

# Maternal and fetal neudesin levels in pregnancy: associations with gestational diabetes mellitus and pregnancy outcomes

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## Abstract

**Objective:** Gestational diabetes mellitus (GDM) is significantly associated with short- and long-term adverse maternal and perinatal outcomes. Despite the important role of neudesin in modulating glucose metabolism and insulin sensitivity, extant literature is scarce on the link between neudesin and GDM. This study investigated neudesin in GDM and its potential as a diagnostic marker and future therapeutic target.

**Material and Methods:** We conducted a case control study at our department. Forty-five Pregnant women with GDM were included in the study group, while an equal number of healthy pregnancies constituted the controls. The enzyme-linked immunosorbent assay technique was employed to quantify the concentration of neudesin in both maternal and cord samples.

**Results:** Women with GDM (n=45) exhibited significantly higher maternal and umbilical cord serum neudesin levels compared to controls (median maternal neudesin: 4.9 ng/mL vs. 1.9 ng/mL; median umbilical cord neudesin: 2.6 ng/mL vs. 1.2 ng/mL). Maternal neudesin levels correlated positively with body mass index, fasting insulin, measures of insulin resistance, and neonatal birth weight and inversely with APGAR scores. A maternal neudesin cut-off of 5.25 ng/mL demonstrated high diagnostic accuracy for GDM (area under the curve =0.967, 91.1% sensitivity, 93.3% specificity, 92.2% accuracy).

**Conclusion:** Neudesin may serve as a potential diagnostic tool for GDM. Future investigations into neudesin as a novel GDM biomarker and potential therapeutic target are urgently warranted.

**Keywords:** Gestational diabetes mellitus, neudesin, pregnancy, diagnostic biomarker

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## Introduction

Gestational diabetes mellitus (GDM) refers to any form of glucose intolerance that develops during pregnancy (1). According to the international diabetes federation, GDM affects approximately 12% of pregnancies worldwide, impacting roughly 20 million births annually (2). In the eastern mediterranean region, the

prevalence of GDM is higher, reaching 14.5%, perhaps due to a pre-existing higher prevalence of diabetes mellitus in the region (2). Women with GDM face an increased risk of complications, including gestational hypertension, preeclampsia, prolonged labor, cesarean delivery, and macrosomic babies. These complications may have significant health consequences for both mother and child (3).



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Several mechanisms may explain the pathophysiological process behind GDM (3-5). Insulin resistance (IR), a natural physiological change during pregnancy, plays an important role in the development of GDM. IR is influenced by factors such as placental hormone production, maternal obesity, and inflammation (3). Moreover, IR intensifies as pregnancy progresses in certain expectant individuals, particularly those with pre-existing obesity and IR (4). Consequently, pancreatic beta cells are unable to maintain normoglycemia by increasing insulin production. The onset of GDM is indicated by the development of aberrant blood glucose levels as a result of this failure (6). Following the establishment of the placenta, the regulatory impact of a variety of signaling molecules, including proteins (including cytokines, growth factors, and glycoproteins), hormones, and other molecules, begins to affect IR (7).

Neudesin, a protein involved in various biological systems, is thought to play a role in regulating glucose metabolism and insulin sensitivity (8). Neudesin has the potential to function as a modulative agent within the regulatory frameworks that govern glucose metabolism and the modulation of insulin responsiveness, as evidenced by research conducted in pediatric cohorts with type one diabetes mellitus and adult populations with type two diabetes mellitus (9). GDM is an aberrant example of carbohydrate metabolic decompensation, and neudesin is purported to play a critical regulatory function in carbohydrate metabolism and energy (10).

The objective of this study was to investigate the levels of neudesin in the blood of pregnant women with GDM and their babies and compare this with pregnancies unaffected by GDM, and thereby shed light on the potential role of neudesin in the development and progression of GDM.

## Material and Methods

### Study design and approval

From June 2023 to September 2024, we conducted a case-control study on patients of the Department of Obstetrics and Gynecology in Kafr El-Sheikh University Hospital. The study protocol was approved by the Mansoura Faculty of Medicine Mansoura University Ethics Committee (approval number: 20.05.2573, date: 02.05.2023).

### Patient selection and enrollment

Participation was voluntary for pregnant women, aged 18-35 years, in whom pregnancies were complicated with GDM, and they were not treated with insulin. Exclusion criteria were: existence of maternal comorbid conditions, including chronic hypertension; pregestational diabetes mellitus; preeclampsia; and chronic renal disease. Further exclusion criteria included the presence of

confirmed fetal structural or chromosomal abnormalities. After obtaining informed consent, full history taking was conducted for all participants, including personal, medical, obstetric, and gynecological histories.

### GDM ascertainment

GDM was diagnosed by administering a 75-gram oral glucose tolerance test (OGTT) between 24 and 28 weeks of gestation. GDM was diagnosed when one or more abnormal plasma glucose values (fasting >92 mg/dL; one hour >180 mg/dL; and/or two hours >153 mg/dL) were obtained using the criteria of The International Association of Diabetes and Pregnancy Study Groups (11).

### Maternal and fetal neudesin ascertainment

Following a 12-hour fast, maternal venous blood samples were drawn from all study participants on the day of OGTT screening. Maternal serum was evaluated for neudesin concentration, fasting glucose and insulin levels and homeostatic model assessment for insulin resistance (HOMA-IR) was calculated. HOMA-IR was calculated using the standard formula: fasting glucose (mmol/L)  $\times$  fasting insulin (IU/mL)/22.5 (12). In addition, umbilical venous blood samples were obtained at delivery and fetal neudesin concentrations were evaluated. An enzyme-linked immunosorbent assay (ELISA) technique was used to quantify the concentration of neudesin in maternal and cord samples. We utilized the human neudesin neurotrophic factor ELISA kits (catalog number: 201-12-7672), which were maintained at a temperature of 2-8 °C. The test's sensitivity was 0.073 ng/mL, and the assay range was 0.08 to 20 ng/mL.

### Statistical analysis

Statistical analyses were performed using SPSS, version 28 (IBM Inc., Armonk, NY, USA). Normality was assessed with the Shapiro-Wilk test. Descriptive statistics included means/SDs and medians/ interquartile range (IQRs), as appropriate. For non-parametric comparisons, the Mann-Whitney U test was used while for parametric comparisons, the independent samples t-test was employed. Receiver operating characteristic curves determined optimal cut-off values for diagnostic parameters. The Spearman rank correlation coefficient was used to assess relationships between variables. Binary logistic regression identified independent risk factors. statistical significance was defined as  $p < 0.05$  and high significance as  $p \leq 0.001$ . Maternal age, body mass index (BMI), parity, family history of diabetes, fasting blood glucose levels, and HbA1c were identified as potential confounding variables in the multivariate regression analysis of predictors for GDM. After adjusting for the covariates, maternal serum neudesin levels were identified as a significant independent predictor of GDM risk.

### Sample size calculation

A post-hoc power analysis was conducted based on the primary outcome of interest: the difference in median maternal serum neudesin levels between the GDM and control groups. Based on the observed medians (GDM: 4.9 ng/mL vs. control: 1.9 ng/mL) and the IQRs, our sample size of 90 patients provided a high statistical power (>99%) to detect the substantial difference in neudesin concentration at a significance level ( $\alpha$ ) of 0.05 (two-sided test).

## Results

### Patients' baseline characteristics

Ninety patients were recruited to the study, 45 in the GDM group and 45 controls. Figure 1 shows the flow diagram of the final included study participants. The mean BMI for women with GDM was  $29.2 \pm 4.55$  kg/m<sup>2</sup>, while the mean BMI for the control group was  $25.6 \pm 6.23$  kg/m<sup>2</sup> ( $p < 0.001$ ). Gestational age at the study enrollment was similar in both groups. As expected, there were significantly higher levels of fasting insulin and HOMA-IR in women with GDM compared to the control group. The GDM group exhibited a median fasting insulin level of (7-17.5)  $\mu$ U/mL compared to 10 (8-12)  $\mu$ U/mL in the control group. Similarly, median HOMA-IR values were substantially elevated in the GDM group at 3.1 (2.1-4.2) compared to 1 (range: 0.79-1.2) in

the control group. Table 1 summarizes the baseline data of the study participants.

### Maternal and umbilical cord serum neudesin levels

Compared to controls, we observed significantly elevated neudesin levels in both the maternal serum of women with GDM and umbilical cord samples of fetuses of GDM-complicated pregnancies. The median maternal serum neudesin level was 4.9 (4.45-5.9) ng/mL in the GDM group, considerably higher than the 1.9 (1.65-2.1) ng/mL observed in the control group. Similarly, the median umbilical cord neudesin level was significantly higher in the GDM group at 2.6 (2.1-3.25) ng/mL compared to 1.2 (1.1-1.4) ng/mL in the control group. Table 2 compares GDM-complicated pregnancies and controls according to maternal and umbilical neudesin levels.

### Maternal and neonatal outcomes at delivery

Table 3 summarizes the maternal and neonatal outcomes at delivery. Compared to controls, women with GDM had significantly higher BMI at delivery ( $30.67 \pm 4.57$  kg/m<sup>2</sup> vs.  $27.14 \pm 3.23$  kg/m<sup>2</sup>,  $p < 0.001$ ). Women without GDM delivered at a later gestational age than those GDM-complicated pregnancies ( $38.2 \pm 0.41$  weeks vs.  $37.93 \pm 0.5$  weeks,  $p = 0.006$ ). Furthermore, whereas the neonatal birth weight was significantly later in the GDM group ( $3455 \pm 402$  grams vs.

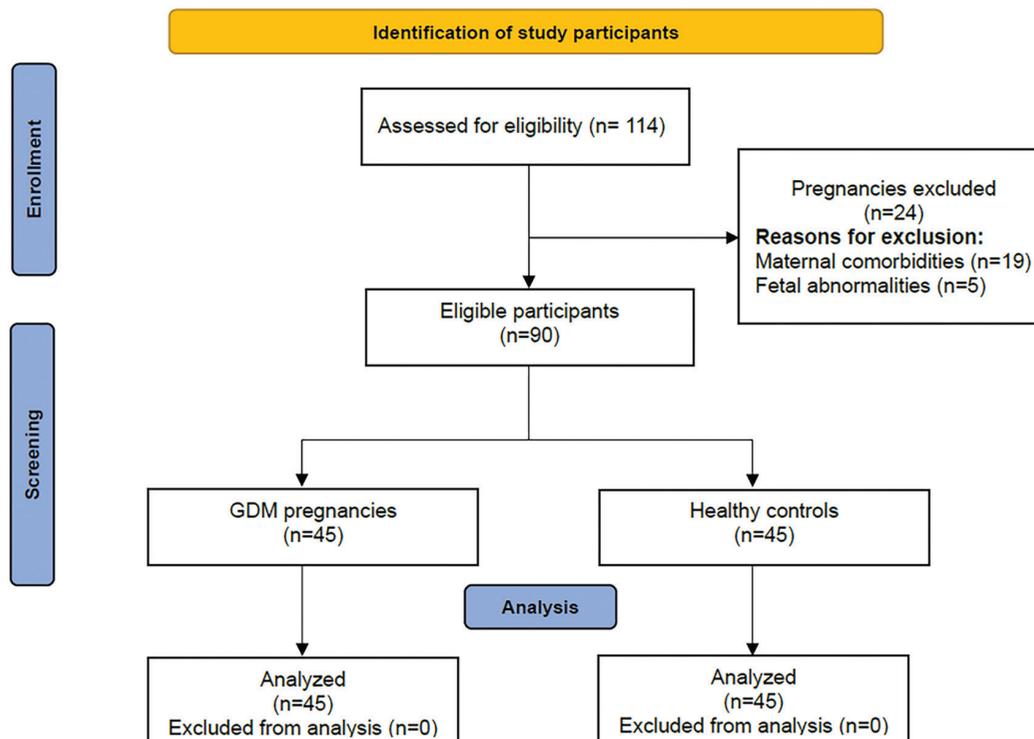


Figure 1. Flow diagram of the final included study participants

**Table 1. Comparison between the study groups regarding baseline data**

Parameter	GDM group (n=45)	Control group (n=45)	t	p
	Mean ± SD	Mean ± SD		
Age (year)	28.73±5.52	28.13±5.24	0.528	0.598
Gestational age at blood sampling (week)	26.69±1.35	26.58±1.37	0.388	0.699
BMI at sampling	29.18±4.55	25.63±3.23	4.256	<0.001*
Fasting insulin (range)	12 (7-17.5)	10 (8-12)	-1.483	0.138
HOMA-IR (range)	3.1 (2.1-4.2)	1 (0.79-1.2)	-7.948	<0.001*

GDM: Gestational diabetes mellitus, t: Independent sample t-test, SD: Standard deviation, BMI: Body mass index, HOMA-IR: Homeostasis model assessment of insulin resistance. \*p<0.05 is statistically significant

**Table 2. Comparison between the study groups regarding maternal and umbilical serum neudesin levels**

Neudesin (ng/mL)	GDM group (n=45)	Control group (n=45)	z	p
	Median (IQR)	Median (IQR)		
Maternal serum	4.9 (4.45-5.9)	1.9 (1.65-2.1)	-7.655	<0.001*
Umbilical cord	2.6 (2.1-3.25)	1.2 (1.1-1.4)	-7.25	0.006*

IQR: Interquartile range, ng/mL: Nanograms per milliliter, GDM: Gestational diabetes mellitus. \*p<0.05 is statistically significant

**Table 3. Comparison between the study groups regarding maternal and neonatal outcomes**

Parameter	GDM group	Control group	t	p
	Mean ± SD	Mean ± SD		
BMI at delivery	30.67±4.57	27.14±3.23	4.243	<0.001*
Gestational age at delivery (week)	37.93±0.5	38.2±0.41	-2.797	0.006*
Birth weight (gm)	3455±402	3151±167	4.684	<0.001*
APGAR at 1 minute	8.07±0.48	8.91±0.29	-10.652	<0.001*
APGAR at 5 minutes	9.02±0.45	9.91±0.29	-11.133	<0.001*

APGAR: Appearance, pulse, grimace, activity, and respiration, GDM: Gestational diabetes mellitus, SD: Standard deviation, t: Independent sample t-test, \*p<0.05 is statistically significant

3151±167 grams, p<0.001), APGAR scores at 1 and 5 minutes were significantly higher for neonates delivered to women in the control group [(8.91±0.29, and 9.91±0.29) vs. (8.07±0.48, 9.02±0.45), p<0.001], respectively.

#### Correlation between neudesin levels and participants' baseline characteristics

Significant positive correlations were observed between maternal neudesin levels and BMI, both at sampling (r=0.377) and delivery (r=0.361) as well as fasting insulin levels (r=0.215), and HOMA-IR (r=0.782) indices. Neonatal birth weight was positively correlated with maternal serum neudesin level (r=0.213), and umbilical cord neudesin level (r=0.209). Both APGAR scores at 1 and 5 minutes after delivery were significantly correlated with maternal serum neudesin level (r=0.61, r=0.65, respectively), and umbilical cord serum neudesin level (r=0.55, r=0.57, respectively). Tables 4 and 5 show the correlations between neudesin levels and participants' characteristics at baseline and delivery.

#### Performance of neudesin levels in GDM diagnosis

We further investigated the diagnostic potential of maternal and umbilical cord neudesin levels for GDM. For maternal serum neudesin, a cut-off value of 5.25 ng/mL or higher demonstrated high diagnostic accuracy, with an area under the curve (AUC) of 0.967 (Figure 2). This translated to 91.1% sensitivity, 93.3% specificity, and an overall accuracy of 92.2% (Supplementary Table 1). Further, the umbilical cord neudesin, with a cut-off value of 3.85 ng/mL or higher, showed promising results. It exhibited a sensitivity of 95.6%, a specificity of 86.7%, and an AUC of 0.942 (Figure 3). The overall accuracy was 91.1% (Supplementary Table 2). Finally multivariate regression analysis demonstrated that maternal serum neudesin levels were independently associated with a 620-fold risk of GDM (Supplementary Table 3).

**Table 4. Correlation between maternal, neonatal neudesin and baseline participants' characteristics**

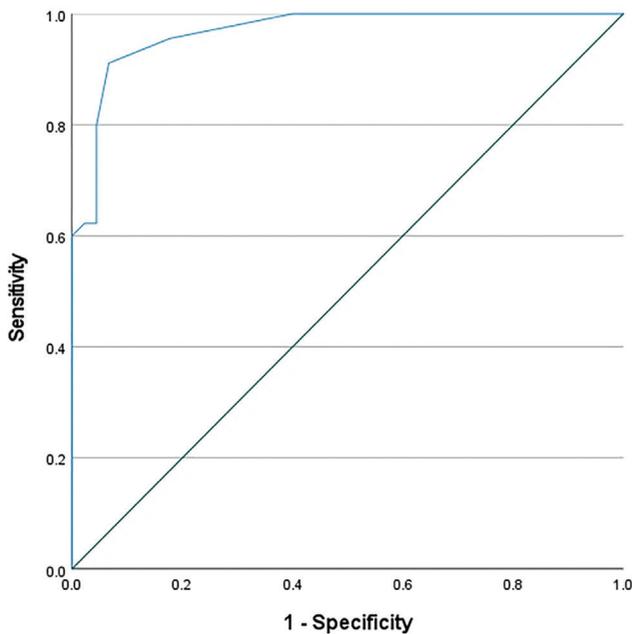
Variable	Maternal serum		Umbilical cord	
	r	p	r	p
Age (year)	-0.017	0.847	0.037	0.728
Gestational age at sampling	-0.304	0.004*	-0.341	0.001*
BMI at sampling	0.377	<0.001*	0.299	0.004*
Fasting insulin	0.215	0.041*	0.296	0.005*
HOMA-IR	0.782	<0.001*	0.774	<0.001*
Maternal serum neudesin	-	-	0.92	<0.001*
Umbilical cord neudesin	0.92	<0.001*	-	-

HOMA-IR: Homeostasis model assessment of insulin resistance, r: Spearman rank correlation coefficient, BMI: Body mass index. \*p<0.05 is statistically significant

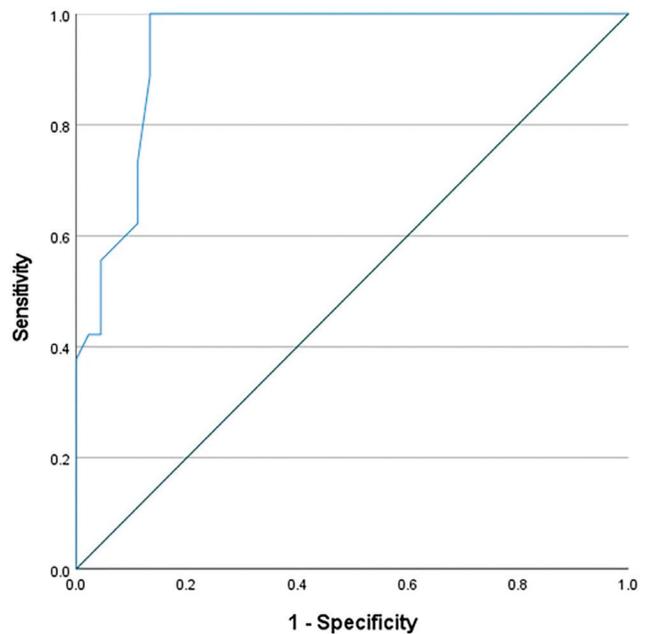
**Table 5. Correlation between maternal neudesin and delivery outcomes**

Variable	Maternal serum		Umbilical cord	
	r	p	r	p
BMI at delivery	0.361	<0.001*	0.29	0.006*
Gestational age at delivery (week)	-0.216	0.041*	-0.187	0.078
Birth weight (gm)	0.213	0.044*	0.209	0.049*
APGAR at 1 minute	-0.615	<0.001*	-0.552	<0.001*
APGAR at 5 minutes	-0.65	<0.001*	-0.577	<0.001*

APGAR: Appearance, pulse, grimace, activity, and respiration, r: Spearman rank correlation coefficient, BMI: Body mass index, \*p<0.05 is statistically significant



**Figure 2. Receiver operating characteristic curve showing performance of maternal neudesin in diagnosis of gestational diabetes**



**Figure 3. Receiver operating characteristic curve showing performance of umbilical cord neudesin in diagnosis of gestational diabetes**

## Discussion

### Findings summary

This study investigated associations between neudesin and GDM. Women with GDM exhibited higher maternal and umbilical cord neudesin levels, higher BMI, fasting insulin, and HOMA-IR compared to controls. Elevated neudesin levels correlated with adverse pregnancy outcomes, including higher birth weight and lower APGAR scores in newborns. Importantly, maternal serum neudesin demonstrated high diagnostic accuracy for GDM, with high sensitivity, specificity, and AUC. These findings suggest that neudesin may serve as a valuable biomarker for GDM diagnosis and could potentially aid in identifying women at increased risk for adverse pregnancy outcomes.

### Our findings in the context of previous literature

Our findings are consistent with previous reports that implicated high BMI as a potent risk factor for GDM (13,14). We also found elevated fasting insulin and HOMA-IR levels in women with GDM, consistent with studies by Paracha et al. (15) and Adam et al. (4). With a larger sample size, our current study complements and extends earlier reports by Eren et al. (10) on significantly higher maternal serum and umbilical cord neudesin levels in pregnancies complicated by GDM.

However, previous reports on the association between neudesin, BMI and GDM are not always consistent. For instance, contrary to our findings, Atalay et al. (16) reported lower neudesin levels in women with GDM. Furthermore, the significantly lower BMI at delivery reported by Eren et al. (10) in women with GDM is at variance with the higher delivery BMI observed in our study and also reported by Atalay et al. (16). This discrepancy may be attributable to differences in the study populations, particularly the baseline prevalence of obesity or ethnic-specific variations in metabolic risk factors, given the higher baseline prevalence of diabetes in the eastern mediterranean region. Our study population, characterized by generally high BMI, elevated fasting insulin, and high HOMA-IR in the GDM group, may represent a cohort where GDM development was strongly driven by pre-existing obesity and pre-pregnancy IR which worsened further during pregnancy. The significant positive correlation we observed between maternal neudesin levels and BMI, fasting insulin, and HOMA-IR (with  $r=0.782$  for HOMA-IR) suggests that in this specific, higher-BMI population, neudesin elevation is closely tied to the degree of metabolic dysfunction and IR. These variations highlight the complex relationship between neudesin levels, BMI, and GDM.

In terms of delivery outcomes, our findings are consistent with previous reports (17-19), demonstrating significantly lower gestational ages at delivery, higher birth weights, and lower APGAR scores in neonates of women with GDM-complicated

pregnancies. In contrast, although Eren et al. (10) reported lower APGAR scores in neonates of women with gdm-complicated pregnancies, they found no significant differences in gestational weight at delivery or birth weight. The adverse outcomes in our cohort suggest that women with GDM in the present study may have experienced a greater degree of uncontrolled maternal hyperglycemia or more severe underlying placental dysfunction compared to the populations in the contrasting studies. The weak positive correlation between maternal and umbilical cord neudesin levels and neonatal birth weight ( $r=0.213$  and  $r=0.209$ , respectively), and the negative correlation with APGAR scores highlight a potential role for neudesin as both a diagnostic biomarker and as a mechanistic link in the placental-fetal programming that leads to macrosomia and fetal distress. Further research is warranted to elucidate the specific mechanisms by which neudesin influences fetal growth and development in the context of GDM pathophysiology.

### Study limitations

Our findings should be interpreted in the context of the following limitations: first, we could not conduct repeated measures of maternal and umbilical cord neudesin levels due to logistical constraints. Second, since GDM diagnosis preceded neudesin evaluation, we could not ascertain a temporal biological sequence of events between GDM and neudesin. The small sample size ( $n=90$ ), the single-center, and the case-control design all restrict the generalizability of the findings. Furthermore, the study lacks long-term follow-up to assess the postnatal metabolic status of mothers or the long-term health outcomes of the infants. Finally, the absence of a formal pre-study power calculation may be seen as a methodological limitation but the post-hoc analysis confirmed that the study was sufficiently powered to detect the substantial difference in neudesin levels observed between the groups.

### Conclusion

This study provides compelling evidence that neudesin may be independently associated with GDM. Elevated neudesin levels in maternal and umbilical cord serum and strong correlations with key metabolic parameters and neonatal outcomes highlight its potential as a valuable diagnostic marker. The high diagnostic accuracy achieved with specific neudesin cut-offs suggests its potential clinical utility in GDM screening and risk assessment. Furthermore, the substantial increase in GDM risk associated with elevated maternal neudesin levels underscores its potential pathophysiological role. Future research should focus on elucidating the underlying mechanisms by which neudesin contributes to gdm and exploring its potential as a therapeutic target.

## Ethics

**Ethics Committee Approval:** *The study protocol was approved by the Mansoura Faculty of Medicine Mansoura University Ethics Committee (approval number: 20.05.2573, date: 02.05.2023).*

**Informed Consent:** *All study participants gave informed written consent.*

## Footnotes

**Author Contributions:** *Surgical and Medical Practices: A.W.M., N.A.N., Concept: A.I.M., Design: A.F., M.F.E., Data Collection or Processing: A.F., A.S., Analysis or Interpretation: A.S., M.F.E., Literature Search: N.A.N., A.I.M., Writing: A.I.M., A.W.M., N.A.N., A.F., A.S.*

**Conflict of Interest:** *No conflict of interest is declared by the authors.*

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**Supplementary File Tables:** <https://d2v96fxpocvxx.cloudfront.net/17d041fe-057c-4c8e-a75d-948e33c0152a/content-images/7cba4a2e-c6f1-4ab1-972f-2f4c629b1611.pdf>