or poor	49	60			45	70		
Pregnancy overall health status	Excellent or very good	85	71	1.43	0.232	84	78	3.32	0.068
	Good, fair, or poor	70	79			64	92		
Pre-pregnancy overweight or obesity	BMI ≥25	71	63	0.25	0.618	69	70	0.376	0.540
	≤24.9	78	80			75	90		
Gestational weight gain trajectory	Above recommended range	62	53	0.33	0.565	60	60	0.42	0.515
	Within or below recommended range	84	85			80	96		
GDM status	Diagnosed with GDM	9	9	0.01	0.908	7	12	1.27	0.258
	Not diagnosed with GDM and gestational age 25+ weeks	71	59			73	63		

Table 3
Associations between reported pre-/pro-biotic use during pregnancy and socio-demographic and pregnancy characteristics in M2B survey respondents.

Independent variable	Estimate, log-odds (s.e.)	Adjusted odds ratio	95 % CI	p
Agrees probiotics healthy during pregnancy	2.645 (0.311)	14.09	7.81-26.48	0.000***
Household income mainly from government cash transfers	-0.740 (0.581)	0.48	0.15-1.47	0.202
Household income below $20,000 per annum	-0.172 (0.544)	0.84	0.29-2.44	0.752
Holds college or university degree	0.959 (0.406)	2.61	1.19-5.88	0.018*
Gestational age	0.008 (0.015)	1.01	0.98-1.03	0.607

data, which suggest that positive attitudes towards and the taking of probiotics during pregnancy are concentrated among pregnant people of relatively high socio-economic positions, imply that there are other (e.g., social status) reasons for these attitudes and behaviours.

The results of the study reported here differ in several respects from those of the only previous comparable quantitative study on pregnant people's attitudes towards probiotics.i.e [32]. (but see [33] for a randomized controlled trial approach to integrating probiotic administration to community-engaged strategies for mitigating GDM). This other study, by Bridgman and colleagues, of 413 post-partum people living in urban and suburban Alberta, Canada, focused mainly on giving probiotics to infants but also presented retrospective data on maternal use of probiotics during pregnancy [32]. Bridgman et al. [32] reported that fully 73 % of respondents perceived probiotics as likely to be beneficial to health and 89 % reported having taken probiotics during pregnancy; these rates, respectively, are 1.6 and 1.7 times greater than what we found in the M2B sample. Furthermore, Bridgman and colleagues did not report any differences between socio-demographic groups in probiotic use [29], whereas we found clear associations between education and pro-probiotic attitudes and intake. The most likely explanation for these differences in findings is that the Alberta sample is more homogenously well-educated and of middle or higher income than the Hamilton cohort. That is, 93 % of the Albertan respondents had completed some form of post-secondary education compared to only 71 % in the Hamilton sample, and only 2 % of Albertan respondents had household incomes below $20,000/annum compared to 21 % in the Hamilton sample. Given that science journalism tends to be tailored largely to a well-educated audience [34], the well-educated Albertan respondents were likely more exposed to the idea of taking probiotics by science media. Indeed, 43 % of the Albertan mothers indicated that they had learned about probiotics through one or more media channels. In keeping with this reasoning, our supplementary analyses may provide some (weak) evidence that identifying a higher number of sources of pregnancy health and nutrition information (including traditional and social media channels) is associated with a greater likelihood of reporting positive views on taking probiotics during pregnancy (again, see S Text 2, and S Table 2.1). Additionally, as few of the Albertan respondents were living with poverty and thus did not face financial barriers, they were relatively likely to translate their perception of probiotics as beneficial into the purchase of probiotics.

Our study has a number of limitations and therefore we are unable to offer alternative, data-driven explanations for the discrepancies between the Alberta findings and ours [29], or for our intriguing null result that probiotic use does not appear to be related to indicators of pre-pregnancy or pregnancy health. Specifically, because the questionnaire was designed to characterize respondents' pregnancy health and nutrition experiences and knowledge broadly, no specific questions were asked about sources from which respondents learned about probiotics, why respondents perceived probiotics to be beneficial or not, or whether respondents were aware that probiotics *may* be protective against some complications associated with excess adiposity in pregnancy. Additionally, our relatively small sample size and low cell numbers with respect to GDM diagnoses may contribute to a Type II error where we failed to detect a relationship between reported GDM diagnosis and probiotic use.

Despite these limitations, this study extends our current, almost non-existent, understanding of the general public's perceptions about probiotic use during pregnancy in diverse populations from high-income, high-information countries like Canada. Our findings highlight three key points. First, while some pregnant respondents appear to perceive probiotics as beneficial to pregnancy health and are thus taking them, many are not, and these attitudes and behaviours are strongly patterned by income and education. In other words, familiarity with the idea that probiotics *may* be beneficial to metabolic health and, more importantly, the ability to purchase them, is socio-economically inequitable. Rather than reaching segments of the population who might be especially in need of a hand up, i.e., people living with poverty and people with lower educational attainment levels, and/or people at elevated risk for metabolic complications of pregnancy, pro-probiotic messaging has mainly reached the wealthiest, most-educated segments of the population who are already expected to be at the top of the health gradient [36]. As the state of scientific knowledge regarding whether and how to manipulate gut microbiomes in ways beneficial to metabolic health catapults forward [13,15], the attitudinal and behavioural inequities in pregnancy probiotic use and the problems in the knowledge/ information translation pipelines underline the need for deeper understandings of who takes probiotics in pregnancy, under which conditions, and why. The present study represents a small step in this direction, but many more, in different contexts and with different populations, are needed. Expanding this line of inquiry will require overcoming considerable economic and socio-political barriers to research, collaboration, and dissemination, alongside challenging corporate interests in marketing probiotics, often of unknown efficacy [36]. Second, if the case is made more convincingly that probiotic use in pregnancy can attenuate some of the key negative effects of pregnancy metabolic disorders like GDM, we will need to think seriously at policy as well as messaging and behavioural change intervention (e.g., self-efficacy building) levels about what can be done to overcome income- and education-based inequities in who takes probiotics. Finally, irrespective of whether the emerging science ultimately supports or contraindicates the consumption of probiotics during pregnancy, the science media and the public seem to be ringing bells of endorsement prematurely [10]. This eagerness to spread the probiotic word and to encourage allocation of personal resources to nutraceuticals when the evidence base remains mixed or even counter-indicative suggests that the complexity and uncertainty in this knowledge is not being effectively exchanged among researchers, clinicians, community health and social care professionals, and pregnant people. Building communications and engaging stakeholders regarding what we do know about the role of the gut microbiome in pregnancy metabolism, adiposity, and health may better prepare relevant audiences to make sense of the pregnancy probiotics and larger pregnancy nutraceuticals literatures as they continue to emerge. Improving the relevant knowledge exchange environment may, in turn, constitute one small component of mitigating the growing public health challenge that is poor metabolic health in pregnancy, concentrated disproportionately among people with low incomes and lower educational attainment. Supporting better metabolic health during pregnancy among the most socio-economically disadvantaged should, ultimately, improve equity in health and mitigate inequitable disease risks in the next and subsequent generations.

5. Conclusions

We sought to raise and answer the questions 'who is taking probiotics during pregnancy?', 'Are there inequities in who is taking probiotics during pregnancy?' and, 'Are pregnant people who are most likely to benefit health-wise from taking probiotics more likely to be taking them?' To address these questions, we first reviewed the evidence regarding efficacy of taking probiotics during pregnancy to prevent and/or treat pregnancy complications. Recent evidence syntheses (systematic reviews and/or meta-analyses) do not support the claim that there are likely to be prophylactic benefits to taking probiotics during pregnancy, although they do suggest that there may be modest health benefits to pregnant people who take probiotics as a treatment for gestational diabetes mellitus.

Our study is among the first to characterize attitudes to probiotic use in a socio-demographically diverse sample of pregnant people. Consistent with what, to our knowledge, is the only other previous study on this topic, we show that a plurality of healthy, pregnant Canadians are consuming probiotics during pregnancy, despite a lack of empirical evidence for the idea that taking probiotics during pregnancy offers health benefits to otherwise normal, healthy pregnancies. These analyses offer the novel insight that alterable socio-demographic factors linked with the well-documented social gradient in health [35], like income and education, may be more important determinants of probiotic use during pregnancy than clinical indications for pregnancy complications that perhaps can be partly managed or mitigated through probiotic consumption.

Guidelines and clinical recommendations should underline that there are no known benefits to taking probiotics during pregnancy in the absence of a diagnosis with a pregnancy complication like gestational diabetes mellitus (GDM), that there may even be some possible detrimental outcomes, that the probiotics market is complicated and flooded with many strains of probiotics of unknown efficacy which should be treated with skepticism, and that there are significant financial costs associated with taking probiotics. Guidelines should also suggest that if clinicians consider recommending probiotic consumption during pregnancy, this must be done alongside other changes to diet and exercise, following GDM diagnoses. Our view is that subsidies should be made available to lower-income pregnant people diagnosed with GDM to facilitate equitable access to probiotics when (and if) they are shown to confer health benefits.

Ethical Approval

The protocol for this study was reviewed and approved by the Hamilton Integrated Research Ethics Board (HIREB), protocol #0570.

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CRediT authorship contribution statement

L McKerracher: literature search re probiotics and pregnancy health knowledge exchange; study design; data collection, analysis, interpretation; writing; editing; funding acquisition

T Moffat: literature search re pregnancy health knowledge exchange; data collection, interpretation; editing; supervision; funding acquisition

ME Barker: data interpretation, editing, supervision, funding acquisition

B Murray-Davis: data collection, interpretation; editing; funding acquisition

KM Kennedy: literature search re probiotics in pregnancy and pregnancy microbiome; data analysis, interpretation; editing

CJ Bellissimo: literature search re probiotics in pregnancy and pregnancy microbiome; data interpretation; editing

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V Parlette: data collection, interpretation; editing; funding acquisition

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DM Sloboda: study design; data collection, interpretation; editing; supervision; funding acquisition

Declaration of Competing Interest

The authors declare no competing/ conflicts of interest.

Data availability

Link to data archived on OSF is available in manuscript; data also available on request from lead author

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.phanu.2023.100344.

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