# Longitudinal Changes of High Molecular Weight Adiponectin are Associated with Postpartum Development of Type 2 Diabetes Mellitus in Patients with Gestational Diabetes Mellitus

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**Background:** The influence of serial changes of adipokines on maternal glucose metabolism from pregnancy to postpartum periods in women with previous gestational diabetes mellitus (pGDM) has not been thoroughly explored. We tried to examine the relationship between the serial changes of adipokines and the development of diabetes mellitus (DM) in women with pGDM.

**Methods:** We longitudinally measured following adipokines: high molecular weight (HMW) adiponectin, retinol-binding protein-4 (RBP-4), lipocalin-2, and chemerin, during pregnancy, and at 2 months and 3 years after delivery. Based on glucose status at postpartum 3 years, we divided into three groups: normal glucose tolerance (GDM-NGT, $n=20$), impaired glucose tolerance (GDM-IGT, $n=23$), and GDM-DM ($n=22$). We analyzed the correlations between adipokines and various metabolic parameters.

**Results:** Plasma HMW adiponectin levels were not different among the three groups during pregnancy. However, HMW adiponectin levels increased at 3 years after the delivery in women with GDM-NGT compared with women with GDM-DM. In the GDM-IGT group, HMW adiponectin levels increased at 2 months postpartum compared to pregnancy period. In contrast, HMW adiponectin levels showed no alternation after parturition in women with GDM-DM. HMW adiponectin was negatively correlated with body mass index and a homeostasis model assessment of insulin resistance. Other adipokines such as RBP-4, lipocalin-2, and chemerin neither showed any differences among the groups nor any significant correlations with 3 years postpartum status of glucose intolerance.

**Conclusion:** Serial changes of HMW adiponectin are associated with the maintenance of glucose metabolism in women with pGDM after delivery.

**Keywords:** Diabetes, gestational; Diabetes mellitus, type 2; Adipokines; Adiponectin

## INTRODUCTION

Gestational diabetes mellitus (GDM) is defined as glucose intolerance of variable severity and is first diagnosed during pregnancy [1]. The prevalence of GDM is different according to race and ethnicity [2]. The prevalence of GDM was reported as 7.6% in the United States according to the National Health and Nutrition Examination Surveys (2007 to 2014), and a previous meta-analysis showed that its prevalence was 7.12% in Korean women [3,4]. It is well known that women with GDM have a high risk of the development of type 2 diabetes mellitus (T2DM) [5,6]. In Korea, women with previous gestational diabetes mellitus (pGDM) have a 3.5 times increased risk of developing T2DM compared with the general population [7].

Adipokines are proteins secreted by adipose tissue and are involved in a wide range of physiological processes. Adiponectin is one of the most abundant adipokines and is synthesized almost exclusively by adipose tissue. Many previous studies demonstrated that adiponectin plays an important role in insulin sensitivity, anti-inflammatory processes, and anti-atherogenesis [8-10]. Pregnancy is a unique condition in which the maternal metabolism is focused on fetal growth. During the pregnancy period, relative insulin resistance was progressed by alteration of glucose metabolism [11,12]. Previous studies showed that adiponectin concentrations were lower in women with GDM compared with women without GDM [13-15]. Furthermore, hypoadiponectinemia during pregnancy was associated with postpartum insulin resistance, β-cell dysfunction, and fasting hyperglycemia [16]. High molecular weight (HMW) adiponectin, which consists of large multimers of 12 to 18 subunits, is considered to be the most biologically active form of adiponectin regarding glucose metabolism [17].

Retinol-binding protein-4 (RBP-4) is an adipokine that may contribute to insulin resistance and obesity [18]. We previously reported that higher plasma RBP-4 concentrations and lower adiponectin concentrations in postpartum in women with pGDM are correlated with early postpartum converters for T2DM [19]. Lipocalin-2 and chemerin are also adipokines that potentially link obesity and T2DM. Previous studies demonstrated that lipocalin-2 and chemerin were related to inflammation, insulin resistance, and hyperglycemia [20-22]. Therefore, these adipokines may play a pathophysiological role in the development of T2DM in women with pGDM.

There is one longitudinal study that measured adipokines during pregnancy and the postpartum follow-up [23]. However, there were no significant differences in postpartum plasma adi-

pokine levels between women with and without GDM; but, in that study, adipokines were followed up only for a relatively short period, at 6 weeks and 6 months postpartum.

Thus far, the influence of serial changes of adipokines on maternal glucose metabolism from pregnancy to several years after postpartum in women with pGDM has not been thoroughly explored. Therefore, in this study, we investigated the relationship between the serial changes of adipokines, which are candidate markers for insulin resistance, and the development of diabetes mellitus (DM) in women with pGDM.

## METHODS

### Study subjects

Between January 1999 and December 2002, we identified 551 women with GDM, of whom 510 undertook a 75 g oral glucose tolerance test (OGTT) at 2 months postpartum. Our protocol for the diagnosis of GDM and the postpartum examination has been described in detail previously [24,25]. Briefly, they were asked to overnight fasting at least 10 hours before the OGTT. Postpartum OGTT results were interpreted to American Diabetes Association (ADA) criteria. The threshold values were: fasting ≥126 mg/dL; 2-hour ≥200 mg/dL [26]. The diagnosis of GDM was made using the criteria of the Third International Workshop Conference on GDM [27]. After excluding 28 women with T2DM at 2 months after delivery and women not willing to participate in the study, we recruited 189 women with pGDM. Of the remaining women, 165 women were followed up annually with a standard 75 g OGTT. Finally, at 3-year postpartum, 68 women had normal glucose tolerance (NGT), eight women had impaired fasting glucose (IFG), 45 women had impaired glucose tolerance (IGT), 11 women had IFG and IGT, and 24 women had DM. Eleven women were excluded because they were taking an oral contraceptive or tested positive for the glutamic acid decarboxylase antibody. To compare the plasma adipokine concentrations between age- and body mass index (BMI)-matched groups at 3 years after delivery, we selected 22 women with diabetes (GDM-DM), 23 women with IGT and/or IFG (GDM-IGT), and 20 women with NGT (GDM-NGT) by matching them within a range of ±2.0 years and ±1.0 kg/m², respectively.

All participants were examined in the morning after a 14-hour overnight fast. Height, weight, waist and hip circumferences, and blood pressure were measured. Fasting blood samples were drawn for measurements of adipokines, glucose, insulin, total cholesterol, triglycerides, and high-density lipoprotein choles-

terol concentrations. A 75 g OGTT and a bioimpedence test were performed and abdominal fat was assessed using computed tomography (CT) the day after the OGTT test. The Institutional Review Board (IRB) of the Clinical Research Institute at the Seoul National University Hospital approved the study protocol (IRB Number: H-0412-138-017), and written informed consent was obtained from each subject.

**Measurement of plasma HMW adiponectin, RBP-4, lipocalin-2, and chemerin**

Plasma HMW adiponectin concentrations were measured using an enzyme-linked immunosorbent assay (ELISA) kit according to the manufacturer's instructions (ALPCO Diagnostics, Salem, NH, USA). The ELISA system had an intra-assay coefficient of variation (CV) of 3.3% to 5.0% and an inter-assay CV of 5.7%. RBP-4 concentrations were measured by an ELISA (Adipogen, San Diego, CA, USA; intra-assay CV 5.5%, and inter-assay CV 7.2%). Lipocalin-2 concentrations were measured using an ELISA kit (R&D, Minneapolis, MN, USA; intra-assay CV 2.3% to 4.1%, and inter-assay CV 5.1% to 7.6%). Chemerin concentrations were measured using an ELISA kit (Biovendor, Brno, Czech Republic; intra-assay CV 6.0%, and inter-assay CV 7.6%).

**Homeostasis model assessment**

The degree of insulin resistance and β-cell function were estimated by the homeostasis model assessment of insulin resistance (HOMA-IR) as described by Matthew et al. [28]. HOMA-IR was calculated by the following formula: fasting plasma glucose (mmol/liter)×fasting plasma insulin (mU/L)/22.5. HOMA-β, a measure of β-cell function, was calculated as 20× fasting plasma insulin divided by fasting plasma glucose −3.5.

**Measurement of body fat**

Body fat was measured by tetrapolar bioelectrical impedance analysis (Inbody 3.0, Biospace, Seoul, Korea). Bioelectrical impedance measures two parameters, fat and lean tissue, using empirically derived formulas that have been validated by earlier studies and that correlate well with values obtained using underwater weighing [29]. The abdominal fat areas were quantified by a single scout of a CT scan (Somatom Sensation 16, Siemens, Erlangen, Germany). A 5 mm CT slice scan was acquired at the umbilical level to measure the total abdominal and visceral fat areas. Fat attenuation was determined by measuring the mean value of all pixels within the range of −190 to −30 Hounsfield units.

**Statistical analysis**

All continuous variables with normal distribution are expressed as mean±standard deviation, and variables with a skewed distribution are expressed as the median and range. Variables with skewed distribution were log-transformed for statistical analysis. Baseline clinical characteristics and adipokine levels were compared among groups using analysis of variance (ANOVA) with *post hoc* analysis. Correlations between variables were analyzed using Spearman correlation because of the relatively small numbers of women in each group. To compare the adipokine levels longitudinally in various states of glucose tolerance after GDM, linear mixed model testing was applied. Statistical analyses were performed using SPSS version 22.0 software for Windows (SPSS Inc., Chicago, IL, USA). A *P*<0.05 was considered significant.

## RESULTS

**Clinical and metabolic characteristics of the study subjects**

The clinical characteristics at 3 years after delivery of the study subjects are summarized in Table 1. The mean age, systolic and diastolic blood pressure, BMI, waist and hip circumferences, and body fat percentage estimated by bioelectrical impedance analysis were not different among the three groups. The fasting plasma glucose concentrations and 2-hour post-OGTT glucose concentrations were highest in the GDM-DM group. However, fasting plasma triglycerides and cholesterol concentrations, total, visceral, and subcutaneous abdominal fat areas measured by CT, HOMA-IR, and HOMA-β were not different among the three groups.

**Longitudinal changes of adipokine levels in subjects with pGDM**

During pregnancy, the plasma concentrations of HMW adiponectin, RBP-4, lipocalin-2, and chemerin were not different among the three groups (Table 2). However, the plasma HMW adiponectin concentrations increased at 2 months postpartum in the GDM-IGT group (*P*<0.05), the elevated levels of HMW adiponectin were maintained up to 3 years postpartum. In the GDM-NGT group, the plasma HMW adiponectin levels significantly increased at 3 years postpartum compared with levels during pregnancy (*P*<0.05). In contrast, no significant changes could be observed at 2 months and 3 years postpartum in the GDM-DM group (Fig. 1). At 3 years postpartum, the plasma levels of HMW adiponectin were significantly lower in the GDM-DM group than in the GDM-NGT and GDM-IGT group

**Table 1.** Baseline Characteristics of the Subjects 3 Years after Delivery

| Characteristic | GDM-NGT ($n=20$) | GDM-IGT ($n=23$) | GDM-DM ($n=22$) | $P$ value |
|---|---|---|---|---|
| Age at pregnancy, yr | 31.1±4.1 | 31.8±3.5 | 31.2±3.0 | 0.75 |
| SBP, mm Hg | 108.6±12.0 | 109.1±12.8 | 109.6±14.9 | 0.98 |
| DBP, mm Hg | 71.6±9.8 | 73.2±10.6 | 73.6±13.0 | 0.87 |
| BMI, kg/m$^2$ | 22.2±3.2 | 23.1±3.2 | 22.4±2.7 | 0.72 |
| Waist circumference, cm | 75.0±7.3 | 77.8±7.1 | 75.6±7.4 | 0.58 |
| Hip circumference, cm | 93.2±5.5 | 94.8±6.3 | 93.5±4.5 | 0.76 |
| FPG, mg/dL | 82±12 | 90±16 | 109±24 | <0.01 |
| PP2, mg/dL | 124±35 | 154±25 | 228±56 | <0.01 |
| Fasting insulin, mIU/L | 10.3±3.8 | 10.5±4.6 | 13.7±9.3 | 0.52 |
| 2-hr insulin, mIU/L | 41.3±24.6 | 88.4±101.6 | 77.0±61.7 | 0.47 |
| HOMA-IR | 2.3±1.0 | 2.5±1.1 | 3.6±2.7 | 0.36 |
| HOMA-β | 139.0±37.9 | 119.4±66.9 | 105.7±58.2 | 0.51 |
| Total cholesterol, mg/dL | 180±23 | 186±29 | 180±33 | 0.84 |
| Triglycerides, mg/dL | 151±46 | 90±31 | 151±129 | 0.34 |
| HDL-C, mg/dL | 47±13 | 59±28 | 49±12 | 0.26 |
| LDL-C, mg/dL | 106±26 | 109±33 | 99±34 | 0.71 |
| HMW adiponectin, μg/mL | 4.8 (1.4–8.1) | 4.4 (1.7–6.8) | 2.9 (1.5–8.3) | 0.65 |
| RBP-4, μg/mL | 58.8 (42.1–85.0) | 45.0 (29.0–82.8) | 52.0 (17.5–70.3) | 0.19 |
| Lipocalin-2, μg/L | 92.0 (25.2–266.5) | 73.2 (29.2–187.0) | 92.8 (19.8–200.8) | 0.26 |
| Chemerin, μg/L | 183.9 (149.9–318.0) | 203.8 (142.3–306.4) | 196.8 (108.0–376.1) | 0.74 |
| % Body fat | 29.0±4.8 | 29.5±5.4 | 28.9±5.5 | 0.96 |
| Total abdomen fat area, cm$^2$ | 281.4±126.3 | 281.2±114.7 | 256.0±126.0 | 0.80 |
| Visceral fat area, cm$^2$ | 98.7±39.4 | 96.5±66.0 | 93.7±79.9 | 0.98 |
| Subcutaneous fat area, cm$^2$ | 182.8±95.7 | 184.7±60.0 | 162.2±58.3 | 0.60 |

Values are expressed as mean±standard deviation or median (range). $P$ values were calculated using analysis of variance (ANOVA) with *post hoc* analysis. GDM, gestational diabetes mellitus; NGT, normal glucose tolerance; IGT, impaired glucose tolerance; DM, diabetes mellitus; SBP, systolic blood pressure; DBP, diastolic blood pressure; BMI, body mass index; FPG, fasting plasma glucose; PP2, post-prandial 2-hour glucose; HOMA-IR, homeostasis model assessment of insulin resistance; HOMA-β, homeostasis model assessment of β-cell function; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; HMW, high molecular weight; RBP-4, retinol-binding protein-4.

**Table 2.** Plasma Adipokine Levels in Women with Previous GDM during Pregnancy, 2 Months, and 3 Years after Delivery

| Variable | GDM-NGT ($n=20$) | | | GDM-IGT ($n=23$) | | | GDM-DM ($n=22$) | | |
|---|---|---|---|---|---|---|---|---|---|
| | During pregnancy | Postpartum 2 mo | Postpartum 3 yr | During pregnancy | Postpartum 2 mo | Postpartum 3 yr | During pregnancy | Postpartum 2 mo | Postpartum 3 yr |
| HMW adiponectin, μg/mL | 2.1 (1.1–5.0) | 2.3 (1.2–5.0) | 4.8 (1.4–8.1)[a,b] | 2.7 (1.1–5.6) | 4.3 (1.0–7.9)[a] | 4.4 (1.7–6.8)[a] | 3.0 (1.2–5.9) | 2.4 (1.4–8.5) | 2.9 (1.5–8.3) |
| RBP-4, μg/mL | 45.1 (23.1–69.3) | 49.3 (33.4–75.5) | 58.8 (42.1–85.0) | 38.7 (25.4–48.3) | 41.4 (29.1–63.7) | 45.0 (29.0–82.8) | 41.4 (29.1–86.7) | 43.7 (23.4–85.4) | 52.0 (17.5–70.3) |
| Lipocalin-2, μg/L | 74.6 (40.3–121.9) | 56.4 (29.8–88.7) | 92.0 (25.2–266.5) | 55.2 (11.8–102.7) | 53.6 (24.8–155.7) | 73.2 (29.2–187.0) | 56.3 (19.8–112.1) | 50.7 (7.4–183.6) | 92.8 (19.8–200.8) |
| Chemerin, μg/L | 178.5 (109.8 –276.2) | 202.6 (138.6–427.1) | 183.9 (149.9–318.0) | 169.7 (108.1–294.7) | 210.2 (143.5–328.0) | 203.8 (142.3–306.4) | 154.4 (111.0–272.5) | 209.6 (130.0–300.7) | 196.8 (108.0–376.1) |

Values are expressed as median (range).
GDM, gestational diabetes mellitus; NGT, normal glucose tolerance; IGT, impaired glucose tolerance; DM, diabetes mellitus; HMW, high molecular weight; RBP-4, retinol-binding protein-4.
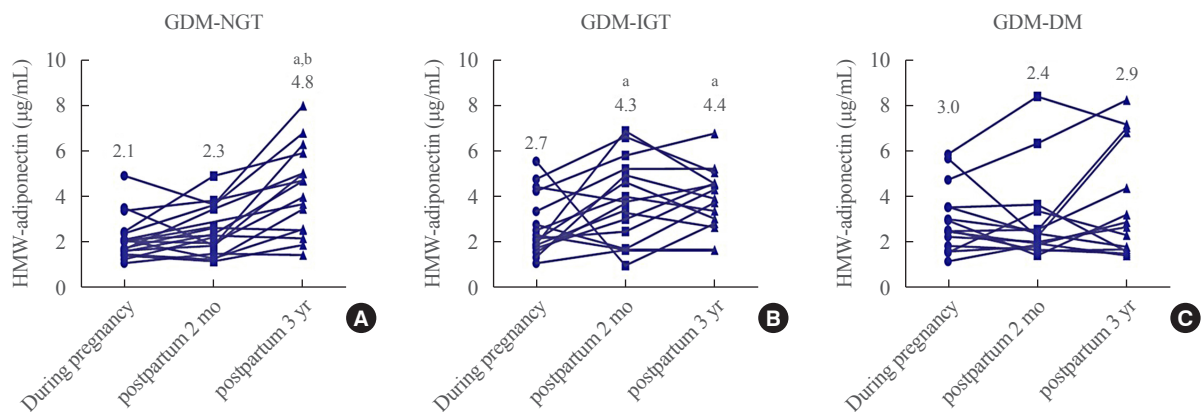[a]$P<0.05$ vs. during pregnancy; [b]$P<0.05$ vs. postpartum 2 months.

**Fig. 1.** Serial change of plasma high molecular weight (HMW) adiponectin concentrations during pregnancy, 2 months, and 3 years after delivery. (A) In gestational diabetes mellitus (GDM)-normal glucose tolerance (NGT) group, HMW adiponectin concentrations significantly increased at 3 years postpartum compared with during pregnancy and at 2 months postpartum. (B) In GDM-impaired glucose tolerance (IGT) group, HMW adiponectin concentrations significantly increased at 2 months and 3 years postpartum compared with during pregnancy. (C) In GDM-diabetes mellitus (DM) group, no significant changes in HMW adiponectin concentration were observed. [a]$P<0.05$ vs. during pregnancy; [b]$P<0.05$ vs. postpartum 2 months.

($P<0.05$).

No significant longitudinal changes in plasma RBP-4, lipocalin-2, and chemerin concentrations could be found in each group. Also, no among-group differences in plasma RBP-4, lipocalin-2, and chemerin concentrations were found during pregnancy, after 2 months delivery and at 3 years postpartum (Table 2).

**Correlations between plasma HMW adiponectin concentrations and metabolic parameters at 3 years postpartum**

All study subjects, regardless of their glucose status, were included in the correlation analyses (Table 3). Plasma HMW adiponectin levels significantly negatively correlated with BMI (Spearman's correlation coefficient –0.34, $P=0.01$) and HOMA-IR (Spearman's correlation coefficient –0.47, $P=0.04$) in all subjects. RBP-4, lipocalin-2, and chemerin levels did not correlate significantly with these metabolic parameters (data not shown).

## DISCUSSION

In this study, serial changes of the plasma HMW adiponectin from pregnancy to 3 years postpartum in women with pGDM showed different patterns according to glucose tolerance groups. The plasma levels of HMW adiponectin did not change during the study period in the GDM-DM group, while other groups showed significant increases during 3 years after delivery. Consequently, at 3 years postpartum, the plasma levels of HMW ad-

**Table 3.** Correlations between Plasma High Molecular Weight Adiponectin Concentrations and Various Metabolic Parameters

| Parameter | Postpartum 3 years | |
| --- | --- | --- |
| | Spearman's coefficient | *P* value |
| Age | –0.09 | 0.53 |
| BMI | –0.34 | 0.01 |
| Fasting plasma insulin | –0.30 | 0.20 |
| HOMA-IR | –0.47 | 0.04 |
| Visceral fat area | –0.20 | 0.29 |

BMI, body mass index; HOMA-IR, homeostasis model assessment of insulin resistance.

iponectin were significantly lower in the GDM-DM group than the GDM-NGT and GDM-IGT groups. Moreover, the plasma HMW adiponectin was negatively correlated with BMI, fasting plasma insulin, and HOMA-IR at 3 years postpartum status.

Previous studies demonstrated that plasma adiponectin levels were lower in women with GDM than in women without GDM [13,14,17]. However, some studies did not show changes of adiponectin levels or an association with insulin resistance as estimated by HOMA-IR in women with GDM [23,30]. In the present study, we measured HMW adiponectin, which is considered as the more biologically active form of adiponectin and may play a key role in insulin sensitivity and the development of T2DM [17,31]. Plasma HMW adiponectin levels were decreased in the GDM-DM group compared with the GDM-NGT and GDM-IGT groups at 3 years postpartum. However, the

plasma HMW adiponectin levels were not different among the three groups during pregnancy. In this study, only GDM subjects were enrolled and there was no group with normal pregnancy. This might be contributed to the different results shown in the present study.

Pregnancy is a unique condition characterized by increased insulin resistance, which leads to GDM in some women [11,12, 32]. Among them, development of T2DM after delivery was reported in up to 60% of women according to a long-term follow-up study [33]. T2DM and pGDM have the same predisposing factors including family history of diabetes, high BMI, increased age, and, therefore, these two disorders might have overlapping causes [34]. The pathophysiological mechanisms underlying the progression to T2DM in women with pGDM are not well known. However, possible mechanisms were suggested, such as impaired β-cell function, insulin resistance, and inflammation [35]. Adiponectin is a well-known adipokine, and it has anti-inflammatory and insulin sensitizing properties resulting in an inverse relationship with insulin resistance [36]. HMW adiponectin levels showed elevation in postpartum period (2 months or 3 years) of pGDM subjects who returned to NGT or to prediabetes, but no elevation was observed in pGDM-T2DM converters in our results.

We found that HMW adiponectin concentrations are negatively correlated with BMI and HOMA-IR at postpartum 3 years. Our results are consistent with previous studies, and they show an association between adiponectin and BMI, impaired β-cell function, and insulin resistance [7,34]. All of these factors showed a significant association with low plasma HMW adiponectin levels in our study, and, therefore, we can assume that HMW adiponectin acts as an important mediator relating the process β-cell recovery and the improvement of insulin resistance after delivery in women with pGDM.

Adiponectin is mainly secreted in adipose tissue [8,9], and it would be interesting to know whether the amount of visceral fat is associated with plasma HMW adiponectin concentrations. In this study, there were no significant differences of total abdominal, visceral, and subcutaneous fat areas among the glucose-tolerant groups, although HMW adiponectin concentrations showed significant differences among the three groups. Previous studies reported an association between serum adiponectin levels and visceral fat areas [37,38]. Our study population was limited to Korean women who were not obese (mean BMI 22.8±2.9 kg/m$^2$ [range, 17.3 to 29.1]). These factors might affect our results, and further studies are needed for clarification.

Regarding other adipokines, RBP-4, lipocalin-2, and chemer-

in, we did not find statistical differences among the three groups. Furthermore, in this study, there was no significant correlation between these adipokines and other metabolic parameters. In previous studies, RBP-4 level in GDM showed various results according to studies [39,40]. There are a few studies that measured plasma RBP-4 levels during the postpartum period. One study measured plasma RBP-4 levels during pregnancy, and at 6 weeks and 6 months postpartum, but no significant changes were observed [23]. Another study performed by our group showed that RBP-4 levels at 2 months postpartum increased significantly in women with pGDM-T2DM converters compared with control women. Although plasma RBP-4 concentrations did not differ significantly among the pGDM groups, there was a trend toward increasing RBP-4 concentrations according to the severity of glucose intolerance (*P* for linearity=0.006) at early postpartum [19]. However, in the present study, we excluded subjects who developed T2DM at 2 months postpartum who showed higher level of RBP-4 in our previous study. The current status of glucose intolerance in the present study was determined at the point of postpartum 3 years. Therefore, subjects who developed T2DM before postpartum 3 years were excluded in the present study. Taken together, to predict for diabetic conversion in women with pGDM, we suggest that RBP-4 is a more reliable marker for early conversion to T2DM (as in 2 months postpartum), whereas the decreased HMW adiponectin concentration can be a more useful marker for later development (several years postpartum).

To the best of our knowledge, this is the first report to assess serial changes of various adipokines in women with pGDM at 2 months and up to 3 years postpartum. There are a few studies that investigated the changes of adipokine during the postpartum period [14,15,23]. However, the measurement of adipokines in those studies was performed in the relatively early postpartum period between 3 days and 1 year postpartum. We assessed both early and long-term postpartum period adipokine changes in women pGDM. Considering that the incidence of T2DM in women with pGDM increases rapidly in the first 2 years after delivery, and progressively increases up to 5-year postpartum [7,41], it is important to investigate long-term changes of adipokines after delivery. In this point, this study results have clinically meaningful.

There are some limitations in our study. First, the number of study subjects was relatively small because of the stringent longitudinal follow-up period up of 3 years. Second, this study did not include a normal pregnancy group. Third, the study population was limited to Korean women with relatively low BMI

(mean BMI 22.8±2.9 kg/m$^2$ [range, 17.3 to 29.1]). Further investigations in larger populations with multiple ethnicities are needed to validate our results.

In conclusion, in women with pGDM, plasma HMW adiponectin concentrations showed a serial increase in women with GDM-NGT and GDM-IGT at 3 years postpartum whereas it showed no alternation in women with GDM-DM. Serial changes of HMW adiponectin are associated with the glucose intolerance in women with pGDM after delivery.

## CONFLICTS OF INTEREST

No potential conflict of interest relevant to this article was reported.

## AUTHOR CONTRIBUTIONS

Conception or design: S.H.C., H.C.J. Acquisition, analysis, or interpretation of data: D.H.L., J.A.L. Drafting the work or revising: D.H.L., S.H.C., H.C.J. Final approval of the manuscript: D.H.L., J.A.L., J.H.K., S.H.K., S.H.C., H.C.J.

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