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Postpartum lifestyle behaviour among women with prior gestational diabetes mellitus: evidence from the HUNT study

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ABSTRACT

Introduction Women with a history of gestational diabetes mellitus (GDM) are at increased risk of type 2 diabetes mellitus (T2DM) and cardiovascular disease (CVD). Recommendations for postpartum follow-up include targeted lifestyle advice to lower the risk.

The aim of this study was to compare postpartum lifestyle behaviours and perceptions among women with and without a history of GDM. In addition, we examined whether lifestyle behaviours of women with a history of GDM participating in a lifestyle intervention study differed from lifestyle behaviours of women with a history of GDM in the general population.

Research design and methods We linked data from the fourth survey of the population-based Trøndelag Health Study (HUNT4) to information from the Medical Birth Registry of Norway for women with registered births between 2000 and 2019. Using logistic regression, we compared lifestyle behaviours in women with and without GDM. In secondary analyses, lifestyle behaviours in women with GDM participating in a postpartum lifestyle intervention study were compared with HUNT participants with GDM using Fisher's exact tests/t-tests.

Results A high proportion of the women in our population, regardless of GDM history, reported several unhealthy lifestyle behaviours. We found no significant association between history of GDM and lifestyle behaviours. The lifestyle intervention study for women with a history of GDM appeared to recruit women with more favourable lifestyle behaviours.

Conclusions Women, regardless of GDM history, could potentially benefit from further support for lifestyle improvement, but it may be especially important in women with a history of GDM given their increased risk of T2DM and CVD. Interventions targeting women with GDM might not reach the women with the unhealthiest lifestyle behaviours, and measures to reach out to all women should be further investigated.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Women with a history of gestational diabetes mellitus (GDM) should be encouraged to implement healthy lifestyle modification but studies on modifiable postpartum lifestyle behaviours of women with a history of GDM are limited.

WHAT THIS STUDY ADDS

⇒ A high proportion of parous women, regardless of GDM history, reported low adherence to current lifestyle behaviour recommendations. Future studies may benefit from more focus on effective recruitment strategies for women with less favourable lifestyle behaviours.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Women, regardless of GDM history, could potentially benefit from support for healthy lifestyle modifications, but it may be especially important in women with a history of GDM given their increased risk of type 2 diabetes and cardiovascular disease.

INTRODUCTION

Gestational diabetes mellitus (GDM) is a form of diabetes with onset during pregnancy that usually resolves after giving birth.[1] It is one of the most common medical disorders in pregnancy. Worldwide, approximately 1 in 10 pregnant women is diagnosed with GDM, with varied prevalence between countries and ethnical groups.[2–4] In Norway, the prevalence of GDM has increased from around 1% to 5%–6% over the last decades. This change is partially due to higher maternal age and obesity rates,[3] and possibly changes in diagnostic criteria.[5] The increase of GDM poses a significant healthcare challenge, as it is associated with higher risk of a range of adverse perinatal outcomes for both mother and child.[6] Furthermore, women with GDM have a 10-fold increased risk of developing type 2 diabetes mellitus (T2DM)[7] and a 1.5–2 folds higher risk of cardiovascular disease (CVD)[8 9] later in life, compared with women without a history of GDM.

Given the increased risk of T2DM and CVD, many see GDM as a first 'warning flag' for future disease and the postpartum period as a window of opportunity for diabetes and CVD prevention in women with GDM.[10–12] Studies have shown that lifestyle modifications, including increased physical activity and

dietary changes, can delay or prevent onset of CVD and T2DM in high-risk individuals.[13–17] Based on this, recommendations for postpartum management of women with GDM often include glucose testing and advice to implement lifestyle modification.[18 19] Results from lifestyle intervention studies targeting women with GDM suggest clinically relevant benefits for these individuals.[20]

However, lifestyle intervention studies often face difficulties in recruiting participants who are representative of the target population,[21] and little is known of the representativeness of women who are willing to participate in lifestyle intervention studies for women with GDM. A systematic review of qualitative studies among women with GDM found that women were often aware of the increased risk of T2DM and benefit of prevention, but faced multiple barriers to undertaking preventive behaviours.[22] Qualitative studies, including previous work from our group, underlined women's need for more support for lifestyle change.[22 23] In view of these challenges, information about postpartum lifestyle behaviours of women with a history of GDM could be useful in a potential improvement of current lifestyle modification programmes. Existing studies on the postpartum lifestyle behaviours of women with a history of GDM are limited.

The main aim of this study was therefore to examine if postpartum lifestyle behaviours of women with a history of GDM differ from that of women with only normoglycaemic pregnancies. Second, we aimed to compare the characteristics and lifestyle behaviours of women with a history of GDM participating in a pilot intervention study—Mom's Healthy Heart (MHH)—to women with a history of GDM from a population-based sample.

METHOD

Study population

The study population of the main analyses consists of women who participated in the fourth survey of the Trøndelag Health Study (HUNT4) and are registered with one or more births in the Medical Birth Registry of Norway (MBRN) from 2000 to 2019. In secondary analyses, we compared HUNT4 participants with GDM to participants of the pilot intervention study MHH.

The HUNT Study is a longitudinal population-based cohort study conducted in the Northern region of Trøndelag county, Norway. All inhabitants 20 years or older have been invited to participate in four repeated surveys since the 1980s. This study is restricted to the fourth survey HUNT4 (2017–2019), which had a participation rate of 58.8% among women.[24] The study gathered comprehensive information on participants' general health and lifestyle behaviours, including smoking, alcohol intake, sleeping pattern, physical activity and broad information on dietary intake.

In Norway, registration of births in the MBRN from 16 weeks of gestation onwards is compulsory since 1967.[25] The MBRN collects information on pregnancy, birth, maternal and neonatal health, including diagnosis of GDM.

This study included data from 8775 parous HUNT4 participants with one or more births registered in the MBRN between 2000 and 2019. Data from prior births have additionally been used for covariate assessment and identifying women with a history of GDM. We excluded women for the following non-mutually exclusive criteria: Being pregnant during the HUNT4 survey (n=400), having a first birth after participation in HUNT4 (n=173), no liveborn children (n=12), diagnosis of chronic hypertension (n=399), CVD (n=139) or diabetes (n=146) (self-reported or registered in the MBRN) and self-reported use of cholesterol lowering medication (n=106). Furthermore, we excluded women with missing information on education (n=68). The remaining 7551 participants with information on one or more lifestyle behavioural factors were included in the main analysis (figure 1). For the analysis of each outcome variable, we excluded participants with missing data on the respective lifestyle behavioural factors. The numbers of participants included in each analysis of behavioural lifestyle factors varied from 6278 to 7551 (online supplemental table 1).

Exposure

The study exposure was retrieved from the MBRN and defined as the history of GDM in one or more pregnancies. Every woman contributed once to the analysis. Diagnoses of GDM used current nationally recommended guidelines. Norwegian maternal healthcare guidelines recommend a risk-based screening for GDM with an oral glucose tolerance test (OGTT) between 24 and 28 weeks of pregnancy.[18] The criteria for the diagnosis are diverse and have changed over time.[5] In Norway, the WHO 1999 criteria (fasting plasma glucose ≥7.0 or OGTT 75 g 2 hours glucose ≥7.8 mmol/L) were previously used to diagnose GDM,[5] but in 2017, a new national guideline was published. The criteria since 2017 have been fasting plasma glucose level from 5.3 to 6.9 mmol/L and/or a plasma glucose level of 9.0–11.0 mmol/L after a 75 g OGTT during pregnancy.[18] A previous validation study of GDM registration in the MBRN reported a high positive predictive value (89% confirmed in medical records).[26]

Outcome

In HUNT4, a self-administrated questionnaire was used to assess a broad variety of lifestyle behaviours, and the following were included in this study: diet, smoking, alcohol consumption, physical activity and sleep. In addition, answers regarding lifestyle perception were included. We dichotomised lifestyle behaviours, and as closely as possible defined healthy/unhealthy outcomes in accordance with Norwegian and international guidelines. Additional details about the measurement and dichotomisation of lifestyle behaviours are presented in online supplemental table 2.

Diet was reported on frequency per week of intake of fruit/berries, vegetables, red meat, lean fish and fatty fish.

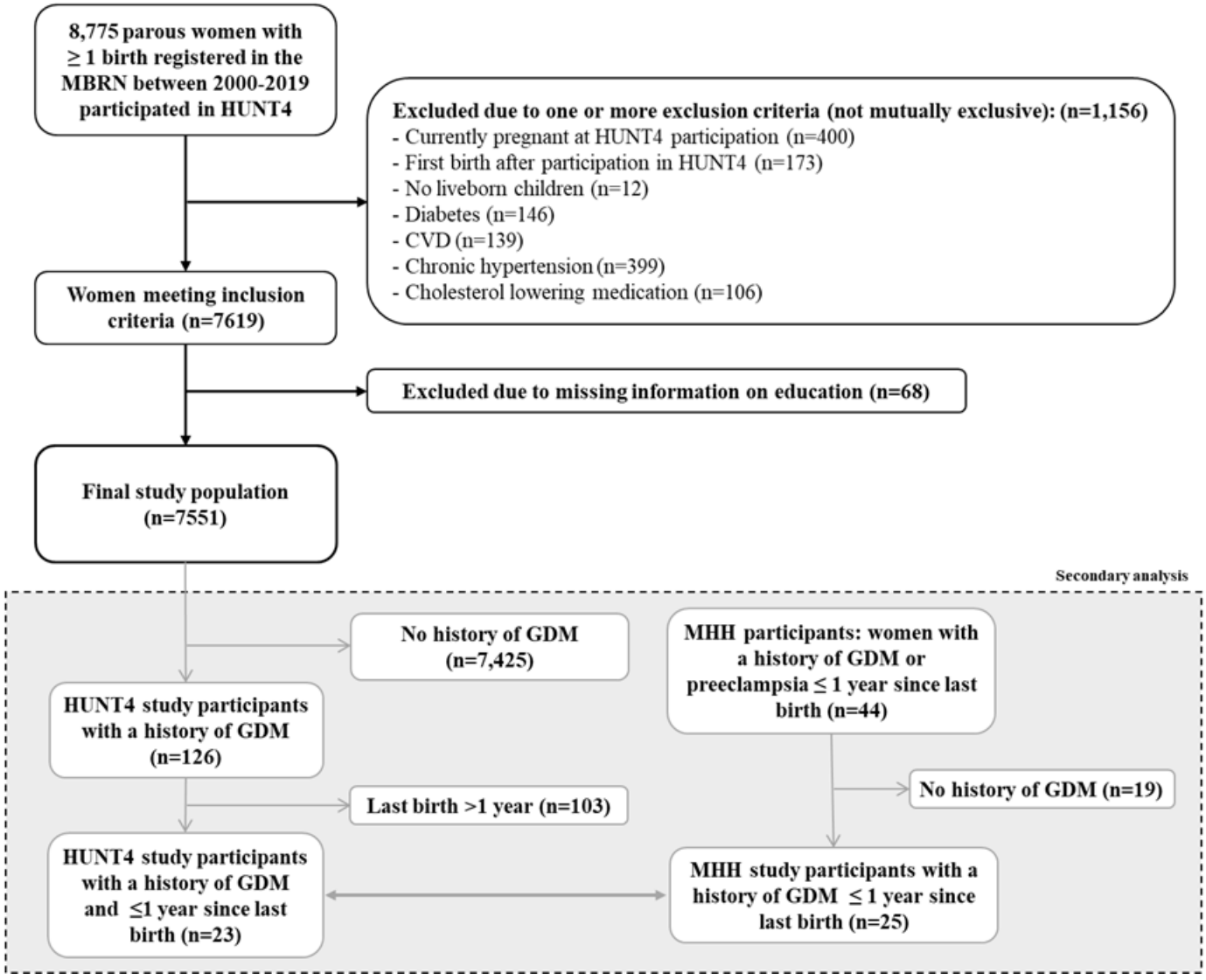

Figure 1 Flow chart of the study population. CVD, cardiovascular disease; GDM, gestational diabetes mellitus; HUNT4, Trøndelag Health Study (fourth survey); MBRN, Medical Birth Registry of Norway; MHH, Mom's Healthy Heart.

Beverages with added sugar (eg, soda, squashes) were reported as number of glasses/cups per week/day.

Alcohol consumption: Total amount of alcohol units/week were calculated based on frequency and amount (glasses) per week of beer, wine and/or liquor.

Smoking: Current smoking was defined as daily or occasionally current smoking.

Physical activity: Physical activity was derived from two items, measuring the number of weekly minutes with moderate intensity activities and high intensity activities. By the total minutes per week activity score, a metabolic equivalent (MET) was calculated and we divided into two levels: Above and below the international recommendations of at least 500 MET-minutes per week which reflects the amount of weekly physical activity necessary to achieve significant health benefits.[27] Online supplemental table 2 includes additional details on MET calculation.

Sleep: Participants reported on duration of night-time sleep, and how often they experienced daytime dysfunction due to insomnia.

Lifestyle perception: Participants reported on lifestyle satisfaction and importance of healthy lifestyle by the following questions: 'How satisfied are you with your own lifestyle (diet, physical activity, smoking and drinking habits)?', and 'How important is a healthy lifestyle for you?'.

Covariate assessment

The following variables, associated with lifestyle behaviours and the risk of GDM, were considered as potential confounders: Age at HUNT4 participation, parity (categorised as 1 or ≥2 births), time since last birth (<1 year/1 to <5 years/5 to <10 years/≥10 years), country of birth (Norway/outside of Norway), highest obtained level of education (secondary/tertiary), and living with a partner (yes/no).

Secondary analysis: MHH

We extended our analysis by including an additional comparison group of 25 women with GDM participating in the pilot intervention study MHH (figure 1). MHH included women in the county of Trøndelag with a prior diagnosis of pre-eclampsia (PE) and/or GDM who were 3–12 months post partum in 2020–2021.[28] All diagnoses of PE and GDM were confirmed by medical record review. Study participants answered a baseline questionnaire including questions on meal-pattern, alcohol consumption, smoking, sleep pattern, physical activity and lifestyle perception. Dietary intake was measured using a short semiquantitative Food Frequency Questionnaire (FFQ), that has been developed and validated by Henriksen *et al*.[29] The questions asked in MHH and included in this study were comparable to questions asked in HUNT4.

Statistical analysis

Descriptive characteristics of the study population are presented as means and SD for continuous variables or as numbers and percentages for categorical variables. We used t-test and χ^2 test for comparisons between women with and without a history of GDM. We estimated the association of history of GDM and modifiable lifestyle behaviours and lifestyle perceptions using logistic regression analysis. The reference group was women with normoglycaemic pregnancies. The primary model was unadjusted. Multivariable models were additionally adjusted for age, birth country, living with a partner or not, education, parity and time since delivery. As a sensitivity analysis, we examined whether changes in screening recommendations may have influenced the results by restricting our analysis to women with <5 years since last birth. We additionally performed sensitivity analyses restricting to women living with children under age 18, as well as analyses including women with diagnosis of hypertension, CVD or diabetes, and women with self-reported use of cholesterol-lowering medication.

For our secondary analysis, Fisher's exact tests for categorical variables and t-tests for continuous variables were conducted to examine whether HUNT participants with a history of GDM and MHH participants with a history of GDM differed with respect to demographic characteristics, lifestyle behaviours and perception of lifestyle. Data analysis was performed in STATA V.17.0 (StataCorp).

RESULTS

Among 7551 eligible HUNT4 participants, 126 were registered with a history of GDM (1.7%). Table 1 shows the characteristics of the study population. Compared with women with normoglycaemic pregnancies, women with a history of GDM appeared to be younger and to have higher body mass index (BMI). They were also more likely to have lower education and more likely to report diabetes in first degree relatives.

A high proportion of women regardless of history of GDM appeared to have several unhealthy lifestyle behaviours (table 2). Among women with a history of GDM and women with normoglycaemic pregnancies respectively, 81.6% and 77.0% had an insufficient intake of fruit/berries (p=0.23), 78.4% and 72.4% reported insufficient intake of vegetables (p=0.13), and 53.8% and 41.2% did not fulfil recommendation for physical activity (p=0.02).

There were no significant associations between history of GDM and postpartum lifestyle behaviours (table 2). However, most estimates suggested a trend towards more unfavourable lifestyle behaviours among women with a history of GDM. For example, women with a history of GDM appeared to be more likely to report insufficient intake of fruit and berries (OR 1.33; 95% CI 0.84 to 2.12) and vegetables (OR 1.41; 95% CI 0.91 to 2.19). Furthermore, women with a history of GDM tended to be less physically active (OR 1.33; 95% CI 0.88 to 2.03) and appeared to be more likely to report current smoking (OR 1.47; 95% CI 0.83 to 2.61). Analysis of sleep duration suggested that women with GDM were less likely to report short sleep duration (<6 hours/night) compared with women without GDM (OR 0.47; 95% CI 0.20 to 1.07).

Women with a history of GDM appeared to be more likely to value a healthy lifestyle as less important (OR 1.73; 95% CI 0.97 to 3.10) (table 2). They were also more likely to be unsatisfied with their lifestyle compared with women with no GDM (OR 1.62; 95% CI 1.13 to 2.34). Adjusting for BMI attenuated the association between history of GDM and lifestyle dissatisfaction (OR 1.11; 95% CI 0.75 to 1.65).

Sensitivity analyses restricted to women with less than 5 years since last birth (online supplemental table 3) and women living with children under age 18 (online supplemental table 4) yielded nearly unchanged estimates. Furthermore, sensitivity analyses including women with diagnosis of hypertension, CVD or diabetes and women with self-reported use of cholesterol lowering medication did not substantially change the results (online supplemental table 5).

Mom's Healthy Heart

A total of 23 women with GDM had given birth within the last year before participating in HUNT4 and were compared with 25 MHH participants with GDM (figure 1). Compared with women participating in HUNT4, although not significant, women in MHH appeared to be older and have a higher level of education and income. MHH participants were more likely to be primiparous and a significantly higher percentage were currently breast feeding (88% MHH vs 56.5% HUNT4, p=0.02) (table 3).

Women participating in MHH were less likely to consume fruit and berries <7 times/week (32% MHH vs 87% HUNT4, p<0.001) and vegetables <7 times/week (12% MHH vs 72.7% HUNT4, p<0.001) compared with women participating in HUNT4. They were more likely to sleep <6 hours/night (44% MHH vs 4.4% HUNT4, p=0.002), and to report daytime dysfunction due to insomnia (32% MHH vs 0% HUNT4, p=0.004).

Table 1 Descriptive characteristics of HUNT4 participants according to history of GDM

Characteristics	Overall (n=7551)	No history of GDM (n=7425)	History of GDM (n=126)	P value
Age, years	39.9 (7.7)	39.9 (7.8)	37.4 (7.1)	<0.001
Birth country				0.07
Norway	7065 (93.6)	6952 (93.6)	113 (89.7)	
Other	486 (6.4)	473 (6.4)	13 (10.3)	
Education				0.02
Lower/upper secondary education	2797 (37.0)	2738 (36.9)	59 (46.8)	
Tertiary education	4754 (63.0)	4687 (63.1)	67 (53.2)	
Living with partner	6431 (85.2)	6321 (85.1)	110 (87.3)	0.5
Parity				0.62
1 birth	855 (11.3)	839 (11.3)	16 (12.7)	
≥2 births	6696 (88.7)	6586 (88.7)	110 (87.3)	
Time since last birth, years				<0.001
<1	528 (7.0)	505 (6.8)	23 (18.3)	
1 to <5	1985 (26.3)	1925 (25.9)	60 (47.6)	
5 to <10	1878 (24.9)	1852 (24.9)	26 (20.6)	
≥10	3160 (41.9)	3143 (42.3)	17 (13.5)	
CVD in first degree relatives	1293 (17.1)	1267 (17.1)	26 (20.6)	0.29
Diabetes in first degree relatives	1563 (20.7)	1514 (20.4)	49 (38.9)	<0.001
BMI				<0.001
Underweight (<18.5 kg/m^2)	98 (1.3)	98 (1.3)	0 (0)	
Normal weight (18.5 to <25 kg/m^2)	3386 (44.8)	3353 (45.2)	33 (26.8)	
Overweight (25 to <30 kg/m^2)	2486 (32.9)	2440 (32.9)	46 (37.4)	
Obese (≥30 kg/m^2)	1559 (20.7)	1515 (20.4)	44 (35.8)	
Missing	22 (0.3)	19 (0.3)	3 (1)	
Living with children under age 18	6479 (85.8)	6367 (85.8)	112 (88.9)	0.32

The data are presented as mean±SD or n (%).
BMI, body mass index; CVD, cardiovascular disease; GDM, gestational diabetes mellitus; HUNT4, Trøndelag Health Study, fourth survey.

DISCUSSION

In this study, we compared the lifestyle patterns of women with and without a history of GDM and found no significant associations between history of GDM and lifestyle behaviours. A high percentage of the women in our population reported an insufficient intake of fruit/berries and vegetables and low physical activity levels regardless of GDM history. Women with a history of GDM were more likely to report dissatisfaction with their lifestyle.

Data on postpartum lifestyle in women with GDM are sparse, and results may not be directly comparable to our results due to differences in populations and measures of lifestyle behaviours. Still, our findings are supported by several previous studies: Kieffer *et al* performed a large cross-sectional study using data from the Behavioural Risk Factor Surveillance System, a national population-based random sample telephone survey conducted in the USA. Analysing answers from 177 420 women, they found in unadjusted analysis that approximately half met physical activity guidelines, and approximately one-quarter met fruit and vegetable consumption guidelines,[30] which is similar to our estimates. Likewise, they did not find significant differences in levels of fruit and vegetable consumption, physical activity or smoking among women with and without a history of GDM.[30] However, the authors reported that among the subgroup of women who lived with children, women with a history of GDM were less likely to meet fruit and vegetable consumption guidelines and more likely to smoke.[30] In contrast, we observed nearly unchanged estimates when restricting our analyses to women who reported living with children under age 18 (85.8% of our study population). A Swedish study by Persson *et al* assessed the lifestyle behaviours of 444 women 4 years postpartum and did not notice any major differences between women with or without a history of GDM.[31] Likewise, findings from the US CARDIA study did not suggest any differences between the postpartum lifestyle behaviours of women with and without GDM.[32] In contrast to our study, the authors were also able to examine prepregnancy to postpregnancy lifestyle

Table 2 Unhealthy lifestyle behaviours and lifestyle perception in HUNT4 participants with prior GDM relative to women without GDM

	No history of GDM, n (%)	History of GDM, n (%)	P value	Model 1		Model 2	
				OR	(95% CI)	OR	(95% CI)
Lifestyle behaviours							
Diet							
Fruit and berries (<7 times/week)	5690 (77.0)	102 (81.6)	0.23	1.32	(0.84 to 2.08)	1.33	(0.84 to 2.12)
Vegetables (<7 times/week)	5343 (72.4)	98 (78.4)	0.13	1.39	(0.90 to 2.13)	1.41	(0.91 to 2.19)
Red meat (>4 times/week)	923 (12.4)	15 (11.9)	0.86	0.95	(0.55 to 1.64)	0.87	(0.50 to 1.50)
Fatty fish (<1 times/week)	2718 (36.8)	47 (37.3)	0.90	1.02	(0.71 to 1.47)	1.03	(0.71 to 1.49)
Lean fish (<1 times/week)	3607 (48.8)	57 (45.2)	0.42	0.87	(0.61 to 1.23)	0.99	(0.69 to 1.41)
Total fish (<1 times/week)	1937 (26.2)	35 (27.8)	0.69	1.08	(0.73 to 1.61)	1.15	(0.77 to 1.71)
Beverages with added sugar (≥1 glass/week)	3505 (47.7)	53 (42.4)	0.24	0.81	(0.56 to 1.16)	0.72	(0.50 to 1.04)
Alcohol (>7 units/week)	94 (1.4)	2 (1.7)	0.79	1.21	(0.29 to 4.96)	1.68	(0.40 to 7.03)
Physical activity (<500 MET/week)	2548 (41.2)	50 (53.8)	0.02	1.66	(1.10 to 2.50)	1.33	(0.88 to 2.03)
Current smoker	664 (9.0)	15 (11.9)	0.25	1.37	(0.80 to 2.37)	1.47	(0.83 to 2.61)
Sleep							
Sleep duration (<6 hours/night)	585 (8.0)	6 (4.8)	0.18	0.57	(0.25 to 1.30)	0.47	(0.20 to 1.07)
Daytime dysfunction	315 (4.3)	6 (4.9)	0.76	1.14	(0.50 to 2.61)	1.13	(0.49 to 2.61)
Lifestyle perception							
Healthy lifestyle not important	435 (5.9)	14 (11.1)	0.01	1.99	(1.13 to 3.51)	1.73	(0.97 to 3.10)
Not satisfied with own lifestyle	2124 (28.8)	55 (44.0)	<0.001	1.94	(1.36 to 2.77)	1.62	(1.13 to 2.34)

Data presented as OR with 95% CI.
Model 1 is unadjusted, model 2 is adjusted for age, birth country, cohabitant status, education, parity and time since last birth.
GDM, gestational diabetes mellitus; HUNT4, Trøndelag Health Study, fourth survey; MET, Metabolic Equivalent of Task.

changes and reported similar lifestyle changes regardless of GDM status; women similarly decreased physical activity, increased total caloric intake but reduced fast food frequency.[32]

We found that women with a history of GDM were more likely to be dissatisfied with their own lifestyle compared with women without a history of GDM. One possible explanation may be the tendency towards more unfavourable lifestyle behaviours in women with a history of GDM that we observed in our study but were unable to ascertain. Another contributing factor that has been described in previous studies may be a knowledge-behaviour gap after a diagnosis of GDM,[33] potentially leading to a feeling of guilt.[34] Women with GDM may therefore tend to over report more desirable lifestyle behaviours. Moreover, it has been suggested that poor self-rated health perception is associated with higher BMI.[35 36] Although the question did not refer to participants' weight status ('How satisfied are you with your own lifestyle (diet, physical activity, smoking and drinking habits)?'), adjusting for BMI attenuated the observed increased odds of being unsatisfied with their own lifestyle.

Previous studies assessing the representativeness of participants in intervention studies in diverse populations have suggested that intervention studies may not reach those at highest risk who might benefit most from intervention.[21 37]

Our findings support this, showing that women with GDM who participated in a postpartum lifestyle intervention study may differ from HUNT participants with a history of GDM in several demographic and lifestyle characteristics, including a higher intake of fruit/berries and vegetables. MHH participants were more likely to report short sleep-duration and daytime dysfunction due to insomnia. This might be partially due to a shorter time since delivery, wording differences between study questionnaires, and a significantly higher rate of breast feeding.

Strengths and limitations

The strengths of our study include the prospective design, linkage to a national birth registry and broad information allowing adjustment for multiple covariates. The HUNT study population is considered fairly representative for Norway.[24] However, the population is ethnically homogenoeus, making our results less generalisable to more diverse populations.

The results of this study should be interpreted with caution, taking the limitations into account. It is possible that lifestyle behaviours have been misclassified because information on lifestyle was self-reported and prone

Table 3 Women with a history of GDM and ≤1 year since last birth, comparing MHH participants to HUNT4 participants

Descriptive characteristics of the study population	Women with a history of GDM in HUNT4 (n=23)	Women with a history of GDM in MHH (n=25)	P value
Age, years	32 (4.2)	33.6 (5.9)	0.287*
Birth country			1.000
Norway	22 (95.7)	23 (92.0)	
Other	1 (4.4)	2 (8.0)	
Education			0.088
Upper secondary education	8 (34.8)	3 (12.0)	
Tertiary education	15 (65.2)	22 (88.0)	
Household income (NOK)			0.148
≤450 000	4 (18.2)	1 (4.2)	
451 000–750 000	9 (40.9)	7 (29.2)	
>750 000	9 (40.9)	16 (66.7)	
Living with partner	23 (100.0)	24 (96.0)	1.000
Time since delivery (months)	7.2 (3.1)	6.8 (2.8)	0.673*
Parity			0.075
1 birth	2 (8.7)	8 (32.0)	
≥2 births	21 (91.3)	17 (68.0)	
CVD in first degree relatives	7 (30.4)	2 (8.0)	0.068
Diabetes in first degree relatives	7 (30.4)	5 (20.0)	0.511
BMI			0.363
Normal weight	3 (13.0)	4 (16.0)	
Overweight	8 (34.8)	13 (52.0)	
Obese	12 (52.2)	8 (32.0)	
Current breastfeeding	13 (56.5)	22 (88.0)	0.022
Lifestyle behaviours			
Diet			
Fruit and berries (<7 times/week)	20 (87.0)	8 (32.0)	<0.001
Vegetables (<7 times/week)	16 (72.7)	3 (12.0)	<0.001
Red meat (>4 times/week)	2 (8.7)	0	0.224
Fatty fish (<1 times/week)	9 (39.1)	6 (24.0)	0.353
Lean fish (<1 times/week)	12 (52.2)	9 (36.0)	0.383
Total fish (<1 times/week)	6 (26.1)	3 (12.0)	0.279
Beverages with added sugar (≥1 glass/week)	10 (43.5)	16 (64.0)	0.246
Alcohol (> 7 units/week)	0	0	
Physical activity (<500 MET/week)	9 (50.0)	13 (52.0)	1.000
Current smoker	0	0	
Sleep			
Sleep duration (<6 hours/night)	1 (4.4)	11 (44.0)	0.002
Daytime dysfunction	0	8 (32.0)	0.004
Lifestyle perception			
Healthy lifestyle not important	3 (13.0)	1 (4.2)	0.248
Not satisfied with own lifestyle	10 (43.5)	15 (62.5)	0.179

Descriptive characteristics are presented as mean and SD or n (%).
*P values have been calculated using Fischer's exact or t-test.
BMI, body mass index; CVD, cardiovascular disease; GDM, gestational diabetes mellitus; HUNT4, Trøndelag Health Study, fourth survey; MET, Metabolic Equivalent of Task; MHH, Mom's Healthy Heart.

to recall bias. Still, women were asked to give answers regarding their current lifestyle behaviour, thus minimising recall bias. Diagnostic criteria and screening recommendations for GDM have changed over the exposure period. In addition, the prevalence of GDM in Trøndelag is lower compared with other regions in Norway,[38] probably partially due to lower screening adherence. This may have resulted in underdiagnosis of GDM, especially in the early study period, which in turn may have contributed to an underestimation of potential lifestyle differences. Women with more unhealthy lifestyle behaviours may also have been excluded from our study, as they are more likely to have developed chronic diseases. It is also possible that some women with GDM may have been wrongfully excluded, due to self-reporting prior GDM as 'having diabetes' in the HUNT questionnaire, which may partially explain the low prevalence of GDM in our population. Another limitation of this study is that it is hard to accurately measure dietary variables and physical activity based on questionnaires, and we additionally had to dichotomise outcomes due to smaller group sizes. For our secondary analysis comparing women with a history of GDM in HUNT4 and MHH, we had to compare questions from the HUNT4 questionnaire to questions from the short FFQ in MHH. We limited our analysis to the most directly comparable questions, but we cannot discard the possible influence on especially fruit and vegetable intake.

CONCLUSION

A high proportion of the women in our population, regardless of GDM history, reported several unhealthy lifestyle behaviours. We found no significant differences in lifestyle behaviours between women with a history of GDM and women with only normoglycaemic pregnancies. Women, regardless of GDM history, could potentially benefit from support for healthy lifestyle modifications, but it may be especially important to target women with a history of GDM given their increased risk of future diseases.

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Data availability statement Data are available on reasonable request. The Trøndelag Health Study (HUNT) has invited persons aged 13–100 years to four surveys between 1984 and 2019. Comprehensive data from more than 140 000 persons having participated at least once and biological material from 78 000 persons are collected. The data are stored in HUNT databank and biological material in HUNT biobank. HUNT Research Centre has permission from the Norwegian Data Inspectorate to store and handle these data.The key identification in the data base is the personal identification number given to all Norwegians at birth or immigration, whilst deidentified data are sent to researchers on approval of a research protocol by the Regional Ethical Committee and HUNT Research Centre. To protect participants' privacy, HUNT Research Centre aims to limit storage of data outside HUNT databank, and cannot deposit data in open repositories. HUNT databank has precise information on all data exported to different projects and are able to reproduce these on request. There are no restrictions regarding data export given approval of applications to HUNT Research Centre. For more information see: http://www.ntnu.edu/hunt/data.

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REFERENCES

1 Tieu J, McPhee AJ, Crowther CA, *et al*. Screening for gestational diabetes mellitus based on different risk profiles and settings for improving maternal and infant health. *Cochrane Database Syst Rev* 2017;8:CD007222.
2 Al-Rifai RH, Abdo NM, Paulo MS, *et al*. Prevalence of gestational diabetes mellitus in the middle East and North Africa, 2000-2019: a systematic review, meta-analysis, and meta-regression. *Front Endocrinol (Lausanne)* 2021;12:668447.
3 Paulo MS, Abdo NM, Bettencourt-Silva R, *et al*. Gestational diabetes mellitus in Europe: a systematic review and meta-analysis of prevalence studies. *Front Endocrinol (Lausanne)* 2021;12:691033.
4 Nguyen CL, Pham NM, Binns CW, *et al*. Prevalence of gestational diabetes mellitus in Eastern and southeastern Asia: a systematic review and meta-analysis. *J Diabetes Res* 2018;2018:6536974.

5 Behboudi-Gandevani S, Parajuli R, Vaismoradi M. A systematic review of the prevalence of gestational diabetes in Norway. *Int J Environ Res Public Health* 2021;18:1423.
6 HAPO Study Cooperative Research Group, Metzger BE, Lowe LP, *et al*. Hyperglycemia and adverse pregnancy outcomes. *N Engl J Med* 2008;358:1991–2002.
7 Vounzoulaki E, Khunti K, Abner SC, *et al*. Progression to type 2 diabetes in women with a known history of gestational diabetes: systematic review and meta-analysis. *BMJ* 2020;369:m1361.
8 Kramer CK, Campbell S, Retnakaran R. Gestational diabetes and the risk of cardiovascular disease in women: a systematic review and meta-analysis. *Diabetologia* 2019;62:905–14.
9 Xie W, Wang Y, Xiao S, *et al*. Association of gestational diabetes mellitus with overall and type specific cardiovascular and cerebrovascular diseases: systematic review and meta-analysis. *BMJ* 2022;378:e070244.
10 Sattar N, Greer IA. Pregnancy complications and maternal cardiovascular risk: opportunities for intervention and screening *BMJ* 2002;325:157–60.
11 Li N, Yang Y, Cui D, *et al*. Effects of lifestyle intervention on long-term risk of diabetes in women with prior gestational diabetes: a systematic review and meta-analysis of randomized controlled trials. *Obes Rev* 2021;22:e13122.
12 Goveia P, Cañon-Montañez W, Santos D de P, *et al*. Lifestyle intervention for the prevention of diabetes in women with previous gestational diabetes mellitus: a systematic review and meta-analysis. *Front Endocrinol (Lausanne)* 2018;9:583.
13 Wahid A, Manek N, Nichols M, *et al*. Quantifying the association between physical activity and cardiovascular disease and diabetes: a systematic review and meta-analysis. *J Am Heart Assoc* 2016;5:e002495.
14 Toi PL, Anothaisintawee T, Chaikledkaew U, *et al*. Preventive role of diet interventions and dietary factors in type 2 diabetes mellitus: an umbrella review. *Nutrients* 2020;12:2722.
15 Group D. Long-term effects of lifestyle intervention or metformin on diabetes development and microvascular complications over 15-year follow-up: the diabetes prevention program outcomes study. *Lancet Diabetes Endocrinol* 2015;3:866–75.
16 Rees K, Dyakova M, Wilson N, *et al*. Dietary advice for reducing cardiovascular risk. *Cochrane Database Syst Rev* 2013;2013:CD002128.
17 Yang J, Qian F, Chavarro JE, *et al*. Modifiable risk factors and long term risk of type 2 diabetes among individuals with a history of gestational diabetes mellitus: prospective cohort study. *BMJ* 2022;378:e070312.
18 Rettningslinjer, Svangerskapsdiabetes [Helsedirektoratet]. 2018. Available: https://www.helsedirektoratet.no/retningslinjer/svangerskapsdiabetes
19 Maas AHEM, Rosano G, Cifkova R, *et al*. Cardiovascular health after menopause transition, pregnancy disorders, and other gynaecologic conditions: a consensus document from European cardiologists, gynaecologists, and endocrinologists. *Eur Heart J* 2021;42:967–84.
20 Hedeager Momsen A-M, Høtoft D, Ørtenblad L, *et al*. Diabetes prevention interventions for women after gestational diabetes mellitus: an overview of reviews. *Endocrinol Diabetes Metab* 2021;4:e00230.
21 Gesche J, Renault K, Nørgaard K, *et al*. Representativeness of participants in a lifestyle intervention study in obese pregnant women - the difference between study participants and non-participants. *Obes Facts* 2014;7:351–60.
22 Van Ryswyk E, Middleton P, Shute E, *et al*. Women's views and knowledge regarding healthcare seeking for gestational diabetes in the postpartum period: a systematic review of qualitative/survey studies. *Diabetes Res Clin Pract* 2015;110:109–22.
23 Sandsæter HL, Horn J, Rich-Edwards JW, *et al*. Preeclampsia, gestational diabetes and later risk of cardiovascular disease: women's experiences and motivation for lifestyle changes explored in focus group interviews. *BMC Pregnancy Childbirth* 2019;19:448.
24 Åsvold BO, Langhammer A, Rehn TA, *et al*. Cohort profile update: the HUNT study, Norway. *Int J Epidemiol* 2023;52:e80–91.
25 Irgens LM. The medical birth Registry of Norway. Epidemiological research and surveillance throughout 30 years. *Acta Obstet Gynecol Scand* 2000;79:435–9.
26 Stene LC, Eidem I, Vangen S, *et al*. The validity of the diabetes mellitus diagnosis in the medical birth registry of Norway. *Nor J Epidemiol* 2007;17.
27 Kaminsky LA, Montoye AHK. Physical activity and health: what is the best dose *J Am Heart Assoc* 2014;3:e001430.
28 Norwegian University of Science and Technology, Harvard Medical School (HMS and HSDM), University of Oslo. Lifestyle intervention for women with recent pre-Eclampsia or gestational diabetes mellitus ('mom's healthy heart'). 2021. Available: https://ClinicalTrials.gov/show/NCT03993145
29 Henriksen HB, Carlsen MH, Paur I, *et al*. Relative validity of a short food frequency questionnaire assessing adherence to the Norwegian dietary guidelines among colorectal cancer patients. *Food Nutr Res* 2018;62.
30 Kieffer EC, Sinco B, Kim C. Health behaviors among women of reproductive age with and without a history of gestational diabetes mellitus. *Diabetes Care* 2006;29:1788–93.
31 Persson M, Winkvist A, Mogren I. Lifestyle and health status in a sample of Swedish women four years after pregnancy: a comparison of women with a history of normal pregnancy and women with a history of gestational diabetes mellitus. *BMC Pregnancy Childbirth* 2015;15:57.
32 Bennett WL, Liu S-H, Yeh H-C, *et al*. Changes in weight and health behaviors after pregnancies complicated by gestational diabetes mellitus: the CARDIA study. *Obesity (Silver Spring)* 2013;21:1269–75.
33 Swan W, Kilmartin G, Liaw S-T. Assessment of readiness to prevent type 2 diabetes in a population of rural women with a history of gestational diabetes. *Rural Remote Health* 2007;7:802.
34 Craig L, Sims R, Glasziou P, *et al*. Women's experiences of a diagnosis of gestational diabetes mellitus: a systematic review. *BMC Pregnancy Childbirth* 2020;20:76.
35 Darviri C, Artemiadis AK, Tigani X, *et al*. Lifestyle and self-rated health: a cross-sectional study of 3,601 citizens of Athens, Greece. *BMC Public Health* 2011;11:619.
36 Sayón-Orea C, Santiago S, Bes-Rastrollo M, *et al*. Determinants of self-rated health perception in a sample of a physically active population: PLENUFAR VI study. *Int J Environ Res Public Health* 2018;15:2104.
37 Bayley A, Stahl D, Ashworth M, *et al*. Response bias to a randomised controlled trial of a lifestyle intervention in people at high risk of cardiovascular disease: a cross-sectional analysis. *BMC Public Health* 2018;18:1092.
38 Medisinsk Fødselsregister - Statistikkbank: Folkehelseinstituttet. Available: http://statistikkbank.fhi.no/mfr/ [Accessed 11 Jan 2020].