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ORIGINAL RESEARCH

Regional differences in the prevalence of obstetric complications in relation to maternal obesity and food purchases

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Abstract

Introduction: Regional variations exist in the prevalence of type 2 diabetes and cardiovascular disease in Finland. As these conditions share risk factors with major obstetric complications, we aimed to investigate whether there are geographical differences in the prevalence of pregnancy complications and if these differences could be explained by known risk factors such as maternal obesity or dietary intake.

Material and Methods: In this observational study, data from the Finnish Medical Birth Register and the Hospital Discharge Register were analyzed for primiparous women who had singleton births in Finland from 2013 to 2017. We calculated regional prevalence rates of gestational diabetes, gestational hypertension, preeclampsia, and premature birth. Loyalty card data from the largest food retailer were utilized to assess the regional average of food purchases of fertile-age women living in single- or two-adult households between September 2016 and December 2017. The datasets were merged by postal codes and organized by cardinal direction regions.

Results: The birth register included 109 306 women, and data from 3937 purchasers were analyzed. Compared with women living in Southern Finland, those living in the North had higher odds for gestational hypertension (adjusted OR 1.36, 95% CI 1.10–1.68, $p=0.005$), while women living in Eastern Finland had greater odds for preeclampsia (adjusted OR 1.21, 95% CI 1.02–1.44, $p=0.030$). We did not find regional differences in the prevalence of gestational diabetes or preterm birth. Higher average areal fiber content of the purchases decreased the odds of gestational hypertension (OR 0.90, 95% CI 0.89–0.99, $p=0.022$), and diminished gestational hypertension's geographical disparity. Higher means in areal red and processed meat purchases were associated with preterm birth (OR 1.29, 95% CI 1.02–1.62, $p=0.031$), and a high maternal body mass index was related to all

Abbreviations: BMI, body mass index; GDM, gestational diabetes; GH, gestational hypertension; HDR, Hospital Discharge Register; ICD-10, International Statistical Classification of Diseases and Related Health Problems; MBR, Finnish Medical Birth Register.

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pregnancy complications (OR 1.3–9.8, $p<0.001$ in all comparisons), but they did not account for regional differences.
Conclusions: Compared with Southern Finland, hypertensive pregnancy complications were more prevalent in women living in Eastern and Northern Finland. Obesity did not explain regional differences, whereas lower fiber content of purchases in these regions may have contributed to the prevalence of pregnancy hypertension.

KEYWORDS
body mass index, gestational diabetes, gestational hypertension, loyalty card, nutrient, preeclampsia, pregnancy, premature labor

1 | INTRODUCTION

Historically, there has been strong regional differences in obesity and cardiovascular disease prevalence in Finland, with the highest prevalence in North Karelia, Eastern Finland.[1] Fifty years ago, The North Karelia Project was launched, and it successfully managed to reduce cardiovascular disease risk factors and mortality related to them by comprehensive community-based lifestyle counseling intervention.[2,3] Nevertheless, according to recent Finnish Institute for Health and Welfare's statistical reports, regional differences prevail.[4] Especially in the Northern and Eastern parts of Finland, mortality from cardiovascular diseases is still higher.

Pregnancy serves as a metabolic and vascular stress test, as the occurrence of common pregnancy complications has been demonstrated to forecast a woman's susceptibility to later morbidity. Gestational diabetes (GDM) is known to predispose to later type 2 diabetes, hypertension, and cardiovascular diseases,[5,6] and likewise gestational hypertension (GH) and preeclampsia increase the future risk of hypertension, coronary heart disease, stroke, and death due to cardiovascular disease.[7–9] Hence, pregnancy offers an early window of opportunity to identify women at risk and enhance their long-term health.

Multiple lifestyle-related risk factors are likely to lie behind both geographical health discrepancies and adverse pregnancy outcomes.[1,9–11] Understanding the promoters of the regional differences in obstetric complications and morbidity related to it might help to target and provide guidance for the most promising regional intervention strategies in Finland, but also in other high-income countries.

This study investigates potential regional differences in pregnancy complications among the generation following the North Karelia Project. It also explores whether these differences can be attributed to regional variations in maternal obesity prevalence and the healthiness of food purchases among fertile-aged women, utilizing a novel approach that combines at regional level nationwide health registry data with actual food purchase data from consented loyalty card holders.

Key message

Hypertensive pregnancy complications were more prevalent in Eastern and Northern Finland. Low fiber consumption in these regions may increase the odds of gestational hypertension and explain certain regional differences. Conversely, obesity does not seem to explain the regional differences.

2 | MATERIAL AND METHODS

In this study, three separate datasets were utilized. First, information on maternal characteristics and pregnancy complications was extracted from the Medical Birth Register (MBR) and the Hospital Discharge Register (HDR) to study regional differences in pregnancy complications. Usage of the MBR and HDR data was approved by the Finnish Institute for Health and Welfare as the register keeper and the permission was updated by the Finnish Social and Health Data Permit Authority Findata in 2022. Second, to assess the regional differences in food purchases, data obtained from the LoCard study was used. In the LoCard study,[12] large-scale customer loyalty card data from Finland's largest food retailer (S Group) is used to investigate various aspects such as quality and changes in consumers' food consumption patterns. The study was reviewed by the University of Helsinki Ethical Review Board in Humanities and Social and Behavioral Sciences (Statement 21/2018). Food purchase data were first aggregated to summary statistics on the postal code level without individual-level data or identifiers and then merged with the MBR and HDR databases using postal codes converted from women's home municipalities. Combined data were stored and analyzed on a secure and externally audited data analytics platform provided by the Helsinki University Hospital.

2.1 | Data on maternal characteristics and pregnancy complications: MBR and HDR

Data on all primipara women with singleton births in Finland between 1.1.2013 and 31.12.2017 was extracted from the Finnish MBR. This register receives its data electronically from Finnish maternity hospitals, where a form is filled by the hospital staff after each delivery and sent to the register. The data collection form includes comprehensive information on the mother and the neonate, and for the present study, we obtained information on mothers' age and body mass index (BMI), smoking habits, gestational age at delivery, socioeconomic status based on occupation, and pregnancy complications with International Statistical Classification of Diseases and Related Health Problems (ICD-10) codes. MBR collects information on BMI based on pre-pregnancy weight reported by the mother and height measured by public health nurses or midwives at women's first visit to the antenatal clinic. We complemented MBR data with information on maternal pregnancy diagnoses obtained from the Finnish HDR, which includes both hospital inpatient care and outpatient visits from public hospitals, as recorded by the responsible physician as ICD-10 codes.[13] HDR and MBR data were merged using the encrypted unique personal identity code available in both data sources.

GDM, GH, preeclampsia, and preterm delivery were selected as obstetric complications of interest, as they are the most frequent adverse pregnancy outcomes and are known to share common risk factors with cardiovascular disease and type 2 diabetes. To collect data on the prevalence of GDM, information on the pathologic result of the oral glucose tolerance test was extracted from MBR and ICD-10 code O24.4 from both MBR and HDR records. According to the national recommendation, GDM is diagnosed if in 75 g oral glucose tolerance test one or more values are at or above the limits of 5.3 mmol/L (fasting), 10.0 mmol/L (1 h) or 8.6 mmol/L (2 h). Screening for GDM is recommended to be offered to all pregnant women except those few who are at very low risk according to the Finnish Current Care guideline.[14] The diagnosis of GH was extracted as ICD-10 codes O13 and O16 from MBR and HDR records. GH is typically defined as a systolic blood pressure ≥140 mmHg or a diastolic blood pressure ≥90 mmHg after 20 weeks of gestation in previously normotensive women. For preeclampsia, defined as GH with concurrent new onset proteinuria (≥0.3 g/24 h), ICD-10 codes O11, O14, or O15 were searched from both records. Preterm delivery was defined either as ICD-10 code O60 in HDR or duration of gestation between 22 + 0 and 36 + 6 weeks in MBR.

2.2 | Food purchase data

This research leverages extensive data obtained from the loyalty program of Finland's largest food retailer (S Group) with 46% market share in 2018 and a national coverage. In 2018, the retailer's customer loyalty card was held by 2.4 million households in Finland, representing 88% of all Finnish households.[15] Invitations to participate in the study were sent to cardholders nationwide through email, provided they had given consent to be contacted for research purposes. Individuals who granted permission for the use of their purchase data in research were further invited to complete an additional electronic questionnaire that allowed collection of more detailed information such as age-group, household structure, civil status, and education.[16]

Initial food purchase data were obtained from 47 066 participants with purchases between September 1, 2016 and December 31, 2018.[12] To align with the characteristics of women in MBR most effectively, data from September 1, 2016 to December 31, 2017, were included in the study. Only those who had a self-reported degree of loyalty of at least 40% (i.e., participants who made a substantial proportion of their food purchases from the food retailer) were considered to provide sufficient information on their purchase behavior and were included in the analysis. Female participants aged between 18 and 40 years living in single- or two-adult households were included in this study, since their food purchases were considered to best reflect food purchases of primiparous women.

The energy and nutrient content of 1 kg within each product category (such as cucumber, skimmed milk, and vegetarian lasagna) was determined using the nutritional calculation software available at www.fineli.fi. This website relies on the food composition database Fineli®, managed by the Finnish Institute for Health and Welfare. To calculate the absolute energy and nutrient contents of the purchase, the purchase volume (in kg) for each product category was multiplied by the energy and nutrient contents per 1 kg within that category. The resulting energy and nutrient contents of all purchased product categories were aggregated to determine the overall annual energy and nutrient contents of the total purchases.

For the analysis, we included three aggregated food groups and four nutrients, which served as representatives of the healthiness of the food purchases.[17] The aggregated variables were fruits and vegetables, red and processed meat, and discretionary foods, and the following nutrients: fiber, saturated fatty acids, folate, and salt. Discretionary foods included sweets, chocolate, savory snacks (e.g., salted peanuts and potato chips), and sugar-sweetened beverages. The purchased foods and nutrient contents were scaled to 2000 kcal to indicate average individual's daily energy intake, except saturated fat, which was expressed as percentage from total energy intake (E%).

2.3 | Data integration

MBR included information on mother's municipality, which was converted into postal codes, as the food purchases were also aggregated to regional level by postal code. Women with no municipality information in MBR (n = 30) or residence abroad (n = 780) were excluded from the analyses, as were women whose municipality number was incorrect (i.e., municipality number could not be found on official municipality records between 2013 and 2017, n = 34).

Adjacent postal codes were merged to create larger areas. When a municipality encompassed two distinct postal code areas, the area with the greatest number of postal codes within the municipality was selected. Thus, the country was eventually divided into 31 areas.

To assess differences in pregnancy complications on a larger scale, postal code areas were further merged to create four distinct regions representing Southern, Western, Northern, and Eastern Finland. The borders of these areas were selected based on cardiovascular disease morbidity in Finland.[18] Additionally, they follow the genetic division between the east and west among the Finnish population.[19] The region division is visible in Figures 1 and 2.

As the data could not be linked on an individual level (different women in MBR and retailer's database), each woman in MBR was merged with the average food (or nutrient) purchase of their postal code living area, that is, the average amount of food or nutrients purchased per 2000 kcal.

2.4 | Statistical analyses

Baseline characteristics of primipara women in MBR are presented as means and standard deviations, or frequencies and percentages. BMI, the amount of food, and the nutrient content of the purchased food were not normally distributed and are therefore reported as medians with interquartile range, when appropriate.

Regional prevalence of pregnancy complications is reported as a percentage. To estimate the heterogeneity in regional prevalences within each pregnancy complication, a generalized linear mixed model was applied, in which postal code area was used as a random effect.

In a "basic model" generalized linear mixed model, cardinal direction regions were added as fixed effects. In a "confounder adjusted model," the same model was used together with potential confounders: socioeconomic status, age, smoking, and BMI. These confounders were selected since, according to previous literature, they affect the risk of the examined pregnancy complications.[9–11] Socioeconomic status and tobacco smoking were categorized as in MBR, while age and BMI were categorized into four and five groups respectively (Table 1). Missing information was treated as its own category. The sensitivity analysis confirmed that the odds ratios remained practically identical, regardless of whether missing data were treated as a separate category or excluded. The most common category was chosen as a reference category unless the most common category was that with missing information. In the "food and confounder adjusted model" purchases of food groups "fruits and vegetables," "red and processed meat," and "discretionary foods" were added to the confounder adjusted model as continuous variables, using linear terms. Likewise, in the "nutrient and confounder adjusted model," fiber, percentage of saturated fatty acids, folate and salt were in turn added to the confounder adjusted model similarly as continuous variables. If adding food or nutrient in the model notably changed the association between the regions and a pregnancy complication, regional differences in the food purchases or their nutrient content were tested using non-parametric independent samples Kruskal–Wallis test.

The prevalence of relevant pregnancy complications and mean nutrient contents of average food purchases in the cardinal direction regions were illustrated in geographical maps. For the maps of nutrient contents of food purchases, a weighted mean of postal code areas was calculated for each cardinal direction region using the number of participants in each postal code area as the weighting factor.

A p-value <0.05 was considered significant. Analyses were conducted with IBM SPSS statistics version 29.0 for Windows (IBM SPSS Inc). The maps were created using R version 4.3.3. (R Core Team 2024) and packages sf,[20] geofi,[21] ggplot2,[22] RColorBrewer.[23]

3 | RESULTS

MBR and HDR included 109 306 primipara women, and survey data from 3937 loyalty card owners were aggregated for the analyses. The characteristics of women are presented in Table 1.

Food and nutrient content of the food purchases across cardinal direction regions are presented in Table 2 and across postal code areas in Table S1. A median 319 g of fruits and vegetables, 71 g of red and processed meat, and 135 g of discretionary foods were purchased per 2000 kcal of energy. The median fiber content of the purchases was 18.6 g per 2000 kcal and 15.2 E% were saturated fats (Table 2).

The median BMI was 23.1 kg/m^2 (IQR 21.0; 26.2) and varied little across cardinal direction regions (Table 3). The BMI of 25 kg/m^2 or higher significantly increased the odds of all examined pregnancy complications, with the odds growing along with rising BMI (Table 4). Additionally, being above 30 years of age generally increased the odds of the studied complications. However, being under 20 increased the odds of preeclampsia and prematurity. High SES was associated with a reduced likelihood of GDM and preeclampsia but had no influence on premature birth. Furthermore, maternal daily tobacco smoking was protective against developing both preeclampsia and GH but raised the odds of GDM and premature birth.

3.1 | Gestational diabetes

Across the postal code areas, prevalence of GDM ranged from 10% to 23% (median 17.3%) and significant variation was found ($p < 0.001$, Table S2). Although prevalence was highest in Southern Finland (18.2%) and lowest in the North (15.5%) (Table 3), place of residence in any of the cardinal direction regions was not significantly associated with the odds of GDM, and neither were average areal food purchases or nutrient contents of them (Table 4).

3.2 | Gestational hypertension

Across postal code areas, the prevalence of GH ranged from 3.7% to 10.1% (median 6.9%), and variation was significant ($p < 0.001$, Table S2). The prevalence of GH was highest in Northern Finland with 7.9% and lowest in the Southern region with 5.2% (Table 3, Figure 1). In the confounder-adjusted model, living in the Northern region, as opposed to the Southern region of Finland, significantly increased the odds of developing GH (OR 1.36, 95% CI 1.10–1.68, $p = 0.005$ Table 4). After adjusting also for the areal food purchases, the significantly higher odds for GH in the Northern region compared with Southern region persisted but was no longer significant between the four regions ($p = 0.066$). The addition of nutrient

TABLE 1 Characteristics of primiparous women in Medical Birth Register (2013–2017) and Loyalty Card dataset (September 2016–December 2017).

MBR Region		Whole country	North	West	East	South
	n (%)	109 306 (100.0)	14 417 (13.2)	19 152 (17.5)	16 235 (14.9)	59 502 (54.4)
Age (years)		28 (24;32)	26 (23;30)	28 (24;31)	27 (24;31)	29 (25;33)
Age[a]	<20	4250 (3.9)	860 (6.0)	732 (3.8)	766 (4.7)	1892 (3.2)
	20–29	60 611 (55.5)	9236 (64.1)	11 360 (59.3)	10 036 (61.8)	29 979 (50.4)
	30–39	42 143 (38.6)	4125 (28.6)	6734 (35.2)	5160 (31.8)	26 124 (43.9)
	≥40	2302 (2.1)	196 (1.4)	326 (1.7)	273 (1.7)	1507 (2.5)
Socioeconomic status	Upper white-collar workers	12 569 (11.5)	1699 (11.8)	2580 (13.5)	1652 (10.2)	6638 (11.2)
	Lower white-collar workers	27 473 (25.1)	4892 (33.9)	6174 (32.2)	4727 (29.1)	11 680 (19.6)
	Entrepreneurs	1965 (1.8)	309 (2.1)	424 (2.2)	306 (1.9)	926 (1.6)
	Blue-collar workers	9905 (9.1)	1741 (12.1)	2311 (12.1)	1800 (11.1)	4053 (6.8)
	Students	11 026 (10.1)	1819 (12.6)	2584 (13.5)	2266 (14.0)	4357 (7.3)
	Others[b]	1930 (1.8)	395 (2.7)	496 (2.6)	438 (2.7)	628 (1.1)
	No information	44 411 (40.6)	3562 (24.7)	4583 (23.9)	5046 (31.1)	31 220 (52.5)
Marital status	Married or registered partnership	47 838 (43.8)	5989 (41.5)	7733 (40.4)	5941 (36.6)	28 175 (47.4)
	Not married	61 182 (56.0)	8418 (58.3)	11 407 (59.6)	10 264 (63.2)	31 093 (52.3)
	No information	286 (0.3)	10 (0.1)	12 (0.1)	30 (0.2)	234 (0.4)
Cohabiting	Yes	93 794 (85.8)	13 110 (90.9)	17 618 (92.0)	13 186 (81.2)	49 880 (83.8)
	No	6427 (5.9)	866 (6.0)	1216 (6.3)	1450 (8.9)	2895 (4.9)
	No information	9085 (8.3)	440 (3.1)	317 (1.7)	1599 (9.8)	6723 (11.3)
BMI (kg/m^2)		23.1 (21.0;26.2)	23.1 (21.0;26.4)	23.4 (21.2;26.7)	23.4 (21.2;26.7)	22.9 (20.8;25.8)
BMI	<20 kg/m^2	15 384 (14.1)	2095 (14.5)	2426 (12.7)	1973 (12.2)	8890 (14.9)
	20–24 kg/m^2	57 565 (52.7)	7393 (51.3)	9827 (51.3)	8362 (51.5)	31 983 (53.8)
	25–29 kg/m^2	22 125 (20.2)	3019 (20.9)	4141 (21.6)	3460 (21.3)	11 505 (19.3)
	30–34 kg/m^2	8214 (7.5)	1138 (7.9)	1659 (8.7)	1348 (8.3)	4069 (6.8)
	≥35 kg/m^2	4137 (3.8)	581 (4.0)	867 (4.5)	741 (4.6)	1948 (3.3)
	No information	1881 (1.7)	191 (1.3)	232 (1.2)	351 (2.2)	1107 (1.9)
Smoking	No	87 671 (80.2)	11 235 (77.9)	15 438 (80.6)	12 174 (75.0)	48 822 (82.1)
	Stopped during I trimester	10 367 (9.5)	1642 (11.4)	1980 (10.3)	1943 (12.0)	4802 (8.1)
	Smoked after I trimester	8602 (7.9)	1283 (8.9)	1465 (7.6)	1479 (9.1)	4375 (7.3)
	No information	2666 (2.4)	255 (1.8)	269 (1.4)	639 (3.9)	1503 (2.5)
Loyalty Card data	*n*	3937	358	481	733	2365

TABLE 1 (Continued)

MBR						
Region		Whole country	North	West	East	South
Marital status[a,c]	Married or in registered partnership	13.6 (11.1;16.8)	14.3 (6.7;18.1)	16.3 (12.1;29.7)	11.1 (9.5;13.6)	13.6 (11.5;16.0)
	Cohabiting	42.4 (36.9;44.6)	43.2 (37.5:53.3)	42.9 (28.0;49.0)	42.9 (31.8;44.4)	40.9 (36.6;44.3)
	Single	40.5 (35.9;46.1)	38.1 (31.8;44.2)	35.8 (33.0;44.2)	42.9 (39.8;47.7)	45.5 (38.1;46.9)
	Divorced or separated	2.2 (0.0;4.3)	2.2 (0;4.5)	1.3 (0;2.7)	2.8 (0;6.8)	2.4 (1.0;3.8)
Education[a,c]	Master's degree or higher	15.4 (13.3;19.8)	13.6 (11.8;19.0)	16.9 (12.9;37.3)	15.7 (13.6;19.8)	15.4 (12.0;22.7)
	Bachelor's degree or equivalent	38.6 (34.5:43.2)	41.2 (31.0;47.9)	40.9 (27.7;45.0)	38.4 (37.2;41.4)	36.4 (33.0;39.5)
	Upper secondary school	41.2 (33.3;47.7)	41.2 (36.4;50.0)	36.5 (32.9;44.3)	41.7 (41.2;47.6)	40.9 (32.6;51.0)
	Primary school or less	2.22 (0.5;4.2)	2.4 (1.2;4.8)	0.3 (0.0;2.9)	1.4 (0.0;2.3)	2.5 (2.1;4.3)

Note: Results are reported as median (IQR) or *n* (%).
[a]No missing information.
[b]Others: housewives, unemployed, retirees.
[c]Median percentage across 31 postal code areas.

TABLE 2 Food purchases and nutrient content of food purchases of loyalty card holders across cardinal direction regions from September 2016 to December 2017.

	Fruits and vegetables[a]			Red and processed meat[a]			Discretionary foods[a]			Fiber[a]			Saturated fat %[b]			Folate[c]			Salt[d]		
	Median	Q1	Q3	Median	Q1	Q3	Median	Q1	Q3	Median	Q1	Q3	Median	Q1	Q3	Median	Q1	Q3	Median	Q1	Q3
Southern Finland	320	285	380	59	49	81	140	109	153	20.1	18.1	22.0	15.0	15.0	15.5	228	220	249	7102	6897	7225
Western Finland	305	283	321	78	62	78	135	118	146	18.1	17.5	19.4	15.6	14.6	16.0	219	219	224	7320	6391	7581
Eastern Finland	329	286	334	69	69	75	133	133	137	19.5	18.5	19.5	15.0	14.6	15.3	226	215	231	6864	6716	6937
Northern Finland	310	239	416	64	61	81	138	109	153	18.6	17.4	20.1	15.3	14.4	15.6	253	214	286	6992	6992	7218
Whole country	319	285	334	71	59	81	135	118	146	18.6	18.1	20.1	15.2	15.0	15.6	226	219	236	6996	6864	7320

[a]g per 2000 kcal.
[b]Percentage from the total energy content of purchases (E%).
[c]µg per2000 kcal.
[d]mg per 2000 kcal.

TABLE 3 Prevalence of pregnancy complications among primiparous women across cardinal direction regions in Finland between 2013 and 2017.

	n (%)	Gestational diabetes *n* (%)	Gestational hypertension *n* (%)	Preeclampsia *n* (%)	Preterm birth *n* (%)
Southern region	59 502 (54.4)	10 820 (18.2)	3079 (5.2)	2199 (3.7)	3073 (5.2)
Western region	19 152 (17.5)	3253 (17.0)	1355 (7.1)	648 (3.4)	1116 (5.8)
Eastern region	16 235 (14.9)	2638 (16.2)	1086 (6.7)	793 (4.9)	945 (5.8)
Northern region	14 417 (13.2)	2236 (15.5)	1145 (7.9)	667 (4.6)	769 (5.3)
Whole country	109 306 (100.0)	17.3 (15.8;20.8)[a]	6.9 (5.6;8.3)[a]	4.1 (3.6;4.9)[a]	5.5 (5.2;6.0)[a]

[a]Median percentage (IQR).

contents of food purchases to the model diluted geographical differences. Higher average fiber content of the purchases in the area reduced the odds of GH diagnosis (OR 0.90, 95% CI 0.89–0.99, $p=0.022$ Table 4).

The groceries of women living in the Southern region contained more fiber than those of women living elsewhere ($p<0.001$), whereas the least fiber was purchased in the Western part of Finland (Table 2, Figure 2).

3.3 | Preeclampsia

Around 4% of women developed preeclampsia during the study period, with the range across different postal code areas varying from 2.4% to 6.5% (variance $p=0.002$, Supplementary Table S2). The highest prevalence of preeclampsia (4.9%) was found in Eastern Finland and the lowest (3.4%) in Western Finland (Table 3, Figure 1). With or without adjustments for confounders (SES, age, smoking, BMI), women residing in the Eastern region had significantly greater odds of being diagnosed with preeclampsia compared with women residing in the Southern region (OR 1.24, 95% CI 1.03–1.50, $p=0.024$ and adjusted OR 1.21, 95% CI 1.02–1.44, $p=0.030$, Table 4).

When food group purchases in the areas were added to the analysis along with confounding factors and cardinal direction regions, it was observed that women residing in the Western region had reduced odds for preeclampsia compared with women living in the Southern region, although no specific food group had a significant association. Analysis of nutrient contents of purchases yielded no significant associations (Table 4).

3.4 | Preterm birth

Across the postal code areas, median 5.5% of women gave birth prematurely before 37+0 gestational weeks, with the proportion ranging from 4.6% to 7.2% ($p=0.013$, Table S2). Prevalence varied from 5.2% to 5.8% between cardinal direction regions (Table 3). Residence in any of the cardinal direction regions did not significantly influence the odds of premature birth in either adjusted or non-adjusted analyses (Table 4).

The areal food purchases did not significantly explain the geographical variation in the prevalence of premature birth, although purchases of red and processed meat were positively associated with increased odds of preterm birth (OR 1.29, 95% CI 1.02–1.62, $p=0.031$) (Table 4).

4 | DISCUSSION

We found significant regional differences in the prevalence of gestational hypertensive complications in Finland. Women living in the Northern region of Finland had a higher risk of developing GH than women living in Southern Finland. The difference was associated with the regional fiber content of food purchases, with significantly more fiber-rich foods being purchased in the Southern region. Women residing in Eastern Finland had a significantly greater risk for preeclampsia compared to those living in the Southern region. Neither the healthiness of food purchases nor the nutrient contents of food purchases were associated with the geographical differences in the prevalence of preeclampsia. Although high BMI was a strong risk factor for all examined pregnancy complications, adjustment for BMI did not diminish the geographical differences in hypertensive disorders.

GH and preeclampsia are recognized as risk factors for future cardiovascular disease.[24] According to the statistical reports from the Finnish Institute for Health and Welfare,[25] regional variations in the prevalence of coronary heart disease persist, with the highest prevalence observed in the East and North of Finland. Our study confirms that these disparities extend to obstetric complications. Twenty years ago, using data from the FINRISK 2002 survey study, Kaaja et al. examined women with a history of preeclamptic pregnancy.[26] They reported a notably higher risk of preeclampsia in Northern Finland compared with the Southern regions, and this discrepancy to be partially explained by established risk factors for coronary artery disease, such as increased blood cholesterol, blood pressure, and BMI. Additionally, they did not detect regional differences in the prevalence of hypertension, and the higher prevalence of preeclampsia in the Eastern regions was only observed in the age-adjusted logistic regression model.[26] The disparities between their findings and ours may stem from the fact that their study included comprehensively Northern parts of Finland but focused only on

TABLE 4 Association of socioeconomic status, age, tobacco smoking, body mass index and food purchases with the risk and regional variance in the prevalence of pregnancy complications.

		Gestational diabetes			Gestational hypertension			Preeclampsia			Preterm birth <37 gw		
		OR	95% CI		OR	95% CI		OR	95% CI		OR	95% CI	
Basic model													
Regions	Northern Finland	0.92	0.73	1.15	1.39	1.09	1.76	1.2	0.99	1.45	1.03	0.90	1.17
	Western Finland	0.95	0.75	1.21	1.23	0.96	1.58	0.87	0.71	1.06	1.10	0.97	1.26
	Eastern Finland	0.94	0.74	1.18	1.14	0.89	1.45	1.24	1.03	1.5	1.14	1.00	1.30
	Southern Finland	Ref.	Ref.	Ref.	Ref.			Ref.			Ref.		
	p	0.887			0.051			0.004			0.193		
Confounder-adjusted model[a]													
Socioeconomic status	Upper white-collar workers	0.82	0.77	0.87	0.79	0.72	0.86	0.87	0.77	0.97	0.94	0.86	1.04
	Entrepreneurs	1.03	0.91	1.17	0.90	0.74	1.09	0.87	0.68	1.12	0.92	0.75	1.14
	Blue-collar workers	1.04	0.97	1.11	0.90	0.82	0.99	1.01	0.90	1.14	0.98	0.88	1.09
	Students	0.95	0.89	1.01	0.83	0.75	0.91	0.96	0.85	1.07	0.96	0.87	1.06
	Others	1.06	0.93	1.21	0.79	0.65	0.96	1.15	0.92	1.43	0.86	0.69	1.07
	No information	0.95	0.91	0.99	0.78	0.73	0.84	0.90	0.83	0.98	0.98	0.91	1.05
	Lower white-collar workers	Ref.			Ref.			Ref.			Ref.		
	p	<0.001			<0.001			0.028			0.759		
Age (years)	<20	0.59	0.53	0.66	1.03	0.89	1.19	1.39	1.19	1.63	1.18	1.03	1.36
	30–39	1.68	1.62	1.74	1.17	1.11	1.24	1.04	0.97	1.11	1.25	1.18	1.33
	>40	2.79	2.53	3.07	1.88	1.63	2.17	1.62	1.36	1.94	1.93	1.65	2.24
	20–29	Ref.	Ref.	Ref.	Ref.			Ref.			Ref.		
	p	<0.001			<0.001			<0.001			<0.001		
Tobacco smoking	Smoked during I trimester	1.19	1.12	1.26	1.14	1.05	1.24	0.96	0.86	1.06	0.96	0.87	1.06
	Smoked daily	1.17	1.09	1.24	0.89	0.80	0.98	0.79	0.70	0.90	1.26	1.14	1.39
	Smoked infrequently	1.05	0.77	1.43	1.24	0.84	1.82	1.11	0.68	1.81	1.28	0.83	1.98
	No information	1.06	0.93	1.21	1.10	0.92	1.33	1.09	0.87	1.36	1.42	1.19	1.70
	No smoking	Ref.	Ref.	Ref.	Ref.			Ref.			Ref.		
	p	<0.001			<0.001			0.006			<0.001		
Body mass index (kg/m^2)	<20	0.75	0.70	0.80	0.70	0.63	0.77	0.78	0.70	0.87	1.05	0.97	1.14
	25–29.99	2.34	2.25	2.44	1.72	1.61	1.83	1.39	1.29	1.50	1.09	1.02	1.17
	30–34.99	4.54	4.31	4.79	2.88	2.67	3.11	1.98	1.80	2.19	1.29	1.17	1.42
	≥35	9.78	9.13	10.47	4.36	3.99	4.77	2.64	2.34	2.97	1.27	1.12	1.45
	20–24.99	Ref.	Ref.	Ref.	Ref.			Ref.			Ref.		
	p	<0.001			<0.001			<0.001			<0.001		
Regions	Northern Finland	0.93	0.73	1.19	1.36	1.10	1.68	1.17	0.99	1.39	1.06	0.93	1.20
	Western Finland	0.91	0.71	1.17	1.16	0.93	1.44	0.84	0.70	1.00	1.13	1.00	1.28
	Eastern Finland	0.90	0.70	1.14	1.08	0.87	1.34	1.21	1.02	1.44	1.14	1.01	1.29
	Southern Finland	Ref.			Ref.			Ref.			Ref.		
	p	0.808			0.042			<0.001			0.114		

(Continues)

TABLE 4 (Continued)

		Gestational diabetes			Gestational hypertension			Preeclampsia			Preterm birth <37 gw		
		OR	95% CI		OR	95% CI		OR	95% CI		OR	95% CI	
Food and confounder-adjusted model[a,b]													
	Fruits and Vegetables	0.99	0.88	1.11	0.97	0.87	1.07	1.00	0.91	1.09	1.01	0.95	1.08
	p	0.855			0.532			0.912			0.663		
	Red and processed meat	1.18	0.76	1.83	0.91	0.61	1.37	1.16	0.83	1.62	1.29	1.02	1.62
	p	0.471			0.657			0.371			0.031		
	Discretionary foods	0.91	0.75	1.12	1.03	0.86	1.24	0.97	0.84	1.13	0.99	0.89	1.09
	p	0.375			0.719			0.731			0.812		
Regions	Northern Finland	0.88	0.67	1.16	1.38	1.09	1.75	1.15	0.95	1.38	1.03	0.91	1.17
	Western Finland	0.86	0.65	1.14	1.16	0.91	1.49	0.81	0.67	0.99	1.10	0.97	1.24
	Eastern Finland	0.84	0.63	1.11	1.11	0.87	1.43	1.17	0.96	1.41	1.09	0.96	1.23
	Southern Finland	Ref.			Ref.			Ref.			Ref.		
	p	0.599			0.066			0.002			0.404		
Nutrient and confounder-adjusted model[a,b]													
	Fiber	1.07	0.96	1.18	0.90	0.83	0.99	0.98	0.90	1.06	0.97	0.92	1.03
	p	0.227			0.022			0.582			0.354		
	Saturated fatty acids %	0.89	0.78	1.03	1.12	0.99	1.26	0.94	0.84	1.06	0.95	0.88	1.03
	p	0.115			0.074			0.298			0.235		
	Folate	0.99	0.98	1.00	1.01	1.00	1.01	1.00	0.99	1.01	1.00	0.99	1.00
	p	0.068			0.096			0.707			0.646		
	Salt	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	p	0.109			0.237			0.294			0.268		
Regions	Northern Finland	1.06	0.78	1.45	1.11	0.85	1.44	1.16	0.91	1.48	1.04	0.88	1.24
	Western Finland	0.99	0.78	1.27	1.06	0.87	1.30	0.84	0.70	1.01	1.12	0.99	1.27
	Eastern Finland	0.82	0.65	1.05	1.20	0.98	1.46	1.18	0.99	1.42	1.12	0.99	1.28
	Southern Finland	Ref.			Ref.			Ref.			Ref.		
	p	0.391			0.355			0.008			0.164		

Note: Analyses: Generalized linear mixed model.

Abbreviation: GW, Gestational weeks.

[a]Analyses were adjusted for age, socioeconomic status, tobacco smoking, and BMI.

[b]Continuous variables.

specific areas in Eastern and Southern Finland, without including any Western regions. Nonetheless, according to both studies, obstetric complications related to high blood pressure are more prevalent in the Northern and Eastern parts of Finland, even after accounting for most relevant risk factors, such as maternal age, smoking, and BMI. The prevalence of GH and preeclampsia has markedly decreased in Finland since the study by Kaaja et al.,[26] which reported significantly higher rates compared with our findings. This difference may reflect a general decline in cardiovascular disease mortality[27] or differences in study design, as their study was a survey conducted in selected regions.

The finding of increased odds for GH and reduced odds for preeclampsia in the Western region compared with the Southern region is somewhat unexpected. The result related to GH may be coincidental, as it is not statistically significant. Additionally, more severe preeclampsia might be diagnosed with greater consistency than GH. Finally, the elevated blood pressure observed in the Western region could potentially be explained by a slightly higher median BMI,

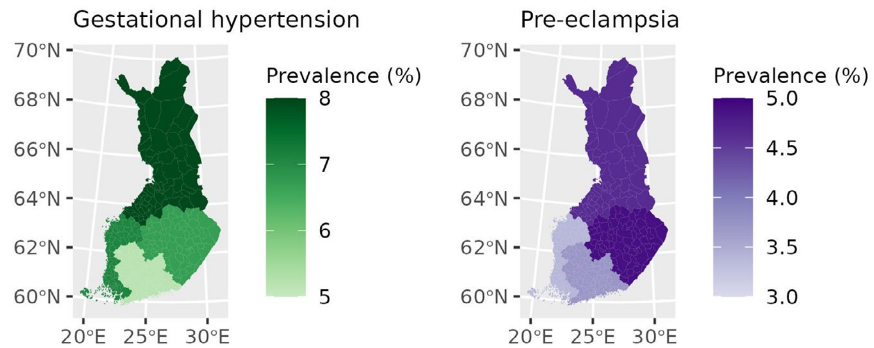

FIGURE 1 Prevalence of gestational hypertension and preeclampsia in the cardinal direction regions of Finland in 2013–2017 (n = 109 306).

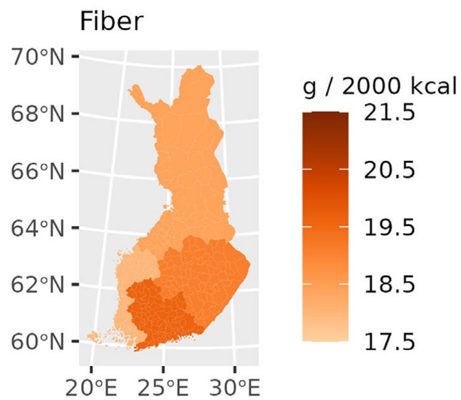

FIGURE 2 Mean fiber content per estimated daily energy intake (2000 kcal) in the food purchases of Finnish loyalty card owners at child-bearing age between September 2016, and December 2017 (n = 3937).

which is more strongly associated with an increased risk of hypertension than with preeclampsia.

Among the nutrients investigated, the areal amount of fiber content in the purchased foods was notably associated with reduced risk for GH. This observation aligns with previous research, as several studies have reported a correlation between higher fiber intake and a lower occurrence of GH and preeclampsia.[28–30] Several pathways of action have been proposed to explain this finding. Dietary fiber may play a role in reducing LDL cholesterol and triglyceride uptake, improving insulin sensitivity, and reducing energy intake through increased satiety.[28,31] Worthy of attention is that fiber intake is lower than the recommendation in all Nordic as well as most high-income countries.[31] Diets dominated by naturally fiber-rich plant food (e.g., vegetables, fruits and berries, nuts and seeds, and whole grains) are generally lower in energy and higher in micronutrients compared with diets dominated by animal food. Encouraging an increase in fiber intake could therefore both support weight management and help prevent GH.

More purchases of red and processed meat were observed in areas with a higher risk of preterm delivery before 37 gestational weeks in our study. Previous research on the relationship between meat consumption and prematurity has shown some inconsistencies; however, several studies have indicated that diets low in red and processed meat, such as the DASH diet, could reduce the risk of prematurity.[32] We did not observe the previously suggested association between folate intake and prematurity,[33] which could be, in addition to the aggregated nature of the food purchases, due to the inability in assessing folic acid supplementation in our study. Interestingly, we found no area-level correlation between GDM and purchased foods either. High BMI, as a relative representative of the whole diet and energy expenditure, is a clear risk factor for GDM and could mediate the effects of diet on GDM, rather than being examined separately from food purchase groups.

After adjusting for SES, age, smoking, BMI, and food purchases, a considerable portion of the regional disparities in GH and preeclampsia remained. Indeed, genetic predisposition may play a role in these regional differences, as there is a pronounced east-to-west genetic division in Finland due to its historical positioning between Western and Eastern spheres of influence.[19] Moreover, maternal BMI and age exhibited the strongest independent effects on the risks of GDM, GH, and preeclampsia in our study. This aligns with previous literature, as advanced age and having overweight or obesity are well-known risk factors for these pregnancy complications.[34,35]

This study encompassed a large cohort of women giving birth across the entire region of Finland by using high-quality nationwide MBR register data.[36] Given the limited literature on recent geographical variations in obstetric complications in Finland, our study contributes novel insights to this field and predicts future regional cardiovascular morbidity. However, there are limitations to consider; for confidentiality and privacy issues, some hospitals ceased providing information on occupation during the study period, resulting in a considerable amount of missing data. Nevertheless, it is unlikely that such a mechanism of missing data would introduce significant bias. Importantly, it remains unknown whether regional differences existed in the percentage of individuals who agreed to share their food purchase data, which could result in selection bias. Additionally, the characteristics of women in the MBR and loyalty card data do not fully align, indicating the imprecision of food purchases as a proxy for the diets of women in the MBR. As this is a register-based study, the results indicate regional associations rather than causality, and adjustments for all potential confounders, such as overall healthy lifestyle, cultural habits, and income, were not feasible.

Utilizing data on food purchases offers larger datasets and complementary means of assessing dietary habits compared with traditional methods such as food diaries, which have been criticized for their accuracy and self-reported nature.[37] Our approach combining diverse datasets allowed us to explore obstetric complications and contributing factors from a novel perspective. However, a limitation of our study is that we could only analyze regionally aggregated purchase data rather than individuals' purchases, and the data were derived partially from two-adult households. Further, we acknowledge that the retailer's dataset does not include data on eating-out patterns, which may influence the overall dietary quality. Nonetheless, we previously addressed this issue by comparing purchases with each cardholder's dietary habits, as evaluated through a concise food frequency questionnaire.[12] It is noteworthy that we observed correlation coefficients of comparable magnitude to those found in previous studies comparing food diaries with frequency questionnaires.[38,39] Additionally, it appears that food purchasing patterns vary depending on the level of loyalty, which must be considered when using loyalty card data.[16] Therefore, we only included customers with a self-reported loyalty level of at least 40% in our study. Loyalty card data offer a cost-effective means of reaching large and diverse population groups, including those that may be difficult to access through other methods.[16]

5 | CONCLUSION

While the incidence of cardiovascular disease risk factors and morbidity have declined in Finland over recent decades, regional disparities remain.[1,4] Our study reveals that regional differences in Finland are also evident in the varying rates of obstetrical complications, such as GH and preeclampsia. Although BMI, age, and smoking strongly affect the risk of examined pregnancy complications, they do not account for the geographical differences found. Although not examined in this study, genetic predisposition[40] and the quality of healthcare services may influence the findings, alongside the fiber content of food purchases. To overcome these barriers, the usual high motivation of pregnant women should be utilized to reduce the risk factors of pregnancy complications through lifestyle interventions, especially in high-risk areas. Efforts to reduce the risk of hypertensive disorders of pregnancy may help lower the prevalence of cardiovascular morbidity in the future. This could be particularly relevant in regions of Finland with the highest prevalence of hypertensive disorders later in life.

AUTHOR CONTRIBUTIONS

Saila Koivusalo: Conceptualization and methodology. **Jaakko Nevalainen:** Conceptualization and methodology, data collection and analyses. **Outi Pellonperä:** Conceptualization and methodology, data collection and analyses, writing of the manuscript. **Jelena Meinilä:** Conceptualization and methodology, data collection and analyses. **Heidi Sormunen-Harju:** Data collection and analyses. **Johanna Metsälä:** Data collection and analyses. All authors took part in substantial editing and revising the manuscript and have read and approved the final version of the manuscript.

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CONFLICT OF INTEREST STATEMENT

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ETHICS STATEMENT

Usage of the MBR and HDR data was approved by the Finnish Institute for Health and Welfare and the permission was updated to include region-level data from the LoCard study by the Finnish Social and Health Data Permit Authority Findata on November 22, 2022 (Dnro THL/5401/14.06.00/2022). In Finland, ethical approval is not required for research based solely on registry data. Further, obtaining consent from the registered is not required for research based on national health registry data. The LoCard study was reviewed by the University of Helsinki Ethical Review Board in Humanities and Social and Behavioral Sciences (Statement 21/2018) on June 13, 2018. Each participant provided an informed consent. Storage of data: The data analytics platform Acamedic was provided by the Helsinki University Hospital with permission on November 19, 2022 (§34, HUS/117/2022).

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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