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THE IMPACT OF EXCESSIVE SALT INTAKE ON HUMAN HEALTH

PhD,dosent Tuksanova Zebiniso Izatulloevna

Bukhara State Medical Institute named after Abu Ali ibn Sina, Uzbekistan, Bukhara, st. A. Navoi.

1 Tel: +998 (65) 223-00-50 e-mail: info@bsmi.uz

Abstract. Salt (sodium chloride) plays an essential role in physiological processes such as nerve conduction and fluid balance. However, excessive intake has been identified as a major contributor to various chronic health conditions. The World Health Organization (WHO) recommends limiting daily salt consumption to no more than 5 grams, yet global averages exceed 9–12 grams, and in some populations, intake reaches up to 15 grams daily. Excess sodium increases fluid retention, leading to elevated blood volume and, consequently, increased blood pressure. Persistent high sodium intake is a key factor in the pathogenesis of arterial hypertension, left ventricular hypertrophy, and renal dysfunction. Furthermore, fluid retention contributes to peripheral edema, particularly in the lower extremities. Overburdened kidneys are forced to work harder, accelerating glomerular damage and raising the risk of chronic kidney disease (CKD).

Keywords: sodium chloride, fluid retention, hypertension, renal filtration, cardiovascular risk, chronic kidney disease, electrolyte imbalance.

Introduction. As is well known, the human kidneys carry out a complex and tightly regulated process of urine formation, which includes the stages of ultrafiltration, reabsorption, secretion, and concentration. In the first stage—ultrafiltration—under the influence of effective filtration pressure (P_eff), expressed by the formula: P_gc − (P_bs + π_gc), about 160–180 liters of primary urine are formed daily [12; p.102]. This primary urine contains low-molecular-weight substances such as glucose, amino acids, creatinine, urea, and anions of sodium, potassium, calcium, chloride, and others. The role of the vascular-basement membrane and Bowman's capsule is to provide selective filtration, while the activity of hormones such as vasopressin and natriuretic factor regulates the diameter of the afferent and efferent arterioles of the glomerulus, thus influencing the filtration rate [12; p.105]. In the proximal tubules, obligatory reabsorption occurs, which is not hormonally regulated. Here, glucose, amino acids, proteins, and up to 7/8 of the water volume are completely reabsorbed. However, urine concentration begins only in the loop of Henle due to the countercurrent mechanism and continues in the distal tubules [12; p.106].

In the distal segments, facultative reabsorption and electrolyte secretion (including sodium and potassium) become active. The osmolality of the extracellular fluid plays a crucial role in regulating cell volume. In conditions such as diabetes mellitus and chronic kidney disease (CKD), disturbances in water-salt homeostasis occur, requiring additional correction [16; p.10]. Hyperosmia, caused by glucose in diabetes or urea in CKD, affects intracellular osmoregulation differently, despite similar plasma osmolality levels [12; p.104]. Studies show that the use of natural remedies, such as pomegranate seed oil, has a positive effect on

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the function of the kidneys, thymus, and spleen in cases of impaired filtration and osmoregulation [2; p.39], [3; p.165], [4; p.41]. These agents, due to their antioxidant and membrane-stabilizing properties, help improve the morphofunctional condition of the kidneys [29; p.58], reduce the toxicity of sodium salts, and prevent inflammatory processes in the glomerular apparatus [16; p.11]. In certain diseases, such as diabetes mellitus and CKD, additional therapeutic interventions are required to correct plasma osmolality and maintain it within strict limits. However, clinical practice often overlooks the different nature of the substances causing hyperosmia: glucose in diabetes, and urea in CKD. Despite having the same molal concentration, their effects on cellular osmoregulation differ [12; pp.104–105].

As previously mentioned, plasma osmolality is one of the most tightly regulated homeostatic parameters of the body. This is due to the fact that the volume of each cell directly depends on the osmolality of the extracellular (pericellular) fluid. Under conditions of stable osmotic membrane permeability and constant intracellular osmolyte content, the total amount of dissolved substances in the plasma determines the movement of water between compartments and, consequently, the cell volume [12; p.106]. Cell volume osmoregulation (cell volumetry) depends on three key factors:

1. The osmolality of the fluid surrounding the cell,
2. The osmotic permeability of the plasma membrane,
3. The total amount of osmotically active substances inside the cell.

In the kidneys, osmotic free water plays an essential role in maintaining water balance. Its movement is regulated by the osmolality gradient between the cortical and medullary regions of the kidneys. When water needs to be conserved, the medulla creates a high osmotic gradient, promoting water reabsorption from the collecting ducts. In the opposite case—excess water—the gradient decreases, and water is excreted as dilute urine [16; p.10]. To quantitatively assess the kidney's osmoregulatory function, the following are calculated:

- Reabsorption of osmotic free water (TcH_2O):

$$TcH_2O = COsm - V$$

- Excretion of osmotic free water (CH_2O):

$$CH_2O = V - COsm$$

Where V is the urine flow rate (ml/min), and COsm is the osmolar clearance: $COsm = (UOsm \times V) / POsm$, where UOsm and POsm are the osmolality of urine and plasma, respectively [12; p.105]. Normally, with increased secretion of vasopressin (antidiuretic hormone, ADH), TcH_2O rises, reaching up to 5 ml/min per 1.73 m^2 of body surface area, indicating intensive water reabsorption [16; p.11]. With a water load (2% of body weight), which suppresses vasopressin production, maximum diuresis in men can reach 14.7 ml/min. Vasopressin secretion is regulated by the hypothalamus and increases in response to:

- Elevated plasma osmolality (dehydration),

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- Decreased circulating blood volume (hemorrhage, hypotension),
- Stress (via the hypothalamic–pituitary–adrenal axis) [12; p.106].

Once secreted, ADH reaches the kidneys, where it activates receptors in the collecting ducts, increasing water permeability and enhancing reabsorption. This reduces urine volume and increases its concentration. Sodium plays a key role in osmoregulation. Plasma sodium concentration (natremia), as the main extracellular electrolyte, regulates osmotic pressure and water movement between compartments. An increased sodium concentration causes water retention, while hyponatremia leads to water loss. Regulation is mediated by:

- Vasopressin,
- Aldosterone,
- The renin–angiotensin–aldosterone system (RAAS) [29; p.58].

The normal sodium concentration in plasma is 135–145 mmol/L. Deviations from this range (hypernatremia, hyponatremia) may be markers of pathologies such as dehydration, adrenal dysfunction, or chronic kidney failure [16; pp.10–11].

Given the role of the kidneys in regulating water-electrolyte homeostasis, especially in conditions like CKD, diabetes, and acute dehydration, attention should be paid not only to the quantitative, but also the qualitative characteristics of the osmolytes that determine plasma osmolality. In particular, sodium, glucose, and urea differently affect intracellular and extracellular osmoregulation [12; p.104]. Recent studies have shown that in renal failure, not only water balance is disturbed, but also the morphology and function of immune and hematopoietic organs such as the spleen. It has been confirmed that using natural phyto-remedies, including pomegranate seed oil, helps normalize homeostasis. In experimental animals with kidney dysfunction, pomegranate seed oil had a positive effect on the morphofunctional condition of the spleen, indirectly indicating normalization of osmoregulation and water-salt balance [33]. As noted by M.F. Hikmatova (2022), the introduction of pomegranate seed oil into the diet of experimental animals produces a pronounced immunomodulatory effect, reduces signs of intoxication, and stabilizes metabolic processes. This is likely due to the antioxidant and membrane-stabilizing properties of the oil's components [31; pp.137–139]. Furthermore, the use of medicinal plants in treating kidney diseases may play a supportive role in stabilizing electrolyte and water balance. Under conditions of chronic intoxication or inflammation in the kidneys, herbal preparations exert a mild diuretic effect and regulate sodium- and potassium-dependent transport mechanisms [36; pp.427–428]. On the other hand, the treatment approach should consider not only biochemical parameters but also homeopathic and historical–philosophical concepts, especially within the framework of Eastern medicine. In the works of Ibn Sina, as highlighted by M.F. Hikmatova (2022), the influence of "natural spirits," moisture, and heat on kidney function and overall bodily health is discussed systematically. These texts describe the kidneys not only as organs responsible for urine outflow but also for fluid balance regulation, which in modern interpretation corresponds to osmoregulation [32; p.221]. Additionally, anthropometric and morphophysiological studies have revealed that the hydration status of the body affects body composition and physical condition, especially in children and adolescents. As shown in the works of H.M. Furkatovna (2021), water-salt balance is significant for metabolic adaptation and may serve

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as a marker of the body's internal osmoregulatory capacity when assessing physical development and endurance [34; 35].

Methods. The experiment was conducted on 100 rat specimens under vivarium conditions. The study involved 3-month-old edentulous (toothless) rats. At the initial stage, all animals underwent a one-week quarantine, after which, excluding cases of somatic or infectious diseases, they were allowed to follow the standard vivarium regimen with three meals per day. To study the effect of salt on kidney function, a physiological saline solution of the following concentration was used in the experimental groups. The experiment was conducted using the methodology described by Sanders (2004) and Lambers Heerspink, Navis, and Ritz (2012).

In the observation group, where the expected daily sodium intake was 4 to 5.99 g (equivalent to 10–15 g of sodium chloride per day), the amount of salt was calculated in mg/kg of the animal's body weight using the formula: Salt amount (mg/kg) = Total salt consumed (mg) / Body weight (kg)
For example, if a person weighs 70 kg and consumes 7 g of salt per day, the salt amount per kg would be:
7000 mg / 70 kg = 100 mg/kg.

During the experiment, one group of animals received 15 g of salt dissolved in 500 ml of water daily over a specified period, while the other group received salt in a standard manner. The results showed that animals consuming higher amounts of salt exhibited elevated blood pressure and no positive changes in kidney function. Additionally, water retention and kidney stone formation were observed. This experiment confirms the potential negative effects of excessive salt intake on kidney function and the development of various disorders. Therefore, salt intake control is considered an important aspect of maintaining healthy kidney function. In this study, animals were divided into two groups to examine the potential impact of salt on kidney health and the possible consequences of excessive dietary intake:

- The first group was the control group, in which the rats were maintained on a standard diet with normal salt content to provide a baseline for comparison.
- The second group received salt water as part of their diet—approximately 12–14 ml per 100 g of body weight per day. This amount of salt water was administered for one month. Such intake may lead to effects such as elevated blood pressure and kidney damage due to water and sodium retention in the body.

Out of all the animals used in the experiment, only one did not complete the study.

Animal Grouping Based on Experimental Design

Groups	Experiment Description	Number of Animals
I – Control Group	Standard diet	50
II – Salt Solution Group	Received salt solution	50

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Throughout the experiment, researchers monitored body weight dynamics, the overall condition, and behavior of the animals. No abnormalities were observed in the general condition or behavior. At the end of the experiment, the animals were carefully weighed, and under anesthesia, they were decapitated using obstetric scissors for tissue sampling and further experimental analysis. The medical-biological assessments were carried out in accordance with international recommendations for the use of laboratory animals in scientific research. The study utilized organometric, histological, histomorphometric, microscopic, and statistical methods. Using these methods, the morphogenesis of the kidneys was investigated at the organ, tissue, and cellular levels. To process the research results, statistical tools and data analysis were applied. After removal, the kidneys were weighed using VLR-200 laboratory scales (2019) with an accuracy of 0.25 mg. The length, width, and thickness were measured using a caliper with a precision of 0.05 mm. All measurements were recorded in material collection protocols. The absolute and relative mass and volume of the kidneys were calculated using a standard empirical coefficient formula based on sonographic data:

Volume formula:
$V = 0.523 \times a \times b \times c$,
where a = length, b = width, and c = thickness of the kidney.

After organometric assessment, the kidneys were preserved in a 10% solution of neutral formalin. Following fixation, the specimens were immersed in water for one hour, then processed using a standard protocol: dehydration in ethanol and subsequent embedding in paraffin blocks. Using the MC-2 microtome, paraffin sections 4–6 µm thick were prepared and stained with hematoxylin-eosin and Van Gieson's method. The sections were analyzed morphometrically using an eyepiece micrometer DN-107 T / Model NLSD-307 B ("Nobel," China).

Measurements included: Kidney capsules Arterial vessels Proximal and distal tubules Other structural elements of the organ

Morphometric indicators of kidneys in the control group (3-month-old rats)

Parameter	Capsule Thickness (µm)	Cortical Layer Thickness (µm)	Medullary Layer Thickness (µm)
Location	Upper Pole	Hilum	Below Pole
Values	7.93±0.63	10.11±0.55	7.65±0.79

Note: Significant difference compared to the previous study period ($P < 0.05$)** - $P < 0.01$*** - $P < 0.001$

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When the body needs to retain water, the medullary regions of the kidneys create a high osmotic gradient, which leads to the retention of osmotically free water and the formation of concentrated urine. Conversely, when the body needs to eliminate excess water, the medullary regions reduce the osmotic gradient, promoting the excretion of osmotically free water and the formation of dilute urine. It has been conclusively proven that consuming more than 5 g of NaCl per day is a risk factor for the development and progression of cardiovascular diseases. Epidemiological data have been provided on NaCl consumption in various countries and regions around the world, along with the challenges of detecting excessive salt intake. The most successful models and preventive strategies aimed at limiting salt intake have also been reviewed. The kidneys filter blood and excrete excess sodium and other substances through urine. However, excessive salt consumption can overload the kidneys, potentially leading to kidney tissue damage and renal failure. High salt intake may also contribute to the formation of kidney stones. This is because excess sodium in urine can increase the concentration of calcium and other minerals, which promotes stone formation. Sodium control is especially important for people with hypertension or other kidney diseases, as high salt intake can worsen symptoms and increase the risk of complications. Additionally, excess salt can impair urinary tract function, increasing the risk of urinary tract infections (UTIs) and other urogenital disorders. Water retention in Liddle syndrome occurs due to disrupted sodium reabsorption, accompanied by hypokalemia, metabolic alkalosis, and decreased levels of renin and aldosterone in plasma.

Morphometric Indicators of Kidneys in the Experimental Group

Research Duration	Capsule Thickness (µm)	Cortex Thickness (µm)	Medulla Thickness (µm)
Location	Upper Pole	Hilum	Below Pole
3 months	9.02±0.82**	12.03±0.85**	8.20±0.80*

Note: significant difference compared to the control group ($P < 0.05$) ** - $P < 0.01$ *** - $P < 0.001$

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Results. Salt-induced kidney damage can lead to various conditions, such as kidney stones, renal failure, and other urogenital problems. The primary echanism of salt's impact on the kidneys is through increased blood volume. High salt intake causes the body to retain water, which increases blood volume. This increase puts pressure on blood vessel walls and burdens the kidneys, which are responsible for filtering blood and removing excess water and waste. Chronic salt consumption can lead to a range of kidney problems. First, high blood pressure can damage the renal blood vessels, impairing kidney function. Second, excess salt promotes kidney stone formation, as elevated sodium levels in the urine increase the risk of salt crystal buildup, forming kidney stones.

Discussion. Excessive salt consumption in the diet can have serious negative health consequences. One of the main harmful effects of high salt intake is its association with elevated blood pressure. An excess of sodium in the body can cause fluid retention in tissues, increasing the volume of blood in the vessels and, consequently, the pressure on arterial walls. High blood pressure raises the risk of developing cardiovascular diseases, such as heart attacks, strokes, and arrhythmias. Excessive salt intake can also have a negative impact on kidney function. The kidneys play a critical role in regulating the body's sodium levels, and too much salt can overload and damage them. Elevated sodium levels in the body can lead to calcium loss through urine, which in turn may increase the risk of developing osteoporosis and other bone diseases. Some studies have also linked excessive salt consumption to an increased risk of stomach cancer. Furthermore, high salt intake can result in fluid retention in tissues, leading to swelling and edema. This may also worsen skin conditions, causing puffiness and irritation.

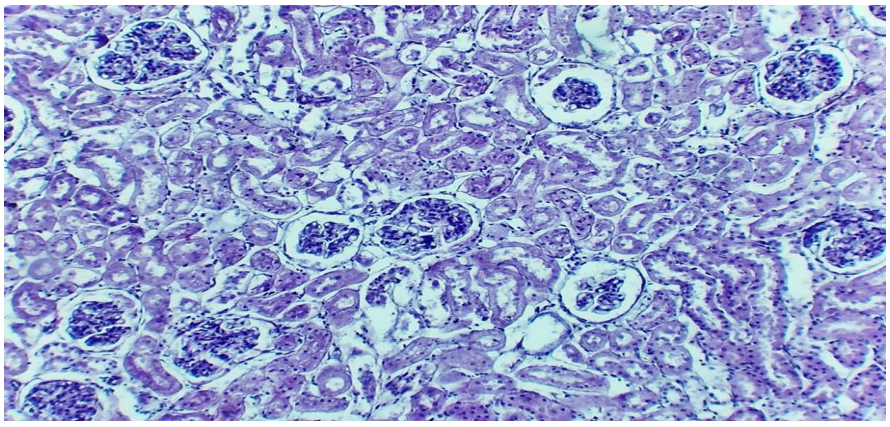

Figure 2. Microscopic view of renal failure. Hydropic degeneration and nuclear necrosis are observed in the proximal and distal tubules

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(1).
Vacuolar degeneration and foci of karyolysis are also detected (2). Staining: hematoxylin and eosin, magnification 10×10.

Thus, studies show that a diet high in sodium chloride (NaCl) can have negative effects on human health. Excessive salt intake may lead to various problems, including high blood pressure, an increased risk of cardiovascular diseases such as heart attack and stroke, as well as a higher risk of kidney diseases and osteoporosis. Therefore, it is important to moderate salt consumption and opt for healthier alternatives, such as using herbs and spices to enhance the flavor of food, and increasing the intake of fresh fruits and vegetables. Reducing salt intake can significantly lower the risk of developing serious diseases and help maintain overall health.

Conclusion

In conclusion, excessive salt consumption can negatively affect the kidneys, leading to elevated blood pressure, damage to blood vessels, and the formation of kidney stones. Therefore, limiting salt intake and drinking an adequate amount of water are essential for maintaining kidney health.

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