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ORIGINAL ARTICLE

Adherence to dietary and lifestyle measures and glycemic control in Moroccan women with gestational diabetes: A cross-sectional study

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ABSTRACT

Background and aim: Gestational diabetes (GD) represents a frequent complication of pregnancy, affecting approximately 7-10% of pregnant women in Morocco. This study examined the relationships among therapeutic adherence, glycemic control, and weight changes in pregnant Moroccan women with GD.
Methods: A cross-sectional study was conducted among 120 pregnant women diagnosed with GD. Sociodemographic, clinical, anthropometric data, and glycemic measurements were collected. Adherence to dietary and lifestyle measures (DLM) was assessed by standardized questionnaire, and participants were categorized based on adherence levels.
Results: Initially, all participants (100%) had uncontrolled glycemia. After intervention, 53.3% of participants achieved glycemic balance. Adherence varied considerably: high for vegetable consumption (78.3%) and limiting sugars (75.8%), moderate to high for choosing low glycemic index foods (68.3%), moderate for controlling starchy foods (57.5%), and low for raw vegetables (40.8%). Significant correlations were identified between pre-gestational BMI and weight gain (r=-0.218; p=0.017), between weight gain and evening blood glucose (r=0.249;

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p=0.006), and between weight gain and overall adherence score (r=-0.236; p=0.009). Notably, 15% of participants experienced weight loss during pregnancy, raising concerns about inadequate nutritional intake. **Conclusions:** This study demonstrates that DLM alone can achieve glycemic balance in 53.3% of Moroccan women with GD. However, the 15% prevalence of gestational weight loss highlights the need for comprehensive monitoring that includes both glycemic and weight surveillance. These findings support culturally-adapted interventions, integrated weight monitoring protocols, and personalized nutritional counseling in GD management. Healthcare providers should maintain heightened vigilance for weight loss as a warning signal of inadequate nutritional status, even in women achieving apparent glycemic control. (www.actabiomedica.it)

Key words: gestational diabetes, therapeutic adherence, dietary and lifestyle measures, glycemic control, cross-sectional study, Morocco

Introduction

Gestational diabetes is defined as glucose intolerance of variable severity that is first diagnosed during pregnancy (1). According to the latest International Diabetes Federation Diabetes Atlas (11th edition, 2025), hyperglycemia in pregnancy affects approximately 19.7% of pregnancies worldwide, equivalent to 23 million births annually (2). Global prevalence varies between 3% and 32% depending on diagnostic criteria, populations studied, and geographic regions (2,3). In Europe, this condition is common among pregnant women, affecting approximately 11% of them, with a higher prevalence reported among pregnant women in Eastern European countries (31.5%) (3). In France, according to the latest National Perinatal Survey GD affected 16.4% of pregnant women in 2021, compared to 10.8% of women in 2016 (4). A systematic review and meta-analysis reported that GD prevalence in mainland China was 15.6% (95% CI: 14.9-16.2%) using IADPSG criteria (5). The prevalence of GD in Africa varies considerably by region, but represents a growing public health concern. A 10-year systematic review in sub-Saharan Africa reported a pooled prevalence of 3.05% (95% CI: 1.85%-4.54%) (6). In Morocco, this prevalence is estimated between 7% and 10% of pregnancies and is constantly increasing in parallel with the progression of obesity and sedentary lifestyles (7). GD is associated with numerous maternal and fetal complications; including fetal macrosomia, shoulder dystocia, obstetric trauma, preeclampsia, preterm delivery, and an increased risk of developing type 2 diabetes after pregnancy (8). GD management primarily relies on dietary and lifestyle measures (DLM) comprising a balanced diet, regular and adapted physical activity, as well as rigorous glycemic monitoring (7). Insulin therapy is generally reserved for cases where DLM alone fails to achieve glycemic targets. Diet and lifestyle modifications represent the cornerstone of GD management, with substantial evidence demonstrating their effectiveness in achieving glycemic control and reducing adverse outcomes. A comprehensive systematic review and meta-analysis of 116 studies involving 40,940 participants found that dietary interventions reduced GD incidence by 27% (RR 0.73; 95% CI 0.61-0.86), physical activity interventions by 31% (RR 0.69; 95% CI 0.55-0.85), and combined interventions by 18% (RR 0.82; 95% CI 0.74-0.94) compared to control groups (9). Importantly, the effectiveness of lifestyle interventions varies significantly based on implementation characteristics: group-based physical activity programs demonstrated superior effectiveness (RR 0.66) compared to individual-based delivery (RR 1.03), and healthcare facility-based interventions outperformed home-based approaches (9). International guidelines, including the 2024 American Diabetes Association Standards of Care, report that 70-85% of women diagnosed with GD using Carpenter-Coustan criteria can achieve glycemic control through lifestyle modifications alone, with even higher success rates anticipated when using the more stringent IADPSG diagnostic thresholds (10). However, recent evidence from the UK's National Institute for Health and Care Excellence (NICE) comprehensive review noted that while mixed lifestyle interventions show important benefits for neonatal outcomes, there is currently no convincing evidence that one particular diet is superior to another, emphasizing the need for individualized, culturally appropriate dietary counseling (11). These findings underscore both the potential and the complexity of implementing effective lifestyle interventions across diverse populations and healthcare settings. Beyond conventional dietary and physical activity interventions, emerging evidence has explored the potential role of probiotic supplementation in GD prevention and management, though findings remain inconclusive. An umbrella review of meta-analyses published in 2024 synthesized evidence from multiple systematic reviews and found that probiotic supplementation showed beneficial effects on certain metabolic parameters including fasting glucose and insulin resistance in pregnant women with gestational diabetes (12). A systematic review and meta-analysis specifically examining probiotic interventions during pregnancy reported potential benefits for glycemic control in women with GD, with some studies showing reduced fasting glucose levels and improved insulin sensitivity (13). Some evidence suggests that probiotic supplementation may reduce the risk of developing gestational diabetes, particularly with multi-strain formulations, though study results have been inconsistent (14). while in women already diagnosed with GD, probiotics improve glucose and lipid metabolism markers (15). Meta-analyses confirm that probiotic supplementation in women with gestational diabetes significantly reduces insulin resistance (HOMA-IR), fasting serum insulin, and fasting glucose levels compared to placebo (15,16). The results of randomized trials have shown involving women with GD who received probiotics (Lactobacillus and Bifidobacterium) or a placebo for four consecutive weeks showed a significant improvement in glucose metabolism in the group that received probiotics in terms of fasting blood glucose, insulin, and HOMA-IR index (16). However, the quality of evidence remains limited, and results vary considerably across studies depending on probiotic strains, dosages, timing of initiation, and study populations. Importantly, a 2021 Cochrane review raised safety concerns by identifying an increased risk of preeclampsia among women receiving probiotic supplementation (17), highlighting the need for caution in recommending probiotics as a routine preventive measure. The mechanisms by which probiotics might influence glucose metabolism are hypothesized to involve modulation of gut microbiota, reduction of systemic inflammation, and improvement of intestinal barrier function, though these pathways require further investigation (17). Given the inconsistent evidence and safety concerns, conventional dietary and lifestyle modifications remain the first-line management for GDM, while probiotics require further high-quality research before routine clinical use (18). Therapeutic adherence, defined as the concordance between patient behavior and medical recommendations, is a determining factor in the effectiveness of GD management (19). However, adherence to DLM remains a major challenge, influenced by multiple socio-cultural, psychological, economic, and healthcare system-related factors (20). In the Moroccan context, where the prenatal care system has recently been revised to increase from 4 to 8 prenatal visits in accordance with World Health Organization (WHO) recommendations, particular attention is given to the screening and management of GD (7). This reform aims to improve the quality of prenatal care, notably through the introduction of rapid screening tests for glycemia and the establishment of education classes for pregnant women ("Mother Classes"). Despite these efforts, few studies have evaluated the relationship between adherence to DLM and glycemic control in Moroccan pregnant women with GD. This is particularly important since the effectiveness of DLM may vary according to cultural contexts, local dietary habits, and available resources. The primary aim of this study was to analyze the relationship between adherence to dietary and lifestyle measures and glycemic control in pregnant women with gestational diabetes in Morocco. Secondary aims were to evaluate gestational weight changes and to identify factors associated with therapeutic adherence and glycemic outcomes.

Materials and Methods

Reporting guidelines

This study was reported according to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for cross-sectional studies (21). The STROBE checklist is provided as supplementary material.

Study type and population

This is a prospective observational study with before-after analysis conducted among 120 pregnant women diagnosed with gestational diabetes and followed under the Pregnancy and Child birth Surveillance Program (PCSP) in Morocco. The study design involved prospective enrollment of participants at GD diagnosis Participants received standard care according to PCSP protocols, and outcomes were measured at follow-up visits after a minimum of 2 weeks from diagnosis.

Study timeline and sample size

Participants were recruited between October 2024 and April 2025 from health centers and hospital maternity wards in the Rabat-Salé-Kénitra region. The sample size of 120 participants was determined by the recruitment capacity during the study period and represents consecutive eligible patients attending participating centers. This convenience sampling approach was chosen given the specialized nature of GD follow-up and available resources within the PCSP framework.

Inclusion and exclusion criteria

Inclusion criteria

Inclusion criteria included:

1. Pregnant women aged 18 to 45 years;
2. Confirmed diagnosis of gestational diabetes according to the International Association of Diabetes and Pregnancy Study Groups (IADPSG) criteria;
3. Singleton pregnancy;
4. Absence of drug treatment for diabetes (insulin or oral antidiabetics);
5. Follow-up of at least 2 weeks for gestational diabetes;
6. Completion of at least 2 glycemic cycles, each comprising 3 daily measurements: fasting glucose (GAJ), postprandial glucose (GPP), and evening postprandial glucose (GPP evening);
7. Regular follow-up at participating study centers under the PCSP.

Exclusion criteria

Exclusion criteria included:

1. Pre-existing diabetes mellitus diagnosed before pregnancy;
2. Multiple pregnancies;
3. Severe obstetric complications requiring hospitalization;
4. Psychiatric or cognitive disorders that could affect the understanding of medical recommendations;
5. Incomplete glycemic monitoring (fewer than 3 measurements per cycle);
6. Insufficient follow-up period (less than 2 weeks from GD diagnosis).

Adherence assessment

Adherence to dietary and lifestyle measures was assessed using a structured 22-item questionnaire administered during follow-up visits. The questionnaire evaluated three domains:

1. Dietary habits (15 items): meal patterns (meal frequency, timing, portion control), food selection (vegetable consumption, sugar limitation, glycemic index choices, protein sources), and cooking methods;
2. Physical activity (4 items): frequency, duration, and type of physical activities including regular exercise and active walking;
3. Glucose monitoring (3 items): measurement frequency, technique, and record-keeping practices.

Each item was rated on a 5-point scale: always (4), often (3), sometimes (2), rarely (1), never (0). Total adherence scores were calculated by summing individual item scores. Participants were categorized as having low, medium, or high adherence based on tertile distribution of total scores.

The 22-item structured questionnaire was developed based on current GD management guidelines and pilot-tested with 10 participants for cultural appropriateness. Total possible scores ranged from 0-88 points, with participants categorized using tertile distribution: low adherence (0-58 points), medium adherence (59-74 points), and high adherence (75-88 points).

Glycemic control assessment

Glycemic balance was evaluated using standardized home glucose monitoring. Each "glycemic cycle" consisted of three daily measurements:

Fasting glucose (GAJ): measured upon waking before any food intake
Postprandial glucose (GPP): measured 2 hours after breakfast
Evening postprandial glucose (GPP soir): measured 2 hours after dinner

Glycemic balance was defined according to target values: fasting blood glucose ≤0.95 g/L, postprandial glucose ≤1.20 g/L, and evening postprandial glucose ≤1.20 g/L. Participants achieving all three targets were classified as having "balanced glycemia," while those with any value above these thresholds were classified as "unbalanced."

Data collection

Data were collected from patients through direct interviews during follow-up visits. Baseline measurements (sociodemographic, anthropometric and initial glycemic values) were collected at the time of GD diagnosis. Follow-up measurements (adherence assessment, current weight, and glycemic control evaluation) were obtained during subsequent PCSP visits, with a minimum interval of 2 weeks from diagnosis. Information gathered included:

- Sociodemographic data: age, education level, occupational activity, place of residence (urban/rural).
- Anthropometric data: pre-pregnancy weight, current weight, height, Body Mass Index (BMI).
- Obstetric data: gravidity, parity, gestational age, obstetrical history.
- Clinical and biological data: blood pressure, fasting blood glucose (FBG), postprandial blood glucose (PPG), evening postprandial blood glucose (EPPG).

Ethical considerations

The study protocol was previously approved by the ethics committee of regional direction of health and social protection rabat sale kenitra (N 7223/2024). All precautions according to the Declaration of Helsinki were taken to protect the privacy and confidentiality of the personal information of those involved in the research. Informed consent was obtained from the participants, who were properly informed of the objectives and methods.

Statistical analysis

Data were entered and analyzed using IBM SPSS Statistics version 25 software. Qualitative variables were expressed as numbers and percentages, while quantitative variables were presented as means and standard deviations or medians and interquartile ranges according to their distribution. Bivariate analyses were performed to explore the relationship between adherence to DLM and glycemic control. Chi-square test or Fisher's exact test were used to compare qualitative variables, while Student's t-test or Mann- Whitney U test were used to compare quantitative variables according to their distribution. ANOVA with post-hoc Tukey tests was used to compare weight gain between different adherence categories. Pearson correlation coefficients were calculated to examine relationships between continuous variables including BMI, weight gain, glycemic values, and adherence scores. Multiple regression analyses were performed to identify significant predictors of glycemic control. The threshold for statistical significance was set at $p < 0.05$.

Results

Characteristics of the study population

A total of 120 pregnant women with gestational diabetes were included in this study (Figure 1). The mean age of participants was 31.9 ± 6.1 years, with an age range from 18 to 44 years. The majority of participants (67.5%) were between 25 and 35 years old, while 25.9% were over 35 years old and 6.6% were under 25 years old. Regarding education level, 18.3% were illiterate, 17.5% had a primary education level, 46.7% had a secondary level, and 17.5% had a higher education level. Occupationally, 76.7% of participants were unemployed, while 23.3% had an occupation. The mean pre-pregnancy BMI was 27.2 ± 4.9 kg/m², indicating a high prevalence of overweight and obesity in our sample. Indeed, 34.2% of participants were overweight (BMI between 25 and 29.9 kg/m²) and 25.8% were obese (BMI ≥ 30 kg/m²) before their pregnancy (Table 1). Participants resided equally in three areas of the region: Rabat (33.3%), Salé (33.3%), and Témara (33.3%) (Table 2). Family history of diabetes was reported by 45.8% of participants, personal history of GD by 15.8%, and history of macrosomia by 8.3%. Hypertension was present in 19.2% of women and digestive transit disorders in 23.3%. More than half (56.7%) had received nutritional education. Regarding the frequency of medical follow-up, 80.0% had weekly follow-up and 15.0% had biweekly follow-up.

Adherence to dietary and lifestyle measures

Analysis of adherence to dietary and lifestyle measures revealed that 96.7% of participants (n=116) were considered adherent according to the defined criteria, while only 3.3% (n=4) were non-adherent. Among the different components of DLM, adherence was particularly high for meal fractionation (94.2%), limitation of rapid sugars (88.3%), and regular consumption of vegetables (85.0%). In contrast, adherence was lower for regular physical activity (68.3%) and blood glucose self-monitoring at the recommended frequency (72.5%) (Table 3). For the choice of low glycemic index foods, more than half of the participants (55.8%) had very high adherence (score 4), 12.5% had moderately high adherence (score 3), 21.7% had moderate adherence (score 2), and only 10.0% had low adherence (scores 0 and 1) (Figure 2). For physical activity, 60.0% of participants reported high adherence to regular physical activity, but only 46.7% performed the recommended active walking (Figure 3).

Glycemic control

The mean glycemic values before intervention were as follows (Table 4):

- Fasting blood glucose (FBG): 1.04 ± 0.09 g/L (target value ≤ 0.95 g/L)
- Postprandial blood glucose (PPG): 1.30 ± 0.05 g/L (target value ≤ 1.20 g/L)
- Evening postprandial blood glucose (EPPG): 1.32 ± 0.06 g/L (target value ≤ 1.20 g/L)

After implementation of dietary and lifestyle measures, mean glycemic values showed significant improvement:

- Fasting blood glucose (FBG): 0.95 ± 0.11 g/L
- Postprandial blood glucose (PPG): 1.11 ± 0.10 g/L
- Evening postprandial blood glucose (EPPG): 1.12 ± 0.12 g/L

Relationship between adherence and glycemic control

Cross-analysis between adherence to dietary and lifestyle measures (DLM) and glycemic control revealed interesting patterns. From an initial state where 100% of participants had unbalanced glycemia, significant improvements were observed after intervention. Among participants who received nutritional education (n=68), 54.4% achieved glycemic control while 45.6% remained unbalanced. Similarly, among those who did not receive nutritional education (n=52), 51.9%

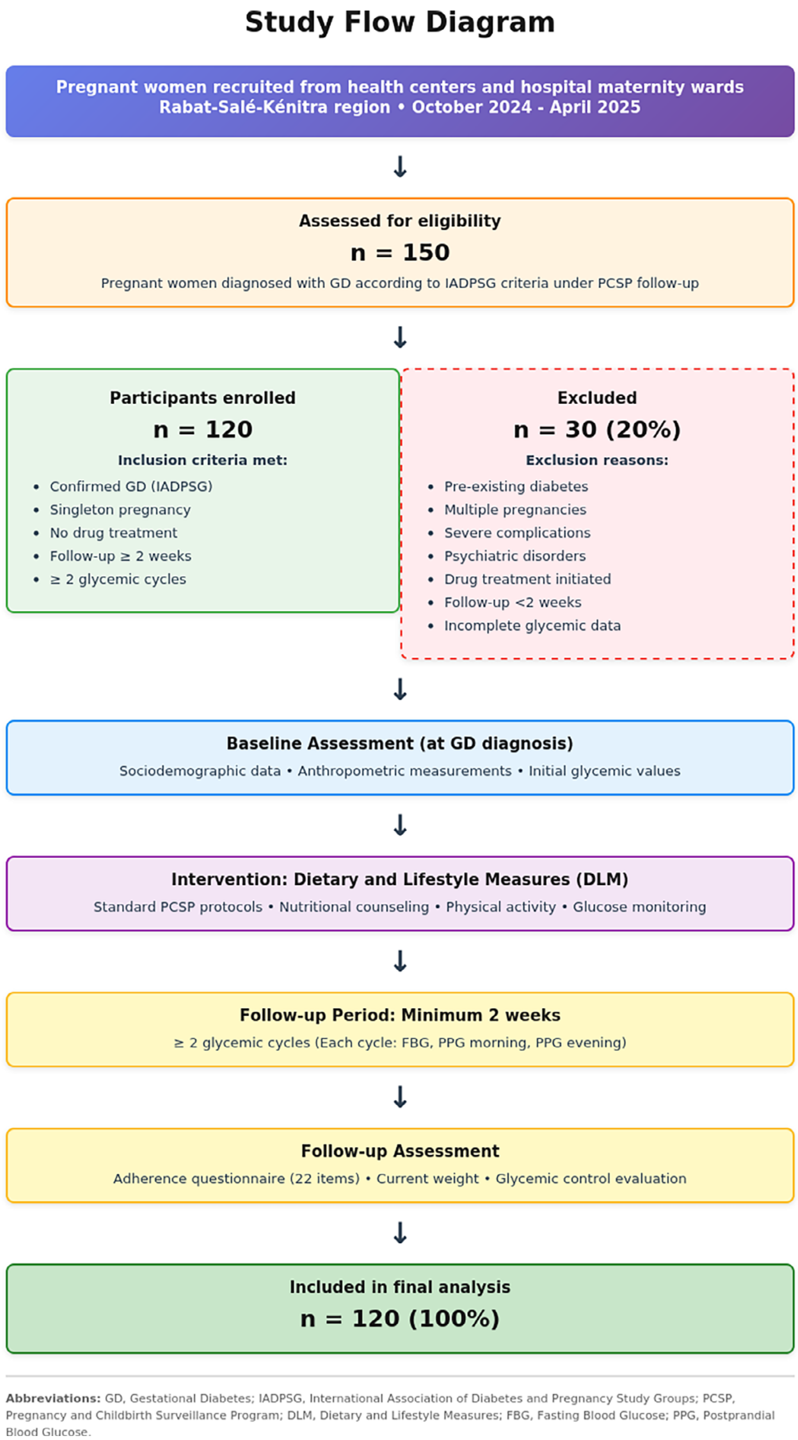

Figure 1. Study flow diagram.

achieved glycemic balance while 48.1% remained unbalanced (Table 5). Statistical analysis showed no significant association between nutritional education and glycemic balance ($\chi2 = 0.073$, $p = 0.787$), suggesting that factors beyond formalized nutritional education contribute to achieving glycemic targets. Despite the absence of a significant association between formalized nutritional education and glycemic balance,

Table 1. Sociodemographic and clinical characteristics of the study population (N=120).

Characteristics	**N**	**%**
Age (years)		
18-24	8	6.6
25-35	81	67.5
>35	31	25.9
Education level		
Illiterate	22	18.3
Primary	21	17.5
Secondary	56	46.7
Higher	21	17.5
Occupational activity		
Unemployed	92	76.7
Employed	28	23.3
Pre-pregnancy BMI (kg/m²)		
<18.5 (Underweight)	1	0.8
18.5-24.9 (Normal)	47	39.2
25-29.9 (Overweight)	41	34.2
≥30 (Obese)	31	25.8
Parity		
Nulliparous	60	50.0
Primiparous	25	20.8
Multiparous (≥2)	35	29.2
Gestational age (weeks)		
28-31	23	19.2
32-36	65	54.2
≥37	32	26.6

Table 2. Characteristics of participants by geographic origin.

Characteristic	**Rabat**	**Sale**	**Temara**	**p-value**
Age (years)	33.6 ± 6.1	30.8 ± 6.3	30.9 ± 5.4	0.135
BMI (kg/m²)	27.7 ± 6.3	28.4 ± 4.5	25.6 ± 3.2	0.028*
Weight gain (kg)	6.0 ± 7.1	6.8 ± 6.7	5.3 ± 5.8	0.625
Occupational activity (%)	27.5	15.0	27.5	0.312
Family history (%)	47.5	42.5	47.5	0.874
Transit disorders (%)	17.5	30.0	22.5	0.413

Note: Values are presented as mean ± standard deviation for continuous variables and percentages for categorical variables. P-values were determined using one-way ANOVA for continuous variables and Chi-square test for categorical variables. *Abbreviation:* BMI, Body Mass Index. * Indicates statistical significance at $p < 0.05$.

Table 3. Adherence to different components of dietary and lifestyle measures (N=120).

Components of DLM	N	%
Diet		
Meal fractionation (3 meals + 2-3 snacks)	113	94.2
Limitation of rapid sugars	106	88.3
Regular consumption of vegetables	102	85.0
Control of starchy food portions	92	76.7
Appropriate fruit consumption	97	80.8
Physical activity		
Regular practice (≥3 times/week)	82	68.3
Appropriate duration (≥30 min/session)	89	74.2
Blood glucose self-monitoring		
Recommended frequency	87	72.5
Correct technique	101	84.2
Attendance at follow-up appointments	111	92.5

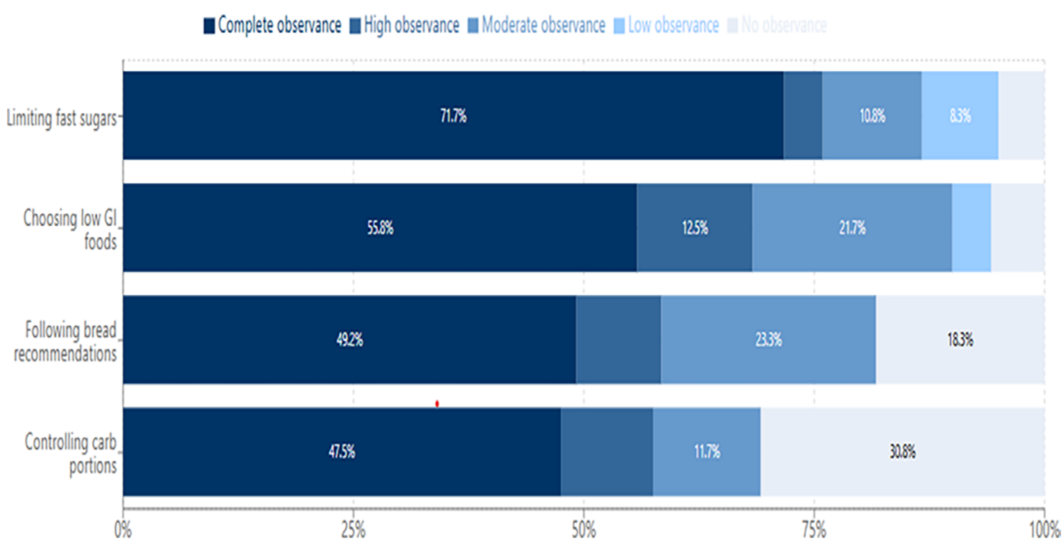

Figure 2. Adherence to recommendations regarding management of starchy foods and foods with low glycemic index.

a significant improvement in glycemic values was observed after the implementation of DLM in all participants. The mean improvement was 0.11 ± 0.13 g/L for FBG, 0.19 ± 0.11 g/L for PPG, and 0.20 ± 0.12 g/L for EPPG.

Consumption of animal proteins

The analysis of dietary habits regarding animal proteins revealed significant variations in consumption frequencies according to the type of protein. Our survey showed that eggs were the most frequently consumed source of animal protein, with 50% of participants consuming them three or more times per week. Poultry was the second most consumed, with 40% of participants reporting frequent consumption (three or more times per week). In contrast, fish consumption was mainly occasional, with 60% of women consuming it only once or twice a week, and only 25% consuming it regularly. Red meat showed a more

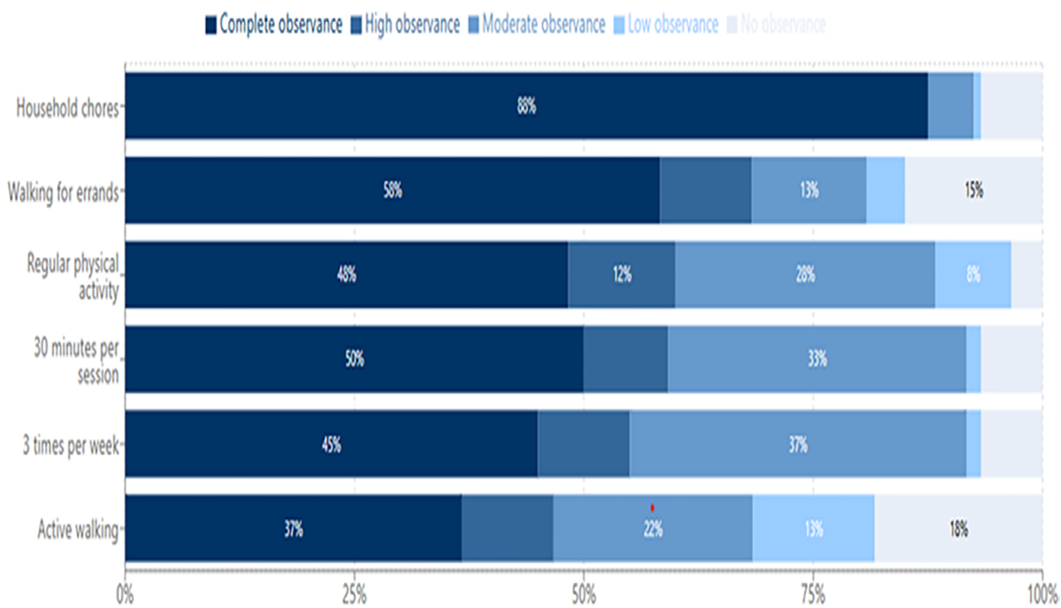

Figure 3. Adherence levels by type of physical activity.

Table 4. Glycemic values before and after implementation of dietary and lifestyle measures (N=120).

Parameter	Initial value Mean ± SD	Value after DLM Mean ± SD	Mean improvement Mean ± SD
FBG (g/L)	1.04 ± 0.09	0.95 ± 0.11	0.11 ± 0.13
PPG (g/L)	1.30 ± 0.05	1.11 ± 0.10	0.19 ± 0.11
EPPG (g/L)	1.32 ± 0.06	1.12 ± 0.12	0.20 ± 0.12

Table 5. Comparison of glycemic balance according to nutritional education status.

Nutritional Education	Balanced Glycemia	Unbalanced Glycemia	Total
Yes	37 (54.4%)	31 (45.6%)	68 (100.0%)
No	27 (51.9%)	25 (48.1%)	52 (100.0%)
Total	64 (53.3%)	56 (46.7%)	120 (100.0%)

balanced distribution, with a predominance of moderate consumption (50% of participants consuming it once or twice a week) (Figure 4).

Relationships between glycemic values, adherence, and weight gain

Our correlation analysis revealed a significant positive correlation between weight gain and evening blood glucose ($r = 0.249$, $p = 0.006$), suggesting that greater weight gain is associated with higher glycemic values in the evening. In contrast, no significant correlation was found between weight gain and fasting blood glucose ($r = -0.100$, $p = 0.279$). A significant negative correlation was identified between the overall adherence score and weight gain during pregnancy ($r = -0.236$, $p = 0.009$), indicating that better adherence was associated with more moderate weight gain (Table 6). Multiple regression analysis with evening blood glucose as the dependent variable showed a statistically significant model ($F = 4.823$, $p = 0.003$, R2 = 0.111). In this model, weight gain ($\beta = 0.284$, $p = 0.003$) and pre-pregnancy BMI ($\beta = 0.220$, $p = 0.016$) were significant predictors of evening blood glucose, while

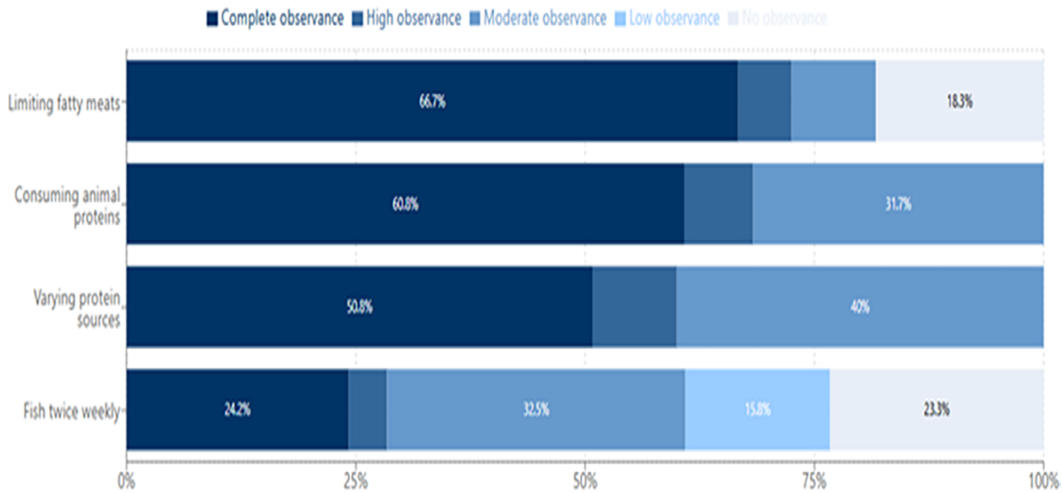

Figure 4. Frequency of consumption of animal proteins.

Table 6. Statistical relationships reported in the study.

Variable	Correlation (r)	p-value	Significance
Weight gain and evening blood glucose	0.249	0.006	Significant positive correlation
Weight gain and fasting blood glucose	-0.100	0.279	No significant correlation
Weight gain and postprandial blood glucose	0.073	0.432	No significant correlation
Adherence score and weight gain	-0.236	0.009	Significant negative correlation
Pre-pregnancy BMI and weight gain	-0.218	0.017	Significant negative correlation
Pre-pregnancy BMI and fasting blood glucose	0.103	0.261	No significant correlation
Pre-pregnancy BMI and evening blood glucose	0.153	0.094	No significant correlation
Adherence score and fasting blood glucose	-0.026	0.775	No significant correlation
Adherence score and postpran- dial blood glucose	-0.050	0.588	No significant correlation
Adherence score and evening blood glucose	-0.109	0.236	No significant correlation

the adherence score was not (β = -0.059, p = 0.514). ANOVA analyses revealed a significant difference in weight gain according to the adherence category (F = 3.668, p = 0.029). Tukey post-hoc tests showed that the low adherence group had significantly higher weight gain (mean = 9.55 kg) than the medium adherence (5.17 kg, p =0.035) and high adherence (5.42 kg, p = 0.037) groups, with the latter two not differing significantly from each other (p = 0.979).

Differences according to pre-gestational BMI

Pre-gestational BMI was negatively correlated with weight gain during pregnancy (r = -0.218, p = 0.017) (Table 6). Participants with a higher pre-gestational BMI generally gained less weight than those with a normal BMI, which could reflect differences in nutritional advice given to women based on their initial weight status. Geographic area analyses showed significant differences in pre-pregnancy BMI (p = 0.028), with higher values in Salé (28.4 kg/m^2) than in Témara (25.6 kg/m^2), which could reflect socioeconomic disparities or different dietary habits between these areas (Table 2).

Weight loss during pregnancy: A warning signal

A particularly concerning result was the presence of weight loss in 15% of participants, with losses up to -12 kg. These weight losses were observed across all pre-gestational BMI categories: 27.8% had a normal BMI, 38.9% were overweight, and 33.3% were obese.These observations are even more concerning as they were not necessarily accompanied by glycemic disturbances. Indeed, t-tests comparing the glycemic values of women with and without weight loss did not show significant differences (fasting blood glucose: p = 0.678; evening blood glucose: p = 0.376), suggesting that these women maintain apparent glycemic control at the cost of potentially excessive and inappropriate caloric restriction during pregnancy.

Discussion

This study demonstrates that 53.3% of Moroccan women with GD achieved glycemic balance through DLM alone. While this represents meaningful improvement from 100% unbalanced at baseline, it is lower than the 70-85% success rate reported by the 2024 American Diabetes Association for Carpenter-Coustan criteria, with even higher rates anticipated using IADPSG thresholds (10), and the 82.6% achieved in a Vietnamese study with identical criteria and timeline (22). Meta-analytic evidence provides important context for interpreting these differences. A systematic review of 116 studies (40,940 participants) found that intervention effectiveness depends critically on implementation characteristics: group-based physical activity reduced GD by 34% (RR 0.66) versus no effect for individual-based delivery (RR 1.03), and facility-based interventions (RR 0.59) outperformed home-based approaches (9). Combined interventions in middle-income countries reduced GD by 31% (RR 0.69), less than in low-middle income countries (49% reduction). The UK NICE review similarly noted that most GD intervention evidence is "very low quality (11). Our study utilized individual counseling in routine settings rather than intensive group-based programs, and our population had 60% with BMI ≥25 versus only 6.6% in the Vietnamese cohort (22). These factors likely explain our 53.3% success rate, which aligns with meta-analytic predictions for individual-based delivery in middle-income settings. Our findings thus reflect real-world effectiveness when intensive infrastructure is limited, contributing implementation science evidence from an underrepresented North African population.

Variability of adherence according to recommendations

Our results highlight considerable variability in adherence to different dietary recommendations. High adherence to vegetable consumption at each meal (78.3%) and limitation of rapid sugars (75.8%) likely reflects that these recommendations are relatively simple to understand and implement. Similarly, the high adherence concerning the choice of low glycemic index foods (68.3%) demonstrates a good understanding of this concept by participants, probably thanks to the nutritional education received by the majority of them (56.7%). In contrast, the more moderate adherence regarding the control of starchy food portions (57.5%) suggests difficulties in implementing these specific aspects of carbohydrate management. This may reflect the central role of starchy foods, particularly bread, in the traditional Moroccan diet (23). The low adherence to the preference for raw vegetables (40.8%) could reflect local culinary habits favoring cooked vegetables. The significant negative correlation between the overall adherence score and weight gain (r = -0.236, p = 0.009) and the significant differences in weight gain between adherence categories (p = 0.029) confirm the clinical impact of adherence to dietary and lifestyle recommendations. Participants with low adherence gained significantly more weight (9.55 kg) than those with medium (5.17 kg) or high (5.42 kg) adherence.

Understanding the high overall adherence rate

The high overall adherence rate (96.7%) requires careful interpretation within the context of our assessment methodology. Our 22-item questionnaire included behaviours ranging from basic meal patterns (naturally performed by most individuals) to complex lifestyle modifications. The tertile-based categorization system meant that participants could be classified as "adherent" while still showing significant variation in individual behaviors. Furthermore, our study population consisted of women actively engaged in specialized GD care within the PCSP framework, representing a self-selected group likely more motivated toward health-promoting behaviors than the general population. Social desirability bias may also have contributed during face-to-face interviews. The significant variation in individual component adherence (ranging from 40.8% to 94.2%) provides a more nuanced and realistic picture of actual compliance patterns.

Variability according to geographic location

Our study revealed significant differences in pre-pregnancy BMI according to the geographic origin of participants ($p = 0.028$), with higher values in Salé and lower values in Témara. This variation could reflect socioeconomic differences or specific dietary habits in each area. However, these differences did not significantly influence glycemic values.

Correlation between BMI, weight gain, and glycemia

The significant negative correlation between pre-gestational BMI and weight gain ($r = -0.218$, $p = 0.017$) is consistent with established literature demonstrating an inverse relationship between pre-pregnancy BMI and gestational weight gain (24,25). This pattern likely reflects multiple factors including more restrictive dietary counseling for women with elevated BMI, heightened maternal awareness of weight-related risks, and metabolic differences in nutrient partitioning (25). However, it is important to emphasize that while lower weight gain may occur, international guidelines still recommend positive weight gain even for obese women (5-9 kg for BMI ≥30 kg/m²), as weight loss during pregnancy is associated with adverse neonatal outcomes regardless of maternal BMI (26). Recent population-based evidence from the United States has further refined optimal gestational weight change ranges for women with GDM across BMI categories, demonstrating U-shaped or J-shaped relationships between weight change and perinatal outcomes (27).

Physical activity adherence and delivery characteristics

Our 68.3% physical activity adherence rate, while substantial, was not significant in multivariable analysis, suggesting that implementation strategies require optimization. Meta-analytic evidence demonstrates that PA effectiveness is highly delivery-dependent: group-based interventions achieved 34% GD reduction (RR 0.66) versus no effect for individual-based delivery (RR 1.03) (subgroup p=0.04) (9). Group-based exercise programs during pregnancy have demonstrated superior outcomes through multiple mechanisms including peer support, professional supervision, and structured programming (28). Successful programs utilized quantified FITT-VP prescriptions (Frequency, Intensity, Time, Type, Volume, Progression), professional supervision, and peer support—elements largely absent in our individual counseling approach. The enhanced effectiveness of group-based programs likely stems from social support networks, accountability mechanisms, and motivational reinforcement that individual counseling cannot replicate (28). Future Moroccan programs should consider group-based, facility-supervised PA interventions adapted to local cultural contexts and infrastructure, drawing on evidence from both prevention studies (9) and systematic reviews of group exercise programs in pregnancy (28). Such programs should account for cultural norms regarding women's exercise, accessibility of facilities, and availability of qualified supervisors while maintaining the core elements that drive effectiveness.

Weight loss: A concerning signal not identified by glycemic monitoring

The 15% prevalence of gestational weight loss in our study appears higher than rates typically observed in large international cohorts of women with GDM, suggesting potential cultural, healthcare, or socioeconomic factors specific to the Moroccan context that warrant immediate clinical attention. International guidelines explicitly recommend against weight loss during pregnancy, evening obese women, emphasizing that management should focus on adequate nutrition rather than caloric restriction (29).

Weight loss during pregnancy may indicate inadequate nutritional intake or metabolic disturbances that could negatively affect fetal development. This is particularly concerning as the literature notes that weight loss is not recommended during pregnancy" and that overweight and obese women should be advised to aim for a moderate weight loss prior to conception and during the postpartum period". Similarly, clinical guidelines emphasize controlled weight gain rather than weight loss during pregnancy, with specific recommendations of 5–9 kg total gestational weight gain for women with pre-pregnancy BMI ≥30 kg/m^2 (30). The risk factors associated with insufficient gestational weight gain appear to be independent of glycemic control, suggesting that current monitoring protocols focusing primarily on blood glucose levels may fail to identify women experiencing inadequate nutritional status. This finding highlights the importance of regular weight monitoring throughout pregnancy, alongside glycemic assessment, especially in women with diabetes or other metabolic conditions.

The 2024 ADA Standards explicitly state that "losing weight is NOT recommended because of increased risk of small-for-gestational-age infants" (10), and clinical guidelines recommend 5-9 kg weight gain even for women with BMI ≥30 kg/m² (30). NICE guidelines similarly emphasize adequate nutrition over caloric restriction (11). Our three-fold higher prevalence of weight loss compared to international norms suggests Moroccan-specific factors requiring urgent investigation and clinical vigilance.

Relationship between nutritional education and glycemic balance

Our study revealed that 53.3% of participants achieved glycemic balance according to the defined criteria, with no significant difference between those who received formalized nutritional education (54.4%) and those who did not (51.9%). This finding challenges the conventional assumption that structured nutritional education is the primary determinant of glycemic control in GD.

Our finding that more than half of participants achieved glycemic balance with DLM alone is encouraging and suggests that non-pharmacological approaches can be effective for a significant proportion of women with GD. However, the 46.7% who remained unbalanced despite intervention highlight the need for more intensive or personalized approaches for this subgroup.

Glycemic response to dietary and lifestyle measures

Our study provides important insights into the effectiveness of DLM in managing GD in the Moroccan context. At baseline, all participants (100%) had unbalanced glycemia according to our defined criteria (GAJ > 0.95 OR GPP > 1.20 OR GPPsoir > 1.20). After intervention, 53.3% of participants achieved glycemic balance through DLM alone, while 46.7% maintained some level of glycemic imbalance despite intervention. This transition from 0% to 53.3% of participants with balanced glycemia demonstrated the significant positive impact of appropriate dietary and lifestyle measures in this population.

Despite these challenges, our results showed a significant improvement in glycemic values after the implementation of DLM (FBG: -0.11 g/L, PPG: -0.19 g/L, EPPG: -0.20 g/L). This improvement was sufficient to achieve the set objectives in more than half of our participants, suggesting that DLM have a meaningful impact on glucose metabolism during pregnancy. These results are consistent with the international literature, which shows that DLM can effectively reduce hyperglycemia in many, though not all, patients with GD (22).

Cultural adaptation and evidence gaps

The UK NICE 2025 review of 29 GD studies explicitly noted "NO EVIDENCE specific for... specific ethnic groups" and lack of data on cultural dietary preferences, with all studies from high-income countries excluding North Africa (11). Only 7 of 116 studies (6%) in the Takele meta-analysis were from low-middle income countries (9). Our documentation of Moroccan dietary patterns—moderate starchy food control (57.5%), high cooked vegetable consumption (70.8%), low raw vegetable preference (40.8%)—addresses this evidence gap. The central role of bread in Moroccan cuisine exemplifies why individualized dietary plans are essential, as recommended by international guidelines **(29)**. Large-scale studies in North African populations are needed to develop region-specific guidelines accounting for genetic, metabolic, and sociocultural factors.

Implications for clinical practice

Our results have several practical implications for GD management in Morocco:

1. The need for careful monitoring of weight gain, interpreted according to pre-gestational BMI, alongside glycemic monitoring.
2. The importance of adapting nutritional advice not only to glycemic status but also to weight profile and the dynamics of weight gain during pregnancy.
3. Consideration of circadian glycemic variations, with particular attention to evening values that seem more sensitive to the effects of weight gain and pre-gestational BMI, as demonstrated by our regression model ($F = 4.823$, $p = 0.003$, $R^2 = 0.111$).
4. The development of therapeutic education programs adapted to cultural specificities and local dietary habits, taking into account the regional disparities identified.
5. A stratification of nutritional advice according to the level of adherence, with particular attention to patients with low adherence who, in our study, had significantly higher weight gain (9.55 kg versus 5.17-5.42 kg, $p = 0.029$).
6. The implementation of more objective methods to evaluate the actual adherence to dietary and lifestyle recommendations.
7. More frequent re-evaluation of the need for insulin therapy in women with persistent glycemic imbalance despite good adherence to DLM, in accordance with current recommendations.
8. Greater vigilance for women with weight loss during pregnancy, who may need specific nutritional interventions to ensure adequate caloric intake while maintaining glycemic balance.

Study limitations

This study has several important limitations. The convenience sampling approach and lack of formal power calculations limit generalizability. The high overall adherence rate may reflect selection bias toward more motivated patients and social desirability bias in self-reporting. While statistically significant, the observed correlations were modest in magnitude ($r = -0.236$ to 0.249), and our regression model explained only 11.1% of variance, suggesting multiple unmeasured factors influence outcomes. The pragmatic monitoring approach may not capture all glycemic fluctuations between visits. Future studies should employ prospective designs with objective adherence measures and larger representative samples. Our findings should be interpreted within broader methodological context: NICE found most GD evidence is "very low quality" with serious bias (11), and our limitations are consistent with field-wide challenges. Differences in population characteristics (60% BMI ≥25 vs 6.6% in Vietnamese studies), intervention intensity, and IADPSG's broader diagnostic threshold limit direct comparability with other studies.

Conclusion

This study provides important insights into GD management in Moroccan women, highlighting the complex, multifactorial nature of adherence and glycemic balance. Key findings include demonstration that over half of participants achieved glycemic balance through non-pharmacological approaches, identification of cultural variation in adherence patterns, and most critically, documentation of concerning gestational weight loss in 15% of participants despite apparent adherence to recommendations. These findings support comprehensive, culturally-adapted GD care that integrates weight surveillance with glycemic monitoring and recognizes that effective management requires more than adherence to standardized protocols.

Ethic Approval: The study protocol was previously approved by the ethics committee of regional direction of health and social protection rabat sale kenitra (N 7223/2024).

Conflict of Interest: Each author declares that he or she has no commercial associations (e.g., consultancies, stock ownership, equity interests, patent/licensing, arrangement etc-) that might pose a conflict of interest in connection with the submitted article.

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