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ANALYSIS OF CORRELATION AND REGRESSION RELATIONSHIPS BETWEEN THYROID DYSFUNCTION, ADRENAL DYSFUNCTION AND CARDIOPULMONARY DISORDERS IN PATIENTS WITH DIABETES MELLITUS

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Abstract

Introduction: Diabetes mellitus is a widespread non-communicable disease with a significant impact on public health. **The study aimed** to investigate the interrelationships between hormonal-metabolic and cardiorespiratory disorders in patients with type 2 diabetes mellitus (T2DM).

Materials and methods: Study design - longitudinal cohort study of correlation and regression analyses to assess the relationship between various morphometric parameters of the thyroid gland, adrenal glands and respiratory function. A total of 175 patients with T2DM were included in the study, classified into subgroups based on body mass index (BMI). Research period: 03.01.2024-02.05.2024.

Results: The study revealed strong correlations between thyroid and adrenal gland parameters in all patient groups. Additionally, significant associations were found between lung function indicators and insulin resistance index (IRI). Regression analysis confirmed these relationships and provided insights into the functional dependencies between these parameters.

Conclusions: The findings highlight the complex interplay between hormonal-metabolic and cardiorespiratory systems in T2DM. These interrelationships emphasize the importance of a comprehensive approach to managing diabetes, considering not only metabolic control but also the impact on other organ systems. Further research is needed to elucidate the underlying mechanisms and develop targeted interventions.

Keywords: *Diabetes mellitus, correlation analysis, morphometric indicators, thyroid hormones, adrenal hormones, echocardiography, normal weight and obesity.*

Резюме

АНАЛИЗ КОРРЕЛЯЦИОННЫХ И РЕГРЕССИОННЫХ СВЯЗЕЙ МЕЖДУ НАРУШЕНИЕМ ФУНКЦИИ ЩИТОВИДНОЙ ЖЕЛЕЗЫ, НАДПОЧЕЧНИКОВ И КАРДИОПУЛЬМОНАЛЬНЫМИ НАРУШЕНИЯМИ У БОЛЬНЫХ САХАРНЫМ ДИАБЕТОМ

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Введение: Сахарный диабет — широко распространенное неинфекционное заболевание, оказывающее значительное влияние на общественное здоровье. **Целью исследования** было изучение взаимосвязи между гормонально-метаболическими и кардиореспираторными нарушениями у пациентов с сахарным диабетом 2 типа (СД2).

Материалы и методы: Дизайн исследования — продольное когортное исследование корреляционного и регрессионного анализов для оценки взаимосвязи между различными морфометрическими параметрами щитовидной железы, надпочечников и дыхательной функцией. В исследование было включено 175 пациентов с СД2, которые были разделены на подгруппы в зависимости от индекса массы тела (ИМТ). Период проведения исследования: 03.01.2024-02.05.2024гг.

Результаты: Исследование выявило сильные корреляции между параметрами щитовидной железы и надпочечников во всех группах пациентов. Кроме того, были обнаружены значимые связи между показателями функции легких и индексом инсулинорезистентности (ИРИ). Регрессионный анализ подтвердил эти взаимосвязи и дал представление о функциональных зависимостях между этими параметрами.

Выводы: Результаты подчеркивают сложное взаимодействие гормонально-метаболической и кардиореспираторной систем при СД2. Эти взаимосвязи подчеркивают важность комплексного подхода к лечению диабета, учитывающего не только метаболический контроль, но и влияние на другие системы органов. Необходимы дальнейшие исследования для выяснения базовых механизмов и разработки целевых вмешательств.

Ключевые слова: *Сахарный диабет, корреляционный анализ, морфометрические показатели, гормоны щитовидной железы, гормоны надпочечников, эхокардиография, нормальный вес и ожирение.*

Түйіндеме

ҚАНТ ДИАБЕТІМЕН АУЫРАТЫН НАУҚАСТАРДА ҚАЛҚАНША БЕЗІНІҢ ДИСФУНКЦИЯСЫ, БҮЙРЕК ҮСТІ БЕЗІНІҢ ДИСФУНКЦИЯСЫ ЖӘНЕ ЖҮРЕК-ӨКПЕ АУРУЛАРЫ АРАСЫНДАҒЫ КОРРЕЛЯЦИЯЛЫҚ ЖӘНЕ РЕГРЕССИЯЛЫҚ ҚАТЫНАСТАРДЫ ТАЛДАУ

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Кіріспе: Қант диабеті – халықтың денсаулығына айтарлықтай әсер ететін кең таралған жұқпалы емес ауру. **Зерттеудің мақсаты** 2 типті қант диабеті (ҚД2) бар науқастарда гормоналды-метаболикалық және жүрек-тыныс алу бұзылыстары арасындағы байланысты зерттеу болды.

Материалдар мен әдістері: Зерттеу дизайны – қалқанша бездің, бүйрек үсті бездерінің және тыныс алу функциясының әртүрлі морфометриялық параметрлері арасындағы байланысты бағалау үшін корреляциялық және регрессиялық талдауларды бойлық когорталық зерттеу. Зерттеуге дене салмағының индексіне (ДСИ) байланысты кіші топтарға бөлінген 175 ҚД2 пациенттері енгізілді. Зерттеу жүргізу кезеңі: 03.01.2024-02.05.2024 жж.

Нәтижелер: Зерттеу барлық пациенттер топтарында қалқанша безі мен бүйрек үсті безінің параметрлері арасындағы күшті корреляцияны анықтады. Сонымен қатар, өкпе функциясының параметрлері мен инсулинге төзімділік индексі (ИТИ) арасында маңызды байланыстар анықталды. Регрессиялық талдау осы қатынастарды растады және осы параметрлер арасындағы функционалдық тәуелділіктер туралы түсінік берді.

Қорытындылар: Нәтижелер ҚД2 кезінде гормоналды-метаболикалық және кардиореспираторлық жүйелердің күрделі өзара әрекеттесуін көрсетеді. Бұл қарым-қатынастар метаболизмді бақылауды ғана емес, сонымен қатар басқа органдар жүйелеріне әсерін де қарастыратын қант диабетін басқаруға кешенді көзқарастың маңыздылығын көрсетеді. Негізгі механизмдерді түсіндіру және мақсатты араласуды әзірлеу үшін қосымша зерттеулер қажет.

***Түйінді сөздер*:** Қант диабеті, корреляциялық талдау, морфометриялық көрсеткіштер, қалқанша безінің гормондары, бүйрек үсті безінің гормондары, эхокардиография, қалыпты салмақ және семіздік

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Жаутикова С.Б., Абикенова Ф.С., Жиенбаева К.М., Бакарамова Г.А., Ким В., Володина А., Досанова А. Анализ корреляционных и регрессионных связей между нарушением функции щитовидной железы, надпочечников и кардиопульмональными нарушениями у больных сахарным диабетом // Наука и Здравоохранение. 2024. Т.26 (5). С. 7-15. *doi 10.34689/SH.2024.26.5.001*

Жаутикова С.Б., Абикенова Ф.С., Жиенбаева К.М., Бакарамова Г.А., Ким В., Володина А., Досанова А. Қант диабетімен ауыратын науқастарда қалқанша безінің дисфункциясы, бүйрек үсті безінің дисфункциясы және жүрек-өкпе аурулары арасындағы корреляциялық және регрессиялық қатынастарды талдау // Ғылым және Денсаулық сақтау. 2024. Т.26 (5). Б. 7-15. *doi 10.34689/SH.2024.26.5.001*

Introduction

Diabetes mellitus is called a "non-communicable epidemic" due to its rapid spread and the large number of people affected. In 2006, at the initiative of the International Diabetes Federation, a UN resolution (No. 61/225 of December 30, 2006) was adopted aimed at combating diabetes mellitus [3, 4, 15]. In addition to the cardiovascular system, DM is associated with significant changes in the respiratory tract: increased bronchial reactivity, impaired elasticity of the lungs and bronchi [16,17], as well as disorders in the pulmonary vascular system [5]. It is known that hyperglycemia, endothelial dysfunction and the mechanical effect of visceral obesity [8, 18] play a role in the development of ventilation disorders and respiratory diseases in DM. However, issues of diabetological control, metabolism and its disorders in DM require further study due to numerous contradictory research results. It is important to understand that type 2 diabetes is a chronic disease that requires constant monitoring and compliance with all doctor's recommendations. Therefore, it is necessary to determine the relationship between hormonal-metabolic and cardiorespiratory disorders during the course of the disease.

It is important to understand that type 2 diabetes is a chronic disease that requires constant monitoring and compliance with all doctor's recommendations. Therefore, it is necessary to determine the relationship between hormonal-metabolic and cardiorespiratory disorders during the course of the disease.

The mechanisms of the relationship can be classified as follows:

1) Insulin resistance and inflammation,
2) Oxidative stress,
3) Autonomic neuropathy,
4) Changes in the lipid profile,
5) Left ventricular hypertrophy.

At the same time, these mechanisms are clinically manifested through cardiovascular diseases, arterial hypertension, respiratory disorders, sleep apnea. Among these clinical manifestations, we considered the presence or absence of coronary heart disease. Patients with and without this concomitant factor were considered.

The aim of the present study was to investigate the relationship between hormonal-metabolic and cardiorespiratory disorders in patients with type 2 diabetes mellitus (DM2). To interpret the results obtained, correlation and regression relationships were constructed for clinical manifestations of hormonal-metabolic disorders affecting the state of the cardiovascular and respiratory systems in patients with diabetes mellitus.

Materials and methods

The study group of patients included 175 patients with type 2 diabetes mellitus (T2DM group). Research period: 03.01.2024-02.05.2024. The research topic was approved at the meeting of the Ethics Committee (Protocol No. 3 dated 03.01.2024). All study participants signed voluntary informed consent. All patients were classified as follows:

1. Subgroup T2DMn - 36 patients with normal BMI (20.6%);
2. Subgroup T2DMo - 139 people (56 men and 83 women) suffering from obesity, whose BMI was 35-39.9 kg/m2 (79.4%).

Correlation and regression analyses were constructed for all types of clinical abnormalities. In this case, relationships were found between the levels of various hormones produced by the thyroid gland and the adrenal glands. We determined the type of correlation and, based on the Pearson correlation coefficient (r), deciphered hypotheses about the presence or absence of a relationship between the studied features.

The types of relationships were determined using graphs to visually assess how the data points were distributed relative to each other. These graphs had different shapes (linear, parabolic, exponential), directions (positive or negative slope) and strength of the relationship (shows how closely two variables are related to each other). This method allowed us to get a general idea of the nature of the relationship between the variables without complex mathematical calculations. The correlation coefficient is calculated using formula 1:

$$r = \frac{\sum (x-\bar{x})(y-\bar{y})}{\sqrt{\sum (x-\bar{x})^2 \sum (y-\bar{y})^2}}, \quad (1)$$

$$\sum (x-\bar{x})^2 = \sum x^2 - \frac{(\sum x)^2}{n}; \quad (2)$$

$$\sum (x-\bar{x})^2 = \sum x^2 - \frac{(\sum x)^2}{n}. \quad (3)$$

where: n - is the number of observations.

The strength of the relationship was assessed using Pearson and Spearman coefficients.

A regression analysis was performed for the most significant relationships. The formulas for the most probable value of y corresponding to a given value of x are as follows [9]:

$$y = a + b(x-\bar{x}) \quad (4)$$

$$a = \frac{\sum y}{n}; \quad (5)$$

$$b = \frac{\sum (x-\bar{x})(y-\bar{y})}{\sum (x-\bar{x})^2}; \quad (6)$$

$$\bar{x} = \frac{\sum x}{n}, \quad (7)$$

where: a - is the bias coefficient,

b is the regression coefficient.

The value of the standard deviation σr of the scatter of points on both sides of the regression line, which is a measure of the usefulness of the regression line equation in predicting y values given x values, is determined by the following formula:

$$\sigma_r = \sqrt{1-r^2}\sqrt{\frac{\sum (y-\bar{y})^2}{N}} \quad (8)$$

The confidence interval on both sides of the regression line, within which all points were located, was 95%.

We established linear relationships between two variables, for which:

- the correlation coefficient r and the corresponding number of degrees of freedom are a convenient measure of the strength of the relationship;

- the regression coefficient b is a measure of the slope of the regression line, that is, the average increment of y per unit increment of x;

- the residual variance σ_r is a measure of the spread of y values around the regression line, i.e. a measure of the reliability of the estimate of y for given values of x along the regression line.

The regression equation can only be used within the range of the independent variable, including the data used in the calculation.

The study of all the obtained indicators was carried out for the following groups of patients according to Figure 1.

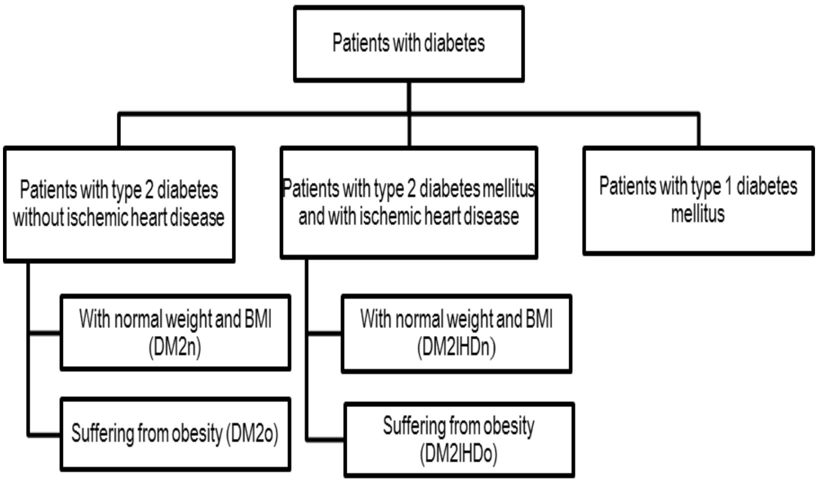


Figure 1. Research groups.

All correlation values were divided into 3 groups:

1. Weak relationship ($0.5 < r \le 0.7$).
2. Moderate relationship ($0.7 < r \le 0.9$).
3. Strong relationship ($r > 0.9$).

The results of the research are described below.

Results

Various types of statistical relationships were identified for all the morphometric parameters studied. Figure 2 shows the statistical relationships between the parameters of the thyroid gland and adrenal glands. The following relationships were identified: weak ($r > 0.5$; $p<0.05$), moderate ($r > 0.7$; $p<0.02$) and strong significance ($r > 0.9$; $p<0.01$). The parameters studied were the morphometric indices of the adrenal glands and thyroid gland, presented in Table 1.

The analysis showed the presence of statistically significant and moderate correlations. The data are presented in Table 2. The table shows strong positive correlations ($r > 0.8$) between several parameters in both the DM2n and DM2o groups, suggesting a close relationship between the thyroid gland and adrenal glands in individuals with type 2 diabetes mellitus.

Table 1.

Morphometric indices of the adrenal glands and thyroid gland.

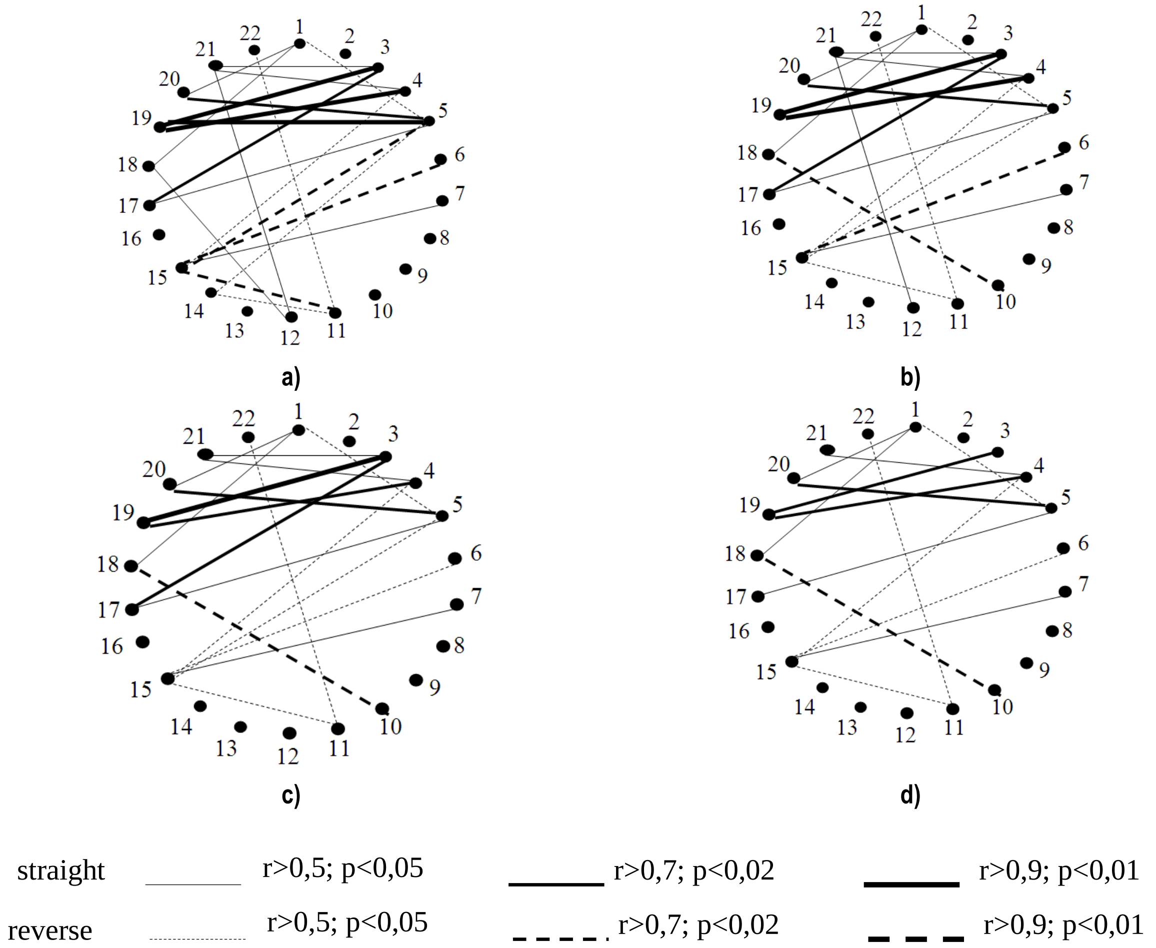
№	Parameter	Unit of Measurement
1	Volume	mm³
2	Adrenal gland weight	g
3	Cortex width	µm
4	Zona glomerulosa width	µm
5	Zona fasciculata width	µm
6	Zona reticularis width	µm
7	Zona glomerulosa nuclei diameter	µm
8	Zona fasciculata nuclei diameter	µm
9	Zona reticularis nuclei diameter	µm
10	Epithelial cell volume fraction	%
11	Vascular bed volume fraction	%
12	C-cell volume fraction	%
13	Connective tissue volume fraction	%
14	Thyroid gland weight	g
15	% m of thyroid gland	%
16	Follicular cell height	µm
17	Nuclear diameter	µm
18	Follicle internal diameter	µm
19	Thyroid epithelium volume fraction	%
20	Volume fraction of vascular bed	%
21	Volume fraction of C-cells	%
22	Volume fraction of connective tissue	%

Table 2.

Determination of correlations between thyroid and adrenal parameters.

Group	Parameter 1	Parameter 2	Correlation Coefficient (r)	p-value
DM2n	Volume fraction of thyroid epithelium	Width of adrenal cortex	0.938	<0.01
DM2n	Volume fraction of thyroid epithelium	Width of glomerular zone	0.916	<0.01
DM2n	Volume fraction of thyroid epithelium	Width of fascicular zone	0.923	<0.01
DM2n	Diameter of thyroid nuclei	Thickness of adrenal cortex	0.841	<0.02
DM2n	Width of fascicular zone	Volume fraction of vascular bed	0.817	<0.02
DM2o	Volume fraction of thyroid epithelium	Width of adrenal cortex	0.922	<0.01
DM2o	Volume fraction of thyroid epithelium	Width of glomerular zone	0.908	<0.01
DM2o	Width of adrenal cortex	Diameter of thyroid nuclei	0.821	<0.02
DM2o	Width of fascicular zone	Volume fraction of vascular bed	0.773	<0.02

All these indices according to their ordinal numbers are presented in Figure 2.



a) DM2n; b) DM2o; c) DM2IHDn; d) DM2IHDo

Figure 2. Results of correlation analysis of morphometric parameters of the adrenal glands and thyroid gland.

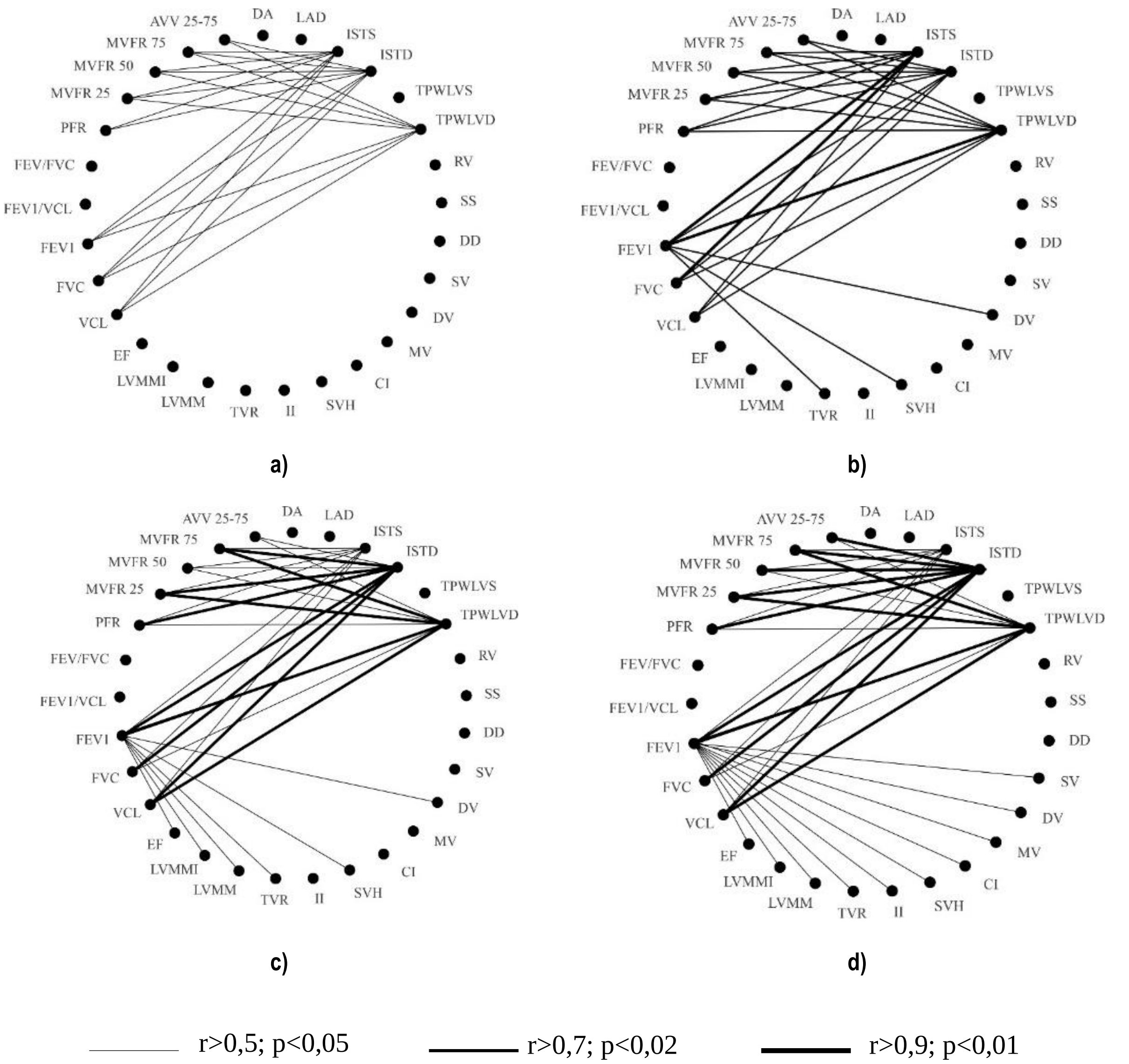
The study found that there is a link between the shape and size of the thyroid and adrenal glands in people with type 2 diabetes, with or without coronary heart disease. The link is statistically significant, meaning it is not due to chance. The data for both DM2IHDn and DM2IHDo groups of patients are presented in Table 3.

Table 3.

Values of the correlation coefficients between parameters of the thyroid gland and adrenal glands.

Group name	Thyroid parameter	Adrenal parameter	r value	p value
DM2IHDn	volume fraction of thyroid epithelium	Thickness of the cortex	0,904	p<0,01
	diameter of nuclei	Width of the cortex	0,721	p<0,02
	volume fraction of vascular bed	Width of the fascicular zone	0,854	p<0,02
	volume fraction of thyroid epithelium	Width of the cortex	0,722	p<0,02
DM2IHDo	volume fraction of thyroid epithelium	Thickness of the cortex	r=0,775	p<0,02
	diameter of nuclei	Width of the cortex	r=0,714	p<0,02
	volume fraction of vascular bed	Width of the fascicular zone	r=0,764	p<0,02

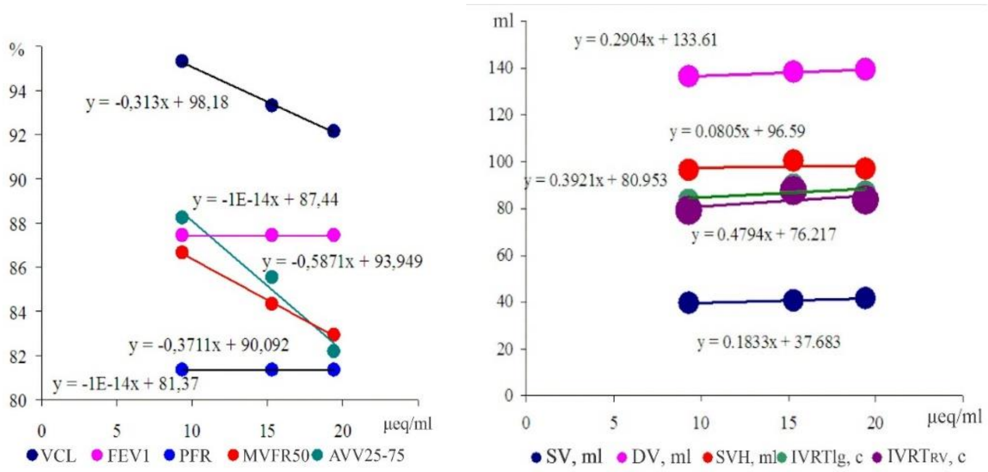
Figure 3 shows relationships with moderate (r>0.5; p<0.05), medium (r>0.7; p<0.02) and high significance (r>0.9; p<0.01).



a) group DM2n; b) group DM2o; c) group DM2IHDn; a) group DM2IHDo

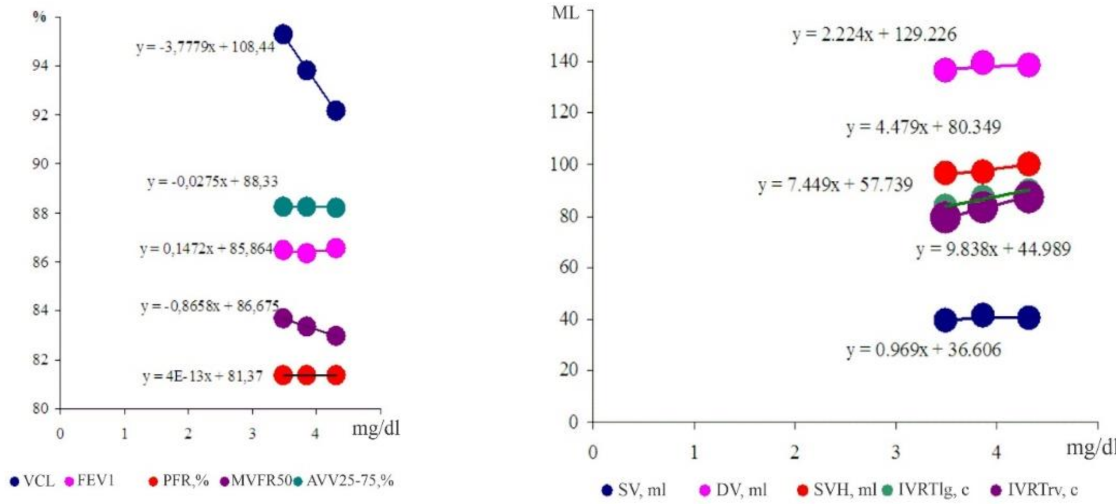
Figure 3. Results of the correlation analysis of hemodynamic parameters in patients with diabetes (Doppler echocardiography data) with FVD parameters.

The results of the correlation analysis indicate the presence of strong relationships between the studied parameters in both studied groups of DM2IHDn and DM2IHDo, and in the DM2IHDo group there is an increase in the relationship between the indicators of TPWLVD (r = 0.75; p < 0.02) with FEV1 (r = 0.901; p < 0.01) and VCL (r = 0.706; p < 0.02), ISTD with VCL (r = 0.926; p < 0.01), PFR (r = 0.901; p < 0.01), MVFR25 (r = 0.917; p < 0.01), MVFR50 (r = 0.909; p < 0.01), AVV 25-75 (r = 0.916; p < 0.01). The identified relationships made it possible to conduct regression analysis and build reliable models. A regression analysis of the biochemical blood parameters in patients with diabetes mellitus with the parameters of the external respiration function and hemodynamics was carried out. The reliability of the obtained functions is not less than 0.99, therefore the graphs of the regression analysis equations have the form of a straight line, for example, Figure 4 shows the regression relationship between the IRI indicator and the parameters of the external respiration function and hemodynamics.

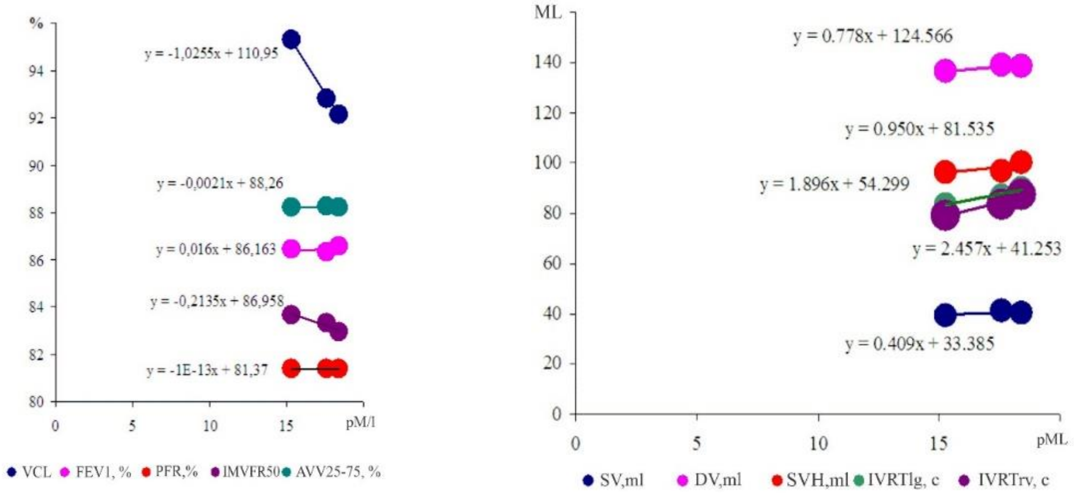


a) with indicators of external respiration function; b) with indicators of hemodynamics

Figure 4. Regression dependencies of the IRI indicator with indicators of external respiration and hemodynamic functions.



a) Regression dependence of IA with FES parameters; b) **Regression dependence of TSH with hemodynamic parameters;**



c) Regression dependence of CTG with FES parameters; **d) Regression dependence of CTG with hemodynamic parameters**

Figure 5. Regression dependencies of IA, CTG and TSH parameters with parameters of external respiration and hemodynamic functions.

For the VCL indicator y=-0.313x+98.18, -0.313 is the regression coefficient; 98.18 is the bias coefficient. For the SV indicator y=-0.29x+133.61, -0.29 is the regression coefficient; 133.61 is the bias coefficient. The results indicate a close correlation relationship between the specified indicators for the studied groups of patients with diabetes, which is confirmed by the regression model.

Diabetes mellitus affects the entire body, and for its effective treatment it is necessary to take into account the relationships between various systems: biochemical blood parameters, hemodynamics and external respiration parameters. Figure 5 shows their functional dependencies.

Discussion

In summary, our studies have shown that the thyroid gland and adrenal glands work together and influence each other. This is very important because it helps to better understand how various diseases associated with these organs develop. Highly significant relationships were found between thyroid and adrenal gland parameters in the DM2n, DM2o, and DM2IHDn groups, according to Figure 6.

group DM2n	group DM2o	group DM2IHDn
high degree of significance between the indicators of the volume fraction of thyroid epithelium of the thyroid gland and the indicators of the width of the cortical layer (r=0.938; p<0.01), the width of the glomerular zone (r=0.916; p<0.01), the width of the fascicular zone (r=0.923; p<0.01) of the adrenal glands	high degree of significance between the indicators of volume fractions of thyroid epithelium of the thyroid gland and the indicators of the width of the cortical layer (r=0.922; p<0.01), the width of the glomerular zone (r=0.908; p<0.01) of the adrenal glands	high degree of significance between the indicators of volumetric proportions of thyroid epithelium of the thyroid gland and indicators of the width of the cortical layer (r=0.904; p<0.01) of the adrenal glands

Figure 6. Highly significant relationships were found between thyroid and adrenal gland parameters in the DM2n, DM2o, and DM2IHDn groups.

Table 4 shows significant correlations between various lung function parameters and insulin resistance index (IRI) in the DM2o and DM2IHDo groups.

Table 4.

Correlation Parameters between Lung Function and Insulin Resistance Index.

Group	Parameter 1	Parameter 2	Correlation Coefficient (r)	p-value
DM2o	TPWLVD	FEV1	0.901	<0.01
DM2o	ISTD	VCL	0.926	<0.01
DM2o	PFR	VCL	0.901	<0.01
DM2o	MVFR 25	VCL	0.917	<0.01
DM2o	MVFR 50	VCL	0.909	<0.01
DM2o	IRI	VCL	0.798	<0.02
DM2o	IRI	FEV/VCL	0.83	<0.02
DM2IHDo	IRI	VCL	-0.864	<0.02
DM2IHDo	IRI	FEV/VCL	-0.805	<0.02
DM2o	AT	VCL	-0.745	<0.02
DM2o	AT	FEV1	-0.798	<0.02
DM2o	AT	MVFR 25	-0.775	<0.02
DM2o	AT	MVFR 50	-0.724	<0.02
DM2IHDo	AT	MVFR 50	-0.945	<0.01

As can be seen from Table 4, respiratory functions influence the metabolic parameters of the thyroid and adrenal glands. There is a negative correlation in the DM2IHDo group, indicating a potential link between obesity and respiratory failure in diabetes.

Several studies have highlighted the intricate relationship between these two endocrine glands. This aligns with our findings, which show strong correlations between various morphometric parameters of both glands [2, 6, 7, 10, 14]. Moreover, our results are consistent with the growing body of evidence suggesting that diabetes mellitus is associated with alterations in both thyroid and adrenal function [1, 11, 12, 13].

While our study provides valuable insights, it is important to acknowledge its limitations. The sample size was relatively small. Longitudinal studies are required to investigate the temporal relationship between changes in thyroid and adrenal function and the development of diabetes complications.

Future studies should focus on exploring the underlying mechanisms that drive the observed correlations between thyroid, adrenal, and respiratory parameters. This may involve investigating the role of neuroendocrine factors, inflammatory markers, and genetic factors.

Conclusions

1. A correlation relationship was established between pathogenetic disorders of carbohydrate metabolism, hormonal status and disorders of the thyroid-adrenal system during the development and progression of diabetes both in patients and in the model of experimental diabetes.

2. Calculation of linear regression analysis allowed us to obtain linear equations of the functional relationship between the thyroid-adrenal and cardiorespiratory systems in diabetes mellitus, which can be used in clinical and experimental conditions.

3. The established regression dependencies allow us to better understand the pathophysiological mechanisms of interaction between these systems in diabetes mellitus. The data obtained can be used to develop new approaches to the diagnosis and treatment of complications associated with diabetes, which will potentially improve the quality of life of patients and increase the effectiveness of medical interventions.

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References:

1. *Biondi B., Kahaly G.J., Robertson R.P.* Thyroid Dysfunction and Diabetes Mellitus: Two Closely Associated Disorders. Endocr Rev. 2019. №40(3). P.789-824. doi: 10.1210/er.2018-00163. PMID: 30649221; PMCID: PMC6507635.

2. *Brown E.D.L., Obeng-Gyasi B., Hall J.E., Shekhar S.* The Thyroid Hormone Axis and Female Reproduction. International Journal of Molecular Sciences. 2023. №24(12). P.9815. https://doi.org/10.3390/ijms24129815

3.*Budyal S., Jadhav S.S., Kasaliwal R., et al.* Is it worthwhile to screen patients with type 2 diabetes mellitus for subclinical Cushing's syndrome? Endocr Connect. 2015. №4(4). P.242. doi: 10.1530/EC-15-0078.

4.*Davis T.M.E., Drinkwater J.J., Davis W.A.* Pulmonary Function Trajectories Over 6 Years and Their Determinants in Type 2 Diabetes: The Fremantle Diabetes Study Phase II. Diabetes Care. 2024 №47(3). P. 483-490. doi: 10.2337/dc23-1726.

5.*Deed G., Atherton J.J., d'Emden M., Rasalam R., Sharma A., Sindone A.* Managing Cardiovascular Risk in Type 2 Diabetes: What Do the Cardiovascular Outcome Trials Mean for Australian Practice? Diabetes Ther. 2019. №10(5). P. 1625-1643. doi: 10.1007/s13300-019-0663-x.

6. *Feher J.* 9.1 - General Principles of Endocrinology. Quantitative Human Physiology. 2012. P. 761-776

7. *Harhaun O.* Study of Morphofunctional Relationships Between Adrenal Pathology and Hypothyroidism and Iodine Deficiency (Review). Archive of Clinical Medicine. 2024. P. 10. doi: 16. 10.21802/acm.2023.2.5.

8. *Maimaitituerxun R., Chen W., Xiang J., Xie Y., Xiao F., Wu X.Y., Chen L., et al.* Predictive model for identifying mild cognitive impairment in patients with type 2 diabetes mellitus: A CHAID decision tree analysis. Brain Behav. 2024. №14(3). P. 3456. doi: 10.1002/brb3.3456.

9. Mamaev A.N., Kudlai D.A. Statistical models in medicine: Textbook. manual. - M.: Practical medicine, 2020.-- 136 p.

10. *Ogbonna S., Ezeani I.* Risk Factors of Thyroid Dysfunction in Patients With Type 2 Diabetes Mellitus. Frontiers in Endocrinology. 2019. №10. P.1-8. https://doi.org/10.3389/fendo.2019.00440

11. *Pillay M., Mosili P., Akinnuga A., Sibiya N., Ngubane P., Khathi A.* Association between Altered Thyroid Function and Prediabetes in Diet-Induced Prediabetic Male Sprague Dawley Rats. Diabetology. 2023. № 4(3). P.406-417. https://doi.org/10.3390/diabetology4030034

12. *Popoviciu M.S., Kaka N., Sethi Y., Patel N., Chopra H., Cavalu S.* Type 1 Diabetes Mellitus and Autoimmune Diseases: A Critical Review of the Association and the Application of Personalized Medicine. Journal of Personalized Medicine. 2023. №13(3). P.422. https://doi.org/10.3390/jpm13030422

13. *Roa Dueñas O., Van der Burgh A., Ittermann T., Ligthart S., et al.* Thyroid Function and the Risk of Prediabetes and Type 2 Diabetes. The Journal of Clinical Endocrinology & Metabolism. 2022. №6 (107). P.1789–1798. https://doi.org/10.1210/clinem/dgac006

14. *Ryabukha O., Greguš M.* Correlation Analysis as a Thyroid Gland, Adrenal Glands, and Liver Relationship Tool for Correcting Hypothyroidism with Organic and Inorganic Iodine. Procedia Computer Science. 2019. №160. P.598-603. doi:10.1016/j.procs.2019.11.041.

15. *Sumin A.N., Bezdenezhnykh N.A., Bezdenezhnykh A.V., Artamonova G.V.* Cardio-Ankle Vascular Index in the Persons with Pre-Diabetes and Diabetes Mellitus in the Population Sample of the Russian Federation. Diagnostics (Basel). 2021. №11(3). P.474. doi: 10.3390/diagnostics11030474.

16. *Zelenskaya V., Seisembekov T., Zhautikova S. et al.* Content of total lipids in the exhaled breath condensate in type 1 diabetic mellitus patients with different level HbA1c. 14th ERS Annual Congress. 2004. P. 556.

17. *Zhautikova S.B, Seisembekov T.Z., Zelenskaya V.N., Bjiul E.V.* The characteristic of exhaled brath condensate in patients with diabetes mellitus. European Respiratory Journal. - 13th ERS Annual Congress. - Vienna, 2003. P. 210.

18. *Yuzhakova A.E., Nelaeva A.A., Khasanova Yu.V.* The role of adipose tissue in maintaining homeostasis of carbohydrate metabolism. Effective pharmacotherapy. Endocrinology. 2019. № 1 (5).

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