Investigation of the relationship between glucose potassium ratio and insulin resistance in polycystic ovary syndrome infertile women

Polikistik over sendromlu infertil kadınlarda glukoz potasyum oranı ile insülin direnci arasındaki ilişkinin araştırılması

Naziye Gurkan[1]

[1] Department of Gynecology and Obstetric, Samsun VM Medical Park Hospital

Abstract

Aim: The aim of this study was to evaluate the relationships between glucose potassium (Glu/K^+) ratio and insulin resistance (IR) in infertile women with polycystic ovary syndrome (PCOS). It is necessary to identify a new diagnostic parameter such as Glu/K^+ ratio for IR in PCOS patients.

Methods: A total of 198 reproductive-aged women were included in this retrospective case–control study. Women aged 20-39 years diagnosed with infertility and PCOS constituted the PCOS group. Women who were diagnosed with infertility but not PCOS formed the control group.

Result: The age and body mass index (BMI) of the participants were 30.31±4.68 and 26.53±4.80, respectively. Fasting blood glucose was found to be higher in those with a diagnosis of PCOS ($p<0.05$). Homeostatic model assessment for insulin resistance (HOMA-IR) and fasting insulin were found to be higher in those with a diagnosis of PCOS ($p<0.05$). Serum Glu/K^+ ratio was found to be higher in those diagnosed with PCOS ($p<0.05$). A positive correlation was found between fasting insulin and Glu/K^+ ratio in PCOS women ($p<0.05$). The area under the ROC curve for the Glu/K^+ ratio was found to be 0.719, close to the insulin.

Conclusion: Our outcomes indicate that the serum Glu/K^+ ratio is favorable and closely related to insulin, which has diagnostic properties for PCOS. We believe the serum Glu/K^+ ratio may be a valuable biomarker for insulin resistance in PCOS.

Keywords: Glucose; insulin resistance; polycystic ovary syndrome; potassium

Öz

Amaç: Bu çalışmanın amacı, polikistik over sendromlu (PKOS) infertil kadınlarda glukoz potasyum (Glu/K^+) oranı ile insülin direnci (İR) arasındaki ilişkiyi değerlendirmektir. PKOS'lularda insulin direnci için Glu/K^+ oranı gibi yeni bir tanı parametresinin tanımlanması gereklidir.

Yöntemler: Bu retrospektif vaka kontrol çalışmasına üreme çağındaki toplam 198 kadın dahil edildi. PKOS grubunu 20-39 yaş arası infertilite ve PKOS tanısı almış kadınlar oluşturdu. Kontrol grubunu infertilite tanısı almış ancak PKOS olmayan kadınlar oluşturdu.

Bulgular: Katılımcıların yaş ve vücut kitle indeksi sırasıyla 30.31±4.68 ve 26.53±4.80 idi. Açlık kan şekeri PKOS tanısı olanlarda daha yüksek bulundu ($p<0.05$). İnsülin direnci için homeostatik model değerlendirmesi (HOMA-IR) ve açlık insülini PKOS tanısı olanlarda daha yüksek bulundu ($p<0.05$). PKOS tanısı olanlarda serum Glu/K^+ oranı daha yüksek bulundu ($p<0.05$). PCOS'lu kadınlarda açlık insülini ile Glu/K^+ oranı arasında pozitif bir ilişki bulundu ($p<0.05$). Glu/K^+ oranı için işlem karakteristiği (ROC) eğrisi altında kalan alan insüline yakın 0.719 olarak bulundu.

Sonuç: Sonuçlarımız serum Glu/K^+ oranının olumlu olduğunu ve PKOS için tanısal özellikleri olan insüline yakın olduğunu göstermektedir. Serum Glu/K^+ oranının PKOS'ta inslin direnci için değerli bir biyobelirteç olabileceğini düşünmekteyiz.

Anahtar Sözcükler: Glukoz; insulin rezistansı; potasyum; polikistik over sendromu

Received/*Geliş* : 02.10.2022
Accepted/*Kabul*: 11.05.2023

DOI: 10.21673/anadoluklin.1183228

Corresponding author/*Yazışma yazarı*

Naziye Gurkan
Samsun VM Medical Park Hospital
Department of Gynecology and Obstetric
Türkiye
E-mail: nazeyg987@gmail.com

ORCID
Naziye Gurkan: 0000-0003-1088-018X

INTRODUCTION

Polycystic ovary syndrome (PCOS) is a complex common metabolic disorder among women, with 8-13% prevalence dependent on the studied population and the applied diagnostic criteria, and is characterized by a heterogeneous presentation of hair loss, menstrual irregularity, hyperandrogenism, insulin resistance (IR), reduced quality of life, hirsutism, obesity, and polycystic ovaries (1-3). In addition, there is evidence that PCOS women are highly exposed to IR, abdominal obesity, cardiovascular disease (CVD), dyslipidemia, type 2 diabetes mellitus (DM), and infertility (4). Obesity plays an effective role in enhancing oxidative stress as one of the common disorders in PCOS women, which contributes to IR while aggravating hypergonadism (5-7). The PCOS diagnosis has lifelong implications, increasing the risk for infertility, type 2 DM, metabolic syndrome, endometrial carcinoma, and CVD (8).

There are different diagnostic criteria for PCOS, but the Rotterdam criterion is now used more widely in its diagnosis (9). Based on this criterion, the presence of two of the following three cases can help diagnose PCOS. These cases include 1) biochemical or clinical signs of hyperandrogenism 2) amenorrhea or oligomenorrhea and 3) sonography evidence of PCOS (10).

Although the pathophysiology of this disease has not yet been correctly determined, several factors alone or together can be considered as the main causes of it, including increased gonadotropin-releasing hormone, increased release of androgenic hormones, IR, genetic factors, and oxidative stress. Oxidative stress has attracted the attention of toxicologists over the last two decades as one of the etiological factors of chronic diseases, and its relationship at the preclinical level with several chronic diseases such as DM, CVD, cancer, and PCOS has been cited in the sources. The researchers are still interested in finding diagnostic criteria, and identifying new diagnostic criteria paves the way for more innovative and more effective treatments (6,11-13). In this study, the glucose-potassium (Glu/K^+) ratio besides insulin was evaluated as a new diagnostic criterion for IR in PCOS.

Several studies have confirmed the importance of insulin rates in PCOS women. This study evaluated the role of the Glu/K^+ ratio in these patients. Potassium and serum glucose are two important blood indicators that have common clinical applications (14). Glucose is important for maintaining cellular metabolism as the main source of energy for cells in the human body. Potassium ion plays a role in the physiological processes including muscle contraction, cardiac pulsation, normal renal function maintenance, and neural conduction as the most abundant ion in the cells. The serum glucose level is divided by the serum potassium level to yield Glu/K^+ ratio (14).

There is a need for a better understanding and proper screening of women with PCOS to reduce the long-term risks and to provide effective interventions to minimize metabolic complications. This study discussed whether IR is specific to PCOS and is associated with obesity alone or with both factors. The need for alternative diagnostic parameters for this disease, such as metabolic syndrome, has not yet been met. This study determines the IR rate by analyzing and matching fasting insulin and potassium glucose values. It is essential to identify new diagnostic parameters for PCOS to propose new treatment methods.

This study aimed to examine the association between PCOS and Glu/K^+ ratio as a new clinic value and to examine the association between IR and Glu/K^+ ratio among infertile PCOS women.

MATERIAL AND METHODS

The retrospective case-control study was designed as a single-centered, between January 2019 and March 2021, for PCOS infertile patients who applied to Samsun MedicalPark Hospital gynecology and obstetrics clinic.

This study was started after the ethical approval of the study was obtained from Ondokuz Mayıs University Faculty of Medicine Clinical Researches Ethics Committee (Date: 22.06.2022, Decision No: 2022/173). All study processes were conducted under the principles of the Declaration of Helsinki and ethical rules.

This study included 99 women in the control group and 99 women with PCOS included in the case group. The inclusion criteria were: (1) women between the ages of 20 and 39, (2) women with PCOS according

Table 1. Main characteristics of women with PCOS and healthy controls included in the study

Study parameters	Case(n=99) Mean±SD	Control(n=99) Mean±SD	*p*-value
Age(yrs)	30.32±4.89	30.31±4.48	0.843**
BMI	26.72±5.09	26.35±4.51	0.681**
HOMA-IR	3.59±2.25	1.74±0.81	**<0.001****
FSH	5.65±1.96	6.06±1.81	0.131*
LH	8.74±6.75	5.26±2.07	**<0.001****
Estradiol	71.71±62.07	54.91±49.28	**<0.001****
Free T4	1.24±0.31	1.25±0.89	0.957**
TSH	2.75±1.43	1.81±0.85	**<0.001****
Prolactin	27.00±20.91	23.18±10.74	0.741**
Fasting blood glucose (mg/dl)	95.04±8.32	88.79±6.72	**<0.001****
Fasting insulin	15.25±9.15	8.01±3.81	**<0.001****
Total cholesterol	175.60±41.10	206.87±56.69	**<0.001****
LDL	101.75±36.48	121.22±42.15	**<0.001****
HDL	53.45±15.37	64.80±16.92	**<0.001****
Triglyceride	100.61±50.70	101.60±51.50	0.955**
Sodium	140.60±1.51	140.03±2.48	0.108**
Potassium	4.06±0.27	4.13±0.32	0.064**
Blood urea nitrogen	20.09±5.86	17.80±4.94	**0.003****
Creatine	0.71±0.10	0.68±0.10	0.057**
ALT	14.13±3.58	14.43±6.99	0.190**
AST	16.42±5.37	16.82±6.08	0.727**
Serum Glu/K^+ ratio	23.49±2.54	21.59±2.41	**<0.001***

* Independent t-test

** Mann-Whitney test

BMI:Body mass index , PCOS: Polycystic ovary syndrome, LH: Luteinizing hormone, FSH:Follicle stimulating hormone , TSH:Thyroid stimulating hormone , HOMA-IR: Homeostatic model assessment of insulin resistance , T4: Thyroxine , LDL:Low density lipoprotein , HDL:High density lipoprotein , ALT: Alanine transaminase , AST:Aspartate aminotransferase , Serum Glu/K^+ ratio: Serum glucose/potassium ratio

Table 2. ROC analysis results of PCOS patients and controls

Test result variables	Area	Std Error[a]	Asymptotic Sig[b]	Asymptotic 95% Confidence Interval	
				Lower Bound	Upper Bound
Fasting blood glucose	0.725	0.036	**<0.001**	0.654	0.795
Fasting insulin	0.804	0.030	**<0.001**	0.744	0.863
Glu/K^+ ratio	0.719	0.037	**<0.001**	0.647	0.791

ROC:Receiver Operating Characteristic, PCOS: Polycystic ovary syndrome, Glu/K^+ ratio: Glucose/potassium ratio, Std error: Standard error of mean, Asymptotic sig: Asymptotic significance

Table 3. The correlation between Glu/K^+ ratio and insulin

		Serum Glu/K^+ ratio
Case	Fasting insulin	
	Correlation coefficient	0.280
	p-value	**0.005**
Control	Fasting insulin	
	Correlation coefficient	-0.183
	p-value	0.069

Glu/K^+ ratio: Glucose/potassium ratio

to the Rotterdam diagnostic criteria, (3) women who cannot have children despite having unprotected sexual relations for the last year. The exclusion criteria were: (1) medical or surgical treatment during the last three months, (2) absence of diabetes, thyroid dysfunction, hyperprolactinemia, active liver disease, and systemic diseases. Patient data was obtained from previous laboratory records. The transfer and analysis of the study laboratory data were carried out by a biostatistician.

The samples of the patients were taken early in the morning after 12 hours of fasting and after waiting for at least 15 minutes, they were separated by centrifugation and the serum samples were separated. The samples were studied on the same day and the results were transferred to the hospital automation system via LIS connection. For insulin, glucose, and potassium analysis, kits using the electrochemiluminescent method (Beckman, Los Angeles, CA, USA) were preferred and measured using Beckman DxC clinical biochemistry autoanalyzer (Beckman Diagnostic Products Corporation, Los Angeles, CA, USA). The data obtained were transferred digitally to the EXCEL (MS Office 2016, USA) program and the serum Glu/K^+ ratio was calculated by dividing the serum fasting glucose by the serum potassium levels. The transfer and analysis of the study laboratory data was carried out by an independent biostatistician. Since it was a retrospective study, patients were excluded from the study if there was missing data in their file or if they did not meet the study criteria. While the control group was selected from healthy individuals, they were included in the study in the light of ultrasonography reports, clinical evaluation, and laboratory data.

Statistical Analysis

We performed the Kolmogorov-Smirnov test to investigate the normality, and the nonparametric tests performed given the non-normality of the groups before the statistical analyses. Mean and standard deviations (SD) were measured to check each continuous variable, including age, BMI, HOMA-IR, FSH, LH, Estradiol, Free T4, TSH, prolactin, glucose, insulin, total cholesterol, LDL, HDL, Triglyceride, sodium, potassium, blood urea, nitrogen, creatine, ALT, AST, and Glu/K^+. The Mann-Whitney test and the Independent t-test were performed to study the difference between the two groups. The SPSS Statistics for Windows (Statistical Package for the Social Sciences package program version 22.0, IBM Corp., Armonk, N.Y., USA) is used for statistical analyses. p value< 0.05 was regarded as statistically significant.

To calculate the sample size with the G-Power 3.1 (http://www.gpower.hhu.de/) program, the difference between two independent means(two groups) was measured using the Independent t-test with power of 95%, effect size of 47%, and 0.05 type 1 error for at least 198 patients (15).

RESULTS

In Table 1, the main features of age-matched and BMImatched PCOS women and controls were included in the study. PCOS groups showed a significantly higher serum Glu/K^+ ratio (p-value<0.001). PCOS groups showed significantly higher HOMA-IR (p-value<0.001), LH (p-value <0.001), estradiol (p-value<0.001), fasting insulin (p-value<0.001), fasting blood glucose (p-value< 0.001), total cholesterol (p-value<0.001) levels. LDH (p-value<0.001) and HDL (p-value<0.001) levels were significantly lower in the PCOS groups.

There was not a statistically significant difference between PCOS group and control in terms of FSH (p-value = 0.131), prolactin (p-value = 0.741), triglyceride (p-value = 0.955), sodium (p-value = 0.108), potassium (p-value = 0.064), creatine (p-value = 0.057), ALT (p-value = 0.190), Free T4 (p-value = 0.957) and AST (p-value = 0.727). Figure 1 shows serum Glu/K^+ ratio and fasting insulin levels in control and case groups.

Table 2 and Figure 2 show ROC curves were used for analysis of the different variables' predictive value. The area under the ROC curve shows how accurately the test predicts the result. It was evaluated together with fasting glucose and insulin in the ROC analysis performed to investigate the diagnostic value of the Glu/K^+ ratio for PCOS.

The AUC for glucose was 0.725 (0.036 standard error; 95%CI: 0.654-0.795; p-value<0.001), The AUC for Insulin was 0.804 (0.030 standard error; 95%CI: 0.744-0.863; p-value<0.001). The AUC for Glu/K^+ ratio was 0.719 (0.037 standard error; 95%CI: 0.647-0.791; p-value<0.001).

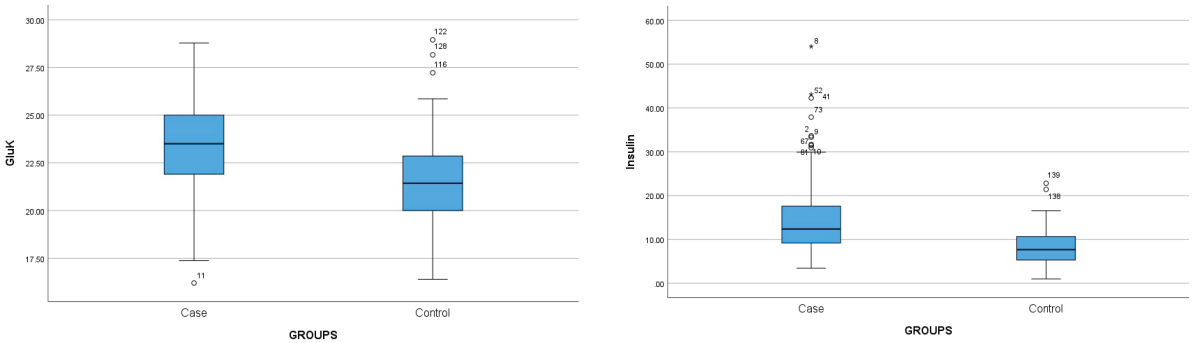

Figure 1. Glu/K⁺ and insulin levels in control and case groups

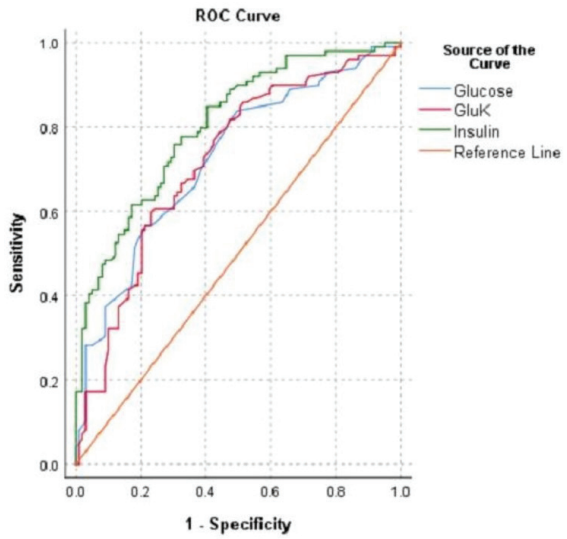

Figure 2. Glucose, Glu/K ratio and ROC analysis of insulin parameters

The relationship between Glu/K⁺ ratio and insulin in case and control groups was determined using Spearman's rank-order correlation. There was a positive moderate correlation between Glu/K⁺ ratio and insulin in women with PCOS, which was statistically significant (r = 0.280, *p*-value = 0.005). There was not a statistically significant correlation between Glu/K⁺ ratio and insulin in the control woman (r = -0.183, *p*-value = 0.069).

DISCUSSION AND CONCLUSION

In our study, we investigated the serum Glu/K⁺ ratio as an alternative and supportive diagnostic parameter to insulin in patients diagnosed with PCOS. In this analysis with a control group created for PCOS independent of age factor, when serum Glu/K⁺ ratio and Insulin were analyzed together, we concluded that serum Glu/K⁺ ratio could be a valuable diagnostic tool with potential for patients with PCOS. According to the results, fasting blood glucose, fasting insulin serum and Glu/K⁺ ratio were significantly higher in the PCOS groups. There was a moderate, positive correlation between Glu/K⁺ ratio and fasting insulin in women with PCOS. The ROC analysis shows that the prediction model by Glu/K⁺ ratio had reasonable accuracy. The accuracy was competitive with fasting insulin.

In our study, PCOS cases showed significantly higher mean fasting blood glucose than the controls. Similar observations were made by Bannigida et al., Liu et al., Zuo et al., and Jabbar et al. (16-19).

In our study, the mean HOMA-IR and fasting insulin were significantly higher in PCOS cases compared to controls. Similar observations were made by Cassar et al, Moghetti et al., and Shang et al. (20-22). Compensatory hyperinsulinemia and IR affect 65–70% of women with PCOS. This rate is higher in obese women with PCOS (23). Fasting insulin and IR assessment are accepted as the definitive diagnosis of PCOS. However, there is an ongoing debate about whether IR is specific to PCOS or is associated with obesity alone or with both factors (24-26). Indeed accurate measurement of IR and compensatory hyperglycemia require "euglycemic hyperinsulinemic clamp" analysis, a technically complex test that is rarely available for routine clinical practice and should be used for research studies. Alternatively, a standard oral glucose tolerance test, which includes measuring insulin and glucose levels, can provide complete information about glucose tolerance while providing a reasonably accurate estimate of IR. However, it should

be noted that precise measurement of insulin serum values needs using reliable immunoassays. Despite all these, there is a need for parameters to support diagnostic insulin measurement. The Glu/K^+ ratio is an influential parameter that needs to be investigated in this sense.

Our study showed a statistically significant difference between the PCOS group and the control in terms of Glu/K^+ ratio. PCOS women showed a significantly higher mean Glu/K^+ ratio. Based on the findings, Glu/K^+ ratio was introduced as a new parameter related to PCOS. Few studies were conducted to identify new clinical and biochemical parameters related to PCOS. Raheem et al. reported that vitamin D deficiency is related to several metabolic chances in women with PCOS (27). Chae et al. reported clinical and biochemical parameters related to PCOS in Korean women (28). Bagheri et al. reported biochemical parameters related to PCOS in Iranian women (29). Shahmoradi et al. studied the relationship of BsmI, TaqI, FokI, and ApaI polymorphisms in the vitamin D receptor gene with PCOS in women (30).

The limitation of this research is in the case and control study design. This problem could cause recall bias. A prospective study with a more significant number of samples is suggested to identify new diagnostic parameters, with the hope that it will become a suitable solution for the timely identification and treatment of PCOS patients. It will also help managers and public officials to make more effective plans and decisions to improve the health of individuals, families, and society.

As a result of this study, insulin presented as a new diagnostic property for PCOS. Identifying new parameters to identify PCOS patients is essential due to the high prevalence and enormous costs of this disease for the health system in countries. According to the study, Glu/K^+ ratio was introduced as a new parameter to identify women with PCOS.

Conflict-of-Interest and Financial Disclosure

The author declares that she has no conflict of interest to disclose. The author also declares that she did not receive any financial support for the study.

REFERENCES

1. Azziz R, Woods KS, Reyna R, Key TJ, Knochenhauer ES, Yildiz BO. The prevalence and features of the polycystic ovary syndrome in an unselected population. J Clin Endocrinol Metab. 2004;89(6):2745-9.
2. Joham AE, Teede HJ. PCOS a metabolic condition with health impacts on women and men. Nat Rev Endocrinol.2022;18(4):197-8.
3. Kale-Gurbuz T, Akhan SE, Bastu E, Telci A, Iyibozkurt AC, Topuz S. Adiponectin, leptin and ghrelin levels in obese adolescent girls with polycystic ovary syndrome. J Pediatr Adolesc Gynecol. 2013;26(1):27-30.
4. Alanya Tosun Ş, Gurbuz T, Cebi A, Tosun A, Gokmen O, Usta M. Association of increased levels of omentin-1 and carotid intima-media thickness with early signs of cardiovascular risk in patients with polycystic ovary syndrome: A prospective case control study. J Obstet Gynaecol Res. 2022;48(1):169-77.
5. Shaw N, Rosenfield M. 2020. Etiology and pathophysiology of plycystic ovary syndrome in adolescents. [cited 15.03.2023]. Available from: htttps://www.uptodate.com
6. Dokuzeylül Güngör N, Güngör K, Yurci A, Cil K, Hatırnaz Ş. Ovarian drilling down-regulates endometrial nuclear factor-κB p65 expression in women with PCOS: A prospective case-control study. Turk J Obstet Gynecol. 2022;19(1):45-50.
7. Ağar M, Güngör K, Güngör ND, Kavrut M, Madenli AA. Vitamin D supplementation inhibits NF-kß signaling pathway in lean and obese women with PCOS. Eur Rev Med Pharmacol Sci. 2022;26(11):3973-7.
8. Fauser BC, Bouchard P. Uncertainty remains in women with PCOS regarding the increased incidence of cardiovascular disease later in life, despite the indisputable presence of multiple cardiovascular risk factors at a young age. J Clin Endocrinol Metab. 2011;96(12):3675-7.
9. Gurbuz T, Alanya Tosun S, Cebi A, Gokmen O, Usta M. Investigating Fetuin-A and Paraoxonase-1 Activity as Markers in Polycystic Ovary Syndrome Based on Body Mass Index: A Prospective Case-Control Study. Cureus. 2021;13(10):e18553.
10. Gürbüz T, Tanridan Okçu N, Dokuzeylül Güngör N. Monocyte/HDL ratio in women with polycystic ovary syndrome and healthy controls. Anatolian Curr Med J. 2021;3(2):98-103.
11. Çetin C, Güngör ND, Yavuz M. First trimester glycosylated hemoglobin for gestational diabetes mellitus screening. Taiwan J Obstet Gynecol. 2021;60(5):899-902.
12. Güngör K, Dokuzeylül Güngör N, Gönen MS. Cortisol

metabolism in obese women with normal and impaired glucose tolerance Anatol J Family Med. 2021;4(3):238–42.
13. Gurbuz T, Dokuzeylül Güngör N. Understanding the Effects of Obesity over Polycystic Ovary Syndrome by Analyzing Insulin Resistance and Thyroid Hormone in Different BMI Levels. Ulutas Med J. 2021;7(1):8-12.
14. Lu Y, Ma X, Zhou X, Wang Y. The association between serum glucose to potassium ratio on admission and short-term mortality in ischemic stroke patients. Sci Rep. 2022;12(1):8233.
15. Faul F, Erdfelder E, Buchner A, Lang AG. Statistical power analyses using G*Power 3.1: tests for correlation and regression analyses. Behav Res Methods. 2009;41(4):1149-60.
16. Bannigida DM, Nayak BS, Vijayaraghavan R. Insulin resistance and oxidative marker in women with PCOS. Arch Physiol Biochem. 2020;126(2):183-6.
17. Liu J, Zhang D. The role of oxidative stress in the pathogenesis of polycystic ovary syndrome. Sichuan Da Xue Xue Bao Yi Xue Ban. 2012;43(2):187-90.
18. Zuo T, Zhu M, Xu W. Roles of Oxidative Stress in Polycystic Ovary Syndrome and Cancers. Oxid Med Cell Longev. 2016;2016:8589318.
19. Jabbar R, Hameed M, Tabassum S, Saeed S, Kazmi T, Rashid S. Glucose Insulin Ratio in Hyper Insulinemic Women with Polycystic Ovarian Syndrome. J Shalamar Med Dent Coll. 2022;3(1):101-5.
20. Cassar S, Misso ML, Hopkins WG, Shaw CS, Teede HJ, Stepto NK. Insulin resistance in polycystic ovary syndrome: a systematic review and meta-analysis of euglycaemic-hyperinsulinaemic clamp studies. Hum Reprod. 2016;31(11):2619-31.
21. Moghetti P, Tosi F. Insulin resistance and PCOS: chicken or egg?. J Endocrinol Invest. 2021;44(2):233-44.
22. Shang Y, Zhou H, Hu M, Feng H. Effect of Diet on Insulin Resistance in Polycystic Ovary Syndrome. J Clin Endocrinol Metab. 2020;105(10):dgaa425.
23. Marshall JC, Dunaif A. Should all women with PCOS be treated for insulin resistance?. Fertil Steril. 2012;97(1):18-22.
24. Dewailly D, Lujan ME, Carmina E, et al. Definition and significance of polycystic ovarian morphology: a task force report from the Androgen Excess and Polycystic Ovary Syndrome Society. Hum Reprod Update. 2014;20(3):334-52.
25. Zeng X, Xie YJ, Liu YT, Long SL, Mo ZC. Polycystic ovarian syndrome: Correlation between hyperandrogenism, insulin resistance and obesity. Clin Chim Acta. 2020;502:214-21.
26. Gürbüz T, Gökmen O, Dokuzeylül Güngör N. Polikistik over sendromu bulunan kadınlarda glikoz potasyum oranının tanısal değerinin insülin ile karşılaştırılması. Cukurova Med J. 2021;46(1):381-6.
27. Majid Raheem N, Hassan Marouf B. Impact of Vitamin D Deficiency on the Pathogenesis of Polycystic Ovary Syndrome. Al-Rafidain J Med Sci. 2022;2:1-7.
28. Chae SJ, Kim JJ, Choi YM, et al. Clinical and biochemical characteristics of polycystic ovary syndrome in Korean women. Hum Reprod. 2008;23(8):1924-31.
29. Bagheri M, Sohrabvand F, Lankarani M, Zandieh Z, Haghollahi F, Shariat M. Comparison of Biomedical Variables in PCOS Patients with Normal Iranian Women. J Family Reprod Health. 2015;9(1):5-11.
30. Shahmoradi A, Aghaei A, Ghaderi K, Jafar Rezaei M, Azarnezhad A. A meta-analysis of the association of ApaI, BsmI, FokI, and TaqI polymorphisms in the vitamin D receptor gene with the risk of polycystic ovary syndrome in the Eastern Mediterranean Regional Office population. Int J Reprod Biomed. 2022;20(6):433-46.