THE MEDICAL BULLETIN OF
SISLI ETFAL HOSPITAL

DOI: 10.14744/SEMB.2022.62592
Med Bull Sisli Etfal Hosp 2023;57(1):79–85

Original Research

The Relationship Between Gestational Diabetes Mellitus and Adipocytokine Levels

Gul Inci Torun,[1] Dilek Tuzun,[2] Murat Sahin,[2] Metin Kilinc[3]

[1]Department of Internal Medicine, Kahramanmaras Sütçü İmam University, Faculty of Medicine, Kahramanmaraş, Türkiye
[2]Department of Endocrinology and Metabolism, Kahramanmaras Sütçü İmam University, Faculty of Medicine, Kahramanmaraş, Türkiye
[3]Department of Biochemistry, Kahramanmaras Sütçü İmam University, Faculty of Medicine, Kahramanmaraş, Türkiye

Abstract

Objectives: The aim of this study was to compare adiponectin, resistin, visfatin, and irisin levels between pregnant women diagnosed gestational diabetes mellitus (GDM) and healthy pregnant women and to evaluate the role of these parameters in GDM pathophysiology and early diagnosis.

Methods: Fifty GDM and 50 healthy pregnant women were included in the study. Anthropometric measurements of pregnant women were performed. Fasting blood glucose, hemoglobin A1c, 75 gr OGTT, low density lipoprotein, triglyceride, and complete blood count results were recorded. Adiponectin, irisin, visfatin, resistin, and C-reactive protein (CRP) levels were evaluated.

Results: Serum adiponectin levels were significantly lower ($p<0.001$) and serum resistin and CRP levels were significantly higher ($p=0.000$ and $p=0.027$, respectively) in pregnant women with GDM compared to healthy pregnants. There was no significant difference between groups according to serum irisin and visfatin levels ($p=0.942$ and $p=0.332$, respectively). There was a negative correlation between adiponectin level and FPG, visfatin, and resistin, while a positive correlation was found between irisin level. While there was a positive correlation between resistin and CRP levels, there was a negative correlation between adiponectin level. While there was a positive correlation between irisin and adiponectin levels, there was a negative correlation between weight and body mass index.

Conclusion: In this study, we think that elevated serum resistin and CRP levels and decreased adiponectin levels in GDM patients may play a role in glucose metabolism changes. Further studies are needed on this subject.

Keywords: Adiponectin, gestational diabetes mellitus, irisin, resistin, visfatin

Please cite this article as "Torun GI, Tuzun D, Sahin M, Kilinc M. The Relationship Between Gestational Diabetes Mellitus and Adipocytokine Levels. Med Bull Sisli Etfal Hosp 2023;57(1):79–85".

Gestational diabetes mellitus (GDM) is a carbohydrate intolerance that appears first during pregnancy. During pregnancy, increased glucose levels can affect both fetus and mother adversely.[1] In GDM pathogenesis, insulin resistance and beta-cell dysfunction take an important role. In addition, adipose tissue has major effect in the pathophysiology of GDM. Today, adipose tissue dysfunction shows that there is a pathophysiological link between obesity and diabetes, characterized by the abnormal production of adipokines.[2] The role of various adipokines in the pathogenesis of this condition has been widely discussed recently in diabetes, but studies with adipocytokines ingestational diabetes are limited.

Address for correspondence: Dilek Tuzun, MD. Kahramanmaras Sutcu Imam Universitesi Tip Fakultesi Endokrinoloji ve Metabolizma Anabilim Dali, Kahramanmaras, Türkiye
Phone: +90 505 318 81 88 **E-mail:** tuzund@gmail.com

Submitted Date: September 06, 2022 **Revised Date:** October 23, 2022 **Accepted Date:** November 15, 2022 **Available Online Date:** March 21, 2023

Adiponectin is a collagen structured plasma protein produced by adipose tissue. In cases with diabetes and hypertension, adiponectin levels were found to be lower than healthy individuals.[3] The molecule of the irisin can stimulate the growth of some parts in adipose tissue as brown adipose tissue, relieve glucose metabolism disorder, and make some reduction in body weight.[4] Visfatin inhibits hepatic glucose production on glucose transport in muscle and adipose tissue. It shows insulinomimetic effect and is not affected by plasma insulin levels.[5] Resistin is an adipokine in the protein structure defined as a peripheral signal molecule that is thought to be associated with diabetes mellitus and obesity. Resistin has important effects in humans; first, it causes insulin resistance in abdominal adipose tissue, and second, it contributes to thedevelopment of diabetes by preventing differentiation in fat cells.[6]

The role of adiponectin, irisin, visfatin, and resistin levels in GDM pathogenesis has not been fully clarified. Therefore, in this study, we aimed to observe serum adiponectin, irisin, visfatin, and resistin levels in pregnant women diagnosed with GDM with the same age healthy pregnant group.

Methods

This study is a cross-sectional study conducted in the department of endocrinology and metabolic diseases. The study was approved by the decision of Ethics Committee dated January 17, 2018 and numbered 10 and a written consent form was obtained from all participants. All procedures performed in studies involving human participants were in accordance with the ethical standards of the Institutional and/or National Research Committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Study Design and Inclusion Criteria

In our study, 50 pregnant women with GDM and 50 healthy women who were followed-up and treated between 2018 and 2019 at the endocrinology and metabolic diseases and obstetrics and clinic of obstetrics department were included in the study. Age, height, weight of pregnant women, and gestational week were questioned. From patient files, complete blood count, glucose, triglyceride TG, low-density lipoprotein (LDL), and hemoglobin A1c (HbA1C) were evaluated in routine examinations. Adiponectin, irisin, visfatin, resistin, and C-reactive protein (CRP) were studied in plasma samples obtained by centrifugation of parameters of blood samples that were stored at–80°C until the working moment.

Admissions and Exclusion Criteria

As a patient group, patients between 18 and 45 years old who were diagnosed with GDM in the 24–28th gestational week and as the control group pregnant women whose OGTT results were within normal limits were included in the stduy. Patients with kidney orliver failure, those with thyroid dysfunction, previously diagnosed with type 2 or type 1 diabetes, and smoking ones were not participated in the study.

Laboratory Analysis

LDL, TG, hemogram, and HbA1c were recorded from the routine hospital data system. Blood for routine biochemical and hormonal examinations was taken intotubes without anticoagulation after 8–10 h of fasting, in the morning. After standing a little at room temperature, it was centrifuged at 4000 rpm (revolutions perminute) for 5 min. Serums formed after centrifugation were used for routine biochemical and hormonal tests. The lipid profile was studied in biochemistry laboratory by spectrophotometric method using the Advia 1800 device. LDL and TG were measured by spectrophotometric method using biochemistry analyzer and commercial kit (Siemens, Advia1800 ChemistrySystem, Germany). HbA1c was measured by high liquid pressure chromatography (HPLC) method using HPLC device and commercial kit (BioRad D–10 Hemoglobintesting system, France). The blood samples taken to the tube were brought to the laboratory and the serum was separated by centrifugation for 15 min at 2500 rpm. Separated serums were stored at–80°C until working time. Serum samples thawed at the time of study and studied manually using the Elisa method. The Elisa reader was the Thermo Scientific (USA). Boster Biologica Technology Philadelphia (USA) kits were used for the measurement of serum fibronectin (irisin) (CV: 10.0%) and Visfatin (CV: 10.1%); while Wuhan USCN Business Co. Ltd. Zhenhua (China) kits were used for mesaurement of serum resistin (CV: 7.8%) andadipokine (CV: 7.6%) levels: 10.1%. The results ofthe cases were calculated by comparing unknown samples with the standard curve created from the standards in the kit.

Statistical Analysis

Statistical analysis was conducted with the Statistical Package for the Social Sciences 25.0 packet program (SPSSInc., Chicago, IL). While evaluating the study data, mean standard deviation (mean±SD) of the descriptive statistical methods, Student t-test was used forthe comparison of parameters with normal distribution inthe comparison ofquantitative data. Pearson correlation test was used to examine the relationships between parameters. $p \leq 0.05$ was accepted statistically significant.

Results

Fifty GDM and 50 healthy volunteer pregnant control group were participated in our study. There was nostatistically significant difference between the two groups in terms of age (p=0.062). Body mass index (BMI) of GDM group was 32.71±5.42, while BMI of control group was 27.82±4.12. BMI of GDM group was statistically higher than control group (p<0.001). Demographic characteristics of cases are given in Table 1.

When the hemograms of GDM and control group were compared, the difference was not statistically significant when compared interms of hemoglobin, mean corpuscular hemoglobin (MCH) level, red blood cell distribution width (RDW), and platelet (PLT) number values (Table 2). The white bloodcell (WBC) level in the patient group was significantly higher than the control group (p<0.000). When the two groups were compared interms of mean corpuscular volume (MCV) level, the MCV level was statistically significantly lower inthe patient group (p=0.030) (Table 1).

When the patients were compared in terms of biochemical and hormonal data, FBG, HbA1c, LDL, and TG levels were statistically significantly higher in the patients with GDM than control group (Table 2). The level of CRP and resistin was statistically significantly higher in the GDM patients than thecontrol group. When the two groups were compared interms of irisin and visfatin levels, the difference was not statistically significant. While the adiponectin level was 9.77±5.01 µg/mL in the GDM group, it was 16.57±5.47 µg/mL in the control group. Adiponectin level was statistically significantly lower in the patient groupcompared tothe control group (p=0.000) (Table 2).

In the correlation analysis, a statistically significant positive correlation was found between CRP and resistin andweight (r=0.223, p=0.033; r=0.222, p=0.039, respectively). Furthermore, there was a statistically significant correlation between serum irisin level and adiponectin (r=0.270, p=0.014). A statistically significant negative correlation was found between serum irisin level and weight and BMI (r=–0,248, p=0.025; r=–0.230, p=0.037, respectively). There was a statistically significant negative correlation between irisin level and BMI (r=–0.230, p=0.037). A statistically significant negative correlation was detected between serum visfatin level and adiponectin (r=–0,245, p=0.027). A statistically significant negative correlation was found between serum adiponectin level and BMI (r=–0.277, p=0.012) (Table 3).

Table 1. Comparison of the demographic characteristics and hemograms of the cases

Variables	Cases (n=50)	Control (n=50)	p
Age (year)	31.88±5.81	29.36±5.71	0.062
Height (cm)	158.88±5.38	162.23±6.18	0.012*
Weight (kg)	82.56±13.37	73.36±12.03	0.003*
BMI (kg/m^2)	32.71±5.42	27.82±4.12	0.000*
HGB (g/dL)	11.70±1.13	11.99±1.24	0.274
MCV (fL)	83.61±6.12	86.61±5.49	0.030*
MCH (pg)	29.17±7.02	29.47±2.52	0.828
RDW (fL)	45.35±6.98	43.80±3.78	0.264
PLT (x10^3/µL)	219.53±61.48	227.60±77.69	0.606
WBC (x10^3/µL)	9.97±2.08	8.09±1.19	0.000*

BMI: Body mass index; n: Number; HGB: Hemoglobin; MCV: Mean erythrocyte volume; MCH: Mean corpuscular hemoglobin; RDW: Red cell distribution width; PLT: Platelet; WBC: White blood count; * Statistically significant.

Table 2. Comparison of the biochemical and hormonal parameters

Variables	Cases (n=50)	Control (n=50)	p
FBG (mg/dL)	101.76±30.25	78.03±10.72	0.000*
LDL (mg/dL)	127.24±42.25	109.12±27.09	0.038*
TG (mg/dL)	248.127±87.16	192.08±74.11	0.004*
HbA1c (%)	5.68±0.82	5.17±0.36	0.002*
CRP (mg/dL)	8.28±5.91	5.44±4.71	0.027*
İrisin (µg/mL)	344.55±103.26	346.55±78.98	0.942
Visfatin (ng/mL)	6.98±0.60	6.86±0.41	0.324
Resistin (ng/mL)	6.98±0.60	3.39±0.51	0.000*
Adiponectin (µg/mL)	9.77±5.01	16.57±5.47	0.000*

FBG: Fasting bolood glucose; LDL: Low density lipoprotein; TG: Triglyceride; HbA1c: Hemoglobin A1c; CRP: C reactive protein; n: Number; * Statistically significant.

Discussion

The diagnosis of GDM is very important for mother and fetus. It has been shown that mediators called adipocytokines secreted from adipose tissue can play a role in any physiological processes such as energy metabolism, nutrition, inflammation, and lipid metabolism. Various studies have examined the relationship between adipocytokines and diabetes. There are very few studies on adipocytokines in GDM.[7,8] Adiponectin is a hormone primarily secreted by adipocytes, with anti-inflammatory, anti-atherogenic, and insulin-sensitizing effects. Adiponectin reduces hepatic glucose production and increases fatty acid oxidation and potentiates the effects of insulin in the liver, thereby increasing insulin sensitivity.[3] There are studies showing the decrease in adiponectin levels in patients with GDM[9-13] and do not change[14,15] compared to normal pregnants. In our study, we found lower serum adiponectin levels in the GDM patients compared to the control group. Some studies found a negative correlation between BMI and adiponectin levels both before pregnancy and at 24–28

Table 3. Correlation of cases with adipocytokine and CRP levels and anthropometric measurements

Variables	CRP (mg/dL)	Irisin (µg/ml)	Visfatin (ng/mL)	Resistin (ng/mL)	Adiponectin (µg/mL)	Height (cm)	Weight (kg)	BMI (kg/m^2)
CRP (mg/dL)								
r	1	0.065	0.021	0.239*	0.069	0.099	0.229*	0.193
p		0.562	0.851	0.033	0.536	0.377	0.039	0.082
Irisin (µg/mL)								
r	0.065	1	−0.181	−0.162	0.270*	−0.036	−0.248*	−0.230*
p	0.562		0.105	0.152	0.014	0.750	0.025	0.037
Visfatin (ng/mL)								
r	0.021	−0.181	1	−0.120	−0.245*	−0.004	0.113	0.100
p	0.851	0.105		0.291	0.027	0.975	0.310	0.370
Resistin (ng/mL)								
r	0.239*	−0.162	−0.120	1	−0.284*	−0.207	0.056	0.108
p	0.033	0.152	0.291		0.011	0.066	0.621	0.340
Adiponectin (µg/mL)								
r	0.069	0.270*	−0.245*	−0.284*	1	0.178	−0.196	−0.277*
p	0.536	0.014	0.027	0.011		0.109	0.078	0.012
Height (cm)								
r	0.099	−0.36	−0.004	−0.207	0.178	1	0.214	−0.190
p	0.377	0.750	0.975	0.066	0.109		0.053	0.088
Weight (kg)								
r	0.229*	−0.248*	0.113	0.056	−0.196	0.214	1	0.893*
p	0.039	0.025	0.310	0.621	0.078	0.053		0.000
BMI (kg/m^2)								
r	0.193	−0.230*	0.100	0.108	−0.277*	−0.190	0.893*	1
p	0.082	0.037	0.370	0.340	0.012	0.88	0.000	

CRP: C reactive protein; BMI: Body mass index; * Statistically significant.

weeks,[13,16] while Goymen et al.[17] found maternal serum adiponectin levels do not correlate with maternal body weight and BMI. In our study, we found a significant negative correlation between BMI and adiponectin. Worda et al. and Ott et al.[12, 18] showed negative correlation between adiponectin and glucose levels in women while screening for gestational diabetes. In our study, we found statistically significant negative correlation between serum adiponectin level and glucose levels.

Irisin is released from skeletal muscle and adipose tissue, transforms white adipose tissue cells into brown ones, and helps regulate glucose homeostasis by providing energy expenditure. It is an indicator molecule inthe regulation of BMI and promising inthe treatment of metabolic diseases.[4] Ural et al.[19] determined lower serum irisin levels in GDM pregnant women compared to healthy pregnant controlswhile Bostrom et al.[4] showed higher irisin levels. Garces et al.[20] showed increased placental expression of irisin precursor protein compared to the control group. There are contradictory results inprevious studies on this subject. Kuzmicki et al.[21] reported that irisin concentrations in pregnant patients were negatively correlated with 2nd h glucose levels. However, Ebert et al.[22] reported that fasting insulin was positively associated with serum irisin in pregnancy compared with non pregnant group. In our study, there was no statistically significant difference between groups in terms of irisin levels. We found no significant relationship between the serum level of irisin and FPG and HbA1c andan negative relationship between serum irisin level and BMI. Irisin may play an important role in the development of gestational diabetes, but needs more research to show this. It will be useful to understand the mechanism of action of irisin to develop new therapeutic strategies for diabetes and obesity, whose incidence is increasing day by day, and toreduce the prevalence ofthese diseases.

Resistin is an adipokine, decreases glucose uptake into adipose tissue, and so increases plasma glucose concentration and decreases insülin sensitivity. The physiological role of resistin in pregnancy has not been sufficiently determined in humans yet. Studies on levels of resistin during pregnancy with GDM have yielded conflicting results; in-

creased,[23-25] decreased[26] or even unchanged values[27] are reported. Insulin has a two phase effect on the release of resistin, while lower insulin concentrations increase resistin secretion, higher insulin concentrations decrease resistin levels.[28] There is a positive relationship between resistin and obesity. Resistin levels are inreasing during pregnancy, possibly due to weight gain.[29] In our study, we found significantly higher levels of resistin in GDM patients. The change in the level of resistin in different study groups may be due to heterogeneity in patient selection, genetic diversity of study groups.

Irisin is anovel adipokine, myokine, and neurokine which are mainly secreted byskeletal muscle.[4] Tabak et al.[30] found that higher irisin concentrations and lower adiponectin levels in patients with metabolic syndrome compared to the control group. Kulhan et al.[31] showed that levels of serum irisin were lower inpregnant women with GDM compared to women with uncomplicated pregnancies. Crujeiras et al.[32] found that risk factors for insulin resistance are directly related to circulating irisin levels and inversely proportional to adiponectin. We found positive relationship between serum adiponectin levels and irisin. We think that further studies are needed to clarify the relationship between the levels of adiponectin and irisin in GDM development. In our study, negative relationship was detected between serum adiponectin level and visfatin. This relationship has led us to think that we need to work on this topic with more examples and more comprehensively. Shang et al.[33] showed negative correlation between adiponectin an dresistin levels, while Siddiqui et al.[34] found loweradiponectin and higher resistin levels inwomen with GDM. Guelfi et al.[35] showed decrease inmaternal adiponectin concentrations an increase in leptin and resistin levels with the progression of pregnancy. We found a negative correlation between serum adiponectin and resistin levels. This results will assist indetermining the cumulative effect of circulating adiponectin and resistin on GDM development, together with traditional risk factors.

Visfatin, anadipokine, expressed in adipose tissue, secreted from amniotic epithelium, and has antiapoptotic effects on fibroblasts and amniotic epithelial cells and reduces plasma glucose levels.[36] Filippatos et al.[37] observed no relationship between visfatin and visceral fat mass or BMI. There are conflicting results in plasma visfatin levels in GDM because both increased[38] and decreased[39] that concentrations have been reported. In our study, difference in visfatin levels was not statistically significant. The results obtained so far visfatin in GDM potential biomarkers indicate that, further, investigations between GDM and visfatin are definitely needed.

Conclusion

Our study is the first study conducted in Turkish society comparing serum adiponectin, resistin, visfatin, and irisin levels in pregnant women with GDM diagnosis and healthy ones. In our study, serum adiponectin levels were statistically significantly lower in GDM group compared to the control group, while resistin and CRP levels were higher in the GDM group than the control group. No significant difference was detected between GDM and control group in terms of visfatin and irisin. There was a negative relationship between adiponectin levels and BMI. Our results suggest that elevated serum resistin levels, decreased adiponectin levels play arole in glucose metabolism changes in GDM patients. In this study, contrary to the thought of gestational diabetes pathophysiology, it has been shown that it is not only simple insülin resistance but amore complex pathophysiology that has not been clarified yet. Further studies are needed to clarify the pathophysiology of the relationship between gestational diabetes and serum adiponectin, resistin, visfatin, irisin, and CRP levels. Studies with larger patient groups are needed to use these changes in serum markers detected in GDM patients in the diagnosis and screening of GDM. In order for these investigated markers tobe used in the prediction of GDM, it is recommended to evaluate them with prospective studies to be done in early gestational weeks.

Study Limitations

A number of limitations should be noted for the study. This was a single-center and prospective study with a small sample size. The case and control groups were not of similar weight and age. The case group is older and has higher BMI values than control group. Large, prospective, and randomized clinical studies are needed to evaluate the clinical applicability of our results.

Disclosures

Ethics Committee Approval: This study is a cross-sectional study conducted in Department of Endocrinology and Metabolic Diseases. The study was approved by the decisionof Ethics Committee dated 17.01.2018 and numbered 10 and awritten consentform was obtained from all participants.

Peer-review: Externally peer-reviewed.

Conflict of Interest: None declared.

Authorship Contributions: Concept – D.T., G.I.T., M.S., M.K.; Design – G.I.T., D.T., M.S., M.K.; Supervision – G.I.T., D.T., M.S., M.K.; Materials – G.I.T., D.T.; Data collection &/or processing – G.I.T., D.T.; Analysis and/or interpretation – G.I.T., D.T.; Literature search – G.I.T., D.T., M.S.; Writing – G.I.T., D.T.; Critical review – D.T., M.T., M.K.

References

1. Öztürk FY, Altuntaş Y. Gestational diabetes mellitus. [Article in Turkish]. Sisli Etfal Hastan Tip Bul 2015;49:1–10. [CrossRef]
2. Blüher M. Clinical relevance of adipokines. Diabetes Metab J 2012;36:317–27. [CrossRef]
3. Cook JR, Semple RK. Hypoadiponectinemia--cause or consequence of human "insulin resistance"? J Clin Endocrinol Metab 2010;95:1544–54. [CrossRef]
4. Boström P, Wu J, Jedrychowski MP, Korde A, Ye L, Lo JC, et al. A PGC1-α-dependent myokine that drives brown-fat-like development of white fat and thermogenesis. Nature 2012;481:463–8.
5 Fukuhara A, Matsuda M, Nishizawa M, Segawa K, Tanaka M, Kishimoto K, et al. Visfatin: a protein secreted by visceral fat that mimics the effects of insulin. Science 2005;307:426–30. [CrossRef]
6. Rabe K, Lehrke M, Parhofer KG, Broedl UC. Adipokines and insulin resistance. Mol Med 2008;14:741–51. [CrossRef]
7. Retnakaran R, Hanley AJ, Raif N, Connelly PW, Sermer M, Zinman B. Reduced adiponectin concentration in women with gestational diabetes: a potential factor in progression to type 2 diabetes. Diabetes Care 2004;27:799–800. [CrossRef]
8. Lain KY, Daftary AR, Ness RB, Roberts JM. First trimester adipocytokine concentrations and risk of developing gestational diabetes later in pregnancy. Clin Endocrinol (Oxf) 2008;69:407–11.
9. Tsai PJ, Yu CH, Hsu SP, Lee YH, Huang IT, Ho SC, et al. Maternal plasma adiponectin concentrations at 24 to 31 weeks of gestation: negative association with gestational diabetes mellitus. Nutrition 2005;21:1095–9. [CrossRef]
10. Beltcheva O, Boyadzhieva M, Angelova O, Mitev V, Kaneva R, Atanasova I. The rs266729 single-nucleotide polymorphism in the adiponectin gene shows association with gestational diabetes. Arch Gynecol Obstet 2014;289:743–8. [CrossRef]
11. Altinova AE, Toruner F, Bozkurt N, Bukan N, Karakoc A, Yetkin I, et al. Circulating concentrations of adiponectin and tumor necrosis factor-alpha in gestational diabetes mellitus. Gynecol Endocrinol 2007;23:161–5. [CrossRef]
12. Worda C, Leipold H, Gruber C, Kautzky-Willer A, Knöfler M, Bancher-Todesca D. Decreased plasma adiponectin concentrations in women with gestational diabetes mellitus. Am J Obstet Gynecol 2004;191:2120–4. [CrossRef]
13. Williams MA, Qiu C, Muy-Rivera M, Vadachkoria S, Song T, Luthy DA. Plasma adiponectin concentrations in early pregnancy and subsequent risk of gestational diabetes mellitus. J Clin Endocrinol Metab 2004;89:2306–11. [CrossRef]
14. Matyjaszek-Matuszek B, Lenart-Lipińska M, Kowalczyk-Bołtuć J, Szlichtyng W, Paszkowski T. Correlation between atherogenic risk and adiponectin in gestational diabetes mellitus. Ann Agric Environ Med 2014;21:143–7. [CrossRef]
15. McLachlan KA, O'Neal D, Jenkins A, Alford FP. Do adiponectin, TNFalpha, leptin and CRP relate to insulin resistance in pregnancy? Studies in women with and without gestational diabetes, during and after pregnancy. Diabetes Metab Res Rev 2006;22:131–8.
16. Weerakiet S, Lertnarkorn K, Panburana P, Pitakitronakorn S, Vesathada K, Wansumrith S. Can adiponectin predict gestational diabetes? Gynecol Endocrinol 2006;22:362–8. [CrossRef]
17. Göymen A, Altınok T, Uludağ S, Şen C, Öçer F, Uzun H, et al. Gestasyonel diabetes mellitus tani ve taramasinda maternal serum adiponektinin yeri. [Article in Turkish]. Perinatoloji Dergisi 2008;16:49–55.
18. Ott R, Stupin JH, Melchior K, Schellong K, Ziska T, Dudenhausen JW, et al. Alterations of adiponectin gene expression and DNA methylation in adipose tissues and blood cells are associated with gestational diabetes and neonatal outcome. Clin Epigenetics 2018;10:131. [CrossRef]
19. Ural UM, Sahin SB, Tekin YB, Cüre MC, Sezgin H. Alteration of maternal serum irisin levels in gestational diabetes mellitus. Ginekol Pol 2016;87:395–8. [CrossRef]
20. Garcés MF, Peralta JJ, Ruiz-Linares CE, Lozano AR, Poveda NE, Torres-Sierra AL, et al. Irisin levels during pregnancy and changes associated with the development of preeclampsia. J Clin Endocrinol Metab 2014;99:2113–9. [CrossRef]
21. Kuzmicki M, Telejko B, Lipinska D, Pliszka J, Szamatowicz M, Wilk J, et al. Serum irisin concentration in women with gestational diabetes. Gynecol Endocrinol 2014;30:636–9. [CrossRef]
22. Ebert T, Stepan H, Schrey S, Kralisch S, Hindricks J, Hopf L, et al. Serum levels of irisin in gestational diabetes mellitus during pregnancy and after delivery. Cytokine 2014;65:153–8. [CrossRef]
23. Gürlek B, Çolak S. Saliva resistin as a screening marker of gestational diabetes mellitus. Gynecol Endocrinol 2021;37:324–7.
24. Hu SM, Chen MS, Tan HZ. Maternal serum level of resistin is associated with risk for gestational diabetes mellitus: a meta-analysis. World J Clin Cases 2019;7:585–99. [CrossRef]
25. Megia A, Vendrell J, Gutierrez C, Sabaté M, Broch M, Fernández-Real JM, et al. Insulin sensitivity and resistin levels in gestational diabetes mellitus and after parturition. Eur J Endocrinol 2008;158:173–8. [CrossRef]
26. Chan TF, Yuan SS, Chen HS, Guu CF, Wu LC, Yeh YT, et al. Correlations between umbilical and maternal serum adiponectin levels and neonatal birthweights. Acta Obstet Gynecol Scand 2004;83:165–9. [CrossRef]
27. O'Sullivan AJ, Kriketos AD, Martin A, Brown MA. Serum adiponectin levels in normal and hypertensive pregnancy. Hypertens Pregnancy 2006;25:193–203. [CrossRef]
28. Lappas M, Yee K, Permezel M, Rice GE. Release and regulation of leptin, resistin and adiponectin from human placenta, fetal membranes, and maternal adipose tissue and skeletal muscle from normal and gestational diabetes mellitus-complicated pregnancies. J Endocrinol 2005;186:457–65. [CrossRef]
29. Miehle K, Stepan H, Fasshauer M. Leptin, adiponectin and other adipokines in gestational diabetes mellitus and pre-eclampsia. Clin Endocrinol (Oxf) 2012;76:2–11. [CrossRef]
30. Tabak O, Simsek G, Erdenen F, Sozer V, Hasoglu T, Gelisgen R, et al.

The relationship between circulating irisin, retinol binding protein-4, adiponectin and inflammatory mediators in patients with metabolic syndrome. Arch Endocrinol Metab 2017;61:515–23.
31. Kulhan NG, Kulhan M, Turkler C, Ata N, Kiremitli T, Kiremitli S. Could serum levels of irisin be used in gestational diabetes predicting? Taiwan J Obstet Gynecol 2019;58:434–37. [CrossRef]
32. Crujeiras AB, Zulet MA, Lopez-Legarrea P, de la Iglesia R, Pardo M, Carreira MC, et al. Association between circulating irisin levels and the promotion of insulin resistance during the weight maintenance period after a dietary weight-lowering program in obese patients. Metabolism 2014;63:520–31. [CrossRef]
33. Shang M, Dong X, Hou L. Correlation of adipokines and markers of oxidative stress in women with gestational diabetes mellitus and their newborns. J Obstet Gynaecol Res 2018;44:637–46.
34. Siddiqui K, George TP, Nawaz SS, Shehata N, El-Sayed AA, Khanam L. Serum adipokines (adiponectin and resistin) correlation in developing gestational diabetes mellitus: pilot study. Gynecol Endocrinol 2018;34:502–6. [CrossRef]
35. Guelfi KJ, Ong MJ, Li S, Wallman KE, Doherty DA, Fournier PA, et al. Maternal circulating adipokine profile and insulin resistance in women at high risk of developing gestational diabetes mellitus. Metabolism 2017;75:54–60. [CrossRef]
36. Ognjanovic S, Ku TL, Bryant-Greenwood GD. Pre-B-cell colony-enhancing factor is a secreted cytokine-like protein from the human amniotic epithelium. Am J Obstet Gynecol 2005;193:273–82.
37. Filippatos TD, Derdemezis CS, Gazi IF, Lagos K, Kiortsis DN, Tselepis AD, et al. Increased plasma visfatin levels in subjects with the metabolic syndrome. Eur J Clin Invest 2008;38:71–2. [CrossRef]
38. Bawah AT, Seini MM, Abaka-Yawason A, Alidu H, Nanga S. Leptin, resistin and visfatin as useful predictors of gestational diabetes mellitus. Lipids Health Dis 2019;18:221. [CrossRef]
39. Akturk M, Altinova AE, Mert I, Buyukkagnici U, Sargin A, Arslan M, et al. Visfatin concentration is decreased in women with gestational diabetes mellitus in the third trimester. J Endocrinol Invest 2008;31:610–3. [CrossRef]