ŁOJEWSKA, Julia Natalia, ROSIŃSKA, Kamila, BOCHENEK, Oliwia, KOPER, Mateusz, JANICKA, Ewelina Justyna, PERKO, Agnieszka, ROSIŃSKI, Mateusz and NIEDŹWIEDZKA, Monika. The Impact of Nutrition and Exercise on Kidney Health: How to Prevent Kidney Stones? Quality in Sport. 2024;22:54268. eISSN 2450-3118.
https://dx.doi.org/10.12775/QS.2024.22.54268
https://apcz.umk.pl/QS/article/view/54268

The journal has been 20 points in the Ministry of Higher Education and Science of Poland parametric evaluation. Annex to the announcement of the Minister of Higher Education and Science of 05.01.2024. No. 32553.
Has a Journal's Unique Identifier: 201398. Scientific disciplines assigned: Economics and finance (Field of social sciences); Management and Quality Sciences (Field of social sciences).
Punkty Ministerialne z 2019 - aktualny rok 20 punktów. Załącznik do komunikatu Ministra Szkolnictwa Wyższego i Nauki z dnia 05.01.2024 r. Lp. 32553. Posiada Unikatowy Identyfikator Czasopisma: 201398.
Przypisane dyscypliny naukowe: Ekonomia i finanse (Dziedzina nauk społecznych); Nauki o zarządzaniu i jakości (Dziedzina nauk społecznych).

The authors declare that there is no conflict of interests regarding the publication of this paper.
Received: 13.08.2024. Revised: 12.09.2024. Accepted: 13.09.2024. Published: 16.09.2024.

Impact of Nutrition and Exercise on Kidney Health: How to Prevent Kidney Stones?

1. Julia Natalia Łojewska [JNŁ] - corresponding author
Grochowski Hospital, Grenadierów 51/59, 04-073 Warsaw, Poland
https://orcid.org/0009-0000-1832-2938
e-mail: julia.lojewska@gmail.com

2.Kamila Rosińska- [KR]
Voivodeship Integrated Hospital of Jędrzej Śniadecki in Bialystok, Marii Skłodowskiej-Curie 26, 15-278 Bialystok, Poland
https://orcid.org/0009-0001-8158-2051
e-mail: kamrosinska98@gmail.com

3. Oliwia Bochenek [OB]
Grochowski Hospital, Grenadierów 51/59, 04-073 Warsaw, Poland
https://orcid.org/0009-0005-1482-2544
e-mail: bochenekoliwia1998@gmail.com

4. Mateusz Koper [MK]
National Medical Institute of the Ministry of the Interior and Administration, Wołoska 137, 02-507 Warsaw, Poland
https://orcid.org/0000-0002-1048-2774
e-mail: mateusz.koper1998@gmail.com

5. Ewelina Justyna Janicka [EJJ]
COPERNICUS Medical Entity Sp. z o. o. Nowe Ogrody 1-6, 80-803 Gdańsk, Poland
https://orcid.org/0009-0006-5139-1728
e-mail: ewelina.janicka97@gmail.com

6. Agnieszka Perko [AP]
Independent Public Hospital them. prof. W. Orlowski Medical Centre of Postgraduate Education, Czerniakowska 231, 00-416 Warsaw
https://orcid.org/0009-0005-0942-8470
e-mail: agnieszka.perko97@gmail.com

7. Mateusz Rosiński [MR]
Medical University of Bialystok, Jana Kilińskiego 1, 15-089 Białystok, Poland
https://orcid.org/0009-0009-6193-8282
e-mail: mattt03300@gmail.com

8. Monika Niedźwiedzka [MN]
Medical University of Bialystok, Jana Kilińskiego 1, 15-089 Białystok, Poland
https://orcid.org/0009-0004-9952-3414
e-mail: mon.niedzwiedzka@gmail.com

ABSTRACT

Introduction

Kidney stone disease, characterized by the formation of calculi in the kidneys, is becoming an increasingly common urinary tract disorder in developed countries. Although kidney stone disease may be caused by metabolic disorders, anatomical, functional, and genetic factors, diet plays a crucial role in its formation. Changing dietary habits has become a primary tool in the treatment and prevention of kidney stone disease.

Objective

The aim of this study is to present research on the impact of diet and its individual components on the risk of kidney stone formation. Special attention is given to the role of vitamins, minerals, and dietary habits in the pathogenesis and prevention of this condition.

Materials and Methods

The study involves a review of the scientific literature, considering research published in reputable medical and scientific journals regarding the impact of diet on the risk of kidney stones, focusing on key dietary components such as calcium, magnesium, sodium, vitamins C and D, as well as the role of physical activity and proper hydration.

Conclusions
A balanced diet, proper hydration and maintaining a healthy body weight are fundamental elements in preventing of kidney stone disease. Adequate hydration is crucial; high fluid intake, especially water, dilutes urine and reduces the concentration of lithogenic substances. Calcium and magnesium intake are particularly important as they influence the absorption and excretion of oxalates, and excessive supplementation with vitamins C and D should be avoided. A diet rich in fruits and vegetables, and the limitation of animal protein and salt, can significantly reduce the risk of kidney stone formation. Ultimately, dietary changes and lifestyle modifications, including weight control and physical activity, play a crucial role in preventing kidney stone disease. However, further research is needed to develop effective dietary guidelines tailored to the individual needs of patients.

Keywords: kidney stone disease, diet, nutrition, physical activity

Introduction

Kidney stone disease is a common and increasingly prevalent urinary tract disorder characterized by the formation of deposits in the kidneys. Its incidence is rising in developed countries, attributed to lifestyle changes, including diet and physical activity levels [1]. Risk factors for kidney stone formation may include metabolic disorders, anatomical and functional abnormalities, and genetic factors; however, diet plays the most crucial role [2]. One factor influencing the risk of its occurrence and recurrence is excessive body weight [1]. Changing dietary habits has become a primary tool in the treatment of kidney stone disease [3]. A diet rich in fruits, vegetables, fiber, potassium, calcium, and adequate hydration is associated with a lower risk of kidney stone formation. In contrast, excessive consumption of fructose, oxalate, animal protein, and vitamin C promotes the formation of kidney stones [4]. This literature review discusses research on the impact of diet and its individual components on the formation of kidney stones.

Kidney Stone Disease - Definition and Formation Process

Kidney stone disease is a condition that may be asymptomatic but can also manifest with severe pain, fever, vomiting, or hematuria when stones pass through the urinary tract [5]. Untreated kidney stone disease can lead to permanent kidney damage [6]. Kidney stones, also known as nephroliths, are hard mineral deposits that form in the kidneys or urinary tract [7]. The process of their formation is complex and multi-stage, involving urine supersaturation, crystallization, growth, and aggregation [6]. Kidney stones are composed of calcium oxalate (65.9%), carbapatite (15.6%), urate (12.4%), struvite (2.7%), and brushite (1.7%) [8]. They can be divided into calcium and non-calcium stones. The most common type is composed of calcium oxalate and calcium phosphate [9]. Low urine volume, reduced magnesium and citrate concentration in urine, increased excretion of calcium, oxalates, and uric acid in urine, excessively acidic or alkaline urine pH are the main factors contributing to the formation of kidney stones [10].

Physical Activity

One of the risk factors for kidney stone disease is obesity and overweight [11]. Since body fat is hydrophobic, the proportion of water in the body decreases as obesity increases, which may lead to dehydration and, consequently, an increased risk of kidney stone formation [5]. Therefore, maintaining a healthy body weight and weight loss through reduced food intake and physical activity is crucial. This leads to increased urinary citrate excretion, which is responsible for stone formation [11]. Physical activity, by contributing to weight control and improving glycemic control, can mitigate risk factors such as increased body fat [12] and prevent systemic diseases such as diabetes, hypertension, and gout, which are risk factors for kidney stone formation [13]. Some studies explain the protective effect of physical activity by improving urine flow, regulating body weight, and altering the excretion of lithogenic substances in urine. The greatest benefits were observed when activity increased from low to moderate levels, while additional benefits were less apparent at very high levels of activity [14]. Individuals who limit themselves to sedentary work and engage in less physical activity are more prone to developing kidney stones [15]

Proper Hydration

One of the main factors contributing to kidney stone formation is inadequate hydration and fluid loss due to chronic diarrhea, heat exposure, excessive stress, high levels of physical activity, and excessive sweating [2]. Therefore, it is important to drink an adequate amount of water so that diuresis is between 2 to 2.5 liters per day [16]. A cross-sectional study based on NHANES 2009–2012 cycles observed that adequate hydration (indirectly measured by markers of urine concentration, blood osmolality, and renal response to altered body hydration) may protect against kidney stone formation. Drinking an adequate amount of water, maintaining proper urine output, also prevents the recurrence of stone formation [17]. High fluid intake, especially water, dilutes urine, reduces the amount of lithogenic substances, and lowers the risk of mineral crystallization [2]. Not only the amount of fluids consumed is important, but also their type. Beverages containing fructose increase the risk of kidney stone formation by increasing urinary calcium, oxalate, and uric acid excretion, while coffee consumption reduces this risk by increasing urinary calcium, sodium, and chloride excretion [18]. In a study conducted by Ferraro, Taylor, Gambaro, and Curhan, published in the Clinical Journal of the American Society of Nephrology (CJASN) in 2013, the effect of various beverages on the risk of kidney stone formation was examined. It was concluded that coffee consumption was associated with a reduced risk of stone formation. People who drank more coffee were less likely to develop kidney stone disease compared to those who did not drink coffee or consumed it in smaller amounts. Similar results were found for tea, red wine, white wine, beer, and orange juice. This is likely due to their effect on increasing urine output and their citrate content, which helps prevent stone formation [19]. Additionally, drinks such as lemon, orange, and grapefruit juices contain citrates, which may help prevent calcium oxalate stone formation by increasing citrate levels in urine. Citrates bind with calcium, reducing the risk of stone formation. Therefore, it can be assumed that juices may be an alternative to pharmacotherapy with alkalizing agents [2].

Calcium

Calcium is an important electrolyte involved in bone growth, muscle contraction, glycolysis, and gluconeogenesis [18]. Although kidney stones often contain calcium, low intake of this element may increase the risk of their formation. This is because dietary calcium binds oxalic acid in the intestines, reducing its absorption and eliminating excess oxalate that could precipitate in the kidneys [11].

Sodium

High table salt intake is associated with increased urinary calcium excretion, which promotes kidney stone formation [20]. Each 100 mmol (2300 mg) increase in dietary sodium causes an increase in urinary calcium excretion by approximately 1 mmol (40 mg) in healthy adults [21]. Limiting salt and adequate hydration are key in preventing kidney stone formation, especially in individuals predisposed to this condition [22].

Oxalates

Oxalate is a compound produced in the body and is synthesized by the liver. It can also be ingested through food. The internal production of oxalate is influenced by hydroxyproline, present in meat and products containing gelatin. Additionally, ascorbic acid can affect oxalate levels, and the amount of this acid in the body depends on the diet [21]. Excessive consumption of foods rich in oxalates such as spinach, beets, rhubarb, peanuts, chocolate, and low dietary calcium intake contributes to the formation of kidney deposits. Therefore, individuals prone to stone formation should avoid excessive consumption of these products but also ensure adequate calcium intake in their diet [23]. Studies have shown that individuals with low calcium intake tend to have higher oxalate levels in urine, highlighting the importance of balancing calcium intake to prevent oxalate-related issues [24].

Animal Protein

A diet high in animal protein, such as meat, fish, and poultry, may increase the risk of kidney stones by increasing calcium excretion, uric acid excretion, and lowering urine pH [25]. Animal protein also causes an increase in poorly soluble, non-dissociated uric acid in the urine, which promotes crystallization [21].High protein intake (HPI) increases the risk of death from kidney disease, accelerates the need for dialysis in patients with chronic kidney disease (CKD), and raises the urinary risk factors for kidney stone formation [26].

Vitamin C

High doses of vitamin C may lead to increased oxalate excretion in the urine, which raises the risk of kidney stone formation. Individuals prone to kidney stones should avoid excessive vitamin C supplementation [27]. During the COVID-19 pandemic, an increase in the occurrence of kidney stones was observed, which can be attributed to the increased intake of vitamin C and D supplements. These vitamins were often taken to boost immunity and protect against viruses, but their excessive supplementation may contribute to an increased risk of kidney stone formation [28].

Magnesium

Magnesium can influence the formation of kidney stones by binding with oxalate in the gastrointestinal tract, thereby reducing its absorption and excretion in the urine. Additionally, it may inhibit the crystallization of calcium oxalate in the urine [3]. In the Health and Nutrition Examination Survey (NHANES) conducted from 2011-2018, individuals with higher magnesium intake had a lower risk of developing kidney stones compared to those with lower intake of this mineral. The balance between calcium and magnesium in the diet is also important. Despite the beneficial effects of magnesium, further research is needed to better understand its mechanisms of action and the optimal dose in the context of kidney stone prevention [29].

Vitamin D

Vitamin D increases calcium absorption from the intestines, which may lead to hypercalciuria (increased calcium excretion in the urine) and potentially increase the risk of kidney stone formation [30]. Some clinical studies indicate an increased risk of kidney stones in individuals taking high doses of vitamin D, but the evidence is not conclusive. Therefore, while calcium and vitamin D supplementation is essential for bone health, it may carry a potential risk of kidney stone formation, especially when high doses are taken without control. Further research is necessary to better understand this relationship and to develop safe supplementation guidelines [10]. There are also studies in which patients with the first episode of calcium-containing kidney stones show disturbances in calcium and vitamin D homeostasis, which may contribute to kidney stone formation. Monitoring vitamin D and calcium levels and their metabolism may therefore be crucial in preventing kidney stones [30].

Vegetarian Diet and DASH Diet

A diet rich in vegetables and fruits, low in animal proteins, but including low-fat dairy products and low salt content, is associated with a reduction in kidney stone risk by up to 45% [3]. Individuals following a vegetarian diet experience increased oxalate excretion in the urine [25]. The DASH diet, due to its beneficial components such as calcium, potassium, and magnesium, and its low levels of sodium, animal protein, sugars, and saturated fats, may be an effective way to reduce the risk of kidney stones. The increase in elements such as magnesium, citrate, and potassium in the body, as well as the process of urine alkalization, has a significant impact on reducing the risk of this condition [31], [32].

Conclusion

Recent studies confirm that diet plays a key role in the prevention and pathogenesis of kidney stones. Proper hydration, a balanced diet, and maintaining a healthy body weight are fundamental elements in the prevention of this condition. It is important that dietary strategies are individually tailored, taking into account the specific needs and risks of the patient, and are diligently followed by them. As previously mentioned, further research on the optimal dietary components and their impact on kidney stone risk is necessary to develop effective dietary guidelines.

Author's contribution

Conceptualization,; JNŁ methodology, JNŁ, OB, EJJ; software, MK, AP, KR, MN, MR; check, MK, OB; formal analysis JNŁ, MK, OB; investigation, AP, KR, MN; resources, MR, AP, MR; data curation, AP, KR; writing– rough preparation; JNŁ, OB, EJJ; writing-review and editing, EJJ, MK; visualization, MN; supervision, OB, AP; project administration, MR

All authors have read and agreed with the published version of the manuscript.

Funding Statement

The article did not receive any funding.

Institutional Review and Board Statement

Not applicable.

Informed Consent Statement

Not applicable.

Data Availability Statement

Not applicable.

Conflict of Interest Statement

Authors declare no conflicts of interest.

References:

[1] K. Stamatelou and D. S. Goldfarb, "Epidemiology of Kidney Stones," Healthcare 2023, Vol. 11, Page 424, vol. 11, no. 3, p. 424, Feb. 2023, doi: 10.3390/HEALTHCARE11030424.

[2] R. Siener, "Nutrition and Kidney Stone Disease," Nutrients, vol. 13, no. 6, Jun. 2021, doi: 10.3390/NU13061917.

[3] P. M. Ferraro, M. Bargagli, A. Trinchieri, and G. Gambaro, "Risk of Kidney Stones: Influence of Dietary Factors, Dietary Patterns, and Vegetarian–Vegan Diets," Nutrients 2020, Vol. 12, Page 779, vol. 12, no. 3, p. 779, Mar. 2020, doi: 10.3390/NU12030779.

[4] A. Rodriguez, G. C. Curhan, G. Gambaro, E. N. Taylor, and P. M. Ferraro, "Mediterranean diet adherence and risk of incident kidney stones," Am J Clin Nutr, vol. 111, no. 5, p. 1100, May 2020, doi: 10.1093/AJCN/NQAA066.

[5] L. FRASSETTO and I. KOHLSTADT, "Treatment and Prevention of Kidney Stones: An Update," Am Fam Physician, vol. 84, no. 11, pp. 1234–1242, Dec. 2011, Accessed: Aug. 07, 2024. [Online]. Available: https://www.aafp.org/pubs/afp/issues/2011/1201/p1234.html

[6] Z. Wang, Y. Zhang, J. Zhang, Q. Deng, and H. Liang, "Recent advances on the mechanisms of kidney stone formation (Review)," Int J Mol Med, vol. 48, no. 2, Aug. 2021, doi: 10.3892/IJMM.2021.4982.

[7] S. R. Khan et al., "Kidney stones," Nat Rev Dis Primers, vol. 2, p. 16008, Feb. 2016, doi: 10.1038/NRDP.2016.8.

[8] Z. Ye et al., "The status and characteristics of urinary stone composition in China," BJU Int, vol. 125, no. 6, pp. 801–809, Jun. 2020, doi: 10.1111/BJU.14765.

[9] Z. Xu, X. Yao, C. Duan, H. Liu, and H. Xu, "Metabolic changes in kidney stone disease," Front Immunol, vol. 14, p. 1142207, 2023, doi: 10.3389/FIMMU.2023.1142207.

[10] M. Bargagli, P. M. Ferraro, M. Vittori, G. Lombardi, G. Gambaro, and B. Somani, "Calcium and Vitamin D Supplementation and Their Association with Kidney Stone Disease: A Narrative Review," Nutrients, vol. 13, no. 12, Dec. 2021, doi: 10.3390/NU13124363.

[11] P. Peerapen and V. Thongboonkerd, “Kidney Stone Prevention,” Advances in Nutrition, vol. 14, pp. 555–569, 2023, doi: 10.1016/j.advnut.2023.03.002.
[12] D. Aune, Y. Mahamat-Saleh, T. Norat, and E. Riboli, “Body fatness, diabetes, physical activity and risk of kidney stones: a systematic review and meta-analysis of cohort studies,” Eur J Epidemiol, vol. 33, no. 11, p. 1033, Nov. 2018, doi: 10.1007/S10654-018-0426-4.
[13] B. Hernawan and N. Gonzales, “The Correlation Between Physical Activity and Kidney Stone Formation: A Literature Review,” Smart Medical Journal, vol. 6, no. 2, pp. 89–98, Oct. 2023, doi: 10.13057/smj.v6i1.71483.
[14] X. Feng et al., “Association between physical activity and kidney stones based on dose–response analyses using restricted cubic splines,” Eur J Public Health, vol. 30, no. 6, pp. 1206–1211, Dec. 2020, doi: 10.1093/EURPUB/CKAA162.
[15] H. Konjengbam and S. Y. Meitei, “Association of kidney stone disease with dietary factors: a review,” Anthropological Review, vol. 83, no. 1, pp. 65–73, Mar. 2020, doi: 10.2478/ANRE-2020-0005.
[16] K. N. Gamage, E. Jamnadass, S. K. Sulaiman, A. Pietropaolo, O. Aboumarzouk, and B. K. Somani, “The role of fluid intake in the prevention of kidney stone disease: A systematic review over the last two decades,” Turk J Urol, vol. 46, no. Suppl 1, p. S92, 2020, doi: 10.5152/TUD.2020.20155.
[17] J. S. Wang, H. Y. Chiang, H. L. Chen, M. Flores, A. Navas-Acien, and C. C. Kuo, “Association of water intake and hydration status with risk of kidney stone formation based on NHANES 2009–2012 cycles,” Public Health Nutr, vol. 25, no. 9, p. 2403, Sep. 2022, doi: 10.1017/S1368980022001033.
[18] M. Xu et al., “DIETETIC AND LIFESTYLE RECOMMENDATIONS FOR STONE FORMERS,” Arch Esp Urol, vol. 7, no. 6, pp. 112–122, Feb. 2021, doi: 10.1007/S13238-016-0264-7.
[19] P. M. Ferraro, E. N. Taylor, G. Gambaro, and G. C. Curhan, “Soda and other beverages and the risk of kidney stones,” Clinical Journal of the American Society of Nephrology, vol. 8, no. 8, pp. 1389–1395, Jul. 2013, doi: 10.2215/CJN.11661112/-/DCSUPPLEMENTAL.
[20] R. Kachkoul, G. B. Touimi, G. El Mouhri, R. El Habbani, M. Mohim, and A. Lahrichi, “Urolithiasis: History, epidemiology, aetiologic factors and management,” Malays J Pathol, vol. 45, no. 3, pp. 333–352, 2023.
[21] J. C. Dai and M. S. Pearle, “Diet and Stone Disease in 2022,” J Clin Med, vol. 11, no. 16, Aug. 2022, doi: 10.3390/JCM11164740.
[22] A. Ticinesi, A. Nouvenne, N. M. Maalouf, L. Borghi, and T. Meschi, “Salt and nephrolithiasis,” Nephrology Dialysis Transplantation, vol. 31, no. 1, pp. 39–45, Jan. 2016, doi: 10.1093/NDT/GFU243.
[23] T. Mitchell et al., “Dietary oxalate and kidney stone formation,” Am J Physiol Renal Physiol, vol. 316, no. 3, p. F409, Mar. 2019, doi: 10.1152/AJPRENAL.00373.2018.
[24] J. L. Nishiura, L. A. Martini, C. O. G. Mendonça, N. Schor, and I. P. Heilberg, “Effect of calcium intake on urinary oxalate excretion in calcium stone-forming patients,” Brazilian Journal of Medical and Biological Research, vol. 35, no. 6, pp. 669–675, 2002, doi: 10.1590/S0100-879X2002000600006.

[25] F. Tamborino et al., “Pathophysiology and Main Molecular Mechanisms of Urinary Stone Formation and Recurrence,” International Journal of Molecular Sciences 2024, Vol. 25, Page 3075, vol. 25, no. 5, p. 3075, Mar. 2024, doi: 10.3390/IJMS25053075.
[26] T. Remer et al., “Protein intake and risk of urolithiasis and kidney diseases: an umbrella review of systematic reviews for the evidence-based guideline of the German Nutrition Society,” Eur J Nutr, vol. 62, no. 5, p. 1957, Aug. 2023, doi: 10.1007/S00394-023-03143-7.
[27] E. N. Taylor and G. C. Curhan, “Diet and fluid prescription in stone disease,” Kidney Int, vol. 70, no. 5, pp. 835–839, Sep. 2006, doi: 10.1038/SJ.KI.5001656.
[28] A. Karam, G. Mjaess, H. Younes, and F. Aoun, “Increase in urolithiasis prevalence due to vitamins C and D supplementation during the COVID-19 pandemic,” J Public Health (Oxf), vol. 44, no. 4, pp. E625–E626, Dec. 2022, doi: 10.1093/PUBMED/FDAB328.
[29] S. Shringi, C. A. Raker, and J. Tang, “Dietary Magnesium Intake and Kidney Stone: The National Health and Nutrition Examination Survey 2011-2018”.
[30] H. Ketha et al., “Altered Calcium and Vitamin D Homeostasis in First-Time Calcium Kidney Stone-Formers,” PLoS One, vol. 10, no. 9, Sep. 2015, doi: 10.1371/JOURNAL.PONE.0137350.
[31] E. N. Taylor, M. J. Stampfer, D. B. Mount, and G. C. Curhan, “DASH-Style Diet and 24-Hour Urine Composition,” Clin J Am Soc Nephrol, vol. 5, no. 12, p. 2315, Dec. 2010, doi: 10.2215/CJN.04420510.
[32] F. G. Rodrigues, T. M. Lima, L. Zambrano, and I. P. Heilberg, “Dietary pattern analysis among stone formers: resemblance to a DASH-style diet,” Jornal Brasileiro de Nefrologia, vol. 42, no. 3, p. 338, Jun. 2020, doi: 10.1590/2175-8239-JBN-2019-0183.