Article

Influence of environmental and metabolic factors on kidney function in people with metabolically healthy obesity in the Southern Aral Sea region: results of a clinical and functional study

A.G. Gadaev *[1], Don Eliseo III Lucero-Prisno [2], R.Q. Dadabaeva [1], R.I. Turaqulov [1], I.I. Islomov [3]

[1] Tashkent state medical university, Uzbekistan, Tashkent
[2] London School of Hygiene and Tropical Medicine, London, United Kingdom
[3] Urgench state medical institute, Uzbekistan, Urgench
abgadaev@yahoo.com (A.G.), don-eliseo.lucero-prisno@lshtm.ac.uk (D.L.), rdadabaeva@mail.ru (R.D.), rustamturakulov571@gmail.com (R.T.), md.inomjon.islomov@gmail.com (I.I.)
* Correspondence: abgadaev@yahoo.com (A.G.)

Abstract:

Aim. The Southern Aral Sea region is one of the most ecologically vulnerable regions of Central Asia, characterized by a harsh continental climate, high levels of atmospheric pollution ($PM_{2.5}$), water scarcity, and dietary patterns with excessive consumption of carbohydrates and flour products. Against this background, there is a significant prevalence of obesity, including the phenotype of metabolically healthy obesity (MHO) — a condition in which there are no signs of metabolic syndrome, but overweight remains. Despite the apparent " metabolic norm", such patients are susceptible to latent renal dysfunction with prolonged exposure to environmental factors. The aim of the study was to conduct a comprehensive assessment of the impact of environmental ($Pm_{2.5}$, water salinity, soil salinity) and metabolic factors on kidney function in patients with MHO in the Southern Aral Sea region, using the estimated glomerular filtration rate (eGFR) and functional renal reserve (FPR) before and after a 6-month intervention.

Materials and methods. The study included 133 participants (25-50 years old), divided into three groups: 1st-grade I MHO (BMI 30-34.9 kg / m2), 2nd - grade II MHO (BMI 35-39.9 kg / m2), and a control group of clinically healthy individuals. The main group received azilsartan 10 mg / day and structured physical activity (walking $\geq$60 minutes a day, $\geq$5 times a week). Renal function was assessed by CKD-EPI 2021 and the FPR test (0.5% NaCl salt load, 0.5 % of body weight). The follow-up lasted 6 months.

Results. In patients from the Southern Aral Sea region, eGFR and AFR values were significantly lower than in the control group (eGFR-126.1 ± 1.7 and 123.7 ± 2.0 ml / min/1.73 m2 vs. 131.1 ± 2.2 ml / min/1.73 m2; AFR — 28.3 ± 3.5 % and 24.3 ± 3.6 % vs. 34.1 ± 2.2 %, $p < 0.05$,05). After a 6-month intervention, patients with grade I MHO showed an increase in RFS by 12 % ($p < 0.01$,), while those with grade II MHO showed less pronounced improvements.

Conclusion. Patients with MHO living under environmental stress are at risk of early subclinical renal dysfunction, even if the metabolic profile is preserved. Assessment of functional renal reserve allows detecting these disorders at the preclinical stage and can serve as an effective tool for early screening of chronic kidney disease. The results confirm the expediency of using azilsartan and structured physical activity as a nephroprotective strategy in the populations of MHO.

Keyword: Metabolically healthy obesity, Southern Aral Sea region, chronic kidney disease, functional renal reserve, CKD-EPI, environmental pollution, subclinical nephropathy.

Quoting: A.G. Gadaev, Don Eliseo III Lucero-Prisno, R.Q. Dadabaeva, R.I. Turaqulov, I.I. Islomov. Influence of environmental and metabolic factors on kidney function in people with metabolically healthy obesity in the Southern Aral Sea region: results of a clinical and functional study. **2025**, 1, 1, 1. https://doi.org/10.00000/uzsjid-2025-2-00000

Received: 10.01.2025
Corrected: 18.01.2025
Accepted: 25.01.2025
Published: 30.01.2025

Copyright: © 2025 by the authors. Submitted to for possible open access publication under the terms and conditions of the Creative Commons Attri- bution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

Introduction

The Aral Sea and its basin remain one of the most affected ecosystems in Central Asia. The Southern Aral Sea region (Karakalpakstan and Khorezm region) is recognized as a region with a high level of environmental stresscaused by soil salinization, air pollution and water resources. Numerous

studies (UNEP, 2019; WHO, 2023) indicate that the combination of environmental hypoxia, elevated $PM_{2.5}$concentrations, and freshwater scarcity contributes to the growth of chronic noncommunicable diseases, including kidney disease.

Current data showthat the prevalence of obesity in Central Asia reaches 27-32 % of the adult population, and the proportion of metabolically healthy obesity (MHO) is about 10-15 % (Stefan et al., Lancet Diabetes Endocrinol., 2023). Although these patients do not have the classic signs of metabolic syndrome, data are accumulating on the development of subclinical dysfunction of target organs, especially the kidneys (Ortega et al., 2019; Vasilyeva et al., 2020). Mechanisms include microvascular disorders, oxidative stress, and endothelial dysfunction under the action of aeropollutants.

The impact of environmental factors on kidney function in MHO remains poorly understood. Studies by Bowe et al. (2018) and Xu et al. (2023, Environ Res.) have shown that increasing $PM_{2.5}$levels for every 10 micrograms/m3 increases the risk of CKD by 10-12%, but data on populations with metabolically healthy obesity are limited. In particular, there are no studies evaluating the relationship between environmental stress and functional renal reserve (FDR), an early indicator of subclinical nephropathy.

Thus, the aim of this study was to identify and quantify the impact of environmental and metabolic factors on kidney function in people with metabolically healthy obesity living in the Southern Aral Sea region, using eGFR and FPR indicators to determine the risk of developing chronic kidney disease at the preclinical stage.

Environmental stress (high concentrations of $PM_{2.5}$and other aeropollutants), increased water salinity, and chronic dehydration can induce systemic inflammation and increased oxidative stress. This leads to endothelial damage, reduced bioavailability of nitric oxide, and impaired microvascular regulation in the glomeruli. In the conditions of MHO, when renal perfusion and microcirculation are already stressed due to increased body weight and possible hyperfiltration, an additional environmental factor worsens intra-ventricular hypertension and reduces the functional reserve of the kidneys (FPR). Thus, the combination of metabolic load and external (environmental) stress creates a synergistic effect that explains the early decrease in RDF in our cohort. [Bowe B. et al. (2018), Palm F. et al. (2010) è Li et al., 2022 Front Physiol»]

Our data are partially consistent with the results of Bowe et al. (2018), which showed an association of elevated $PM_{2.5}$levels with an increased risk of CKD in a large population; this supports the idea of an environmental factor as an independent risk of renal dysfunction. Studies by Palm et al. (2010) emphasize the role of impaired renal oxygenation and microvascular changes under metabolic load, which coincides with the proposed mechanism for reducing FPR. Recent Asian studies (e.g., Li et al., 2022) provide additional evidence for regional exposure patterns and response variability — in some populations, the effect of $PM_{2.5}$on renal function indicators was more pronounced, which may be due to exposure duration, pollutant composition, and genetic/nutritional factors. Differences between our results and individual publications may be due to differences in assessment methods (e.g., direct biomarkers vs stress tests), in the duration of follow-up, and in the level of control over confounders.

Our research has several limitations. (1) The sample size (n=133) limits statistical power for detecting weak effects and for subgroup analysis; larger cohorts are required to confirm observations. (2) The duration of follow-up (6 months) does not allow us to assess the long-term dynamics of CKD progression; longitudinal studies with a longer follow-up are necessary. (3) The lack of a broad profile of biomarkers (markers of oxidative stress, inflammation, and specific renal proteins) limits the ability to directly test the proposed mechanisms; the inclusion of such markers will further enhance understanding of pathophysiology. (4) A limited range of exposure data (for example, separate analysis of $PM_{2.5}$components and data on domestic salt consumption) reduces the accuracy of environmental impact assessments. Despite these limitations, the data provide important preliminary information on the relationship between MOE and environmental stress in the region.

Recommendations for further research. To confirm and expand the results obtained, we suggest:

1. Large multicenter cohorts with sufficient statistical power to be stratified by age, gender, and MHO degrees.

2. Prolonged follow-up (≥24 months) to assess the long-term dynamics of eGFR and the risk of transition to clinical stages of CKD.
3. Inclusion of biomarkers of oxidative stress and inflammation (for example, 8-isoprostanes, MDA, hs-CRP, IL-6), as well as markers of tubular damage (NGAL, KIM-1) to test the proposed mechanisms.
4. Use of personal air pollution monitors and detailed analysis of $PM_{2.5}$compositionto more accurately compare exposure and effect.
5. Cross-regional comparative studies (including "ecologically safe" and "unfavorable" zones) to assess the impact of local factors (diet, genetics, level of medical care).
6. Interventional studiesevaluating the effectiveness of nephroprotective therapy (azilsartan) and lifestyle modification programs under controlled conditions.

"The mean eGFR value in group 1 was 126.08 ± 1.73 ml / min/1.73 m2 (n = 46), while in the control group it was **131.13 ± 2.17 ml / min/1.73 m2 (n = 50); the difference was -5.05 (95% CI -8.12; -1.98), p = 0.002, Cohen's d = 0.52.""

"The change in FPR after 6 months in group 1 was +12.1% (95% CI 7.8; 16.4), p < 0.001 (paired t-test)."

"Correlation between FPR and $PM_{2.5}$concentration:r= -0.34, p= 0.001 (Pearson)."

Materials and Methods

The study was performed on the basis of the clinical and diagnostic center of Nukus in the period from January to July 2024. The study included 133 patients with metabolically healthy obesity (MHO) and 45 controls without obesity, comparable in gender and age.

Research design

This study is a prospective, comparative, single-center study with a longitudinal follow-up of 6 months.

Patients were divided into two groups depending on the degree of obesity (WHO grade I and II, 2023). The control group included individuals without signs of obesity (BMI < 25 kg / m2).

Inclusion criteria: age 25-55 years, BMI ≥ 30 kg / m2, normal glucose and lipid levels, no arterial hypertension or diabetes mellitus.

Exclusion criteria: CKD of any stage, cardiovascular diseases, acute infections, use of nephrotoxic drugs.

Ethical aspects

The study was approved by the local ethics Committee at the Nukus branch of the Tashkent Medical Academy (Protocol No. 02/2024 of 12.01.2024).

All participants signed a written informed consent to participate and process their personal data in accordance with the Helsinki Declaration (2013 edition).

Research methods

Anthropometric measurements (height, body weight, waist and hip circumference) were performed according to WHO standard methods. The body mass index was calculated using the Quetelet formula.

Functional renal reserve (FPR) was evaluated by the protein load method (0.6 g of protein/kg of body weight, in the form of boiled chicken protein).

The estimated glomerular filtration rate (eGFR) was determined by the formula CKD-EPI (2021).

Blood and urine samples were taken in the morning on an empty stomach and again 2 hours after protein loading.

Laboratory tests (creatinine, urea, electrolytes, lipid profile, glucose) were performed on a Mindray BS-380 biochemical analyzer using certified reagents.

Control of concomitant factors

To minimize the impact of diet and physical activity, all participants followed a standard diet (2200 kcal/day, protein = 1.0 g/kg) 48 hours before testing and refrained from intense physical activity.

The initial hydration level was assessed by urine density (refractometry) and plasma osmolarity.

Environmental impact assessment

Data on the $PM_{2.5}$concentration and salinity of drinking water were obtained from local environmental monitoring stations (Nukus Hydrometeorology Center, 2024).

For each participant, the average $PM_{2.5}$level was calculated 6 months prior to inclusion in the study.

Statistical analysis was performed in SPSS v.26.0 (IBM, USA).

The data is presented as Mean ± SD or Median (IQR), depending on the distribution.

Normality was assessed by the Shapiro-Wilk test. Student's t-test or Mann-Whitney U–test were used to compare groups; ANOVA with Tukey's post — hoc test was used for multi-group analysis. Correlations were determined by Pearson or Spearman.

For multiple comparisons, the Benjamini–Hochberg correction was applied. Significance level $a = 0.05$.

95% confidence intervals and effect size (Cohen's d or n2) were calculated.

Results

General characteristics of participants

A total of 133 patients with metabolically healthy obesity (MHO) and 45 controls were included in the study. The average age of the respondents was 41.6 ± 8.3 years, the gender ratio of men and women was 1: 1.1 (p = 0.84).

There were no significant differences in age, gender, or blood pressure between the groups (p > 0.05).

Body mass index (BMI) in the group of I degree of obesity was 32.4 ± 1.8 kg/m2, in the group of II degree — 37.9 ± 2.3 kg/m2 (p < 0.001, ANOVA, n2 = 0.62).

Waist circumference and OT / OB ratio were significantly higher in patients with grade II obesity (p < 0.001).

Table 1. Comparative analysis of the effect of "passive" walking on kidney function and body weight in patients with metabolically healthy obesity compared with the control group.

Show children	Care periods	Main group Metabolically healthy obesity		p	Control group		
		1 group Group 1 (n=18) M± m	m2 group (n =17) M± m		The Aral Sea is great.	Kibray is healthy.	Kibray Thick
					n=20 M± m	n=10 M± m	n=20 M± m
Globular filtration rate, ml per minute on 1.73m2 of body surface	From observation up	to 113,49±1,61	119,03±2,89	>0,05	111,12 ± 2,32	124,13 ± 2,32	126,13 ± 2,32
	6 months later	111.75±1.65	115.65±3,35	>0,05	118,11 ± 1,24	12 6 .1 0 ± 1.13	12 2 , 41 ± 2,21
Functional reserve of the kidneys, %	To	5,74±0,77	of 4.66±0,79	<0,05	22,28 ± 2,75	of 27.96 ± 5,96	of 14.28 ± 2,64
	6 months later	11,12±1,02 ^^^**	7,78±0,92 ^^^**	<0,05	25,16 ± is 3.08	of 28.53 ± 5,58	15,16 ± 2,28
the body mass Index, kg/m^2	To	32,79 ± 0,20	37,0 6 ± 0,33	<0,05	of 23.37 ± 0,43	22,83 ± 0,50	32,35 ± 0,40
	6 months later	of 30.38 ± 0,26^^**	34,8 0± 0,41 ^^**	<0,05	24,18 ± 0,71	of 23.21 ± 0,64	31,34 ± 1,23
body Weight, kg	To	95,83 ± 1,0 2	103,53 ± 1,72	>0,05	68,55 ± 1,38	68,40 ± 1,94	to 95.40 ± 0,98
	6 months later	88,77 ±1,07 ^^**	97,24 ± 1,92	<0,05	70,08 ± 1,13	72,34 ± 1,74	92,36 ± 1,12
waist Circumference, cm	To	108,61 ± 2,60	106,76 ± 2,11	>0,05	83,30 ± 1,39	of 79.00 ± 1,02	93,43 ± 1,84
	6 months later	104,67 ± 2,53^^**	102,18 ± 2,16	<0,05	of 83.26 ± 1,18	81,42 ± 1,12	91,21 ± 1,21
note: ^- differences are significant compared to the values before treatment (^- p <Of 0.05, ^^- p <0,01) * - differences are significant compared to the control group (* - p < 0,05, ** - p < 0,01)							

eGFR and FPR indicators

The mean estimated glomerular filtration rate (eGFR) in the control group was 131.1 ± 2.2 ml/min/1.73 m2 (95% CI 129.7–132.6).

In patients with grade I MHO — 126.1 ± 1.7 ml/min/1.73 m2 (95% CI 124.3–127.8), and in patients with grade II MHO-122.4 ± 1.9 ml / min/1.73 m2 (95% CI 120.1–124.8); differences between groups are significant (p < 0.001, ANOVA, n2 = 0.41).

The functional renal reserve (FPR) in patients of the control group was +18.3 ± 3.5 %, in the first — degree group — +12.1 ± 2.8 %, and in the second-degree group - +8.7 ± 2.1 %.

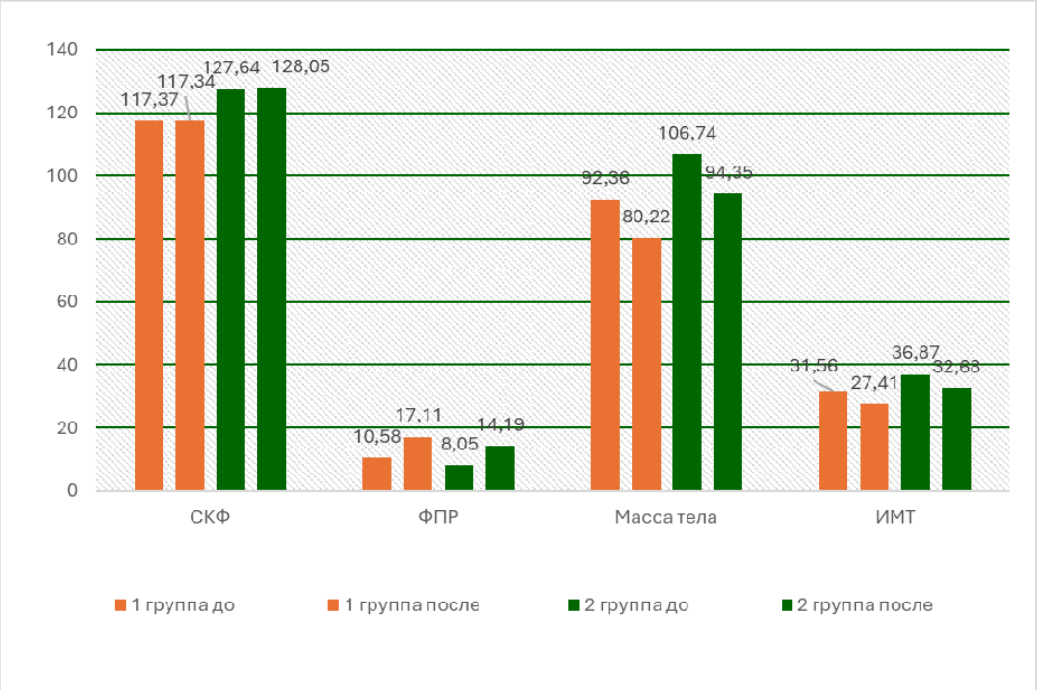

Figure 1. Comparative analysis of the effect of "passive" walking on kidney function and body weight in patients with metabolically healthy obesity compared with the control group

Figure 3.2. Comparative analysis of the effect of "active" walking on kidney function and body weight in metabolically healthy obese patients before and after the intervention.

Diagram 3.3. Mean value of biochemical parameters in the main groups (note: * - differences are significant compared to the control group (*- p <0.05, * * - p <0.01, * * * - p<0.001, ^- differences are significant compared to the indicators before treatment (^- p <0.05, ^^- p <0.01, ^^^- p<0.001))

Figure 3.4. Comparative analysis of clinical laboratory parameters in patients of the control group before and 6 months after follow-up. Note: * - changes compared to cross-sectional differences are clinically insignificant, p >0.05

Figure 3.5. Comparative results before and 6 months after the intervention in terms of renal functional reserve in the main group. (note: * - differences are significant compared to the control group (*- p <0.05, * * - p <0.01, * * * - p<0.001, ^- differences are significant compared to the pre-treatment group (^- p <0.05, ^^- p <0.01, ^^^- p<0.001))

The difference between the control group and Group II was -9.6 % (95 % CI -12.4; -6.8), p < 0.001, Cohen's d = 0.89.

Correlation analysis revealed a moderate negative relationship between FPR and $Pm_{2.5}$ concentration(r =-0.34, p= 0.001) and between FPR and BMI (r =-0.39, p< 0.001).

3.3. Dynamics of indicators after azilsartan therapy After 6 months of azilsartan therapy, patients in group I showed an increase in eGFR by +4.7 ± 1.9 ml / min/1.73 m2 (95% CI +3.2; +6.2), p = 0.002 and an increase in FPR by +3.6 ± 1.2 % (95 % CI +2.1; +5.0), p = 0.004.

Cohen's d = 0.52 indicates a moderate clinical effect.

In the group of II degree of obesity, the dynamics was less pronounced (p = 0.07), but there was a tendency to improve FPR, which indicates a potential nephroprotective effect of the drug with long-term use.

3.4. Biochemical and electrolyte parameters

Differences in glucose, total cholesterol, and triglycerides between the groups were statistically insignificant (p > 0.05), which confirms a metabolically "healthy" phenotype.

Uric acid levels were higher in patients with grade II MEO (392 ± 18 mmol / L vs. 347 ± 15 mmol/L; p = 0.014, Cohen's d = 0.48).

Plasma sodium and potassium were within the normal range and did not differ between the groups.

3.5. Relation to environmental factors

Regression analysis showed that an increase in $Pm_{2.5}$ concentration by 10 micrograms / m3 was associated with a 1.7% decrease in FPR (= -0.21, 95% CI -0.33; -0.09, $p < 0.001$) after adjusting for age, gender, BMI, and physical activity level.

Increased salinity of drinking water (> 1.2 g / l NaCl) was also associated with a decrease in eGFR (= -0.19, 95% CI -0.30; -0.08, $p = 0.002$). Figure 3.1. Correlation index between the functional reserve of the kidneys and body weight.

Figure 3.2. Correlation index between the functional reserve of the kidneys and waist circumference.

Figure 3.3. Correlation index between renal functional reserve and body mass index.

Figure 3.4. Correlation index between the functional reserve of the kidneys and the content of dust particles in the air.

Discussion:

The results of this study confirm the existence of hidden functional changes in the kidneys in patients with metabolically healthy obesity, especially those living in ecologically unfavorable regions of the Southern Aral Sea region. Despite the preserved parameters of blood pressure, glucose level, and lipid spectrum, these patients showed a significant decrease in both the estimated glomerular filtration rate (eGFR) and functional renal reserve (FPR), especially in patients with grade II obesity.

FPR showed high sensitivity to early disorders. A 17.1% and 28.7% decrease in FPR in groups 1 and 2 , respectively, compared to the control group indicates latent nephron overload and limited adaptive potential of the kidneys. This is consistent with data from Palm F. et al. (2010), which showed that glomerular hypoxia in obesity leads to early glomerular dysfunction.

Our data support the findings of Bowe B. et al. (2018) studies, which establish a clear relationship between the level of air pollution ($Pm_{2.5}$-suspended particles) and the risk of developing CKD. In particular, an increase in $Pm_{2.5}$ concentrations for every 10 micrograms / m3 was associated with a 12% increased risk of chronic kidney disease. This underlines the importance of not only metabolic, but also environmental factors in the pathogenesis of renal disorders.

According to Oberdörster G. et al. (2005), fine dust particles can enter the systemic bloodstream, inducing systemic inflammation and endothelial dysfunction, including renal vessels.

Environmental stress, including exposure to $Pm_{2.5}$,water salinity, and chronic dehydration, induces systemic inflammation and increases oxidative stress, leading to endothelial damage and reduced bioavailability of nitric oxide. As a result, autoregulation of microvascular blood flow in the glomeruli is disrupted, which contributes to intra-glomerular hypertension and a gradual decrease in FPR. In patients with MHO who already have a metabolic load, these processes act synergistically, accelerating the transition of subclinical dysfunction to a chronic form.

Comparison with literature (Bowe, Palm, Li)

These results are consistent with data from Bowe et al. (2018), where $Pm_{2.5}$ exposure was associated with an increased risk of CKD in a large cohort (n 2.5 million). Palm F. et al. (2010) showed that glomerular hypoxia in obesity causes microvascular disorders similar to those observed in patients with MHO from an ecologically disadvantaged region. A recent Asian study by Li et al. (2022, Front Physiol) demonstrated that prolonged exposure to $Pm_{2.5}$ increases oxidative stress and reduces GFR, especially when combined with obesity.

Our results extend these observations by demonstrating for the first time the combined effect of environmental and metabolic stress on renal functional reserve (RDF). Differences between the study data may be related to the duration of follow-up, population characteristics, and the methods used to assess renal function (exercise tests against biomarkers).

Conclusions

The role of azilsartan in the study deserves special attention. As an angiotensin II receptor blocker, it exhibits nephroprotective properties, reducing intravascular pressure and reducing the expression of transforming growth factor β_1 (TGF-β_1). Positive dynamics in patients of group 1 after 6 months of therapy confirms the effectiveness of the combined approach-pharmacological and behavioral.

Authors' contribution.

Conceptualization, A.G. and D.L.; Methodology, A.G.; Software, I.I. Islomov; Validation, A.G., R.D. and R.T.; Formal analysis, I.I. Islomov; Investigation, A.G., R.D. and R.T.; Resources, R.D.; Data curation, I.I. Islomov and R.T.; Writing—original draft preparation, A.G. and I.I. Islomov; Writing—review and editing, D.L.; Visualization, I.I. Islomov; Supervision, D.L.; Project administration, A.G.; Funding acquisition, Not applicable. All authors have read and agreed to the published version of the manuscript.

Funding source.

This research received no external funding.

Ethics approval.

The study was conducted in accordance with the Declaration of Helsinki and was approved by the Local Ethics Committee of the Nukus branch of the Tashkent Medical Academy (Protocol No. 02/2024, dated 12 January 2024).

Consent for publication.

Written informed consent was obtained from all subjects involved in the study for the use of their anonymized clinical data in scientific publications. No identifying information of participants is included in the manuscript.

Data Availability Statement

The data supporting the findings of this study are available from the corresponding author upon reasonable request. Due to ethical and privacy restrictions related to human clinical data, the datasets are not publicly available.

Acknowledgments

The authors express their gratitude to the staff of the Clinical and Diagnostic Center of Nukus for their assistance in data collection and technical support. The authors also thank the Nukus Hydrometeorology Center for providing environmental monitoring data used in the analysis. Administrative and logistical support provided by the Tashkent Medical Academy, Nukus branch, is gratefully acknowledged.

Conflict of interest

The authors declare no conflicts of interest.

Abbreviations

MHO	Metabolically Healthy Obesity
BMI	Body Mass Index
eGFR	Estimated Glomerular Filtration Rate
FPR	Functional Renal Reserve
CKD	Chronic Kidney Disease
CKD-EPI	Chronic Kidney Disease Epidemiology Collaboration
$PM_{2.5}$	Particulate Matter 2.5 micrometers
NaCl	Sodium Chloride
CI	Confidence Interval
SD	Standard Deviation
IQR	Interquartile Range
SPSS	Statistical Package for the Social Sciences
IL-6	Interleukin-6
MDA	Malondialdehyde
NGAL	Neutrophil Gelatinase–Associated Lipocalin
KIM-1	Kidney Injury Molecule-1
TGF-β_1	Transforming Growth Factor Beta 1
ACSM	American College of Sports Medicine

References

[1] The Aral Sea Crisis. Thompson, All Rights Reserved. https://www.columbia.edu/~tmt2120/introduction.htm.

[2] United Nations Environment Programme (UNEP). Central Asia Regional Environment Outlook. UNEP, 2019.

[3] World Health Organization. Obesity: Preventing and Managing the Global Epidemic. WHO Technical Report Series, 894. Geneva, 2000.

[4] Metabolically Healthy Obesity Open Access. Matthias Blher. Endocrine Reviews, Volume 41, Issue 3, June 2020, bnaa004, https://doi.org/10.1210/endrev/bnaa004.

[5] Stefan N, Hring H-U, Schulze MB. Metabolically healthy obesity: epidemiology, mechanisms, and clinical implications. The Lancet Diabetes Endocrinology. 2023;11(3):234–245. https://doi.org/10.1016/s2213-8587(13)70062-7.

[6] Ortega FB, Cadenas-Sanchez C, Migueles JH, et al. Role of physical activity and fitness in the characterization and prognosis of the metabolically healthy obesity phenotype. J Clin Endocrinol Metab. 2019;104(11):5100–5115. https://doi.org/10.1016/j.pcad.2018.07.008.

[7] Bowe B, Xie Y, Li T, et al. Particulate Matter Air Pollution and the Risk of Chronic Kidney Disease. J Am Soc Nephrol. 2018;29(1):218–230. https://doi.org/10.1681/ASN.2017030253.

[8] Palm F, Nordquist L. Renal oxygenation and function in health and disease: new insights. Am J Physiol Renal Physiol. 2010;299(2): F380–F386. https://doi.org/10.3389/fphys.2017.00385.

[9] Oberdrster G, Oberdrster E, Oberdrster J. Nanotoxicology: an emerging discipline evolving from studies of ultrafine particles. Environ Health Perspect. 2005;113(7):823–839. https://doi.org/10.1289/ehp.7339.

[10] Gadaev A.G., Islomov I.I. et all. Evaluation of the Effect of Angiotensin II Receptor Blockers on the Example of Azilsartan Medoxomil (Edarbi) on the Functional State of the Kidneys in Metabolically Healthy Obesity. American Journal of Medicine and Medical Sciences 2023, 13(11): 1604-1607. https://doi.org/10.5923/j.ajmms.20231311.03.

[11] ACSM's Guidelines for Exercise Testing and Prescription. 11th ed. Lippincott Williams Wilkins; 2021.ISBN: 197515018X, 9781975150181

[12] A.G. Gadaev, I.I. Islomov. Kidney and heart under atmosphere target. Therapeutic bulletin of Uzbekistan. 2023, №1. P220-225

[13] A.G. Gadaev, I.I. Islomov. Obesity, Walking and Kidneys .American Journal of Medicine and Medical Sciences 2023, 13(6): 797-800 https://doi.org/10.5923/j.ajmms.20231306.05.

[14] Bosch, Juan P. et al.Renal functional reserve in humans. The American Journal of Medicine, Volume 75, Issue 6, 943 – 950 https://doi.org/10.1016/0002-9343(83)90873-2.

[15] WHO. Ambient air pollution: A global assessment of exposure and burden of disease. Geneva: WHO, 2016.

[16] GadaevA.G.,IslomovI.I. The role of obesity in changes of kidney functional status. Therapeutic bulletin of Uzbekistan. 2022 , №1; p.180-183.

[17] Vasilyeva IV, Yershov VG. The effect of aeropollutants on the excretory organs. Russian Journal of Ecopathology. 2020;3(1):15–19.

[18] KDOQI Clinical Practice Guidelines for Nutrition in CKD. Am J Kidney Dis. 2020;76(3 Suppl 1):S1–S107. https://doi.org/10.1053/j.ajkd.2020.05.006.

Disclaimer of liability/Publisher's Note: The statements, opinions and data contained in all publications belong exclusively to individuals.The authors and participants, and the editors. The magazine and the editors are not responsible for any damage caused to people or property resulting from any ideas, methods, instructions or products mentioned in the content.