Nutr Res Pract. 2022;16(Suppl 1):S70-88
https://doi.org/10.4162/nrp.2022.16.S1.S70
pISSN 1976-1457·eISSN 2005-6168

Nutrition Research and Practice

Review

Dietary Reference Intakes of sodium for Koreans: focusing on a new DRI component for chronic disease risk reduction

Hyun Ja Kim [1], **Yeon-Kyung Lee** [2], **Hoseok Koo** [3], **and Min-Jeong Shin** [4§]

[1]Department of Food and Nutrition, Gangneung-Wonju National University, Gangneung 25457, Korea
[2]Department of Food Science and Nutrition, Kyungpook National University, Daegu 41566, Korea
[3]Department of Internal Medicine, Inje University Seoul Paik Hospital, Seoul 04551, Korea
[4]School of Biosystems and Biomedical Sciences, College of Health Science, Korea University, Seoul 02841, Korea

Received: Nov 10, 2021
Revised: Jan 25, 2022
Accepted: Mar 2, 2022
Published online: Mar 16, 2022

§Corresponding Author:
Min-Jeong Shin
School of Biosystems and Biomedical Sciences, College of Health Sciences, Korea University, 145, Anam-ro, Seongbuk-gu, Seoul 02841, Korea.
Tel. +82-2-3290-5643
Fax. +82-2-916-5943
Email. mjshin@korea.ac.kr

ORCID iDs
Hyun Ja Kim
https://orcid.org/0000-0002-0965-9704
Yeon-Kyung Lee
https://orcid.org/0000-0002-5975-3969
Hoseok Koo
https://orcid.org/0000-0001-7856-8083
Min-Jeong Shin
https://orcid.org/0000-0002-8952-4008

Funding
This research was supported by the Policy Research Program for Project No.

ABSTRACT

Sodium is a physiologically essential nutrient, but excessive intake is linked to the increased risk of various chronic diseases, particularly cardiovascular. It is, therefore, necessary to accomplish an evidence-based approach and establish the Korean Dietary Reference Intakes (KDRIs) index, to identify both the nutritional adequacy and health effects of sodium. This review presents the rationale for and the process of revising the KDRIs for sodium and, more importantly, establishing the sodium Chronic Disease Risk Reduction Intake (CDRR) level, which is a new specific set of values for chronic disease risk reduction. To establish the 2020 KDRIs for dietary sodium, the committee conducted a systematic literature review of the intake–response relationships between the selected indicators for sodium levels and human chronic diseases. In this review, 43 studies published from January 2014 to December 2018, using databases of PubMed and Web of Science, were finally included for evaluating the risk of bias and strength of evidence (SoE). We determined that SoE of the relationship between dietary sodium and cardiovascular diseases, cerebrovascular disease, and hypertension, was moderate to strong. However, due to insufficient scientific evidence, we were unable to establish the estimated average requirement and the recommended nutrient intake for dietary sodium. Therefore, the adequate intake of sodium for adults was established to be 1,500 mg/day, whereas the CDRR for dietary sodium was established at 2,300 mg/day for adults. Intake goal for dietary sodium established in the 2015 KDRIs instead of the tolerable upper intake level was not presented in the 2020 KDRIs. For the next revision of the KDRIs, there is a requirement to pursue further studies on nutritional adequacy and toxicity of dietary sodium, and their associations with chronic disease endpoint in the Korean population.

Keywords: Sodium; Dietary Reference Intake; South Korea

INTRODUCTION

Sodium is an essential element that maintains homeostasis and physiological functions. Being a major cation in the extracellular fluid, sodium is involved in osmotic pressure regulation and water balance, and also plays a role in nerve impulse transmission, muscle

20180415A13-00, 25193068200, 25203084501, from the Ministry of Health and Welfare in 2018–2020.

Conflict of Interest

The authors declare no potential conflicts of interests.

Author Contributions

Conceptualization: Kim HJ, Shin MJ; Investigation: Kim HJ, Lee YK, Koo HS, Shin MJ; Supervision: Shin MJ; Writing - original draft: HJ Kim, Shin MJ; Writing - review & editing: HJ Kim, Shin MJ.

contraction, and acid-base balance [1]. Therefore, insufficient sodium intake is usually associated with adverse health outcomes. Contrarily, excessive sodium intake is a risk factor for several chronic diseases [2,3], particularly cardiovascular, mainly through the effect of sodium intake on blood pressure (BP) [2,4-6]. It is well known that a reduction in the dietary sodium decreases BP and the incidence of hypertension, which is also associated with reduced morbidity and mortality resulting from cardiovascular diseases (CVDs) [2,3,7].

Dietary Reference Intakes (DRIs) are defined as a set of quantitative reference values for the apparently healthy population. They are traditionally used in planning and assessing diets based on nutrient deficiencies and/or toxicities [8]. Previously, an attempt was made for the Korean population to set the Estimated Average Requirement (EAR) and the recommended nutrient intake (RNI) for sodium adequacy, and the tolerable upper intake level (UL) for preventing health problems arising from sodium toxicity [9], leading to the establishment of the sodium adequate intake (AI) instead of the EAR and RNI, and the sodium intake goal instead of the UL, in the 2015 DRIs for Koreans (KDRIs). This was based taking into account the lack of appropriate indicators of sodium exposure, and insufficient scientific evidence on sodium adequacy or toxicity [9]. However, considering the impact of nutrition on the prevention, treatment and health promotion of chronic diseases, the use of chronic disease endpoints to establish the DRIs has been addressed. Population aging and the increased prevalence of chronic diseases worldwide, along with accumulating scientific evidence on the health effect of sodium intake, further potentiated the establishment of dietary recommendations aimed at reducing chronic diseases [8]. As such, there has been a consensus to include a new DRI category for the prevention of chronic diseases, in addition to the traditional framework of DRIs [10].

Very recently, chronic disease risk reduction intake (CDRR) for dietary sodium (a new category of reference values specific for chronic disease risk reduction) has been proposed in the Consensus Study Reports published by the committee of the National Academies of Sciences, Engineering, and Medicine [8]. In this report, the CDRR is defined as the lowest level of intake where there is sufficient strength of evidence (SoE) to characterize a chronic disease risk reduction, which was established in the DRIs for US and Canada [8]. This implies that reducing the sodium intake above the CDRR established would decrease the risk of chronic disease [8]. For the 2020 KDRIs, the committee comprehensively reviewed the available evidence, and considered the update of current KDRIs for sodium by focusing on the CDRR. A thorough systematic literature review of the relationship between dietary sodium and the risk of chronic diseases resulted in the committee establishing the sodium CDRR to prevent chronic diseases as a new category in the 2020 KDRIs.

This review presents the rationale and processes of establishing the KDRIs for adequacy and toxicity of dietary sodium, as well as specific values of the 2020 KDRIs for dietary sodium, using the 4-step evidence-based approach suggested by the US sodium committee [8], comprising the following steps: Step 1. Review and selection of indicators; Step 2. Assessment of the intake–response relationships of the selected indicators and establishment of DRI values; Step 3. Comparison of current population intake levels and DRI values to characterize the risk; Step 4. Discussion of public health implications and special considerations. This report provides the sodium intake level as an AI and, more importantly, we herein report a new CDRR value for dietary sodium for Koreans.

Nutrition Research and Practice

INDICATORS TO ESTABLISH THE KDRIs FOR DIETARY SODIUM

Indicators of sodium adequacy

A critical initial step of the DRIs framework is selection of the indicators for adequate and excessive dietary intakes of sodium. As reported earlier, no sensitive biomarkers are available to help characterize the sodium requirements in a healthy population [8]. For the purpose of the literature review, sodium balance, urinary sodium excretion, and sodium level in blood were selected as indicators of sodium exposure in the 2020 KDRIs. In addition, intermediate biomarkers selected for chronic disease indicators include insulin resistance, plasma renin activity, and BP.

Indicators of sodium toxicity

The UL is defined as the highest intake level at which there is no risk of any adverse health effect in apparently healthy individuals. To set the UL for dietary sodium in the US and Canada, the lowest toxic sodium level was calculated on the basis of an increase in BP due to sodium intake, as the toxicity endpoint in the 2005 DRIs [8]. However, the approach to establish the sodium UL in the report of 2019 jointly developed by the US and Canada differs in that health effects of excessive sodium intakes on BP, stroke and coronary heart need to be considered when establishing the sodium CDRR. Under the synthesis of evidence for the 2020 KDRIs, sodium toxicity should be considered based on toxicity, and not on chronic disease endpoint related indicators.

Chronic disease indicators to establish sodium CDRR

While the sodium UL is established based on the toxic effect derived from excessive intake of sodium, the CDRR indicates the decrease in the risks of chronic diseases with reductions in dietary sodium intake [8]. For the 2020 KDRIs, the committee reviewed the causal relationship between sodium intake and indicators that could potentially inform the sodium CDRRs, including chronic disease endpoints and surrogate markers. The scientific evidence and conclusions previously accumulated in the 2015 KDRIs was also considered for this deliberation. To review the causal relationship between sodium intake and chronic disease, we finally selected CVD (cerebrovascular disease and coronary heart disease), hypertension, cancer (gastric cancer and renal cancer), osteoporosis, obesity, diabetes, and chronic kidney disease as potential health outcomes, and renin-angiotensin-aldosterone system (RAAS), high BP, bone mineral density, bone mineral content, body mass index (BMI), and glomerular injury as surrogate markers (**Fig. 1**). Evidence from these indicators can be accumulated to inform the development of a sodium CDRR. More specifically, if there is moderate to high SoE for a causal relationship and an intake–response relationship between sodium intake and chronic disease indicators, a sodium CDRR would be established [11].

INTAKE–RESPONSE RELATIONSHIP AND SPECIFICATION OF KDRI VALUES

The EAR, RNI, and AI for sodium adequacy

In general, the EAR and RNI are established based on available sufficient scientific evidence for nutrient requirements, in the absence of which the AI is established [12]. Due to insufficient scientific evidence of the intake–response relationship for selected adequacy indicators to establish the EAR and RNI in the 2020 KDRIs (which was similar to the 2015 KDRIs), the

https://doi.org/10.4162/nrp.2022.16.S1.S70

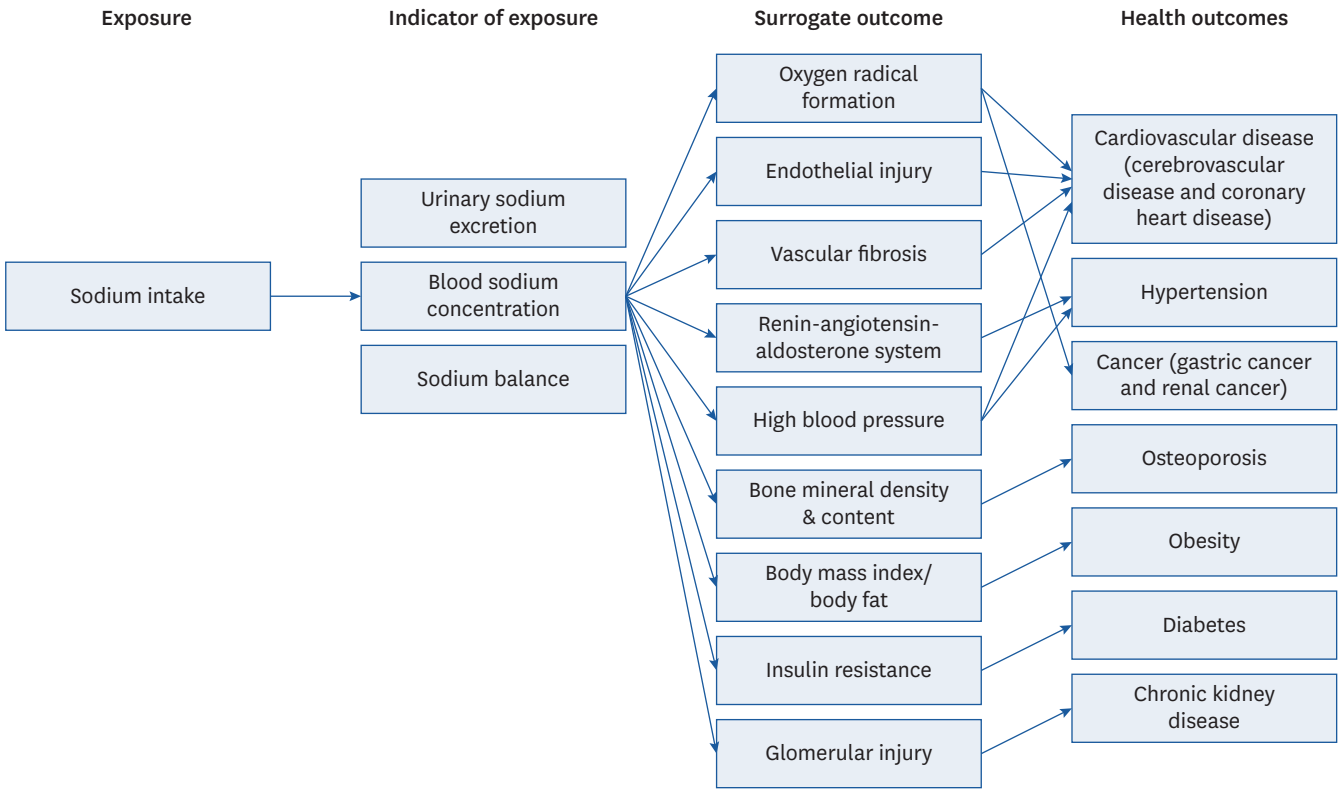

Fig. 1. Indicators of exposure and health outcomes in a systematic review on the causal relationship between sodium intake and chronic disease for establishing the sodium Chronic Disease Risk Reduction Intake level.

committee established the AI of dietary sodium for the 2020 KDRIs. It is generally accepted that AI can be established using the average sodium intake of a healthy population [8] when it is not possible to establish the EAR and RNI. However, the average daily intake of dietary sodium for Koreans was determined to be 3,287 mg according to the 2019 Korea National Health and Nutrition Examination Survey (KNHANES) [13], which is too high to be considered as the sodium AI value. Therefore, the AI for sodium in the 2020 KDRIs was established based on the results of balance studies involving healthy subjects and evidence of the adverse physiological effects of low sodium consumption, such as toxic effects or the occurrence of various diseases [8]. It was established that a diet containing approximately 1,500 mg/day of sodium met the recommended intakes for other nutrients [14]. Increase in plasma levels of total cholesterol was found in the range 460–690 mg/day of sodium intake [15]. When considering the association of sodium intake with insulin resistance, sodium intake lower than 700 mg/day increased insulin resistance [16], while a sodium intake of ≥ 1,200 mg/day was not associated with insulin resistance in non-obese and normotensive men [17]. In addition, evidence from a well-designed balance study conducted among adults [18] reported that sodium intake of 1,525 mg/day among adult men was equivalent to the excreted sodium. Taken together, the appropriateness of the sodium AI value of 1,500 mg/day for adults aged 19–64 years in the 2015 KDRIs was reviewed, and it was decided to recommend this value in the 2020 KDRIs. Since there was no available evidence enough to establish the sodium AI for other age groups, the sodium AI for infants, children, adolescents, and the elderly was calculated by extrapolating from the adult sodium AI value, based on the energy intake involved, as follows [19]:

$$AI_{\text{life stage}} = AI_{\text{adult}} \times (\text{Median Energy Intake of Life Stage/Median Energy Intake of Adult})$$

https://doi.org/10.4162/nrp.2022.16.S1.S70

For males aged 6–8 years, 9–11 years, 12–64 years, 65–74 years, and ≥ 75 years, the sodium AI values were established at 1,100 mg/day, 1,300 mg/day, 1,500 mg/day, 1,300 mg/day, and 1,100 mg/day, respectively. For females aged 6–8 years, 9–64 years, 65–74 years, and ≥ 75 years, the sodium AI values were established at 1,400 mg/day, 1,500 mg/day, 1,400 mg/day, and 1,100 mg/day, respectively. For children aged 1–2 years and 3–5 years, the AI for sodium was 800 mg/day and 1,000 mg/day, respectively, for both genders. The sodium AI for infants was estimated based on the sodium intakes from breastfeeding, and were determined to be 110 mg/day for infants aged 0–5 months, and 370 mg/day for infants aged 6–11 months (**Supplementary Table 1**).

The UL for sodium toxicity

In the 2020 KDRIs, no potential indicators for adverse toxicological effects of sodium were identified subsequent to reviewing the available evidence after excluding the association of sodium intake with chronic disease related indicators. Lethal levels of dietary sodium, primarily due to the ingestion of acute doses, have been previously reported [20-22]. However, they were unsuitable for establishing a sodium UL since the levels did not necessarily reflect the toxicological effects of high sodium intake in our habitual diets. Furthermore, several sodium studies reported that sodium intakes affect the occurrence of headaches [23-25]. However, since the evidence for sodium toxicity was insufficient to determine sodium toxicity risk, the UL for sodium was not established in the 2020 KDRIs. In fact, sodium UL for Koreans has been replaced by intake goal, set at 2,000 mg/day for adults since 2015 KDRIs. The sodium CDRR for reducing the risk of chronic disease is now included as a new category in the 2020 KDRIs; hence, the intake goal of dietary sodium could not be identified in the 2020 KDRIs.

The CDRR for sodium based on chronic disease risk reduction

A systematic literature review was thoroughly conducted to identify scientific evidence of the potential detrimental health effects of excessive intake of dietary sodium. The methods and results of the review are as follows.

Selection of studies for the systematic review

Randomized controlled trials, cohort studies, nested case-control studies, case-control studies, and cross-sectional studies on the relationship between sodium and the risk of several chronic diseases, published between January 2014 and December 2018, were identified using the PubMed (https://pubmed.ncbi.nlm.nih.gov) and Web of Science (https://www.webofknowledge.com) databases. The search keywords used were “salt,” “sodium intake,” “dietary sodium,” and “urinary sodium” for the independent variables, and “CVD,” “cerebrovascular disease,” “coronary heart disease,” “hypertension,” “BP,” “RAAS,” “obesity,” “BMI,” “osteoporosis,” “bone mineral density,” “bone mineral content,” “osteoporotic fracture,” “diabetes,” “chronic kidney disease,” “proteinuria,” “gastric cancer,” and “renal cancer” for dependent variables. Studies written in both Korean and English were included for this review.

Inclusion/exclusion criteria

Articles were extracted based on their titles and abstracts. The inclusion and exclusion criteria were as follows: 1) inclusion of only human studies, 2) in cases of multiple publications involving the same study population, only the most recent study was included, 3) reviews or meta-analyses were excluded. Using these criteria, the studies were reviewed independently by 2 reviewers, and initial disagreements between the reviewers were resolved by eventual consensus between them.

https://doi.org/10.4162/nrp.2022.16.S1.S70

Data collection

The following information was collected from each study: author name, publication year, country, diseases examined, study design, study subjects (health status, life stage, age, and sex), confounding or effect-modifying variables, measures of sodium (dietary sodium intake or urinary sodium excretion), category of sodium intake, outcomes (level of incidence, and mortality and controls), adjusted relative risk/odds ratio with 95% confidence intervals, and trends (P).

Quality evaluation of the study

The quality of each study was evaluated using the Cochrane RoB 2.0 template and the STROBE checklist for intervention and cross-sectional studies, and the Newcastle-Ottawa scale for cohort, nested case-control, and case-control studies. Using these tools, the risk of bias (RoB) level was classified as "low," "some concerns," or "high" for each study. Moreover, the overall SoE was classified into grades I (strong), II (moderate), III (limited), and IV (grade not assignable), based on the criteria employed by the US Department of Agriculture's Nutrition Evidence Library. These grading criteria include quality in relation to RoB, quantity (number of studies and participants), consistency of findings across studies, public health impact (directness and magnitude), and generalizability (references). To establish the sodium CDRR, the SoE for both the causal relationship between sodium intake and chronic disease indicators and their intake–response relationship should be at least moderate, using the Grading of Recommendations, Assessment, Development, and Evaluation (GRADE) system [11].

Results of the systematic literature review

A total of 1,033 articles were identified via the initial computerized literature search. Based on the titles and abstracts of the articles, 248 articles were selected independently by the 2 reviewers. Randomized controlled trials, cohort studies, nested case-control studies, case-control studies, and cross-sectional studies were selected, whereas reviews or meta-analyses were excluded. Moreover, multiple publications that included the same population, insufficient study population, or unhealthy subjects, were excluded. Finally, through a full text review of the remaining articles, 43 studies (7 randomized controlled trials, 18 cohort studies, 3 nested case-control studies, and 15 cross-sectional study) were included for evaluating the RoB and SoE of the harmful effects of sodium intake levels on several chronic diseases (**Fig. 2** and **Table 1**). Details of the eligible studies for the systematic review are presented in **Tables 2** and **3**, **Supplementary Tables 2** and **3**. We found that SoE of the relationship between dietary sodium and CVD, cerebrovascular disease, hypertension, and their surrogate marker systolic/diastolic BP, was at least moderate. Specifically, there was strong evidence for BP lowering the effect of sodium. Furthermore, there was a moderate SoE for the intake–response relationship between sodium intake and the risk of CVD or cerebrovascular disease. However, evidence associating sodium intake with the risk of coronary heart disease, cancer, bone mineral density, RAAS, and obesity were insufficient (limited or grade not assignable) (**Table 4**).

In a meta-analysis of 39 randomized clinical trials on the intake–response, there was a strong SoE that sodium reduction decreased the risk of CVD, hypertension, and systolic/diastolic BP in subjects with a sodium intake of 2,300–4,100 mg/day. In addition, there was a moderate SoE that sodium reduction in subjects with a sodium intake of 4,100–5,000 mg/day decreased the effect of systolic/diastolic BP. However, the SoE was weak for intake levels ≤ 2,300 mg/day [8]. Taken together, we concluded that there is a moderate-to-high SoE for reduced sodium intake decreasing the risk of CVD, hypertension, and BP in persons with

https://doi.org/10.4162/nrp.2022.16.S1.S70

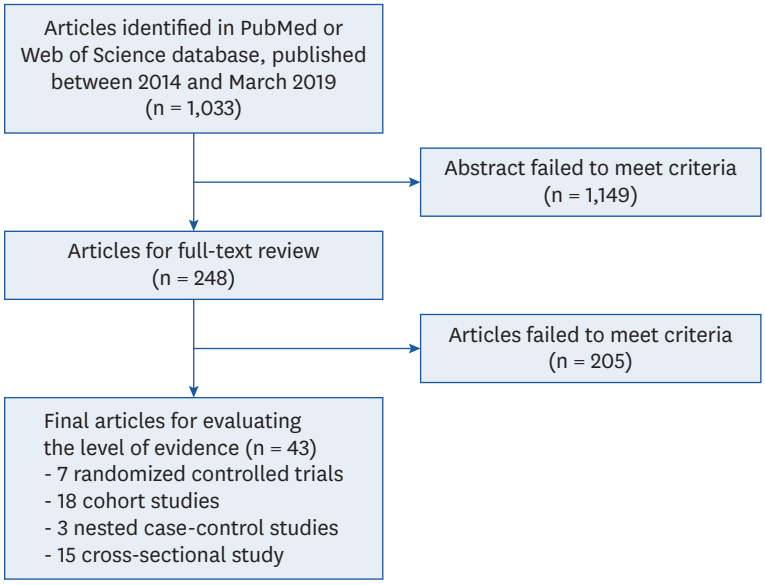

Fig. 2. Study selection process for the systematic review.

sodium intake levels of 2,300–5,000 mg/day. Accordingly, the DRIs jointly developed by US and Canada set 2,300 mg/day as the CDRR of sodium for adults [8]. Based on a systematic review and the CDRR established in the DRIs for US and Canada, the 2020 KDRIs established the CDRR for sodium at 2,300 mg/day for Koreans aged 19–64 years. Moreover, the CDRR for sodium according to age, sex, and life-stage were extrapolated from the adult values by considering the energy intake involved, as follows [19]:

$$CDRR_{life\ stage} = CDRR_{adult} \times (\text{Median Energy Intake of Life Stage/Median Energy Intake of Adult})$$

The sodium CDRR for children aged 1–2 years and 3–5 years was established as 1,200 mg/day and 1,600 mg/day, respectively, for both genders. The CDRR for children aged 6–8 years and 9–11 years was set at 1,800 mg/day and 2,000 mg/day for males, and 2,100 mg/day and 2,300 mg/day for females, respectively, and for adolescents aged 12–18 years the CDRR was set at 2,300 mg for both genders. For the elderly aged 65–74 years and ≥ 75 years, the sodium CDRR values were established as 1,900 mg/day and 1,800 mg/day for males, and 2,200 mg/day and 1,700 mg/day for females, respectively (Supplementary **Table 1**).

Table 1. List of studies included in the systemic literature review

Study design	Author	Year	Title
RCT-parallel	Jenkins *et al*. [38]	2015	The effect of a dietary portfolio compared to a DASH-type diet on blood pressure
	Diaz *et al*. [39]	2014	The effects of weight loss and salt reduction on visit-to-visit blood pressure variability: results from a multicenter randomized controlled trial
	Reidlinger *et al*. [40]	2015	How effective are current dietary guidelines for cardiovascular disease prevention in healthy middle-aged and older men and women? A randomized controlled trial
	Zhou *et al*. [41]	2016	Intake of low sodium salt substitute for 3years attenuates the increase in blood pressure in a rural population of North China - A randomized controlled trial
	Juraschek *et al*. [42]	2017	Effects of sodium reduction and the DASH diet in relation to baseline blood pressure
RCT-crossover	Muth *et al*. [43]	2017	Central systolic blood pressure and aortic stiffness response to dietary sodium in young and middle-aged adults
	Nielsen *et al*. [44]	2016	Changes in the renin-angiotensin-aldosterone system in response to dietary salt intake in normal and hypertensive pregnancy. A randomized trial

(continued to the next page)

Table 1. (Continued) List of studies included in the systemic literature review

Study design	Author	Year	Title
Cohort	Merino *et al*. [45]	2015	Is complying with the recommendations of sodium intake beneficial for health in individuals at high cardiovascular risk? Findings from the PREDIMED study
	Kalogeropoulos *et al*. [46]	2015	Dietary sodium content, mortality, and risk for cardiovascular events in older adults: the Health, Aging, and Body Composition (Health ABC) Study
	Okayama *et al*. [47]	2016	Dietary sodium-to-potassium ratio as a risk factor for stroke, cardiovascular disease and all-cause mortality in Japan: the NIPPON DATA80 cohort study
	Mente *et al*. [48]	2018	Urinary sodium excretion, blood pressure, cardiovascular disease, and mortality: a community-level prospective epidemiological cohort study
	Cook *et al*. [49]	2014	Lower levels of sodium intake and reduced cardiovascular risk
	Willey *et al*. [36]	2017	Dietary sodium to potassium ratio and risk of stroke in a multiethnic urban population: the Northern Manhattan Study
	Prentice *et al*. [50]	2017	Associations of biomarker-calibrated sodium and potassium intakes with cardiovascular disease risk among postmenopausal women
	Li *et al*. [51]	2018	Longitudinal change of perceived salt intake and stroke risk in a Chinese population
	Joosten *et al*. [52]	2014	Sodium excretion and risk of developing coronary heart disease
	Voortman *et al*. [53]	2017	Adherence to the 2015 Dutch dietary guidelines and risk of non-communicable diseases and mortality in the Rotterdam Study
	Takase *et al*. [54]	2015	Dietary sodium consumption predicts future blood pressure and incident hypertension in the Japanese normotensive general population
	Buendia *et al*. [55]	2015	Longitudinal effects of dietary sodium and potassium on blood pressure in adolescent girls
	Timpka *et al*. [56]	2017	Lifestyle in progression from hypertensive disorders of pregnancy to chronic hypertension in Nurses' Health Study II: observational cohort study
	Bertoia *et al*. [57]	2014	Mediterranean and Dietary Approaches to Stop Hypertension dietary patterns and risk of sudden cardiac death in postmenopausal women
	Horikawa *et al*. [58]	2014	Dietary sodium intake and incidence of diabetes complications in Japanese patients with type 2 diabetes: analysis of the Japan Diabetes Complications Study (JDCS)
	Umesawa *et al*. [59]	2016	Salty food preference and intake and risk of gastric cancer: The JACC Study
	Wang *et al*. [60]	2017	Composite protective lifestyle factors and risk of developing gastric adenocarcinoma: the Singapore Chinese Health Study
	Carbone *et al*. [61]	2016	Sodium intake and osteoporosis. Findings from the Women's Health Initiative
Nested case control	Lee *et al*. [62]	2018	Hyponatraemia and its prognosis in acute heart failure is related to right ventricular dysfunction
	Deckers *et al*. [63]	2014	Long-term dietary sodium, potassium and fluid intake; exploring potential novel risk factors for renal cell cancer in the Netherlands Cohort Study on diet and cancer
	Deckers *et al*. [64]	2017	Promoter CpG island methylation in ion transport mechanisms and associated dietary intakes jointly influence the risk of clear-cell renal cell cancer
Cross sectional	Kim *et al*. [65]	2014	The relationship of dietary sodium, potassium, fruits, and vegetables intake with blood pressure among Korean adults aged 40 and older
	Tabara *et al*. [66]	2015	Descriptive epidemiology of spot urine sodium-to-potassium ratio clarified close relationship with blood pressure level
	Noh *et al*. [67]	2015	Association between high blood pressure and intakes of sodium and potassium among Korean adults: Korean National Health and Nutrition Examination Survey, 2007–2012
	Xu *et al*. [68]	2014	Estimation of salt intake by 24-hour urinary sodium excretion: a cross-sectional study in Yantai, China
	Hu *et al*. [69]	2017	Prevalence, awareness, treatment, and control of hypertension among Kazakhs with high salt intake in Xinjiang, China: a community-based cross-sectional study
	Park *et al*. [70]	2016	The effect of the sodium to potassium ratio on hypertension prevalence: a propensity score matching approach
	Navia *et al*. [71]	2014	Sodium intake may promote weight gain; results of the FANPE study in a representative sample of the adult Spanish population
	Ge *et al*. [72]	2016	Are 24 h urinary sodium excretion and sodium:potassium independently associated with obesity in Chinese adults?
	Huh *et al*. [73]	2015	Gender-specific association between urinary sodium excretion and body composition: analysis of the 2008-2010 Korean National Health and Nutrition Examination Surveys
	Murakami *et al*. [74]	2015	Ability of self-reported estimates of dietary sodium, potassium and protein to detect an association with general and abdominal obesity: comparison with the estimates derived from 24 h urinary excretion
	Ma *et al*. [75]	2015	High salt intake: independent risk factor for obesity?
	Grimes *et al*. [76]	2016	24-h urinary sodium excretion is associated with obesity in a cross-sectional sample of Australian schoolchildren
	Oh *et al*. [77]	2017	Associations of sodium intake with obesity, metabolic disorder, and albuminuria according to age
	Nam *et al*. [78]	2017	Association between 24-h urinary sodium excretion and obesity in Korean adults: a multicenter study
	Zhang *et al*. [79]	2018	A positive association between dietary sodium intake and obesity and central obesity: results from the National Health and Nutrition Examination Survey 1999–2006

RCT, randomized controlled trial.

https://doi.org/10.4162/nrp.2022.16.S1.S70

https://e-nrp.org

https://doi.org/10.4162/nrp.2022.16.S1.S70

Table 2. Association between sodium levels and the risk of chronic diseases (event outcomes)

Author (Year), Nation	Study design	Study subjects			Sodium levels		No. of cases/ No. of category	RR/OR (95% CI)	*P* for trend	Confounding variables considered	RoB
		Source of subjects, Mean age (yrs)/Sex (%)	Outcome (incidence or death rate)	Follow-up duration	Measurement unit	Categories					
Cardiovascular disease											
Merino *et al.* (2015) [45], Spain	Cohort	Adults, NA (50–88 yrs)/Males 42.0%	Incidence (125/3,982; 0.031)	1 yr	Intake amounts	Decrease in sodium intake No change in sodium intake Increase in sodium intake	33/1,199 62/2,016 30/767	0.66 (0.38, 1.15) 1.00 1.72 (1.01, 2.91)	0.040	Demographic, anthropic, and medical factors, lifestyles, and foods intake	Low
Kalogeropoulos *et al.* (2015) [46], US	Cohort	Adults, 73.6 (70–79 yrs)/Males 48.8%	Incidence (572/1,981; 0.289)	10 yrs	Intake amounts	< 1,500 mg/day 1,500–2,300 mg/day > 2,300mg/day	63/217 161/576 348/1,188	1.02 (0.79, 1.41) 1.00 1.02 (0.84, 1.24)	0.470	Demographic, anthropic, and medical factors, lifestyles	Low
Okayama *et al.* (2016) [47], Japan	Cohort	Adults, NA (30–79 yrs)/Males 44.5%	Death rate (579/8,283; 0.070)	24 yrs	Intake dietary Na-K ratio	1st quintile 2nd quintile 3rd quintile 4th quintile 5th quintile	110/1,581 114/1,652 100/1,686 113/1,684 142/1,681	1.00 NA NA NA 1.39 (1.20, 1.61)	0.005	Demographic, anthropic, and medical factors, lifestyles, and foods intake	Low
Mente *et al.* (2018) [48], 18 countries	Cohort	Adults, 50.4 (35–70 yrs)/Males 42.1%	Incidence (NA)	8.1 yrs	Intake amounts	1st tertile 2nd tertile 3rd tertile	NA NA NA	−1.00 (−2.00, −0.01) 0.24 (−2.12, 2.61) 0.37 (−0.03, 0.78)	< 0.001	Demographic, anthropic, and medical factors, lifestyles	Low
Cook *et al.* (2014) [49], US	Cohort	Prehypertensive adults, NA (30–54 yrs)/Males 69.5%	Incidence (193/2,312; 0.083)	10–15 yrs	24-h urine	< 2,300 mg/24 h 2,300–< 3,600 mg/24 h 3,600–< 4,800 mg/24hr > 4,800mg/24hr	17/236 61/893 74/768 41/415	0.68 (0.34, 1.37) 0.75 (0.50, 1.11) 1.00 1.05 (0.68, 1.62)	0.130	Demographic, anthropic, and medical factors, lifestyles, and foods intake	Low
Prentice *et al.* (2017) [50], US	Cohort	Postmenopausal women, NA (50–79 yrs)/Female 100%	Incidence (5,897/86,444; 0.068)	12 yrs	Intake	20% increase in intake	5,897/86,444	1.06 (0.92, 1.23)	NA	Demographic, and medical factors, lifestyles	Low
Bertoia *et al.* (2014) [57], US	Cohort	Postmenopausal women, NA (50–79 yrs)/Female 100%	Death rate (237/93,122; 0.003)	10.5 yrs	Intake DASH diet pattern score	1st quintile 2nd quintile 3rd quintile 4th quintile 5th quintile	52/18,465 56/18,216 57/20,220 41/17,808 31/18,413	1.00 1.09 (0.75, 1.60) 1.11 (0.75, 1.63) 0.95 (0.62, 1.45) 0.86 (0.54, 1.38)	0.460	Demographic, anthropic, and medical factors, lifestyles, and foods intake	Low
Horikawa *et al.* (2014) [58], Japan	Cohort	T2DM adults, NA (40–70 yrs)/Males 47.5%	Incidence (132/1,414; 0.09)	8 yrs	Intake amounts	1st quartile 2nd quartile 3rd quartile 4th quartile	23/354 36/350 32/351 41/359	1.00 1.70 (0.98, 2.93) 1.47 (0.82, 2.62) 2.07 (1.16, 3.71)	0.030	Demographic, anthropic, and medical factors, lifestyles, and foods intake	Low
Lee *et al.* (2018) [62], Korea	Nested case-control	Adults, 67.8 ± 14.9 yrs/Males 55.7%	Prevalence (NA)	2 yrs	Serum level	With hyponatraemia Without hyponatraemia	94/116 78/232	1.00 8.00 (4.50, 14.22)	< 0.001	Baseline characteristics	Low
Cerebrovascular disease											
Okayama *et al.* (2016) [47], Japan	Cohort	Adults, NA (30–79 yrs)/Males 44.5%	Death rate (273/8,283; 0.033)	24 yrs	Intake dietary Na-K ratio	1st quintile 2nd quintile 3rd quintile 4th quintile 5th quintile	45/1,581 46/1,652 55/1,686 53/1,684 74/1,681	1.00 NA NA NA 1.43 (1.17, 1.76)	0.002	Demographic, anthropic, and medical factors, lifestyles, and foods intake	Low
Mente *et al.* (2018) [48], 18 countries	Cohort	Adults, 50.4 (35–70 yrs)/Males 42.1%	Incidence (NA)	8.1 yrs	Intake amounts	1st tertile 2nd tertile 3rd tertile	NA NA NA	−0.12 (−0.67, 0.43) 0.28 (−1.26, 1.82) 0.54 (0.12, 0.96)	< 0.001	Demographic, anthropic, and medical factors, lifestyles	Low

(continued to the next page)

https://e-nrp.org

https://doi.org/10.4162/nrp.2022.16.S1.S70

Table 2. (Continued) Association between sodium levels and the risk of chronic diseases (event outcomes)

Author (Year), Nation	Study design	Study subjects			Sodium levels		No. of cases/ No. of category	RR/OR (95% CI)	*P* for trend	Confounding variables considered	RoB
		Source of subjects, Mean age (yrs)/Sex (%)	Outcome (incidence or death rate)	Follow-up duration	Measurement unit	Categories					
Willey *et al.* (2017) [36], US	Cohort	Adults, 69 ± 10 yrs/ Males 36%	Incidence (274/2,496; 0.110)	12 yrs	Intake dietary Na-K ratio	Increase in Na-K ratio	274/2,496	1.58 (1.20, 2.06)	NA	Demographic, anthropic, and medical factors, lifestyles, and foods intake	Low
Prentice *et al.* (2017) [50], US	Cohort	Postmenopausal women, NA (50–79 yrs)/Female 100%	Incidence (2,843/86,444; 0.033)	12 yrs	Intake	20% increase in intake	2,843/86,444	0.98 (0.85, 1.13)	NA	Demographic, and medical factors, lifestyles	Low
Li *et al.* (2018) [51], China	Cohort	Adults, 53.6 ± 12 yrs/ Males 77.8%	Incidence (1,564/79,490; 0.020)	5 yrs	Intake changing pattern	Moderate-stable	1,225/59,241	1.00	NA	Demographic, anthropic, and medical factors, lifestyles	Low
						Moderate-decreasing	141/9,268	0.77 (0.64, 0.91)			
						Moderate-increasing	72/2,975	1.04 (0.82, 1.32)			
						Low-increasing	54/2,879	0.92 (0.70, 1.22)			
						High-decreasing	72/3,242	1.01 (0.79, 1.28)			
Voortman *et al.* (2017) [53], Netherlands	Cohort	Adults, 64.1 (49–83 yrs)/Males 41.9%	Incidence (979/29,442; 0.104)	10.2 yrs	Intake Dutch dietary guidelines	1st quintile	NA	1.00	0.520	Demographic, and anthropic factors, lifestyles, and foods intake	Low
						2nd quintile	NA	0.93 (0.78, 1.12)			
						3rd quintile	NA	0.88 (0.73, 1.06)			
						4th quintile	NA	0.97 (0.80, 1.17)			
						5th quintile	NA	0.92 (0.75, 1.13)			
Hypertension											
Takase *et al.* (2015) [54], Japan	Cohort	Adults, 54.1 ± 10.9 yrs/Males 64.2%	Incidence (1,027/4,523; 0.227)	3.1 yrs	Intake amounts	Lower intake	NA	1.00	< 0.001	Demographic, anthropic, and medical factors, and lifestyles	Low
						Higher intake	NA	1.25 (1.04, 1.50)			
Timpka *et al.* (2017) [56], US	Cohort	Adults, NA (32–39 yrs)/Females 100%	Incidence (572/90,887 PY)	NA	Intake dietary Na-K ratio	1st quartile	NA	1.00	0.650	Demographic, and anthropic factors, lifestyles, and foods intake	Low
						2nd quartile	NA	1.07 (0.82, 1.40)			
						3rd quartile	NA	0.98 (0.75, 1.27)			
						4th quartile	NA	1.07 (0.83, 1.38)			
		Adults, NA (40–49 yrs)/Females 100%	Incidence (5,716/334,976 PY)	NA	Intake dietary Na-K ratio	1st quartile	NA	1.00	0.030		
						2nd quartile	NA	1.04 (0.96, 1.13)			
						3rd quartile	NA	1.10 (1.02, 1.19)			
						4th quartile	NA	1.09 (1.00, 1.18)			
		Adults, NA (50–59 yrs)/Females 100%	Incidence (5,366/20,207 PY)	NA	Intake dietary Na-K ratio	1st quartile	NA	1.00	0.006		
						2nd quartile	NA	1.07 (0.99, 1.15)			
						3rd quartile	NA	1.14 (1.05, 1.23)			
						4th quartile	NA	1.11 (1.02, 1.20)			
Noh *et al.* (2015) [67], Korea	Cross-sectional	Adults, NA (> 19 yrs)/ Males 50.3%	Prevalence (2,812/24,096; 0.120)	-	Intake combinations of Na and K intakes	Low Na/High K	9.50%/4,516	1.00	< 0.001	Demographic, and anthropic factors, lifestyles, and foods intake	Low
						High Na/High K	10.30%/7,532	0.99 (0.84, 1.18)			
						Low Na/Low K	11.80%/7,532	1.19 (1.01, 1.40)			
						High Na/Low K	12.40%/4,516	1.21 (1.02, 1.44)			
Hu *et al.* (2017) [69], China	Cross-sectional	Adults, 46.5 (> 30 yrs)/ Males 46.7%	Prevalence (NA/1,668; 0.455)	-	Intake amounts	1st quartile	NA	1.00	< 0.001	Demographic factors	Low
						2nd quartile	NA	NA			
						3rd quartile	NA	NA			
						4th quartile	NA	1.74 (1.26, 2.39)			
Park *et al.* (2016) [70], Korea	Cross-sectional	Adults, 46.1 (20–79 yrs)/Males 31.8%	Prevalence (NA/30,206; 0.196)	-	Intake dietary Na-K ratio	1st quartile	19.27%/2,356	0.00	NA	Propensity score matching	Low
						2nd quartile	18.00%/2,356	1.02% point			
						3rd quartile	19.44%/2,356	2.74% point			
						4th quartile	21.52%/2,356	3.44% point			

A moderate to strong strength of evidence was determined for the relationship between sodium and cardiovascular disease, cerebrovascular disease, and hypertension.
RR, relative risk; OR, odds ratio; CI, confidence interval; RoB, risk of bias; NA, not available; PY, person years; T2DM, type 2 diabetes mellitus.

Table 3. Association between sodium levels and the risk of chronic diseases (continuous outcomes): hypertension

Author (Year), Nation	Study design	Study subjects			Sodium levels		No. of cases/ No. of category	Mean (95% CI)	*P*-values	Confounding variables considered	RoB
		Source of subjects, Mean age (yrs)/Sex (%)	Outcome	Follow-up duration	Measurement unit	Categories					
Jenkins *et al.* (2015) [38], Canada	RCT	Hyperlipidemia adults, NA (20–85 yrs)/Males 39.0%	Mean arterial pressure	24 wks	Intake	Dietary portfolio	159	−2.1 (−3.0, −1.3)	0.026	-	Low
						DASH-type diet	82	−0.3 (−1.5, 1.0)			
			Systolic blood pressure			Dietary portfolio	159	−2.5 (−3.7, −1.2)	0.045		
						DASH-type diet	82	−0.4 (−2.1, 1.4)			
			Diastolic blood pressure			Dietary portfolio	159	−2.0 (−2.8, −1.2)	0.026		
						DASH-type diet	82	−0.2. (−1.4, 0.9)			
Diaz *et al.* (2014) [39], US	RCT	Overweight adults, 43.9 ± 6.1 yrs/Males 66.0%	Visit-to-visit blood pressure	36 mon	Intake	Sodium light lifestyle	452	7.1 ± 3.0	0.290	-	Low
						Usual care control	463	6.9 ± 2.9			
Reidlinger *et al.* (2015) [40], UK	RCT	Adults, 53 (40–70 yrs)/Males 39.0%	Systolic blood pressure	12 wks	Intake	Restriction on salt and sugar	80	−4.1 (NA)	0.003	-	Low
						Control diet	82	−0.5 (NA)			
			Diastolic blood pressure			Restriction on salt and sugar	80	−2.9 (NA)	0.002		
						Control diet	82	−0.2 (NA)			
Zhou *et al.* (2016) [41], China	RCT	Families, 46.4 ± 13.6 yrs/Males 49.0%	Systolic blood pressure	3 yrs	Intake	Low salt	224	−8.9 (NA)	NA	-	Low
						Normal salt	238	−5.8 (NA)			
			Diastolic blood pressure			Low salt	224	−4.7 (NA)	NA		
						Normal salt	238	−2.4 (NA)			
Juraschek *et al.* (2017) [42], US	RCT	Pre- or stage 1 hypertension adults, 49.1 ± 10.4 yrs/Males 43.0%	Systolic blood pressure	4 wks	Intake	DASH diet	204	−10.4 (−15.5, −5.3)	0.020	-	Low
						Control diet	200	−7.0 (−12.9, −1.2)			
Muth *et al.* (2017) [43], US	RCT	Young adults, 27.0 ± 1.0 yrs	Systolic blood pressure	14 days	Intake	Low sodium diet	85	Young adults: −4.0 (NA)	0.012	-	Some concerns
		Middle-aged adults, 52.0 ± 1.0 yrs/Males 51.0%						Middle-aged: −9.0 (NA)	< 0.001		
						High sodium diet	85	Young adults: NA	NA		
								Middle-aged: NA	NA		
Buendia *et al.* (2015) [55], US	Cohort	Adolescent girl, NA (9–10 yrs)/Females 100%	Systolic blood pressure	10 yrs	Intake dietary Na-K ratio	< 2,000 mg/day	425	108.8 (108.0, 109.7)	0.550	Demographic, and anthropic factors, lifestyles, and foods intake	Low
						2,500–3,000 mg/day	644	109.3 (108.3, 109.6)			
						3,000–4,000 mg/day	905	108.9 (108.6, 109.7)			
						> 4,000 mg/day	211	108.1 (108.0, 110.4)			
			Diastolic blood pressure			< 2,000 mg/day	425	65.6 (64.8, 66.4)	0.560		
						2,500–3,000 mg/day	644	65.6 (64.9, 66.2)			
						3,000–4,000 mg/day	905	65.5 (65.0, 66.0)			
						> 4,000 mg/day	211	64.9 (63.8, 66.1)			

(continued to the next page)

Nutrition Research and Practice

Nutrition Research and Practice

Table 3. (Continued)Association between sodium levels and the risk of chronic diseases (continuous outcomes): hypertension

Author (Year), Nation	Study design	Study subjects			Sodium levels		No. of cases/ No. of category	Mean (95% CI)	*P*-values	Confounding variables considered	RoB
		Source of subjects, Mean age (yrs)/Sex (%)	Outcome	Follow-up duration	Measurement unit	Categories					
Kim *et al.* (2014) [65], Korea	Cross-sectional	Adults, Males 61.5 yrs, Females 59.7 yrs/ Males 38.9%	Systolic blood pressure	-	Intake amounts	Male				Demographic, and anthropic factors, lifestyles, and foods intake	Low
						1st quintile	488	124.6 (123.0, 126.1)	0.600		
						2nd quintile	489	124.4 (123.0, 125.9)			
						3rd quintile	489	124.3 (122.8, 125.7)			
						4th quintile	489	125.5 (124.1, 127.0)			
						5th quintile	488	125.7 (124.1, 127.3)			
						Female					
						1st quintile	768	121.5 (120.2, 122.8)	0.610		
						2nd quintile	768	122.5 (121.3, 123.7)			
						3rd quintile	768	121.9 (120.7, 123.1)			
						4th quintile	768	121.7 (120.5, 123.0)			
						5th quintile	768	121.2 (119.7, 122.4)			
			Diastolic blood pressure			Male					
						1st quintile	488	78.8 (77.8, 79.7)	0.020		
						2nd quintile	489	79.7 (78.8, 80.6)			
						3rd quintile	489	80.5 (79.6, 81.4)			
						4th quintile	489	80.7 (79.9, 81.6)			
						5th quintile	488	80.6 (79.7, 81.6)			
						Female					
						1st quintile	768	76.8 (75.9, 77.3)	0.005		
						2nd quintile	768	78.3 (77.5, 79.0)			
						3rd quintile	768	77.4 (76.7, 78.1)			
						4th quintile	768	78.1 (77.4, 78.9)			
						5th quintile	768	78.4 (77.7, 79.1)			
Tabara *et al.* (2015) [66], Japan	Cross-sectional	Adults, 54 (30–74 yrs)/Males 52.2%	Blood pressure	-	Spot urine	Linear increase in urinary Na-K ratio	9,144	0.112 (NA)	< 0.001	Demographic, anthropic, and medical factors, lifestyles	Low
Noh *et al.* (2015) [67], Korea	Cross-sectional	Adults, NA (> 19 yrs)/ Males 50.3%	Systolic blood pressure	-	Intake combinations of Na and K intakes	Low Na/High K	4,516	113.0 ± 0.30	< 0.001	Demographic, and anthropic factors, lifestyles, and foods intake	Low
						High Na/High K	7,532	113.7 ± 0.22			
						Low Na/Low K	7,532	114.2 ± 0.24			
						High Na/Low K	4,516	114.8 ± 0.31			
			Diastolic blood pressure		Intake combinations of Na and K intakes	Low Na/High K	4,516	73.9 ± 0.21	< 0.001		
						High Na/High K	7,532	75.0 ± 0.17			
						Low Na/Low K	7,532	74.6 ± 0.17			
						High Na/Low K	4,516	75.8 ± 0.22			
Xu *et al.* (2014) [68], China	Cross-sectional	Adults, 42.3 (18–69 yrs)/Males NA	Systolic blood pressure	-	24-h urine	Linear increase in urinary sodium excretion	191	0.16 (NA)	0.010	Demographic, and anthropic factors	Low
			Diastolic blood pressure			Linear increase in urinary sodium excretion	191	0.12 (NA)	0.060		
Park *et al.* (2016) [70], Korea	Cross-sectional	Adults, 46.1 (20–79 yrs)/Males 31.8%	Average treatment effects on systolic blood pressure	-	Intake dietary Na-K ratio	1st quartile	2,356	0.00	NA	-	Low
						2nd quartile	2,356	1.10 ± 0.51			
						3rd quartile	2,356	0.90 ± 0.52			
						4th quartile	2,356	1.40 ± 0.54			
			Average treatment effects on diastolic blood pressure			1st quartile	2,356	0.00			
						2nd quartile	2,356	0.80 ± 0.32			
						3rd quartile	2,356	0.20 ± 0.33			
						4th quartile	2,356	0.90 ± 0.34			

Moderate to strong strength of evidence was determined for the relationship between sodium and hypertension.
CI, confidence interval; RoB, risk of bias; NA, not available; RCT, randomized controlled trial.

Table 4. Level of risk of bias and strength of evidence for the relationship between sodium intakes and chronic diseases

Health outcomes	Authors (Year)	RoB	Overall SoE
Cardiovascular disease	Bertoia *et al.* (2014) [57], Cook *et al.* (2014) [49], Horikawa *et al.* (2014) [58], Kalogeropoulos *et al.* (2015) [46], Okayama *et al.* (2016) [47], Merino *et al.* (2015) [45], Prentice *et al.* (2017) [50], Lee *et al.* (2018) [62], Mente *et al.* (2018) [48]	Low: 8	Moderate
Cerebrovascular disease	Okayama *et al.* (2016) [47], Prentice *et al.* (2017) [50], Voortman *et al.* (2017) [53], Willey *et al.* (2017) [36], Li *et al.* (2018) [51], Mente *et al.* (2018) [48]	Low: 6	Moderate
Coronary heart disease	Joosten *et al.* (2014) [52], Kalogeropoulos *et al.* (2015) [46], Prentice *et al.* (2017) [50], Voortman *et al.* (2017) [53]	Low: 4	Limited
Hypertension	Diaz *et al.* (2014) [39], Kim *et al.* (2014) [65], Xu *et al.* (2014) [68], Buendia *et al.* (2015) [55], Jenkins *et al.* (2015) [38], Noh *et al.* (2015) [67], Reidlinger *et al.* (2015) [40], Tabara *et al.* (2015) [66], Takase *et al.* (2015) [54], Timpka *et al.* (2015) [56], Park *et al.* (2016) [70], Zhou *et al.* (2016) [41], Hu *et al.* (2017) [69], Muth *et al.* (2017) [43], Juraschek *et al.* (2017) [42]	Low: 14 Some concerns: 1	Strong
Gastric cancer	Umesawa *et al.* (2016) [59], Wang *et al.* (2017) [60]	Low: 2	Limited
Renal cancer	Deckers *et al.* (2014) [63], Deckers *et al.* (2017) [64]	Low: 2	Limited
Bone mineral density	Carbone *et al.* (2016) [61]	High: 1	Grade not assignable
RAAS	Nielsen *et al.* (2016) [44]	Some concerns: 1	Grade not assignable
Obesity	Navia *et al.* (2014) [71], Ge *et al.* (2016) [72], Huh *et al.* (2015) [73], Ma *et al.* (2015) [75], Murakami *et al.* (2015) [74], Grimes *et al.* (2016) [76], Nam *et al.* (2017) [78], Oh *et al.* (2017) [77], Zhang *et al.* (2018) [79]	Low: 8 Some concerns: 1	Limited

RoB, risk of bias; SoE, strength of evidence; RAAS, renin-angiotensin-aldosterone system.

INTAKE ASSESSMENT TO CHARACTERIZE RISK

Currently, majority of the populations are reported to consume dietary sodium above the recommended WHO levels [7], while countries consuming less than 2,000 mg of sodium per day are the poor with malnutrition problems [26]. Especially in Asian countries, the mean sodium intakes are higher than 4,600 mg/day [27]. According to the 2019 KNHANES, the average daily sodium intake was 3,287 mg/day (males, 3,851 mg/day; females, 2,699 mg/day) in South Korea, and the percentage of excessive sodium intake of ≥ 2,000 mg/day was 74.0% (84.5% for males and 63.5% for females) among Koreans aged ≥ 9 years [28]. In both developed and developing countries, including South Korea, where various processed foods produced by the modern food supply system are consumed, the feasibility of achieving a sodium intake goal of 2,000 mg/day is constantly questioned. Therefore, it is necessary to set a flexible goal for sodium intake for Koreans, based on the eating habits and food system in this population. Considering the food sources of dietary sodium, the predominant sources of dietary sodium for the Korean population are reported to be salt and kimchi, followed by soy sauce, ramen and soybean paste [13,29]. Moreover, the highest sodium source per serving was ramen (1,563 mg per serving), followed by salted seafood (jeotgal) (956 mg per serving), buckwheat noodles (891 mg per serving), and sandwich/hamburger/pizza (830 mg per serving) [13,29].

PUBLIC HEALTH IMPLICATIONS AND SPECIAL CONSIDERATIONS

Contrary to the conventional idea that a lower sodium intake is healthy, recent studies have reported a U-shaped or J-shaped curve for the association between sodium intake and CVD risks, rather than a continuously increasing positive association [5,30]. Although there is a continuous positive linear relationship between sodium intake and BP, a sodium intake of < 3 g or > 7 g/d increases the risk of CVD in a U-shaped curve, when compared to an intake of 4–5 g/d [30]. Future studies on the effect of very low sodium intakes, and balance studies on adequate sodium intake, are required to establish the AI for sodium in the Korean

https://doi.org/10.4162/nrp.2022.16.S1.S70

population. It should be acknowledged that the absence of reference values of UL or intake goal for dietary sodium does not indicate that there are no adverse toxicological effects of excessive sodium intake. Rather, it means that there is a lack of evidence for the toxicological effects of sodium in healthy populations. Therefore, further studies using the toxicological risk assessment approach are needed in order to set the UL in the future.

It has also been reported that the ratio between dietary sodium and potassium (Na:K ratio) is associated with health outcomes [31-33]. Specifically, a high Na:K ratio is reported to be associated with increased BP, and risk of hypertension and stroke [34-36]. Despite national efforts of reducing sodium intake at the population level, the Na:K ratio remains high among Koreans (ratio of 2.20 in 2019) [37]. Therefore, a health policy that targets lowering of the Na:K ratio is needed to improve public health in the Korean population.

The main limitation is insufficient evidence necessary to assess the relationship between sodium intake and chronic diseases in the Korean population. However, there is considerable evidence worldwide, for understanding the association between sodium intake and chronic disease. Furthermore, a meta-analysis on intake–response conducted by the US committee studying the DRIs of sodium, included Japanese and Chinese studies. Therefore, the CDRR established by the US committee can be used as the provisional CDRR for Koreans. Considering the increasing prevalence of hypertension and CVDs in South Korea, establishing and promoting this CDRR would be beneficial. Further studies on the relationship between sodium intake and chronic diseases are required to establish the CDRR for sodium in the Korean population. Moreover, since the majority of Koreans consume sodium at levels above the CDRR, there is a need to find new solutions, including technological innovations, that can reduce sodium in the food supply and in consumption.

CONCLUSIONS

The 2020 KDRIs established the AI value for dietary sodium intake at 1,500 mg/day for adults aged 19–64 years, which is the same as in the 2015 KDRIs. Moreover, on the basis of a systematic review, the CDRR for sodium was set at 2,300 mg/day for adults aged 19–64 years as a new reference value, specific to chronic disease risk reduction. Intake goal for dietary sodium established in the 2015 KDRIs (instead of the UL) was not presented in the 2020 KDRIs. For the next revision of the KDRIs, further studies are required on sodium adequacy and toxicity, and their associations with chronic diseases, in the Korean population.

SUPPLEMENTARY MATERIALS

Supplementary Table 1

2020 Dietary Reference Intakes for Koreans for sodium and potassium by age, sex, and life stage

Click here to view

Supplementary Table 2

Association between sodium levels and the risk of chronic diseases (event outcomes)

Click here to view

https://doi.org/10.4162/nrp.2022.16.S1.S70

Supplementary Table 3

Association between sodium levels and the risk of chronic diseases (continuous outcomes)

Click here to view

REFERENCES

1. Hall JE. Guyton and Hall Textbook of Medical Physiology. Amsterdam: Elsevier Health Sciences; 2010.
2. He FJ, Li J, Macgregor GA. Effect of longer-term modest salt reduction on blood pressure. Cochrane Database Syst Rev 2013;CD004937.
PUBMED | CROSSREF
3. World Health Organization (WHO). Guideline: Sodium Intake for Adults and Children. Geneva: WHO; 2012.
4. Aburto NJ, Ziolkovska A, Hooper L, Elliott P, Cappuccio FP, Meerpohl JJ. Effect of lower sodium intake on health: systematic review and meta-analyses. BMJ 2013;346:f1326.
PUBMED | CROSSREF
5. 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;27:1129-37.
PUBMED | CROSSREF
6. Whelton PK, Carey RM, Aronow WS, Casey DE Jr, Collins KJ, Dennison Himmelfarb C, DePalma SM, Gidding S, Jamerson KA, Jones DW, et al. 2017 ACC/AHA/AAPA/ABC/ACPM/AGS/APhA/ASH/ASPC/NMA/PCNA guideline for the prevention, detection, evaluation, and management of high blood pressure in adults: a report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. J Am Coll Cardiol 2018;71:e127-248.
PUBMED | CROSSREF
7. Mozaffarian D, Fahimi S, Singh GM, Micha R, Khatibzadeh S, Engell RE, Lim S, Danaei G, Ezzati M, Powles J, et al. Global sodium consumption and death from cardiovascular causes. N Engl J Med 2014;371:624-34.
PUBMED | CROSSREF
8. National Academies of Sciences, Engineering, and Medicine. Dietary Reference Intakes for Sodium and Potassium. Washington, D.C.: The National Academies Press; 2019.
9. Ministry of Health and Welfare (KR). Dietary Reference Intakes for Koreans 2015. Sejong: Ministry of Health and Welfare; 2015.
10. Newberry SJ, Anderson CA, Chen C, Fu Z, Tang A, Zhao N, Booth M, Marks J, Hollands S, Motala A, et al. Sodium and potassium intake: effects on chronic disease outcomes and risks [Internet]. Rockville (MD): Agency for Healthcare Research and Quality; 2018 [cited 2021 October 5]. Available from: https://www.ncbi.nlm.nih.gov/books/NBK519328/.
11. National Academies of Sciences, Engineering, and Medicine. Guiding Principles for Developing Dietary Reference Intakes Based on Chronic Disease. Washington, D.C.: The National Academies Press; 2017.
12. Institute of Medicine. Dietary Reference Intakes: The Essential Guide to Nutrient Requirements. Washington, D.C.: The National Academies Press; 2006.
13. Korea Centers for Disease Control and Prevention (KCDC). Korea Health Statistics 2017: Korea National Health and Nutrition Examination Survey (KNHANES VII-2). Cheongju: KCDC; 2018.
14. Craddick SR, Elmer PJ, Obarzanek E, Vollmer WM, Svetkey LP, Swain MC. The DASH diet and blood pressure. Curr Atheroscler Rep 2003;5:484-91.
PUBMED | CROSSREF
15. Sharma AM, Arntz HR, Kribben A, Schattenfroh S, Distler A. Dietary sodium restriction: adverse effect on plasma lipids. Klin Wochenschr 1990;68:664-8.
PUBMED | CROSSREF
16. Ruppert M, Diehl J, Kolloch R, Overlack A, Kraft K, Göbel B, Hittel N, Stumpe KO. Short-term dietary sodium restriction increases serum lipids and insulin in salt-sensitive and salt-resistant normotensive adults. Klin Wochenschr 1991;69 Suppl 25:51-7.
PUBMED
17. Grey A, Braatvedt G, Holdaway I. Moderate dietary salt restriction does not alter insulin resistance or serum lipids in normal men. Am J Hypertens 1996;9:317-22.
PUBMED | CROSSREF

18. Allsopp AJ, Sutherland R, Wood P, Wootton SA. The effect of sodium balance on sweat sodium secretion and plasma aldosterone concentration. Eur J Appl Physiol Occup Physiol 1998;78:516-21.
PUBMED | CROSSREF

19. Atkinson SA, Koletzko B. Determining life-stage groups and extrapolating nutrient intake values (NIVs). Food Nutr Bull 2007;28:S61-76.
PUBMED | CROSSREF

20. Jung WJ, Park SM, Park JM, Rhee H, Kim IY, Lee DW, Lee SB, Seong EY, Kwak IS, Song SH. Severe hypernatremia caused by acute exogenous salt intake combined with primary hypothyroidism. Electrolyte Blood Press 2016;14:27-30.
PUBMED | CROSSREF

21. Metheny NA, Krieger MM. Salt toxicity: a systematic review and case reports. J Emerg Nurs 2020;46:428-39.
PUBMED | CROSSREF

22. Sakamoto A, Hoshino T, Boku K, Hiraya D, Inoue Y. Fatal acute hypernatremia resulting from a massive intake of seasoning soy sauce. Acute Med Surg 2020;7:e555.
PUBMED | CROSSREF

23. Sacks FM, Svetkey LP, Vollmer WM, Appel LJ, Bray GA, Harsha D, Obarzanek E, Conlin PR, Miller ER 3rd, Simons-Morton DG, et al. Effects on blood pressure of reduced dietary sodium and the Dietary Approaches to Stop Hypertension (DASH) diet. N Engl J Med 2001;344:3-10.
PUBMED | CROSSREF

24. Whelton PK, Appel LJ, Espeland MA, Applegate WB, Ettinger WH Jr, Kostis JB, Kumanyika S, Lacy CR, Johnson KC, Folmar S, et al. Sodium reduction and weight loss in the treatment of hypertension in older persons: a randomized controlled trial of nonpharmacologic interventions in the elderly (TONE). JAMA 1998;279:839-46.
PUBMED | CROSSREF

25. Amer M, Woodward M, Appel LJ. Effects of dietary sodium and the DASH diet on the occurrence of headaches: results from randomised multicentre DASH-Sodium clinical trial. BMJ Open 2014;4:e006671.
PUBMED | CROSSREF

26. Powles J, Fahimi S, Micha R, Khatibzadeh S, Shi P, Ezzati M, Engell RE, Lim SS, Danaei G, Mozaffarian D, et al. Global, regional and national sodium intakes in 1990 and 2010: a systematic analysis of 24 h urinary sodium excretion and dietary surveys worldwide. BMJ Open 2013;3:e003733.
PUBMED | CROSSREF

27. Elliott P, Brown I. Sodium Intakes Around the World. Geneva: World Health Organization; 2007.

28. Korea Disease Control and Prevention Agency. Korea Health Statistics 2019: Korea National Health and Nutritional Examination Survey (KNHANES VIII-1). Cheongju: Korea Disease Control and Prevention Agency; 2020.

29. Rural Development Administration (KR). Food Composition Database 9.1. Wanju: Rural Development Administration; 2019.

30. Mente A, O'Donnell M, Rangarajan S, Dagenais G, Lear S, McQueen M, Diaz R, Avezum A, Lopez-Jaramillo P, Lanas F, et al. Associations of urinary sodium excretion with cardiovascular events in individuals with and without hypertension: a pooled analysis of data from four studies. Lancet 2016;388:465-75.
PUBMED | CROSSREF

31. Teramoto T, Kawamori R, Miyazaki S, Teramukai S; OMEGA Study Group. Sodium intake in men and potassium intake in women determine the prevalence of metabolic syndrome in Japanese hypertensive patients: OMEGA Study. Hypertens Res 2011;34:957-62.
PUBMED | CROSSREF

32. Geleijnse JM, Witteman JC, Stijnen T, Kloos MW, Hofman A, Grobbee DE. Sodium and potassium intake and risk of cardiovascular events and all-cause mortality: the Rotterdam Study. Eur J Epidemiol 2007;22:763-70.
PUBMED | CROSSREF

33. Yang Q, Liu T, Kuklina EV, Flanders WD, Hong Y, Gillespie C, Chang MH, Gwinn M, Dowling N, Khoury MJ, et al. Sodium and potassium intake and mortality among US adults: prospective data from the Third National Health and Nutrition Examination Survey. Arch Intern Med 2011;171:1183-91.
PUBMED | CROSSREF

34. Perez V, Chang ET. Sodium-to-potassium ratio and blood pressure, hypertension, and related factors. Adv Nutr 2014;5:712-41.
PUBMED | CROSSREF

35. Du S, Batis C, Wang H, Zhang B, Zhang J, Popkin BM, Popkin BM. Understanding the patterns and trends of sodium intake, potassium intake, and sodium to potassium ratio and their effect on hypertension in China. Am J Clin Nutr 2014;99:334-43.
PUBMED | CROSSREF

36. Willey J, Gardener H, Cespedes S, Cheung YK, Sacco RL, Elkind MS. Dietary sodium to potassium ratio and risk of stroke in a multiethnic urban population: the Northern Manhattan Study. Stroke 2017;48:2979-83.
PUBMED | CROSSREF

37. Korea Disease Control and Prevention Agency. The Seventh Korea National Health and Nutrition Examination Survey (KNHANES VII-1). Cheongju: Korea Disease Control and Prevention Agency; 2019.

38. Jenkins DJ, Jones PJ, Frohlich J, Lamarche B, Ireland C, Nishi SK, Srichaikul K, Galange P, Pellini C, Faulkner D, et al. The effect of a dietary portfolio compared to a DASH-type diet on blood pressure. Nutr Metab Cardiovasc Dis 2015;25:1132-9.
PUBMED | CROSSREF

39. Diaz KM, Muntner P, Levitan EB, Brown MD, Babbitt DM, Shimbo D. The effects of weight loss and salt reduction on visit-to-visit blood pressure variability: results from a multicenter randomized controlled trial. J Hypertens 2014;32:840-8.
PUBMED | CROSSREF

40. Reidlinger DP, Darzi J, Hall WL, Seed PT, Chowienczyk PJ, Sanders TA; Cardiovascular disease risk REduction Study (CRESSIDA) investigators. How effective are current dietary guidelines for cardiovascular disease prevention in healthy middle-aged and older men and women? A randomized controlled trial. Am J Clin Nutr 2015;101:922-30.
PUBMED | CROSSREF

41. Zhou B, Webster J, Fu LY, Wang HL, Wu XM, Wang WL, Shi JP. Intake of low sodium salt substitute for 3years attenuates the increase in blood pressure in a rural population of North China - A randomized controlled trial. Int J Cardiol 2016;215:377-82.
PUBMED | CROSSREF

42. Juraschek SP, Miller ER 3rd, Weaver CM, Appel LJ. Effects of sodium reduction and the DASH diet in relation to baseline blood pressure. J Am Coll Cardiol 2017;70:2841-8.
PUBMED | CROSSREF

43. Muth BJ, Brian MS, Chirinos JA, Lennon SL, Farquhar WB, Edwards DG. Central systolic blood pressure and aortic stiffness response to dietary sodium in young and middle-aged adults. J Am Soc Hypertens 2017;11:627-34.
PUBMED | CROSSREF

44. Nielsen LH, Ovesen P, Hansen MR, Brantlov S, Jespersen B, Bie P, Jensen BL. Changes in the renin-angiotensin-aldosterone system in response to dietary salt intake in normal and hypertensive pregnancy. A randomized trial. J Am Soc Hypertens 2016;10:881-890.e4.
PUBMED | CROSSREF

45. Merino J, Guasch-Ferré M, Martínez-González MA, Corella D, Estruch R, Fitó M, Ros E, Arós F, Bulló M, Gómez-Gracia E, et al. Is complying with the recommendations of sodium intake beneficial for health in individuals at high cardiovascular risk? Findings from the PREDIMED study. Am J Clin Nutr 2015;101:440-8.
PUBMED | CROSSREF

46. Kalogeropoulos AP, Georgiopoulou VV, Murphy RA, Newman AB, Bauer DC, Harris TB, Yang Z, Applegate WB, Kritchevsky SB. Dietary sodium content, mortality, and risk for cardiovascular events in older adults: the Health, Aging, and Body Composition (Health ABC) Study. JAMA Intern Med 2015;175:410-9.
PUBMED | CROSSREF

47. Okayama A, Okuda N, Miura K, Okamura T, Hayakawa T, Akasaka H, Ohnishi H, Saitoh S, Arai Y, Kiyohara Y, et al. Dietary sodium-to-potassium ratio as a risk factor for stroke, cardiovascular disease and all-cause mortality in Japan: the NIPPON DATA80 cohort study. BMJ Open 2016;6:e011632.
PUBMED | CROSSREF

48. Mente A, O'Donnell M, Rangarajan S, McQueen M, Dagenais G, Wielgosz A, Lear S, Ah ST, Wei L, Diaz R, et al. Urinary sodium excretion, blood pressure, cardiovascular disease, and mortality: a community-level prospective epidemiological cohort study. Lancet 2018;392:496-506.
PUBMED | CROSSREF

49. Cook NR, Appel LJ, Whelton PK. Lower levels of sodium intake and reduced cardiovascular risk. Circulation 2014;129:981-9.
PUBMED | CROSSREF

50. Prentice RL, Huang Y, Neuhouser ML, Manson JE, Mossavar-Rahmani Y, Thomas F, Tinker LF, Allison M, Johnson KC, Wassertheil-Smoller S, et al. Associations of biomarker-calibrated sodium and potassium intakes with cardiovascular disease risk among postmenopausal women. Am J Epidemiol 2017;186:1035-43.
PUBMED | CROSSREF

51. Li Y, Huang Z, Jin C, Xing A, Liu Y, Huangfu C, Lichtenstein AH, Tucker KL, Wu S, Gao X. Longitudinal change of perceived salt intake and stroke risk in a chinese population. Stroke 2018;49:1332-9.
PUBMED | CROSSREF

52. Joosten MM, Gansevoort RT, Mukamal KJ, Lambers Heerspink HJ, Geleijnse JM, Feskens EJ, Navis G, Bakker SJ; PREVEND Study Group. Sodium excretion and risk of developing coronary heart disease. Circulation 2014;129:1121-8.
PUBMED | CROSSREF

53. Voortman T, Kiefte-de Jong JC, Ikram MA, Stricker BH, van Rooij FJ, Lahousse L, Tiemeier H, Brusselle GG, Franco OH, Schoufour JD. Adherence to the 2015 Dutch dietary guidelines and risk of non-communicable diseases and mortality in the Rotterdam Study. Eur J Epidemiol 2017;32:993-1005.
PUBMED | CROSSREF

54. Takase H, Sugiura T, Kimura G, Ohte N, Dohi Y. Dietary sodium consumption predicts future blood pressure and incident hypertension in the Japanese normotensive general population. J Am Heart Assoc 2015;4:e001959.
PUBMED | CROSSREF

55. Buendia JR, Bradlee ML, Daniels SR, Singer MR, Moore LL. Longitudinal effects of dietary sodium and potassium on blood pressure in adolescent girls. JAMA Pediatr 2015;169:560-8.
PUBMED | CROSSREF

56. Timpka S, Stuart JJ, Tanz LJ, Rimm EB, Franks PW, Rich-Edwards JW. Lifestyle in progression from hypertensive disorders of pregnancy to chronic hypertension in Nurses' Health Study II: observational cohort study. BMJ 2017;358:j3024.
PUBMED | CROSSREF

57. Bertoia ML, Triche EW, Michaud DS, Baylin A, Hogan JW, Neuhouser ML, Tinker LF, Van Horn L, Waring ME, Li W, et al. Mediterranean and Dietary Approaches to Stop Hypertension dietary patterns and risk of sudden cardiac death in postmenopausal women. Am J Clin Nutr 2014;99:344-51.
PUBMED | CROSSREF

58. Horikawa C, Yoshimura Y, Kamada C, Tanaka S, Tanaka S, Hanyu O, Araki A, Ito H, Tanaka A, Ohashi Y, et al. Dietary sodium intake and incidence of diabetes complications in Japanese patients with type 2 diabetes: analysis of the Japan Diabetes Complications Study (JDCS). J Clin Endocrinol Metab 2014;99:3635-43.
PUBMED | CROSSREF

59. Umesawa M, Iso H, Fujino Y, Kikuchi S, Tamakoshi A; JACC Study Group. Salty food preference and intake and risk of gastric cancer: the JACC study. J Epidemiol 2016;26:92-7.
PUBMED | CROSSREF

60. Wang Z, Koh WP, Jin A, Wang R, Yuan JM. Composite protective lifestyle factors and risk of developing gastric adenocarcinoma: the Singapore Chinese Health Study. Br J Cancer 2017;116:679-87.
PUBMED | CROSSREF

61. Carbone L, Johnson KC, Huang Y, Pettinger M, Thomas F, Cauley J, Crandall C, Tinker L, LeBoff MS, Wactawski-Wende J, et al. Sodium intake and osteoporosis. J Clin Endocrinol Metab 2016;101:1414-21.
PUBMED | CROSSREF

62. Lee H, Lee SE, Park CS, Park JJ, Lee GY, Kim MS, Choi JO, Cho HJ, Lee HY, Choi DJ, et al. Hyponatraemia and its prognosis in acute heart failure is related to right ventricular dysfunction. Heart 2018;104:1670-7.
PUBMED | CROSSREF

63. Deckers IA, van den Brandt PA, van Engeland M, Soetekouw PM, Baldewijns MM, Goldbohm RA, Schouten LJ. Long-term dietary sodium, potassium and fluid intake; exploring potential novel risk factors for renal cell cancer in the Netherlands Cohort Study on diet and cancer. Br J Cancer 2014;110:797-801.
PUBMED | CROSSREF

64. Deckers IA, van Engeland M, van den Brandt PA, Van Neste L, Soetekouw PM, Aarts MJ, Baldewijns MM, Keszei AP, Schouten LJ. Promoter CpG island methylation in ion transport mechanisms and associated dietary intakes jointly influence the risk of clear-cell renal cell cancer. Int J Epidemiol 2017;46:622-31.
PUBMED | CROSSREF

65. Kim MK, Kim K, Shin MH, Shin DH, Lee YH, Chun BY, Choi BY. The relationship of dietary sodium, potassium, fruits, and vegetables intake with blood pressure among Korean adults aged 40 and older. Nutr Res Pract 2014;8:453-62.
PUBMED | CROSSREF

66. Tabara Y, Takahashi Y, Kumagai K, Setoh K, Kawaguchi T, Takahashi M, Muraoka Y, Tsujikawa A, Gotoh N, Terao C, et al. Descriptive epidemiology of spot urine sodium-to-potassium ratio clarified close relationship with blood pressure level: the Nagahama study. J Hypertens 2015;33:2407-13.
PUBMED | CROSSREF

67. Noh HM, Park SY, Lee HS, Oh HY, Paek YJ, Song HJ, Park KH. Association between High blood pressure and intakes of sodium and potassium among Korean adults: Korean National Health and Nutrition Examination Survey, 2007-2012. J Acad Nutr Diet 2015;115:1950-7.
PUBMED | CROSSREF

68. Xu J, Wang M, Chen Y, Zhen B, Li J, Luan W, Ning F, Liu H, Ma J, Ma G. Estimation of salt intake by 24-hour urinary sodium excretion: a cross-sectional study in Yantai, China. BMC Public Health 2014;14:136.
PUBMED | CROSSREF

69. Hu Y, Wang Z, Wang Y, Wang L, Han W, Tang Y, Xue F, Hou L, Liang S, Zhang B, et al. Prevalence, awareness, treatment, and control of hypertension among Kazakhs with high salt intake in Xinjiang, China: a community-based cross-sectional study. Sci Rep 2017;7:45547.
PUBMED | CROSSREF

70. Park J, Kwock CK, Yang YJ. The effect of the sodium to potassium ratio on hypertension prevalence: a propensity score matching approach. Nutrients 2016;8:482.
PUBMED | CROSSREF

71. Navia B, Aparicio A, Perea JM, Pérez-Farinós N, Villar-Villalba C, Labrado E, Ortega RM. Sodium intake may promote weight gain; results of the FANPE study in a representative sample of the adult Spanish population. Nutr Hosp 2014;29:1283-9.
PUBMED | CROSSREF

72. Ge Z, Zhang J, Chen X, Yan L, Guo X, Lu Z, Xu A, Ma J. Are 24 h urinary sodium excretion and sodium:potassium independently associated with obesity in Chinese adults? Public Health Nutr 2016;19:1074-80.
PUBMED | CROSSREF

73. Huh JH, Lim JS, Lee MY, Chung CH, Shin JY. Gender-specific association between urinary sodium excretion and body composition: analysis of the 2008-2010 Korean National Health and Nutrition Examination Surveys. Metabolism 2015;64:837-44.
PUBMED | CROSSREF

74. Murakami K, Livingstone MB, Sasaki S, Uenishi K; Japan Dietetic Students' Study for Nutrition and Biomarkers Group. Ability of self-reported estimates of dietary sodium, potassium and protein to detect an association with general and abdominal obesity: comparison with the estimates derived from 24 h urinary excretion. Br J Nutr 2015;113:1308-18.
PUBMED | CROSSREF

75. Ma Y, He FJ, MacGregor GA. High salt intake: independent risk factor for obesity? Hypertension 2015;66:843-9.
PUBMED | CROSSREF

76. Grimes CA, Riddell LJ, Campbell KJ, He FJ, Nowson CA. 24-h urinary sodium excretion is associated with obesity in a cross-sectional sample of Australian schoolchildren. Br J Nutr 2016;115:1071-9.
PUBMED | CROSSREF

77. Oh SW, Koo HS, Han KH, Han SY, Chin HJ. Associations of sodium intake with obesity, metabolic disorder, and albuminuria according to age. PLoS One 2017;12:e0188770.
PUBMED | CROSSREF

78. Nam GE, Kim SM, Choi MK, Heo YR, Hyun TS, Lyu ES, Oh SY, Park HR, Ro HK, Han K, et al. Association between 24-h urinary sodium excretion and obesity in Korean adults: a multicenter study. Nutrition 2017;41:113-9.
PUBMED | CROSSREF

79. Zhang X, Wang J, Li J, Yu Y, Song Y. A positive association between dietary sodium intake and obesity and central obesity: results from the National Health and Nutrition Examination Survey 1999-2006. Nutr Res 2018;55:33-44.
PUBMED | CROSSREF