

Clinical Empirical Study on Synergistic Intervention Mode of Diet and Exercise for Pregnancy Risk and Maternal-Infant Outcomes in Patients with Gestational Diabetes Mellitus

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Abstract

Objective: To explore the clinical efficacy of synergistic intervention combining individualized dietary management and low-resistance exercise in regulating glucose metabolism, reducing gestational complications and improving maternal-infant pregnancy outcomes among patients with gestational diabetes mellitus (GDM). **Methods:** A total of 70 pregnant women diagnosed with GDM who underwent antenatal registration and delivery in our hospital from January 2025 to May 2026 were enrolled. This study adopted a prospective randomized controlled design. All participants were enrolled, assessed at baseline and received intervention at 24 - 28 gestational weeks, then randomly divided into control group and observation group via random number table, with 35 subjects in each group. The control group received routine obstetric health education and general dietary guidance, while the observation group was supplemented with synergistic intervention consisting of individualized low-glycemic-index (low-GI) dietary regimen and standardized low-resistance exercise prescription on the basis of conventional care. Insulin and other hypoglycemic medications used during pregnancy were recorded and compared between two groups. Analysis of covariance (ANCOVA) adjusted for baseline values and comparison of changes from baseline were applied to evaluate the intervention effect. Fasting blood sugar (FBS), 2-hour postprandial blood sugar (PBS) and glycosylated hemoglobin (HbA1c) before and after

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intervention, incidence of gestational complications, neonatal birth weight, Apgar score and rates of adverse pregnancy outcomes were compared between two cohorts. **Results:** Baseline data including age, gestational age, gravidity-parity status, education background, comorbidities, FBS, PBS and HbA1c showed no statistically significant intergroup differences before intervention ($P > 0.05$), indicating comparable baseline characteristics. No significant difference was found in the use of hypoglycemic drugs between the two groups. After intervention, the control group had significantly lower FBS level than the observation group ($t = -3.213$, $P = 0.002$), whereas PBS and HbA1c had no significant between-group differences ($P > 0.05$). Intra-group comparison revealed that FBS and PBS were markedly decreased post-intervention in control group ($P < 0.001$); only PBS was significantly reduced after intervention in observation group ($P < 0.001$), while FBS and HbA1c showed no obvious changes before and after intervention in the observation group ($P > 0.05$). No statistical disparities were identified in the incidence of hypertensive disorders of pregnancy, gestational obesity, anemia, premature rupture of membranes and postpartum hemorrhage between groups ($P > 0.05$). Tested by continuity-corrected chi-square test, neonatal birth weight, Apgar score and incidences of preterm birth, macrosomia, fetal growth restriction and overall adverse pregnancy outcomes presented no intergroup statistical differences ($P > 0.05$). **Conclusion:** This study failed to confirm that the combined diet and low-resistance exercise intervention was superior to routine intervention in improving fasting blood glucose of GDM patients. Both interventions could effectively reduce postprandial blood glucose. This combined regimen cannot statistically reduce the incidence of gestational complications and adverse maternal-infant outcomes. It can only be regarded as an exploratory auxiliary strategy for GDM prenatal management, and widespread clinical promotion is not recommended temporarily.

Keywords

Gestational Diabetes Mellitus, Dietary Intervention, Low-Resistance Exercise, Glucose Metabolism, Pregnancy Outcome, Maternal and Infant Safety

1. Introduction

Gestational Diabetes Mellitus (GDM) is a unique endocrinometabolic disorder emerging during gestation, defined as newly-onset abnormal glucose tolerance detected for the first time in pregnancy, excluding patients with pregestational diagnosed diabetes mellitus [1]. Driven by the nationwide three-child policy, growing proportion of advanced-age pregnant women and shifts in residents' dietary pattern and lifestyle, the prevalence of GDM keeps rising in China with current incidence ranging from 10% to 20%, evolving into a critical public health hazard threatening maternal and neonatal health [2].

Disordered glucose metabolism among GDM patients triggers multisystem pathophysiological disturbances, elevating risks of gestational hypertension, pol-

hydramnios, premature rupture of membranes, postpartum hemorrhage and other gestational complications, as well as adverse fetal events including abnormal intrauterine development, macrosomia, preterm delivery and fetal distress, which severely endanger short-term survival and long-term physical health of mothers and newborns [3]. Current routine clinical management for GDM mainly relies on universal health education and standardized general dietary advice lacking personalized and systematic precise intervention. Restricted by varied dietary habits, physical constitution and poor exercise compliance in pregnant population, numerous patients fail to achieve satisfactory glycemic control, leading to persistently high incidence of adverse maternal-infant outcomes [4].

Dietary and exercise interventions constitute core non-pharmacological treatments for GDM. Individualized low-GI diet optimizes carbohydrate composition to stabilize postprandial glycemic fluctuation and enhance insulin sensitivity; low-resistance physical activity boosts peripheral glucose utilization and alleviates insulin resistance, thus synergistically facilitating precise glycemic regulation [5]. Existing literatures have validated the favorable glycemic-controlling effect of combined diet-exercise intervention, yet large-sample systematic clinical verification targeting primary hospital-based GDM population remains insufficient, and long-term impacts of such intervention on gestational complications and pregnancy outcomes require further clinical confirmation [6].

This study enrolled 70 GDM parturients hospitalized in our institution, adopting a prospective randomized controlled design, to verify the clinical benefits of individualized diet plus low-resistance exercise synergistic protocol on glycometabolism, gestational complications and maternal-neonatal outcomes. All interventions were initiated uniformly at 24 - 28 gestational weeks, so as to provide empirical evidence and practical reference for standardized prenatal GDM management in primary medical facilities.

2. Materials and Methods

2.1. Study Subjects

Seventy GDM pregnant women receiving antenatal care and childbirth service at People's Hospital of Guangxi-ASEAN Economic & Technological Development Zone between January 2025 and May 2026 were recruited. This is a prospective randomized controlled trial. All participants completed enrollment and baseline assessment and started intervention at 24 - 28 gestational weeks, then randomized into control group and observation group ($n = 35$ per group). The research protocol was approved by the institutional medical ethics committee, and all enrolled participants signed written informed consent. No prior sample size calculation was performed, and the limited sample size may reduce the statistical power of this trial.

2.2. Inclusion and Exclusion Criteria

Inclusion Criteria: 1) Diagnosis consistent with criteria proposed by the Inter-

national Association of Diabetes in Pregnancy Study Groups (IADPSG) [7]: GDM confirmed via 75g oral glucose tolerance test (OGTT) administered at 24 - 28 gestational weeks, with any single abnormal value: fasting glucose ≥ 5.1 mmol/L, 1-hour post-load glucose ≥ 10.0 mmol/L or 2-hour post-load glucose ≥ 8.5 mmol/L; 2) Singleton pregnancy; 3) Gestational age at enrollment: 24 - 28 weeks; 4) Complete clinical data and full accessibility for follow-up and intervention implementation.

Exclusion Criteria: 1) Pre-gestational type 1 or type 2 diabetes; 2) Severe dysfunction of vital organs (heart, liver, kidney) or concomitant endocrinopathy such as thyroid disorders; 3) Contraindications against physical exercise precluding low-resistance training; 4) Multiple gestation, fetal malformation, abnormal placental morphology and other pathological pregnancy conditions; 5) Severe psychiatric or cognitive impairment interfering with intervention cooperation and data collection.

2.3. Intervention Protocols

All participants received standardized routine obstetric management including scheduled prenatal check-ups, regular blood glucose monitoring and general health education from enrollment (24 - 28 gestational weeks) till delivery. If blood glucose was poorly controlled, insulin or other hypoglycemic agents were used in accordance with clinical guidelines, and the medication usage of the two groups was recorded in detail.

Control Group: Conventional GDM-related health education and universal dietary guidance. Obstetric nurses delivered systematic education covering disease overview, significance of glycemic control and general dietary principles of low-GI eating. Patients were instructed to monitor fasting and 2-hour postprandial glucose routinely, maintain daily mild physical activity and receive ongoing surveillance of blood glucose and gestational complications.

Observation Group: On the basis of conventional management identical to control group, synergistic intervention of customized low-GI diet plus individualized low-resistance exercise was implemented as detailed below:

Individualized Dietary Intervention: Clinical dietitians formulated exclusive low-GI dietary plans tailored to each patient's gestational age, body weight, glycemic profile, dietary preference and comorbidities. Total daily calorie intake was strictly quantified with macronutrient energy allocation: carbohydrates accounting for 50% - 60% of total energy (prioritizing low-GI foods with prohibited refined sugar and high-fat high-oil products), high-quality animal-derived protein covering 15% - 20% and unsaturated fat contributing 25% - 30%. Daily feeding pattern was set as three regular meals plus 2 - 3 supplemental snacks to avoid overeating or prolonged fasting and mitigate glycemic swings. Patients kept daily dietary logs, and diet prescriptions were revised weekly according to real-time glycemic monitoring results to meet targeted glucose levels.

Low-Resistance Exercise Guidance: Professional medical staff designed per-

sonalized low-intensity low-resistance exercise regimens in accordance with gestational age, physical tolerance and baseline exercise habits. Approved activities included daily brisk walking, prenatal yoga, Kegel exercise and upper-extremity resistance training; strenuous high-intensity workout was forbidden. Exercise intensity was limited to tolerable fatigue without abdominal pain or vaginal bleeding, with each session lasting 20 - 30 minutes for 3 - 5 sessions weekly starting 1 hour after meals to prevent fasting-induced hypoglycemia. Participants were taught self-monitoring of heart rate and physical discomfort during exercise with immediate termination and clinical consultation upon adverse symptoms. Exercise schedules were adjusted biweekly based on individual physical endurance assessment to guarantee safety and efficacy.

Full-Cycle Health Administration: Obstetric care providers tracked intervention adherence throughout gestation via weekly telephone follow-ups and bi-weekly outpatient interviews to monitor diet/exercise compliance and blood glucose fluctuation, resolve clinical questions and adjust intervention schemes synchronously. Continuous health literacy promotion was performed to improve patients' self-management capacity and treatment adherence. Quantitative scoring for diet and exercise compliance was not applied in this research.

2.4. Observation Indicators

1) Baseline Information: Demographic data including age, gestational age, gravidity-parity status, educational background and pre-existing medical comorbidities were collected.

2) Glycometabolic Indicators: Peripheral venous blood samples were collected at enrollment (pre-intervention, 24 - 28 gestational weeks) and before childbirth (post-intervention) to detect FBS, PBS and HbA1c. Glucose was quantified via glucose oxidase method, and HbA1c was measured with high-performance liquid chromatography. Analysis of covariance (ANCOVA) adjusted for baseline values and independent-sample t-test on changes from baseline were used to evaluate intervention effects.

3) Gestational Complications: Incidence of hypertensive disorders of pregnancy, obesity, anemia, premature rupture of membranes and postpartum hemorrhage was calculated; postpartum hemorrhage was defined as cumulative vaginal blood loss ≥ 500 mL within 24 hours after fetal delivery [8].

4) Pregnancy Outcomes: Neonatal birth weight, Apgar score and occurrence of preterm birth, macrosomia, fetal growth restriction and fetal distress were documented. Macrosomia referred to neonatal birth weight ≥ 4000 g, fetal growth restriction to birth weight < 2500 g, and fetal distress to 1-minute Apgar score < 7 [9]. Total adverse pregnancy outcome was counted based on affected individual cases rather than cumulative adverse event frequency.

5) Hypoglycemic medication: Record the number and proportion of patients using insulin and other hypoglycemic drugs during pregnancy in the two groups.

2.5. Statistical Analysis

All statistical analyses were processed with SPSS 30.0 software. Measurement data conforming to normal distribution were expressed as mean $\pm$ standard deviation ($\bar{x} \pm s$); Analysis of covariance (ANCOVA) adjusted for baseline values and independent-sample t-test for changes before and after intervention were used for inter-group comparison, and paired t-test was adopted for intra-group pre-post comparison. Enumeration data were presented as case number (n) and constituent ratio (%). Continuity-corrected chi-square test was adopted for fourfold tables with theoretical frequency < 5 , and Fisher's exact test for contingency tables containing zero value. All statistical tests were two-tailed with $\alpha = 0.05$ as significance threshold, where $P < 0.05$ denoted statistically significant difference.

3. Results

3.1. Baseline Demographic Comparison

All 70 enrolled GDM women (35 per group) completed full intervention and follow-up without case dropout. No significant intergroup differences in age, gestational age, gravidity-parity status, education background and comorbidities were observed at baseline ($P > 0.05$) (Table 1). There was no significant difference in the use of hypoglycemic drugs between the two groups ($P > 0.05$).

Table 1. Baseline demographic characteristics of GDM patients ($\bar{x} \pm s$).

Group	n	Age (years)	Gestational age (weeks)
Control	35	33.54 $\pm$ 5.68	38.11 $\pm$ 1.16
Observation	35	31.71 $\pm$ 6.41	38.31 $\pm$ 1.05
t value	-	1.262	-0.757
P value	-	0.211	0.452

3.2. Changes in Glycometabolic Indicators Pre- and Post-Intervention

Pre-intervention FBS, PBS and HbA1c were comparable between two groups ($P > 0.05$). After adjusted by baseline covariates and compared with changes from baseline: Post-intervention FBS level of control group was lower than that of observation group ($P < 0.01$), whereas PBS and HbA1c showed no between-group discrepancy ($P > 0.05$). Intra-group analysis: FBS and PBS decreased significantly after intervention in control group ($P < 0.001$) without notable HbA1c variation ($P > 0.05$); only PBS declined remarkably post-intervention in observation group ($P < 0.001$), while FBS and HbA1c had no significant changes before and after intervention ($P > 0.05$) (Table 2).

3.3. Incidence of Gestational Complications

No statistically significant differences existed in all measured gestational complications between two cohorts ($P > 0.05$) (Table 3).

Table 2. Comparison of glycometabolic indexes before and after intervention ($\bar{x} \pm s$).

Index	Group	n	Pre-intervention	Post-intervention	Intra-group t	Intra-group P	Inter-group t	Inter-group P
FBS (mmol/L)	Control	35	5.14 ± 0.82	4.56 ± 0.49	5.912	0.000	-3.213	0.002
	Observation	35	5.19 ± 1.06	5.23 ± 1.45	-0.227	0.822		
PBS (mmol/L)	Control	35	9.10 ± 1.87	5.96 ± 0.99	10.404	0.000	-1.655	0.103
	Observation	35	8.85 ± 1.90	6.33 ± 0.87	7.792	0.000		
HbA1c (%)	Control	35	5.56 ± 0.52	5.42 ± 0.52	1.362	0.182	-0.351	0.726
	Observation	35	5.61 ± 0.81	5.46 ± 0.43	1.148	0.259		

Table 3. Incidence of gestational complications in the two groups [n (%)].

Complication	Control group (n = 35)	Observation group (n = 35)	Statistical method	Statistic	P value
Hypertensive disorders of pregnancy	7 (20.00)	7 (20.00)	Continuity-corrected χ^2	$\chi^2 = 0.000$	1.000
Gestational obesity	5 (14.29)	3 (8.57)	Continuity-corrected χ^2	$\chi^2 = 0.141$	0.707
Anemia	7 (20.00)	5 (14.29)	Continuity-corrected χ^2	$\chi^2 = 0.101$	0.751
Premature rupture of membranes	7 (20.00)	4 (11.43)	Continuity-corrected χ^2	$\chi^2 = 0.431$	0.511
Postpartum hemorrhage	0 (0.00)	3 (8.57)	Fisher's exact test	OR = 0.000	0.493

3.4. Maternal-Infant Pregnancy Outcomes

Neonatal birth weight and Apgar score had no intergroup statistical difference ($P > 0.05$). Preterm birth, macrosomia, fetal growth restriction, fetal distress and overall adverse pregnancy outcome rates were comparable between groups ($P > 0.05$) (Table 4, Table 5).

Table 4. Neonatal delivery outcome indicators ($\bar{x} \pm s$).

Index	Control (n = 35)	Observation (n = 35)	t value	P value
Birth weight (g)	3171.43 ± 478.71	3262.86 ± 411.66	-0.857	0.395
Apgar score	9.89 ± 0.53	9.86 ± 0.60	0.211	0.834

Table 5. Incidence of adverse pregnancy outcomes in the two groups [n (%)].

Adverse Outcome	Control group (n = 35)	Observation group (n = 35)	Statistical method	Statistic	P value
Preterm birth	2 (5.71)	1 (2.86)	Continuity-corrected χ^2	$\chi^2 = 0.000$	1.000
Macrosomia	2 (5.71)	2 (5.71)	Continuity-corrected χ^2	$\chi^2 = 0.000$	1.000
Fetal growth restriction	3 (8.57)	1 (2.86)	Continuity-corrected χ^2	$\chi^2 = 0.265$	0.607
Fetal distress	0 (0.00)	0 (0.00)	Fisher exact test	OR = nan	1.000
Total adverse pregnancy outcome	7 (20.00)	4 (11.43)	Continuity-corrected χ^2	$\chi^2 = 0.431$	0.511

4. Discussion

GDM is the most prevalent gestational endocrinopathy pathologically character-

ized by insulin resistance and impaired pancreatic β -cell function leading to disrupted glucose homeostasis and elevated risks of multisystem gestational complications and unfavorable perinatal outcomes [10]. Non-pharmacological management serves as first-line prenatal intervention for GDM, with customized diet and structured exercise as core glycemic-controlling modalities; establishing precise, safe and effective synergistic diet-exercise regimens has become a hotspot in contemporary GDM clinical management [11].

This study was designed as a prospective randomized controlled trial, and all interventions were initiated at 24 - 28 gestational weeks uniformly. The results showed that baseline glycemic indicators and hypoglycemic drug usage were comparable between two groups. After intervention, the control group achieved better improvement in FBS than the observation group ($P < 0.01$), and FBS of the observation group did not decrease significantly after intervention, which was inconsistent with some previous studies [12]. It is speculated that individual differences in exercise type, duration and patient compliance may offset the potential benefit of combined intervention on fasting glycemia [13].

Both cohorts achieved remarkable post-intervention PBS reduction compared with baseline ($P < 0.001$) without intergroup statistical divergence ($P > 0.05$), indicating conventional general dietary counseling alone can effectively improve postprandial glycemia, inconsistent with partial previous research conclusions [14]. Possible contributors include limited sample size, relatively short intervention duration and heterogeneous patient adherence to prescribed diet and exercise protocols in observation group, which blunted statistical between-group difference in postprandial glucose. Future trials shall expand sample capacity, prolong intervention period and strengthen adherence supervision to further validate postprandial glycemic benefits of combined intervention.

No significant intergroup differences were detected regarding gestational complication and adverse pregnancy outcome incidence, conflicting with several existing clinical reports [15]. Potential explanations are listed as follows: first, limited sample size lowers statistical power to identify mild between-group outcome discrepancies; second, enrolled primary-hospital participants presented heterogeneous baseline physical status and variable prenatal intervention compliance plus miscellaneous underlying diseases confounding final pregnancy endpoints; third, intervention initiation starting at approximately 24 - 28 gestational weeks left insufficient time to reverse long-term adverse gestational impacts induced by chronic hyperglycemia in GDM. Further stratified large-cohort researches with extended intervention timeline are required to clarify long-term benefits of combined diet-exercise intervention on perinatal complications.

The present study adopted a prospective randomized controlled design and innovatively constructed a targeted synergistic diet-exercise intervention framework tailored to primary hospital GDM population via interdisciplinary collaboration between clinical dietitians and obstetric rehabilitation practitioners, realizing full-cycle precise prenatal management and forming replicable standardized

protocols for grassroots medical institutions. Strict ethical approval and complete informed consent acquisition guaranteed authentic raw data and credible clinical reference value of research outcomes.

Several limitations exist within this trial: small sample size of merely 70 subjects impairs statistical robustness; single-center recruitment restricts external validity of research findings; missing quantitative compliance scoring fails to quantify adherence-related outcome variations; follow-up terminated upon delivery without long-term surveillance of postpartum maternal glycemic status and offspring developmental outcomes; no prior sample size calculation was performed, leading to insufficient statistical power. Subsequent multi-center large-scale trials with standardized adherence rating and prolonged long-term follow-up are scheduled to supplement current evidence.

5. Conclusion

In summary, routine dietary guidance can significantly improve fasting and postprandial blood glucose in GDM patients. The synergistic intervention of individualized diet combined with low-resistance exercise only effectively reduces postprandial blood glucose, without additional benefit on fasting blood glucose control. This combined regimen cannot statistically reduce the incidence of gestational complications and adverse maternal-infant outcomes. It is only suitable as an exploratory auxiliary strategy for routine prenatal GDM care, and large-scale clinical promotion is not recommended for the time being. Further large-sample multi-center prospective researches are warranted to confirm long-term clinical efficacy and enrich evidence for standardized nationwide GDM prenatal management specifications.

6. Study Limitations

This single-center prospective randomized controlled trial suffers from small sample volume limiting result extrapolation; follow-up was terminated at delivery without long-term tracking of maternal postpartum glucose metabolism and infant long-term development; diet and exercise compliance was not quantitatively graded for stratified analysis of adherence-associated efficacy differences; no pre-study sample size estimation was conducted, resulting in inadequate statistical power. Future research will expand sample size, initiate multi-center cooperation and complete standardized compliance assessment plus long-term follow-up design.

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Conflicts of Interest

The authors declare no external industrial funding or commercial sponsorship from pharmaceutical, medical device or food enterprises throughout this research. All clinical data were prospectively collected without commercial conflicts of interest.

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