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Updated Guidelines for Low-Sodium Diets

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CPE Level 2

Sodium is an essential mineral, meaning it's required for humans to consume it in order for the body to function properly. Sodium plays a role in nerve conduction, maintains extracellular fluid volume, and helps maintain proper balance of water and other minerals.

The words sodium and salt are interchangeably used. Sodium is what is found in food, including processed food that uses sodium as a preservative. Sodium also can be found in sauces, salad dressing, fast foods, snacks, salted nuts, and canned foods. Sodium also is naturally occurring in small amounts in some foods, including celery, beets, and milk.[1]

Salt refers to the sodium added to food when the saltshaker is used.[1] It's made of 40% sodium and 60% chloride. Studies show that only 11% of sodium comes from the saltshaker. The focus is on sodium chloride specifically because some studies show that the increase in plasma volume and blood pressure aren't present with other types of sodium compounds, like sodium citrate, sodium phosphate, or sodium bicarbonate, as they are with sodium chloride.[2] In this course, the word sodium is used.

While sodium is an essential mineral, many decades of research have shown that consuming too much of it may contribute negatively to hypertension, CVD, chronic kidney disease (CKD), stroke, and heart failure. This led to many guidelines being instituted to lower dietary sodium intake. The 2020–2025 Dietary Guidelines for Americans recommend less than 2,300 mg of sodium as part of a healthful eating pattern.[3] The World Health Organization recommends that the general population consume less than 2,000 mg of sodium daily to prevent CVD.[4] The American Heart Association guidelines recommend a daily sodium intake of less than 2,300 mg in the general population and 1,500 mg among individuals who are at a greater risk of CVD.[5] This includes those older than age 50, African Americans, and those who have hypertension, type 2 diabetes, or CKD. The American Heart Association emphasizes a sodium restriction of less than 1,500 mg per day to be a dietary metric to achieve optimal heart health for most adults.[6]

This continuing education course reviews the impact of updated guidelines on low-sodium diets for the general population, individuals with chronic conditions, such as hypertension, heart failure and CKD, and those taking certain medications. It concludes with practical advice on how many milligrams of sodium nutrition professionals should recommend to certain populations.

Salt Sensitivity and Sodium Restriction

Salt sensitivity is estimated to be prevalent in about 51% of people with high blood pressure and in 26% of people with normal blood pressure.[7] Some studies show there's a genetic component to our bodies' physiological response to levels of salt intake, also known as salt sensitivity. Individuals who are salt sensitive have a lesser activation of the renin-angiotensin-aldosterone system, a hormone system that helps regulate blood pressure. They also may have a defect of membrane ion transportation, which means their ion transport system that plays a role in blood pressure doesn't work properly, causing an increase in blood pressure when consuming large quantities of salt above their threshold. Moreover, they may have abnormalities in the Na+/Ca2+ exchange, an ion transport system that helps regulate the amount of calcium and sodium in the cells.[8] This means that reducing sodium consumption in these populations may have more of an impact on lowering blood pressure.

Given this faulty mechanism, some individuals retain salt more readily, which can present as headaches, confusion, dizziness, swelling of the hands, and fluid retention after sodium and salt intake.[8] Salt sensitivity has been shown to be more prevalent in the elderly, African Americans, Japanese populations, individuals who are obese (BMI >30), and those who have CKD or metabolic syndrome.[7]

Sodium Restriction and the General Population

In the Prospective Urban Rural Epidemiology study, data from 18 countries that included 95,767 individuals were analyzed to assess the impact of sodium intake and blood pressure. The study participants were between the ages of 35 and 70 and without CVD. The morning fasting urine was used as a 24-hour sodium and potassium excretion to assess sodium and potassium intake. The average blood pressure increased by 2.86 mm Hg per 1,000 mg increase of sodium intake, but significant findings were apparent only in communities that consumed greater than 5,000 mg of sodium per day. Individuals in China who consumed above 5,000 mg of sodium per day had a stronger risk of strokes compared with other countries.[9] International guidelines may vary greatly. Specifically, updated 2022 guidelines from the Taiwan Society of Cardiology and the Taiwan Hypertension Society for the management of hypertension recommend 2 to 4 g per day (5 to 10 g of salt per day) for better blood pressure control and lower cardiovascular risk.[10]

The question that needs to be addressed is should there be different sodium recommendations for those already struggling with a medical condition than the general population who may be seeking prevention and optimal health?

A meta-analysis of 23 cohort studies and two follow-up randomized controlled trials examined the relationship between various sodium intakes and incidence of all-cause mortality and CVD events. The intakes were categorized as low sodium (less than 2,644 mg), usual sodium (low usual sodium: 2,644 to 3,793 mg, high usual sodium: 3,794 to 4,943 mg) and high sodium (> 4,943 mg). Usual sodium intake was associated with

lower all-cause mortality and CVD events than was low sodium intake; both of these factors were increased in high vs usual sodium intake. This study suggests that both low sodium intake as well as high sodium intake can negatively impact health outcomes. The studies in this meta-analysis primarily were based on observational studies and were limited by possible measurement errors of sodium intake, and therefore more studies are needed for guidelines to impact these findings.[11]

Dietary Sodium and Athletes

There are certain populations like athletes who have excess sodium losses and may benefit from replenishment through diet, whether it's because of hot climates or intense exercise. Sodium is lost in exercise by sweating.

The American College of Sports Medicine's (ACSM) position statement on water and sodium replenishment states that excessive fluid consumption can result in hyponatremia, also known as low sodium levels (plasma sodium < 130 millimoles per liter [mmol/L]). This happens from diluting the body's sodium levels when large quantities of water are consumed by prolonged endurance athletes.[12] The Position of the Academy of Nutrition and Dietetics, Dietitians of Canada, and the ACSM's position paper on Nutrition and Athletic Performance state that hyponatremia can worsen when sodium loss from sweat isn't restored by proper electrolyte fluid replacements. Due to varying amounts of sweat rates and electrolyte shifts, they recommend a personalized fluid replacement in which sweat rates can be estimated by comparing body weight before and after exercise.[13]

In a review of 52 qualitative analysis studies by Vitale and colleagues, recommendations include starting with 300 to 600 mg of sodium per hour if it's a high sweat rate of more than 1.2 liters per hour, or if they're a "salty sweater," or are exercising for more than two hours. This amount of sodium is advised to consume during exercise. They recommend adjusting the amount individually based on sweat rates, sodium content in sweat, intensity of exercise, body temperature, ambient temperature, kidney function, and the person's body weight.[14]

It's also important to consider individuals who may be at risk of exercise-associated hyponatremia and personalize their recommendations. This includes those with low body weight, low BMI, weight gain during exercise, slow running pace, intake of nonsteroidal anti-inflammatory drugs, extreme heat or extreme cold, and exercise duration of four hours and longer.[15] This study also states that females (especially if menstruating) have a higher risk of exercise-associated hypernatremia; however, Holtzman and colleagues didn't find hormonal fluctuations to have any significant effects on sodium and fluid utilization in female athletes.[15,16]

The Position of the Academy of Nutrition and Dietetics, Dietitians of Canada, and the ACSM's position paper on Nutrition and Athletic Performance state that after exercise, rehydration strategies shouldn't be restricted in dietary sodium, especially when large

sodium losses have occurred during exercise, since it helps to maintain plasma volume.[13]

Chronic Conditions and Sodium Intake

High Blood Pressure

While the sodium intake recommendation for the general population without any chronic conditions is less than 2,300 mg per day, according to the American Heart Association, those who have high blood pressure are advised to limit sodium to 1,500 mg per day.[17]

When too much dietary sodium is consumed, leading to high sodium and low potassium levels, the sodium pump is inhibited. The sodium pump helps transfer sodium and/or potassium ions into and out of the cells. This increases sodium intracellularly and drives calcium into cells, which causes smooth muscle contraction. This contraction increases peripheral vascular resistance, therefore increasing blood pressure in the population, regardless of whether the individual is or isn't salt sensitive.[18]

It's important to look beyond sodium restriction when addressing dietary contributors to blood pressure since the mechanism described above also can be attenuated by potassium intake. In the INTERMAP study, 4,680 men and women were assessed for sodium and potassium excretion levels and their association with blood pressure. The results showed that higher sodium intake measured by sodium excretion was associated with an increase in blood pressure. At lower but not higher levels of 24-hour sodium excretion, potassium consumption blunted the sodium-blood pressure relation. This points to the importance of not just reducing salt intake but ensuring it's coupled with an increase in potassium intake.[19]

In a study by Mente and colleagues, each 1,000 mg increment in estimated sodium excretion caused a 2.11 mm Hg rise in systolic blood pressure and a 0.78 mm Hg rise in diastolic blood pressure. In those who had sodium intakes above 5 g per day, systolic blood pressure rose by 2.58 points. This was higher compared with those who had less than 3 g of sodium per day and exhibited a 0.74 mm Hg rise in systolic blood pressure per 1,000 mg of sodium intake. The findings also showed that individuals with high blood pressure or increased age had higher rises in systolic blood pressure with more sodium than those who didn't have high blood pressure. Potassium had an inverse association with a more significant impact on those who had hypertension and increased age.[20]

Stroke

In a study by Cao and colleagues, the stroke mortality and sodium intakes were collected and analyzed from the Global Burden of Diseases in Japan and China. Results found 2,585,783 Chinese stroke cases and 105,201 Japanese stroke cases happened between 1990 through 2016. In both Japan and China, higher sodium intake correlated with greater stroke mortality and was attributed to likely persistent high blood

pressure. In Japan, the sodium intake was 25 to 30 g in 1960 and 10 g in 2015. In China, it was 15 g in 1988 and 4.7 g in 2009. As sodium intake decreased, stroke mortality related to high sodium consumption declined. The overall net shifts per year were -3.1% in Chinese men, -5% in Chinese women, -4.6% for Japanese men, and -5.7% for Japanese women.[21] While this study shows the benefit of avoiding a high sodium diet (above 15 g), it doesn't give a specific recommendation of what's the ideal salt restriction necessary to prevent strokes.

A dose-response meta-analysis of 16 prospective cohort studies by Zhu and colleagues found that a 100 mmol increment of sodium intake per day increased the risk of stroke by 10%. However, when assessing the daily total, low sodium intake didn't affect stroke mortality, while moderate and heavy sodium intake was associated with a high risk of stroke mortality (RR 1.5 and 1.81, respectively). Low sodium intake was defined as less than 3 g of sodium per day, moderate was defined as between 3 and 5 g of sodium per day, and heavy was above 5 g of sodium per day.[22]

Research shows that the diet most well studied for the benefits in reducing the risk of high blood pressure and stroke is the DASH diet. In a study by Talaei and colleagues, data were used from 57,078 individuals aged 45 to 74 in the Singapore Chinese Health study. Data on participants' diets were obtained via a validated 165-item food frequency questionnaire, and information on mortality was collected through a registry database for up to 22 years. The study constructed DASH scores based on all principles of the DASH diet, such as high fruit, vegetable, nut, dairy, and whole grain products, low sodium, sugar-sweetened beverages, and fresh and processed red meats. Higher DASH scores were associated with a 38% lower risk of stroke mortality; however, this inverse association didn't appear to be caused by specific mineral changes and wasn't impacted by sodium by itself.[23] This points to the importance of considering the whole diet instead of focusing on just one micronutrient like sodium.

Chronic Kidney Disease

Individuals with CKD also have a history of hypertension, which has been shown to cause CKD, indicating the need for a low sodium diet. However, even without high blood pressure, excess sodium can overwhelm the kidneys, making them work harder and potentially lead to further disease progression.

In people with CKD, a high sodium intake causes an expansion in the extracellular volume, which leads to high blood pressure. The renin-angiotensin-aldosterone system is inappropriately activated in people with CKD, leading to vasoconstriction and sodium retention, which contributes to significant rise in blood pressure.[24]

These mechanisms suggest the need for sodium restriction, but the amount may vary and may need to be individualized to achieve results on a per person basis. In a meta-analysis of 11 randomized controlled trials of 738 CKD patients, Garofalo and colleagues looked at salt restriction in CKD stages 1-4 and its effect on blood pressure, proteinuria, and albuminuria. The findings showed that for a moderate sodium intake

restriction of 4.4 g per day lowered systolic blood pressure by 4.9 mm Hg and diastolic blood pressure by 2.3 mm Hg; proteinuria also improved by 0.4 g per day, and albuminuria by 0.05 g per day.[25]

In another meta-analysis by Garofalo and colleagues, individuals with hypertension have a 75% increased risk of de novo CKD compared with those who are normotensive. It's estimated that there's a 10% increased risk of CKD onset for each 10 mm Hg rise in systolic and diastolic blood pressure.[26]

In the LowSALT study, a randomized crossover study, researchers looked at the impact of a 2,300 mg per day vs a 5,000 mg per day sodium restriction on blood pressure, inflammatory markers, kidney function, and volume markers in 20 individuals who had high blood pressure and stage 3-4 CKD. A 5,000 mg per day diet resulted in an increase in glomerular filtration rate and output, along with an increase in extracellular/intracellular fluid ratio, showing a correlation with high sodium intake and fluid retention. Researchers hypothesized that this level of sodium intake was leading to hyperfiltration and causing damage to the kidney. More research is needed due to the small sample size of this study.[27]

Dialysis

Gong and colleagues looked at sodium intake and its acceleration of the decline of residual renal function in people with peritoneal dialysis. They found that a decrease of residual renal function was significant in the high sodium intake group of 3,101 mg or higher of sodium intake per day.[28]

In a small study (n=21), Rodrigues Telini and colleagues assessed the impact of 2,000 mg of sodium intake per day on patients undergoing hemodialysis. The study looked at participants' total body water, blood pressure, and inflammatory markers such as C-reactive protein, tumor necrosis factor, and interleukin. Researchers found that those who had a sodium restriction lowered their inflammatory response, which improved their prognosis. Researchers saw no significant impact in blood pressure and extracellular fluid change in either group.[29]

Evidence shows that those who have CKD are at a higher risk of CVD. In a study by Mills and colleagues, 3,757 individuals were assessed for the relationship between urinary sodium excretion and risk of CVD in patients with CKD, specifically those who had an estimated glomerular filtration rate between 20 and 70 mL/min/1.73 m^2. Over a median of 6.8 years of follow-up, results showed the incidence of composite CVD, including congestive heart failure, myocardial infarction, and stroke events, were 18.4%, 16.5%, 20.6%, and 29.8% from lowest (< 2,894 mg per day) to highest (higher than or equal to 4,548 mg in 24 hours). This indicates that those with higher sodium excretion had a higher risk of CVD. Patients who had the greatest sodium excretion experienced the highest systolic and diastolic blood pressure, waist circumference, daily calorie intake, glycated hemoglobin levels, and triglycerides, which also may have increased the incidence of CVD.[30]

Moreover, it's important to note that in some studies, researchers looked at sodium sensitivity and found that it was associated with a higher prevalence of altered circadian rhythm and elevated blood pressure at night, also known as nocturnal hypertension.[31]

Heart Failure

The Heart Failure Society of America recommends 2 to 3 g per day of sodium intake in all heart failure patients and less than 2 g per day in individuals with moderate to severe heart failure.[32]

These recommendations are based on the body of evidence showing the importance of moderate to low sodium restriction in the management of heart failure. Hypertension is a risk factor for heart failure, and the lifetime risk of heart failure decreases with adequate treatment of blood pressure. Untreated hypertension can contribute to factors that may lead to heart failure, including the development of left ventricular hypertrophy, diastolic dysfunction, and arterial stiffness.[33]

Paterna and colleagues conducted a single-blinded randomized controlled trial of 1,771 patients and looked at the effects of hypertonic saline solution, moderate sodium intake, and high furosemide dose and their effects on hospitalization time, readmissions, and mortality in individuals with class III heart failure. Furosemide is a diuretic commonly prescribed for individuals with heart failure who have fluid retention. The first group received a 30-minute intravenous infusion of 250 mg of furosemide with hypertonic saline solution twice daily and a moderate sodium restriction of 2,160 mg per day. The second group received 250 mg of furosemide twice per day without hypertonic saline solution and a low sodium diet of 1,440 mg per day. Both groups received a 1,000 mL per day fluid restriction. The groups continued their respective sodium restriction upon hospital discharge. The first group had an increase in diuresis, reduction in hospitalization time (3.5 + 1 vs 5.5 +1 days), a lower rate of readmissions (18.5% vs 34.2%) and mortality (12.9% vs 23.8%). This suggests a moderate sodium restriction likely would be more beneficial in this heart failure class III population, given the other modalities used to effectively reduce water retention.[34]

Individuals with class III heart failure have fatigue, palpitation, and shortness of breath upon physical movement. A hypertonic saline solution and moderate sodium restriction appear to assist with fluid control in this class type of heart failure.[35]

In an analysis of 10 articles on the effects of low sodium intake on neurohormonal and fluid overload on heart failure, Lee and colleagues found that 2.6 to 3 g of daily dietary sodium intake led to an effective and significant decreased brain natriuretic peptide, renin, and aldosterone plasma level.[35]

It's important not to overrestrict sodium intake for individuals with heart failure since it may not confer additional benefits. In a randomized, parallel group clinical trial with blinded outcomes assessments, Aliti and colleagues looked at adult in-patients who

were hospitalized with acute decompensated heart failure and the effect of a strict fluid and sodium restriction on their outcomes. Researchers gave the intervention group a maximum fluid allotment of 800 mL per day and an 800 mg per day maximum sodium intake for seven days or less until discharge. The control group had a regular diet with liberal fluid and sodium intake. Weight loss was similar in both groups (-1.95 to -2.45 kg), as well as change in congestion score on day three. Thirst was significantly worse in the intervention group, and there was no significant change in the admission rate between both groups. This study implied that the strict fluid and sodium restriction may have been unnecessary.[36]

More research is needed to assess the appropriate daily sodium recommendation for individuals with heart failure. A pilot study by Butler and colleagues, supported by a National Heart, Lung, and Blood Institute grant, will be a randomized, double-blinded trial with 50 individuals who have heart failure. For 12 weeks, one group will receive 1,500 mg, and the other group 3,000 mg of sodium from a USDA-certified kitchen prepared under nutritional and sodium-content monitoring. Participants also will be instructed on consuming less than 2 liters of fluids per day. A team of dietitians will assist with the interview process and adherence. The primary endpoint of this study is to assess all-cause mortality plus all-cause hospitalization at 12 weeks. Secondary endpoints include use of health care resources and changes in quality of life.[37]

Sodium and Medication Interactions

It's important to note that certain medications can benefit from a sodium restriction or a consistent amount of sodium intake.

In a meta-analysis of 25 studies, Qi and colleagues looked at the blood pressure–reducing impact of calcium channel blockers and angiotensin receptor blockers with low, moderate, and high salt intakes. The study found that individuals with salt-sensitive hypertension and no other chronic medical conditions who were on calcium channel blockers combined with hydrochlorothiazide and moderate salt intake had the most optimal reduction in blood pressure (26.66 mm Hg). Individuals with coexisting obesity who took a calcium channel blocker combined with metformin and a moderate salt intake had an impactful benefit on blood pressure reduction (17.90 mm Hg). Moderate salt intake was approximately 2,800 mg of sodium per day.[38]

Lithium, a medication that reduces the severity and frequency of manic episodes, can be affected by changes in the person's salt intake. It's important not to make sudden changes in salt intake when someone is prescribed lithium. A sudden decrease in sodium may result in higher lithium levels in the blood, while a sudden increase in sodium might cause lithium levels to fall.[39]

Limitations of Studies

An existing challenge regarding the research on this topic is the difficulty of accurately assessing sodium intake in large populations. Many of the studies in this review article

looked at 24-hour urine collection over a short period of time, and unfortunately complicates the validity of long-term lifestyle accuracy recommendations.

Another limitation in many of these studies is the assessment of sodium in isolation vs the consideration of potassium intake. When some studies also looked at the effect of potassium in the equation, a difference in blood pressure response often was observed. Sodium and potassium work in tandem, and the amount of potassium in the diet can influence the impact of sodium on blood pressure. It would be beneficial to have more studies looking at other nutrients such as potassium, calcium, and magnesium in conjunction with sodium for optimal dietary guidelines.

Role of RDs in Sodium Education

The importance of personalization in assessing individuals' sodium needs is a critical part of patient care. RDs are a vital asset to helping patients understand, interpret, and apply appropriate sodium intake guidelines to help them achieve their health goals.

RDs can review nutrition labels, identify hidden sources of sodium, provide educational tips on how to flavor foods and cook without as much salt. They also can help individuals understand the why behind these recommendations to assist with improving their health and compliance to their specific sodium guidelines.

For instance, in a study by Tan and colleagues, 71 individuals with heart failure were educated on a low sodium diet by an RD and were assessed for change in sodium knowledge. While individuals thought they were knowledgeable about a low sodium diet, the Parkland Sodium Knowledge Test showed they weren't compliant with the low sodium diet. After following the RD's guidance, participants' sodium knowledge was significantly greater, and their sodium intake was significantly lower.[40]

Putting It Into Practice

Many individuals may benefit from a sodium restriction, but quantifying how much must be personalized based on their specific health issue, exercise duration, and whether they have salt sensitivity. Individuals who have heart failure, hypertension, or CKD, or are salt sensitive may benefit from the guidelines to restrict sodium to 2,000 mg per day. Sodium restrictions should be individualized and assessed by a doctor and care team.

There are many things to consider if the recommendations were increased. Individuals or populations with higher prevalence of salt sensitivities may be less efficient at processing sodium and could benefit from sticking to the current sodium intake guidelines. Moreover, individuals with hypertension, heart failure, and kidney disease may have a harder time processing excess salt, and a moderate restriction of 2,000 to 2,300 mg may be warranted.

While it's important to note that while severe sodium restriction of less than 1,000 mg per day may not be warranted, it's also relatively easy for individuals to underestimate

their sodium intake unknowingly and achieve 5,000 mg per day. To help individuals achieve optimal sodium intake and reach their goals, a team approach consisting of doctors, exercise physiologists, social workers, and RDs is vital. When individuals need more support adhering to their dietary guidelines, a referral to an RD is be highly recommended.

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References

1. Strazzullo P, Leclercq C. Sodium. ***Adv Nutr***. 2014;5(2):188-190.

2. Bushinsky DA. Tolerance to sodium in patients with CKD-induced metabolic acidosis: does the accompanying anion matter? ***Am J Kidney Dis***. 2019;73(6):858-865.

3. United States Department of Agriculture; Health and Human Services. Dietary Guidelines for Americans 2020–2025. https://www.dietaryguidelines.gov/sites/default/files/2020-12/Dietary_Guidelines_for_Americans_2020-2025.pdf. Published December 2020. Accessed May 18, 2022.

4. Salt intake. World Health Organization website. https://www.who.int/data/gho/indicator-metadata-registry/imr-details/3082. Accessed July 13, 2022.

5. Appel LJ, Frohlich ED, Hall JE, et al. The importance of population-wide sodium reduction as a means to prevent cardiovascular disease and stroke: a call to action from the American Heart Association. ***Circulation***. 2011;123(10):1138-1143.

6. American Heart Association. How much sodium should I eat per day? https://www.heart.org/en/healthy-living/healthy-eating/eat-smart/sodium/how-much-sodium-should-i-eat-per-day. Updated November 1, 2021. Accessed June 2, 2022.

7. Mishra S, Ingole S, Jain R. Salt sensitivity and its implication in clinical practice. ***Indian Heart J***. 2018;70(4):556-564.

8. Dobrynina LA, Shabalina AA, Shamtieva KV, Gnedovskaya EV, Berdalin AB, Krotenkova MV. The predictive value of salt sensitivity and osmotic fragility in the development of cerebral small vessel disease. ***Int J Mol Sci***. 2020;21(6):2036.

9. Mente A, O'Donnell M, Rangarajan S, et al. Urinary sodium excretion, blood pressure, cardiovascular disease, and mortality: a community-level prospective epidemiological cohort study. ***Lancet***. 2018;392(10146):496-506.

10. Wang TD, Chiang CE, Chao TH, et al. 2022 guidelines of the Taiwan Society of Cardiology and the Taiwan Hypertension Society for the Management of Hypertension. ***Acta Cardiol Sin***. 2022;38(3):225-325.

11. Graudal N, Jürgens G, Baslund B, Alderman MH. Compared with usual sodium intake, low- and excessive-sodium diets are associated with increased mortality: a meta-analysis. ***Am J Hypertens***. 2014;27(9):1129-1137.

12. American College of Sports Medicine, Sawka MN, Burke LM, et al. American College of Sports Medicine position stand. Exercise and fluid replacement. ***Med Sci Sports Exerc***. 2007;39(2):377-390.

13. Thomas DT, Erdman KA, Burke LM. Position of the Academy of Nutrition and Dietetics, Dietitians of Canada, and the American College of Sports Medicine: nutrition and athletic performance. ***J Acad Nutr Diet***. 2016;116(3):501-528.

14. Vitale K, Getzin A. Nutrition and supplement update for the endurance athlete: review and recommendations. ***Nutrients***. 2019;11(6):1289.

15. Knechtle B, Chlíbková D, Papadopoulou S, Mantzorou M, Rosemann T, Nikolaidis PT. Exercise-associated hyponatremia in endurance and ultra-endurance performance-aspects of sex, race location, ambient temperature, sports discipline, and length of performance: a narrative review. ***Medicina (Kaunas)***. 2019;55(9):537.

16. Holtzman B, Ackerman KE. Recommendations and nutritional considerations for female athletes: health and performance. ***Sports Med***. 2021;51(Suppl 1):43-57.

17. Cook NR, He FJ, MacGregor GA, Graudal N. Sodium and health-concordance and controversy. ***BMJ***. 2020;369:m2440.

18. Pirahanchi Y, Jessu R, Aeddula NR. Physiology, sodium potassium pump. ***StatPearls***. 2022.

19. Stamler J, Chan Q, Daviglus ML, et al. Relation of dietary sodium (salt) to blood pressure and its possible modulation by other dietary factors: The INTERMAP study. ***Hypertension***. 2018;71(4):631-637.

20. Mente A, O'Donnell MJ, Rangarajan S, et al. Association of urinary sodium and potassium excretion with blood pressure. ***N Engl J Med***. 2014;371(7):601-611.

21. Cao J, Eshak ES, Liu K, Gero K, Liu Z, Yu C. Age-period-cohort analysis of stroke mortality attributable to high sodium intake in China and Japan. ***Stroke***. 2019;50(7):1648-1654.

22. Zhu Y, Zhang J, Li Z, et al. Association of sodium intake and major cardiovascular outcomes: a dose-response meta-analysis of prospective cohort studies. ***BMC Cardiovascular Disord***. 2018;18(1):192.

23. Talaei M, Koh WP, Yuan JM, van Dam RM. DASH dietary pattern, mediation by mineral intakes, and the risk of coronary artery disease and stroke mortality. ***J Am Heart Assoc***. 2019;8(5):e011054.

24. Laurent S, Boutouyrie P. The structural factor of hypertension: large and small artery alterations. ***Circ Res***. 2015;116(6):1007-1021.

25. Garofalo C, Borrelli S, Provenzano M, et al. Dietary salt restriction in chronic kidney disease: a meta-analysis of randomized clinical trials. ***Nutrients***. 2018;10(6):732.

26. Garofalo C, Borrelli S, Pacilio M, et al. Hypertension and prehypertension and prediction of development of decreased estimated GFR in the general population: a meta-analysis of cohort studies. ***Am J Kidney Dis***. 2016;67(1):89-97.

27. Valtuille R. Potential novel benefits of sodium restriction in chronic kidney disease. ***Curr Hypertens Rev***. 2021;17(1):59-66.

28. Gong N, Zhou C, Hu J, et al. High-salt diet accelerated the decline of residual renal function in patients with peritoneal dialysis. ***Front Med (Lausanne)***. 2021;8:728009.

29. Rodrigues Telini LS, de Carvalho Beduschi G, Caramori JC, Castro JH, Martin LC, Barretti P. Effect of dietary sodium restriction on body water, blood pressure, and inflammation in hemodialysis patients: a prospective randomized controlled study. ***Int Urol Nephrol***. 2014;46(1):91-97.

30. Mills KT, Chen J, Yang W, et al. Sodium excretion and the risk of cardiovascular disease in patients with chronic kidney disease. ***JAMA***. 2016;315(20):2200-2210.

31. Kimura G, Dohi Y, Fukuda M. Salt sensitivity and circadian rhythm of blood pressure: the keys to connect CKD with cardiovascular events. ***Hypertens Res***. 2010;33(6):515-520.

32. Heart Failure Society of America, Lindenfeld J, Albert NM, et al. HFSA 2010 comprehensive heart failure practice guideline. ***J Card Fail***. 2010;16(6):e1-e194.

33. Patel Y, Joseph J. Sodium intake and heart failure. ***Int J Mol Sci***. 2020;21(24):9474.

34. Paterna S, Fasullo S, Parrinello G, et al. Short-term effects of hypertonic saline solution in acute heart failure and long-term effects of a moderate sodium restriction in patients with compensated heart failure with New York Heart Association class III (class C) (SMAC-HF study). ***Am J Med Sci***. 2011;342(1):27-37.

35. Lee YW, Huang LH, Ku CH. Use of dietary sodium intervention effect on neurohormonal and fluid overload in heart failure patients: review of select research-based literature. ***Appl Nurs Res***. 2018;42:17-21.

36. Aliti GB, Rabelo ER, Clausell N, Rohde LE, Biolo A, Beck-da-Silva L. Aggressive fluid and sodium restriction in acute decompensated heart failure: a randomized clinical trial. ***JAMA Intern Med***. 2013;173(12):1058-1064.

37. Butler J, Papadimitriou L, Georgiopoulou V, Skopicki H, Dunbar S, Kalogeropoulos A. Comparing sodium intake strategies in heart failure: rationale and design of the prevent adverse outcomes in heart failure by limiting sodium (PROHIBIT) study. ***Circ Heart Fail***. 2015;8(3):636-645.

38. Qi H, Liu Z, Cao H, et al. Comparative efficacy of antihypertensive agents in salt-sensitive hypertensive patients: a network meta-analysis. ***Am J Hypertens***. 2018;31(7):835-846.

39. Tondo L, Alda M, Bauer M, et al. Clinical use of lithium salts: guide for users and prescribers. ***Int J Bipolar Disord***. 2019;7(1):16.

40. Tan CA, Holland SJ, Mozer ME, Sarcinella KE, Tangney CC, Rasmussen HE. Change in knowledge of and adherence to the low-sodium diet in patients with heart failure after nutrition education by a registered dietitian nutritionist. ***Diabesity***. 2019;5(3).

Quiz

1. Which type of salt is most studied and known to cause a rise in blood pressure and plasma volume?
A. Sodium citrate
B. Sodium phosphate
C. Sodium bicarbonate
D. Sodium chloride

2. Which subgroup has more prevalence for salt sensitivity?
A. African Americans
B. Caucasians
C. Individuals less than age 30
D. Women

3. According to 52 qualitative analysis studies, when should individuals replenish sodium intake?
A. After all types of exercise regardless of sweat level
B. Only if exercising for more than three hours
C. When an individual experiences a high sweat rate of more than 1.2 liters per hour
D. Never

4. In a study by Gorafolo and colleagues, what increase in blood pressure led to a 10% increase in chronic kidney disease onset?
A. 5 mm Hg
B. 10 mm Hg
C. 15 mm Hg
D. 20 mm Hg

5. In heart failure stage III, a study looked at hypertonic saline, furosemide, and sodium restriction. Which daily sodium restriction led to the lower rate of readmissions and mortality?
A. 1,000 mg
B. 1,440 mg
C. 2,160 mg
D. 5,230 mg

6. In a study by Rodrigues Telini and colleagues, a 2,000 mg daily sodium restriction in individuals undergoing hemodialysis leads to which of the following?
A. A decrease in blood pressure
B. An increase in blood pressure
C. Extracellular fluid change
D. Reduced inflammatory response

7. In the Prospective Urban Rural Epidemiology Study, sodium intakes higher than which amount showed a strong association with stroke in individuals in China?
A. 1 g
B. 2 g
C. 4 g
D. 5 g

8. What sodium and fluid restriction lead to an increase in a higher congestion score?
A. 500 mg sodium, 1,000 mL fluid restriction
B. 800 mg sodium, 800 mL fluid restriction
C. 1,000 mg sodium, 1,500 mL fluid restriction
D. 1,500 mg sodium, 2,000 mL fluid restriction

9. In a meta-analysis of 23 cohort studies, which amount of daily sodium intake led to a decrease in all-cause mortality and CVD?
A. Low sodium (2,644 g)
B. Usual sodium (2,644 to 3,793 g)
C. High usual sodium (3,794 to 4,943 g)
D. High sodium (> 4,943 g)

10. What could be the result of a sudden decrease in sodium intake when someone is taking lithium?
A. It may result in lower lithium levels in the blood.
B. It may raise their blood pressure.
C. It may decrease their blood pressure.
D. It may result in higher lithium levels in the blood.