Effectiveness of a Nurse-Led Web-Based Health Management in Preventing Women With Gestational Diabetes From Developing Metabolic Syndrome

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ABSTRACT

Background: Women with gestational diabetes mellitus (GDM) are more likely to develop metabolic syndrome (MS). However, the effectivity of web-based health management in preventing women at high risk of GDM from developing MS has rarely been studied.

Purpose: The aim of this study was to evaluate the longitudinal effects of nurse-led web-based health management on maternal anthropometric, metabolic measures, and neonatal outcomes.

Methods: A randomized controlled trial was conducted from February 2017 to February 2018, in accordance with the Consolidated Standards of Reporting Trials guidelines. Data were collected from 112 pregnant women at high risk of GDM who had been screened from 984 potential participants in northern Taiwan. Participants were randomly assigned to the intervention group (n=56) or the control group (n=56). The intervention group received a 6-month nurse-led, web-based health management program as well as consultations conducted via the LINE mobile app. Anthropometric and metabolic measures were assessed at baseline (Time 0, prior to 28 weeks of gestation), Time 1 (36-40 weeks of gestation), and Time 2 (6-12 weeks of postpartum). Maternal and neonatal outcomes were assessed at delivery. Clinical trial was registered.

Results: Analysis using the general estimating equation models found that anthropometric and metabolic measures were significantly better in the intervention group than the control group and varied with time. At Time 1, the levels of diastolic pressure (β = −4.981, p = .025) and triglyceride (TG; β = −33.69, p = .020) were significantly lower in the intervention group than the control group, and at Time 2, the incidence of MS in the intervention group was lower than that in the control group (χ² = 6.022, p = .014). The number of newborns with low-birth weight in the intervention group was lower than that in the control group (χ² = 6.729, p = .012).

Conclusion/Implications for Practice: This nurse-led, web-based health management was shown to be effective in improving MS outcomes and may play an important role and show feasible clinical value in changing the current pregnancy care model.

Key Words: gestational diabetes mellitus, health management, metabolic syndrome, nurse-led, web-based.
risk of MS and cardiovascular disease than women with no history of GDM (Hakkakainen et al., 2016; McKenzie-Sampson et al., 2018; Puhkala et al., 2017). MS is a clustering of cardiovascular disease risk factors, including dyslipidemia, hypertension, hyperglycemia, and abdominal obesity (Puhkala et al., 2017). A review study revealed that women with a history of GDM had a higher risk of developing MS than those without a history of GDM (relative risk [RR] = 2.36, 95% CI [1.77, 3.14]). Offspring exposed to GDM in utero have a higher risk of developing MS than those not exposed to GDM in utero (RR = 2.07, 95% CI [1.26, 3.42]). Women diagnosed with GDM have an increased risk of developing MS during pregnancy (RR = 20.51, 95% CI [5.04, 83.55]; Pathirana et al., 2021). MS diagnoses are typically made at the first postpartum evaluation in accordance with the International Diabetes Federation classification (Alberti et al., 2005), with modifications made for Asian populations. A diagnosis is made if any of the following five criteria are met: waist circumference (WC) of ≥ 80 cm, elevated blood pressure (BP; ≥ 130 or 85 mmHg), elevated TG (≥ 150 mg/dl), reduced high-density lipoprotein (HDL) cholesterol (<50 mg/dl), and elevated fasting blood glucose (FBG; ≥ 100 mg/dl).

Women at high risk of GDM are encouraged to alter certain lifestyle habits and attend regular follow-up examinations. As pregnancy progresses, the burden on pregnant women and health services increase (Hakkakainen et al., 2016; McKenzie-Sampson et al., 2018; Puhkala et al., 2017). The general prevalence of GDM is rising, with medical and insurance systems facing difficulties in coping effectively with this burden (Carolan-Olah & Sayakhot, 2019). Although interventions such as yoga, physical activity classes, lifestyle adjustments, and face-to-face nutrition counseling are currently provided to women with GDM, these interventions are often limited by time and place restrictions that make it difficult for some women to access these health resources (H. Chen et al., 2018). Thus, there is a need for a sustainable, innovative, and effective care system for GDM women that includes self-care behavior education and strengthening (Carolan-Olah & Sayakhot, 2019; Mackillop et al., 2018).

In previous studies, web-based interventions have been shown to be effective in improving lifestyle modifications; implementing blood glucose self-monitoring; achieving blood-sugar-control, maternal, and neonatal outcomes that are equivalent to the outcomes experienced by pregnant women receiving standard hospital care; and effectively reducing the rate of cesarean section (Homko et al., 2012; Rasekaba et al., 2018; von Storch et al., 2019). Web-based interventions employ a tracking system to improve self-monitoring that uses dietary logs, physical logs, reminders, and graphic progress indicators and, through peer support or real-time feedback interactivity, allow women to interact with one another and their health providers (Carolan-Olah & Sayakhot, 2019). Using this type of intervention in diabetes prevention may empower women to obtain appropriate resources and make positive decisions about lifestyle change and chronic disease control (Given et al., 2015; Homko et al., 2012; Rasekaba et al., 2018).

Over the past two decades, Taiwan’s total fertility rate has declined to one of the lowest in the world, with an average fertility rate of 1.3 children per woman (National Statistics, ROC, 2020). Consequently, developing health policies that prevent high-risk pregnancies, ensure a safe birth process, and protect the health of newborns and mothers should be prioritized. Systematic and meta-analysis appraisals of web-based interventions have been conducted for women at high risk of GDM (Rasekaba et al., 2018; Xie et al., 2020). However, only a few studies of MS and its postpartum components have been conducted in women who were found during early pregnancy to be at higher risk of developing GDM (Puhkala et al., 2013, 2017). Furthermore, long-term follow-up studies are lacking on the use of web-based interventions in preventing the development of MS in women at high risk of GDM.

The aim of this study was to examine the longitudinal effects on pregnant women at high risk of GDM of a nurse-led web-based health management program intervention that was initiated prior to 28 weeks of gestation and lasted through 6–12 weeks postpartum. Maternal anthropometric and metabolic profiles, including weight, body mass index (BMI), BP, FBG, TG levels, HDL levels, cholesterol levels, and WC, were used as the primary outcome measures. Pregnancy-related complications and neonatal outcomes were also accessed.

**Methods**

**Study Design and Setting**

This randomized controlled study without blinding was conducted between February 2017 and February 2018 during regular maternal clinic visits at a medical center in northern Taiwan that delivers approximately 4,000 births per year and has nine obstetricians on staff. The trial was registered at ClinicalTrials.gov. The randomization and concealed allocation procedures were independently handled by a statistician who did not participate in this study using random allocation software (Random Allocation Software 1.0.0) block arrangement random allocation (permuted block randomization), with the number of groups set to 2, the number of samples set to 112, and the area block equal sample set to 4. The random serial numbers and groups generated by the computer were placed in consecutively coded, sealed opaque envelopes.

**Participants**

The inclusion criteria included (a) singleton pregnancy, (b) less than 28 weeks of gestation, and (c) having at least one of the GDM risk factors listed by the National Institute for Health and Care Excellence (2015) modified for Asian populations (i.e., > 34 years old, prepregnancy BMI ≥ 24 kg/m², a macrosomia baby [weight ≥ 4.5 kg], history of GDM in a previous pregnancy, and family history of diabetes). Pregnant women with preexisting diabetes (Type 1 or 2), with limited mobility or inability to perform physical exercise, or < 18 years old were excluded.
G*Power Version 3.1.1 (Heinrich Heine University, Düsseldorf, Germany) was used to estimate the minimum sample size (Faul et al., 2007). An F test with three repeated measurements for two independent groups was used. According to Cohen’s (1988) rule for effect size, a sample of 70 is required to detect the differences in changes with an effect size of 0.25, a power of .80, and an alpha of .05 and, assuming a dropout rate of 20%−25%, a minimum sample size of 94 for the randomized controlled trial was needed in this study. A total of 112 participants were enrolled.

Measures
The participants in both groups filled out a questionnaire with demographic and health information at Time 0 (prior to 28 weeks of gestation). Anthropometric and metabolic measures were accessed at Time 0, Time 1 (36–40 weeks of gestation), and Time 2 (6–12 weeks postpartum). Maternal and neonatal outcome assessments were conducted at delivery.

Demographic characteristics
Demographic and personal health information with respect to height, prepregnancy bodyweight, parity, age, marital status, work status, educational level, family history of diabetes, previous history of premature birth or abortion, GDM, and preeclampsia was gathered using a self-report survey.

Maternal anthropometry and metabolic measures
To determine the effect of web-based health management on women’s outcomes, the maternal anthropometric and metabolic profiles (weight, BMI, BP, FBG, cholesterol, HDL, and TG) for each participant were evaluated. The metabolic measures for analysis after a 12-hour fast were determined. The results were obtained in a hospital setting using laboratory instruments tested by the hospital quality control team. The data were collected from the medical records at the antenatal clinic by a researcher.

Women are typically screened for GDM at 24–28 weeks of gestation by clinical order if risk factors such as advanced maternal age, previous history of GDM, and previous history of fetal macrosomia were present. The International Association of Diabetes and Pregnancy Study Groups’ 75-g oral glucose tolerance test was used to diagnose GDM. The participants drank 75 g of glucose in 330 ml of water, and the samples were taken after 60 and 120 minutes and assessed in accordance with the criteria for FBG, 1-hour, and 2-hour oral glucose tolerance test plasma glucose concentrations mean values (92, 180, and 133 mg/dl, respectively) proposed by the Hyperglycemia and Adverse Pregnancy Outcome Study (International Association of Diabetes and Pregnancy Study Groups Consensus Panel et al., 2010).

Maternal and neonatal outcomes
Maternal outcomes compared the diabetic control between the groups. Weight and BMI were recorded at each visit, as was pregnancy-induced hypertension or preeclampsia, gestational age at birth, birth weight, and the proportion of babies who were large for their gestational age (> 90th percentile for gestation and gender), mode of birth, and severe perineal trauma. Neonatal outcomes of interest included birth-related injuries and neonatal intensive care unit (NICU) admission. The data were collected from the medical records at the antenatal clinic by a researcher.

Nurse-Led Web-Based Health Management Intervention and Control

Development of a nurse-led web-based health management program
The development of the nurse-led web-based health management program was guided by discussion with an obstetrician, gynecologist, dietitian, sports coach (who provided pregnancy exercise guidance), nurse, and information technology engineer. The analysis, design, development, implementation, and evaluation model of system design (Reinbold, 2013) was applied to create the nurse-led web-based health management program (Figure 1). Twenty-two women with GDM were recruited using purposive sampling, and data were collected using in-depth, semistructured and open-ended interviews to explore the design needs of web-based health management. Themes were then mapped onto the web design (Table 1). The evaluation involved a two-stage process. In the first step, we invited nursing information experts and obstetrics and gynecology experts with clinical practice experience with GDM and MS (n = 5) to review the content relevance, wording clarity, and style design. The content validity index values were .97–.99. User evaluations were based on real case scenarios to simulate how women would use the system in a self-management process at home. We invited pregnant women with high risk of GDM of 30–40 years old (n = 10). They measured weight and BP, kept a diet and exercise log, recorded in paper logs, and input their personal health information into the website for 7 days. To confirm the consistency and stability of paper and electronic records, the intraclass correlation should be between .81 and .96. The researcher also interacted with the testers in 7 days to check network stability, operational convenience, and information content. The users evaluated the content relevance, wording clarity, and style design, finding the content validity index to be .91−.99. After evaluation, we made several modifications based on the experts’ and users’ suggestions. For example, the normal range of various metabolic indicators of the health plan were provided to help women set clear goals; embedded advertising was removed from videos and hyperlinks; and details for specific data upload, dietary, and exercise records were provided.

Intervention group
The participants in the intervention group received the standard clinic-based education class and were invited to use the web-based health management program. Each participant had a unique account and website log-in password, which
was encrypted using Secure Socket Layer. The website was enabled to count the number of log-ins by each participant and record usage patterns. The system determined course participation, self-monitoring (records related to the diet diary and exercise log), and satisfaction with online health information. Each participant was required to log into the system at least once per week to fill in their weight measurements and complete the diet diary and exercise log. Reward points were given to participants every time they completed this task, and participants could redeem these points for gifts (e.g., maternity and baby products). This reward mechanism encouraged participants to record information frequently and develop self-monitoring and management competencies. The intervention also included one-on-one, 20- to 30-minute LINE consultation sessions after each blood sample report that facilitated the provision of tailored health education, reinforced strategies, and elicited participant feedback.

**Control group**

Women in this group attended standard clinic-based care sessions. Women diagnosed with GDM were provided with a face-to-face health education program related to diabetes (same as the intervention group, conducted by the same...
This program comprised diet control and guidance related to exercise during pregnancy and maintaining a healthy lifestyle, with each session lasting approximately 1 hour. Because all of the participants were covered by Taiwan’s national health insurance, participants followed the conventional schedule of examinations during pregnancy. Specifically, they received 10 examinations, with biweekly and weekly examinations conducted at 32–36 weeks and after 36 weeks, respectively.

**Procedure**

After institutional review board approval from the participating hospitals, three obstetrics and gynecological nurses with more than 5 years of respective experience assessed the eligibility of potential participants and obtained informed consent. These nurses were trained by the same researcher to ensure their understanding of the eligibility. To ensure the consistency and quality of the intervention, the intervention was carried out by one researcher. After the initial assessment, the qualified participants were transferred to the researcher to obtain consent. The researcher opened the envelopes in order and assigned the participants to the intervention group or control group according to the groups indicated on the envelope. The participants were randomly assigned to the intervention group or control group, and all of the participants received standard maternity care. With the intervention group, the researcher took approximately 15–30 minutes instructing each participant on using the website and setting up a personal account. The participants were then provided with the URL link or QR code and log-in password for the website and instructed that they could use the website at any time during the 6-month study period. To avoid interaction between the two groups, only the intervention group was permitted to log in with their account and password on the web-based health management program and to view/use the information.

The participants in the intervention group were required to log into the website at least once per week to complete dietary, exercise, and self-management information. Their health status levels, weight, and postpartum WC were also measured. The recruitment procedure is shown in Figure 2.

**Data Analysis**

Data analysis was performed using SPSS/PC for Windows 20.0 (IBM, Inc., Armonk, NY, USA). A t test and a chi-square test were conducted to analyze the demographic variables of the participants and determine whether differences in essential

| Major Theme | Website Module |
|-------------|----------------|
| 1. Membership and user-friendly website interface | 1. Unique account and password to log in |
|             | 2. Website manual |
| 2. Access to reliable information and resources | Healthy lifestyle information |
|             | (1) What is gestational diabetes? |
|             | (2) How to avoid becoming diabetic? |
|             | (3) What to do if the oral glucose tolerance test check is abnormal? |
|             | (4) Healthy eating and exercise in GDM. |
|             | (5) Do I need to follow up after delivery? |
|             | (6) Life modification for GDM. |
| 3. Provision of tailored and quick-link health information | 1. Health plan in GDM: setting goals for blood sugar and metabolic indicator control levels |
|             | 2. Weekly pregnancy and fetus changes: system automatically provides customized information on physical changes in the mother and fetus |
| 4. Access to peer support | Social networking group |
|             | (1) Online discussions, browse previous discussions |
|             | (2) Interact with other participants or the researchers on Facebook and LINE groups to provide and receive emotional support |
| 5. Self-monitoring and learning tools | 1. Maternal health log |
|             | (a) diet diary |
|             | (b) exercise log |
|             | (c) recommendations for recipes and exercise |
|             | 2. Maternal notepad |
|             | (a) my health data |
|             | (b) pregnant women’s body changes |
|             | (c) baby growth |
|             | (d) pregnancy highlight for this week |
|             | (e) fetal movements |
|             | 3. Reminder service: motivated through e-mails, Facebook, and LINE messages |

Note. GDM = gestational diabetes mellitus.
attributes were detected between the groups. The data related to MS indicators were processed using an independent-sample t test and a chi-square test to determine whether differences existed between the intervention and control groups. The significance level was set at a two-tailed p value of .05. Generalized estimating equations were applied to analyze intervention effectiveness. An intervention effectiveness evaluation was conducted after the covariates were controlled to assess the levels of MS indicators prior to and after the intervention. The aforementioned data were processed using intention-to-treat analysis.

Ethical Considerations
This study was approved by the regional ethics board in Taiwan (Chang Gung Memorial Hospital IRB No. 105-4129C). The researcher explained the purpose of the study, and all potential participants provided written consent prior to enrollment. The participants were informed they could withdraw during the study at any time for any reason without explanation.

Results

Demographic Characteristics
The mean ages of participants in the intervention and control groups were 35.71 (SD = 4.31) and 35.82 (SD = 4.28) years, respectively. Forty-five and 38 participants in the two groups, respectively, completed the follow-up test. The descriptive analysis results are shown in Table 2. No significant difference between the groups in terms of sociodemographic and clinical characteristics was identified.
Table 2

Baseline Characteristics and Components of Metabolic Syndrome, by Group (N = 112)

| Variable                                      | Intervention (n = 56) | Control (n = 56) | p   |
|-----------------------------------------------|-----------------------|-----------------|-----|
| **Variable**                                  |                       |                 |     |
| **Baseline Characteristics**                  |                       |                 |     |
| Age (years), M ± SD                           | 35.71 ± 4.31          | 35.82 ± 4.28    | .355|
| Education                                     |                       |                 |     |
| Less than high school                         | 7 (12.5)              | 14 (25.0)       | .562|
| College                                       | 12 (21.4)             | 11 (19.6)       |     |
| University                                    | 29 (51.8)             | 23 (41.1)       |     |
| Master's degree or more                       | 8 (14.3)              | 8 (14.3)        |     |
| Work status                                   |                       |                 | .510|
| Full time                                     | 32 (57.1)             | 37 (66.1)       |     |
| Part time                                     | 6 (14.3)              | 5 (8.9)         |     |
| None                                          | 16 (28.6)             | 14 (25.0)       |     |
| Marital status                                |                       |                 | .495|
| Married                                       | 56 (100)              | 54 (96.4)       |     |
| Divorced                                      | 0 (0.0)               | 2 (3.6)         |     |
| **Variable**                                  |                       |                 | .313|
| **Education**                                 |                       |                 |     |
| **Gravidaity**                                |                       |                 |     |
| Primipara                                     | 35 (62.5)             | 29 (51.8)       |     |
| Multipara                                     | 21 (37.5)             | 27 (48.2)       |     |
| Premature or abortion in any previous pregnancy | 17 (30.4)             | 21 (37.5)       | .162|
| GDM in any previous pregnancy                 | 3 (5.4)               | 5 (8.9)         | .118|
| Family history of DM                          |                       |                 | .100|
| Preeclampsia in any previous pregnancy        | 3 (5.4)               | 2 (3.6)         |     |
| **Variable**                                  |                       |                 | .100|
| Oral glucose tolerance test                   |                       |                 | .100|
| Fasting glucose (≥ 92 mg/dl)                  | 3 (8.1)               | 2 (5.9)         |     |
| 1-hour glucose (≥ 180 mg/dl)                  | 2 (5.4)               | 5 (14.7)        |     |
| 2-hour glucose (≥ 153 mg/dl)                  | 3 (8.1)               | 6 (17.6)        | .672|
| BMI (kg/m²)                                   | 24.39 ± 5.45          | 25.15 ± 5.05    |     |
| 18.2–23.9                                     | 31 (55.3)             | 27 (48.2)       | .385|
| 24–26.9                                       | 9 (16.1)              | 15 (26.8)       |     |
| = 27                                          | 16 (28.6)             | 14 (25.0)       |     |
| Waist circumference (cm)                      | 76.20 ± 7.81          | 76.84 ± 7.83    | .664|
| Waist circumference (≥ 80 cm)                 | 19 (33.9)             | 24 (42.9)       | .944|
| Fasting glucose (mg/dl), M ± SD               | 80.79 ± 15.5          | 79.80 ± 14.0    | .823|
| Fasting glucose (≥ 100 mg/dl)                 | 3 (5.4)               | 5 (8.9)         | .716|
| Systolic blood pressure (mmHg), M ± SD        | 125.89 ± 20.7         | 126.50 ± 21.6   | .880|
| Diastolic blood pressure (mmHg), M ± SD       | 75.61 ± 13.0          | 75.09 ± 12.3    | .829|
| Diastolic blood pressure (≥ 85 mmHg)          | 9 (16.1)              | 12 (21.4)       | .333|
| HDL cholesterol (mg/dl), M ± SD               | 71.52 ± 17.1          | 70.55 ± 13.8    | .743|
| HDL cholesterol (≥ 50 mg/dl)                  | 4 (7.1)               | 4 (7.1)         |     |
| Triglycerides (mg/dl), M ± SD                 | 183.89 ± 70.84        | 200.63 ± 109.4  | .132|
| Total cholesterol (mg/dl), M ± SD             | 216.32 ± 47.8         | 222.61 ± 46.9   | .494|
| Metabolic syndrome using IDF criteria          | 11 (19.6)             | 14 (25.0)       | .463|

Note. GDM = gestational diabetes mellitus; BMI = body mass index; HDL = high-density lipoprotein; IDF = International Diabetes Federation.

* Fisher’s exact test; b Prepregnancy.
Effect of Intervention on Risk Factors of Metabolic Syndrome

After the intervention, at Time 1, the levels of diastolic BP ($\beta = -4.98, p = .025$) and TG ($\beta = -33.69, p = .020$) were significantly lower in the intervention group than the control group. Similarly, at Time 2, the intervention group had more favorable TG ($\beta = -21.21, p = .036$) and total cholesterol ($\beta = -41.25, p = .006$) levels than the control group (Table 3). As shown in Table 4, the weight gain differences between the groups were nonsignificant. However, BMI during pregnancy increased by 4.07 kg/m² (95% CI [3.7, 4.4]) in the intervention group and 4.75 kg/m² (95% CI [4.2, 5.3]) in the control group ($p = .025$). At Time 2, the BMI increase was 1.24 kg/m² (95% CI [0.9, 1.6]) in the intervention group and 1.93 kg/m² (95% CI [1.3, 2.5]) in the control group ($p = .045$). The intervention group had seven fewer participants with a WC of $\geq 80$ cm than the control group ($p = .042$).

Generalized estimating equations were used to analyze the BMI levels at prior to pregnancy, Time 0, Time 1, and Time 2. The results indicate that BMI increased with the number of pregnancy weeks in both groups. Subsequently, a significant interaction effect between groups and measurement times was observed. The results revealed that, on average, the average BMI level of the intervention group was 0.708 and 1.512 lower at Time 1 and Time 2, respectively, than that in the control group for the same time periods ($p < .001$). Thus, the web-based intervention was associated with a significant lowering in participant BMI levels. The follow-up results at Time 2 also showed that the number of individuals with MS decreased from 11 to 3 in the intervention group and from 14 to 10 in the control group, indicating that the intervention group achieved better performance in reversing MS ($\chi^2 = 6.022, p = .014$).

Effect of the Intervention on Maternal and Neonatal Outcomes

As shown in Table 5, no differences were found between groups in terms of birth method and NICU admission. The numbers of low birth weight and large-sized newborns in the intervention group were lower than those in the control group ($\chi^2 = 6.729, p = .012$). In terms of pregnancy complications, two participants in the intervention group were diagnosed with preeclampsia, whereas three participants in the control group separately developed pre eclampsia, indicating that the intervention group achieved better performance in reversing MS ($\chi^2 = 6.022, p = .014$).

### Table 3

**Generalized Estimating Equation (GEE) of Baseline and Follow-Up Assessment of Changes in Metabolic Syndrome Markers in Two Groups (N = 112)**

| Characteristic          | Intervention (n = 56) | Control (n = 56) | Group x Time Interaction Effect in the GEE Model |
|-------------------------|----------------------|-----------------|-----------------------------------------------|
|                         | Mean                 | SD              | Mean                          | SD              | $\beta$ | 95% CI             | $p$        |
| Systolic blood pressure |                      |                 |                                |                 |         |                   |           |
| Time 0                  | 125.89               | 20.74           | 126.50                        | 21.57           | -5.69   | [-12.47, 3.48]    | .242      |
| Time 1                  | 120.18               | 13.15           | 126.48                        | 19.97           | -3.84   | [-9.33, 2.15]     | .100      |
| Time 2                  | 120.60               | 16.78           | 125.92                        | 21.04           | -4.71   | [-12.61, 4.03]    | .101      |
| Diastolic blood pressure|                      |                 |                                |                 |         |                   |           |
| Time 0                  | 75.61                | 12.97           | 75.09                         | 12.32           | -4.98   | [-9.33, 0.63]     | .025      |
| Time 1                  | 71.16                | 9.35            | 75.59                         | 12.46           | -3.98   | [-7.98, 2.68]     | .307      |
| Time 2                  | 73.20                | 10.38           | 75.39                         | 13.58           | -2.73   | [-7.98, 2.68]     | .307      |
| Fasting blood glucose   |                      |                 |                                |                 |         |                   |           |
| Time 0                  | 80.79                | 15.50           | 79.80                         | 14.01           | 1.18    | [-4.11, 6.48]     | .662      |
| Time 1                  | 77.64                | 7.91            | 75.73                         | 10.40           | 2.24    | [-4.19, 8.67]     | .495      |
| Time 2                  | 81.36                | 7.49            | 78.42                         | 10.69           | 2.24    | [-4.19, 8.67]     | .495      |
| Triglyceride            |                      |                 |                                |                 |         |                   |           |
| Time 0                  | 183.89               | 70.84           | 200.63                        | 109.41          | -33.69  | [-77.38, 10.10]   | .020      |
| Time 1                  | 199.88               | 89.12           | 236.91                        | 99.10           | -33.69  | [-77.38, 10.10]   | .020      |
| Time 2                  | 178.62               | 94.23           | 221.79                        | 140.46          | -41.25  | [-89.04, -23.46]  | .006      |
| Cholesterol             |                      |                 |                                |                 |         |                   |           |
| Time 0                  | 216.32               | 47.82           | 222.61                        | 46.87           | -10.36  | [-28.34, 7.62]    | .259      |
| Time 1                  | 231.74               | 52.86           | 248.95                        | 43.43           | -10.36  | [-34.69, 9.07]    | .259      |
| Time 2                  | 213.62               | 52.06           | 241.45                        | 46.29           | -21.21  | [-34.69, 9.07]    | .038      |
| High-density lipoprotein|                      |                 |                                |                 |         |                   |           |
| Time 0                  | 71.52                | 17.11           | 70.55                         | 13.78           | 0.47    | [-4.77, 5.70]     | .861      |
| Time 1                  | 70.36                | 16.33           | 69.09                         | 15.88           | 0.47    | [-4.77, 5.70]     | .861      |
| Time 2                  | 68.31                | 16.07           | 70.18                         | 16.74           | -4.73   | [-11.16, 1.70]    | .149      |

*p < .05. **p < .01. ***p < .001.
preeclampsia, postpartum hemorrhage, and a fourth-degree perineal tear.

**Discussion**

This study used an online self-management and learning system to improve conventional health management approaches, thereby helping participants improve MS risk factors. The prevalence of MS in the participants at Time 2 was 15.7%, which is slightly lower than the results obtained in other studies (Nouhjah et al., 2018; Puhkala et al., 2013). The dropout rate was 19.6% and 32.1% in the intervention and control groups, respectively. The stated reasons for withdrawal in the control group included the trouble involved in scheduling and making additional visits for blood tests at nonoutpatient times, switching doctors or hospitals for pregnancy examinations, tocolytic treatments, and preeclampsia-related hospitalization. The main stated reason for withdrawal in the intervention group was the burden of maintaining the dietary log. After delivery, participants did not fast for 12 hours before taking a blood test because of the need to breastfeed. Moreover, both groups were busy caring for their newborns and viewed

### Table 4

**Baseline Data and Changes From Baseline**

| Variable                                | Prepregnancy | 36–40 Weeks of Gestation | 6–12 Weeks of Postpartum |
|-----------------------------------------|--------------|--------------------------|--------------------------|
|                                         | **M ± SD**   | **Mean (95% CI/ p)**     | **Mean (95% CI/ p)**     |
| Weight change (kg)                      |              |                          |                          |
| Intervention                            | 63.8 ± 15.4  | 10.6 [9.7, 11.5]         | 3.2 [2.2, 4.2]           |
| Control                                 | 62.4 ± 13.6  | 11.7 [10.5, 12.9]        | 4.8 [3.3, 6.2]           |
| Difference between groups               | −1.1 (.144)  | −1.6 (.071)              |                          |
| BMI change (kg/m²)                      |              |                          |                          |
| Intervention                            | 24.4 ± 5.4   | 4.07 [3.7, 4.4]          | 1.24 [0.9, 1.6]          |
| Control                                 | 25.2 ± 5.1   | 4.75 [4.2, 5.3]          | 1.93 [1.3, 2.5]          |
| Difference between groups               | −0.68 (.025) | −0.69 (.045)             |                          |
| Waist circumference change (cm /no. of ≥ 80 cm) |              |                          |                          |
| Intervention                            | 76.2 ± 7.81 /19 | 3.55 [2.7, 4.0] /13 |                          |
| Control                                 | 76.8 ± 7.83 /24 | 4.39 [3.7, 5.1] /20 |                          |
| Difference between groups               | −0.84 (.141) /−7 (.042) |                     |                          |
| Metabolic syndrome change a             |              |                          |                          |
| Intervention                            | 11           |                          |                          |
| Control                                 | 14           |                          |                          |
| Difference between groups               | −7 (.014)    |                          |                          |

*Note. BMI = body mass index.  

*a Case numbers met the criteria of metabolic syndrome.*

### Table 5

**Maternal and Neonatal Outcomes in Participants (N = 94)**

| Variable                                | Intervention (n = 50) | Control (n = 44) | p     |
|-----------------------------------------|-----------------------|-----------------|-------|
| Cesarean delivery                       | 19 (38.0)             | 17 (38.6)       | .950  |
| Admitted to NICU                        | 6 (12.0)              | 5 (11.4)        | .925  |
| Preeclampsia/other complications        | 2 (4.0)               | 3 (6.8)         | .549  |
| Premature (<37 weeks of gestation)      | 11 (22.0)             | 13 (29.5)       | .408  |
| Neonatal birth weight (g), M ± SD      | 3,094.0 ± 502.1       | 2,879.0 ± 609.9 | .023* |
| < 2,500                                 | 4 (8.0)               | 10 (22.7)       | .012* |
| 2,500–4,000                             | 46 (92.0)             | 32 (72.7)       |       |
| > 4,000                                 | 0 (0.0)               | 2 (4.5)         |       |

*Note. NICU = neonatal intensive care unit.  

*p < .05.*
themselves as healthy and not in need of follow-up examinations. Similar rates of failure and participant difficulties in similar studies of telemedicine in GDM have been reported (Bartholomew et al., 2015). The dropout rate in the control group exceeded expectations, and the overall statistical power of 80% in this group may have biased the findings.

**Effectiveness of the Intervention in Reducing the Risk Factors of Metabolic Syndrome**

The intervention group had significantly improved TG levels at Time 1, and the intervention group outperformed the control group in terms of both TG and total cholesterol level at Time 2. This finding is consistent with previous studies that offered lifestyle interventions to women with GDM (Grotenfelt et al., 2020). Although a significant difference was also noted in diastolic BP, the difference was in the normal range and was not deemed clinically significant. In addition, there were no significant differences in systolic BP, FBG, and HDL, because the average values of these indicators were normal at Time 0, Time 1, and Time 2. Prepregnancy obesity and excessive weight gain during pregnancy are essential predictors of MS development in women with GDM (Shen et al., 2019; Xu et al., 2014), indicating the importance of effective weight control in MS prevention efforts. By comparing BMI between the two groups was significant, which corresponds to that the intervention group successfully reduced their MS risk.

A previous literature review and meta-analysis supports that regular exercise prior to pregnancy and during early pregnancy has the potential to significantly reduce gestational weight gain (Wang et al. 2019). However, because of the many pregnancy-related taboos in Taiwan (e.g., being discouraged to carry heavy objects and being required to get more rest), 57.1% of Taiwanese women cease to engage in strenuous exercise after becoming pregnant (Tung et al., 2014). Using website guidance, this study encouraged women to engage in an active lifestyle during pregnancy. For example, the web-based health management system allowed the participants to participate in online exercises with customized exercise guidance. By maintaining a diet diary and exercise log on the website, sharing their exercise routines, and supporting others’ posts in the discussion group, participants gradually reduced their MS risk.

**Effects of the Intervention on the Participants and Their Newborns**

No significant difference was observed between the two groups in terms of cesarean section, admission to NICUs, pregnancy complications, or premature birth, which corresponds to the results of similar studies (Given et al., 2015; Homko et al., 2012). The similar incidences of cesarean section in the two groups may be attributed to the Taiwanese belief that birth time affects one’s fortunes in life (Shen Chen Ba Zi). Consequently, the main reason that Taiwanese mothers choose to undergo cesarean section is to deliver their child at a time deemed to be fortuitous. Whether having a cesarean section, usually conducted 2–4 weeks prior to the estimated date of birth, is associated with premature birth and pregnancy complications in overweight mothers requires further investigation. In addition, because Taiwan’s national health insurance covers 10–14 pregnancy examinations, maternal–fetal problems are usually detected at an early stage. Furthermore, the two groups received similar examinations, leading to no difference in intervention effects on maternal–fetal health. Most newborns had a normal weight. However, the number of newborns with low birth weight in the intervention group was significantly lower than in the control group. This finding was different to those of other studies (Homko et al., 2012; Mackillop et al., 2018). It may be that the participants in this study had abnormal metabolic indicators, especially in terms of cholesterol and TGs. Previous studies have reported lower birth
weight as associated with higher concentrations of total cholesterol (L. H. Chen et al., 2017; Nghiem-Rao et al., 2016). The intervention group had better cholesterol control, which may have contributed to this group having a more normal neonatal birth weight.

**Limitations**

The results of this study support the clinical value of web-based health management interventions delivered during pregnancy. However, this study is affected by several limitations. This study was conducted at a single medical center. Thus, the results may not be generalizable to other populations. Also, blinding was not possible because of the nature of the intervention. There was a high dropout rate at 6–12 weeks of postpartum, which may reflect a general trend among women of deemphasizing their own health to focus on taking care of their babies. Future studies should explore how to best balance being a mother and maintaining appropriate self-care. In this study, the normal BMI (18.2–23.9) and normal WC ratios were higher in the intervention group than the control group. Moreover, the TG (≥150 mg/dl), total cholesterol, and MS levels were higher in the control group than the intervention group. Although no statistically significant difference was found between the two groups, the abovementioned differences may have had potential clinical significance. It is suggested that different sampling methods be used in future research to reduce potential biases.

**Conclusions**

The results of this study demonstrated that a nurse-led web-based health management program has the potential to effectively reduce BMI, WC, diastolic BP, cholesterol, and TG levels. This type of program may have a feasible clinical role to play in changing the current pregnancy care model. The findings may serve as a reference for health policy development in the future and provide meaningful suggestions for clinical practice.

The advantages of this study included the experimental design used, the random assignment of subjects, and the relatively long length of follow-up (early pregnancy through 6–12 weeks postpartum). Web-based health management represents an innovative use of current technologies for the prevention of MS in women with GDM, particularly in the Taiwan context. Pregnancy and childbirth are important health transition periods for women. Health providers should understand the factors affecting this transition and provide professional consultation and follow-up care using “anytime/anywhere” web-based programs to assist women with GDM at high risk. We suggest that web-based health management programs become a routine part of maternal and neonatal care because of the ability of this type of platform to provide information (e.g., health tracking, reminders and monitoring of metabolic risk factors after delivery) that is tailored to each user for the effective prevention of MS in women with GDM.

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**Author Contributions**

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