Renal Replacement Therapy

REVIEW

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Renal health benefits of sustainable diets in Japan: a review

Kei Nagai[1,2*], Shiho Kosaka[3], Yuka Kawate[4] and Norihiro Itsubo[5]

Abstract

Global warming may reduce food production and force people to adopt dietary habits of inadequate quantity or quality. Such dietary habits could trigger chronic kidney disease through inappropriate nutrition or lifestyle diseases. Livestock farming and other types of food production are responsible for many greenhouse gases. These problems are being emphasized as a diet-environment-health trilemma to be addressed on a global scale, with various methods being proposed toward its resolution. Diets like plant-based and low-protein diets not only potentially prevent the progression of chronic kidney disease, but are also rational from an environmental preservation perspective. Evidence from Japan on resolutions for this trilemma is sparse, but one concrete proposal is the use of traditional Japanese diets like washoku, the Okinawa diet, and the traditional Buddhist diet. However, traditional Japanese diets also have several problems, such as excessive salt content and caloric deficiencies, and need to be modified and incorporated into the current lifestyle. The progression of chronic kidney disease needs to be prevented with appropriate dietary treatment and environmental friendly manner.

Keywords: Chronic kidney disease, Sustainability, Life cycle assessment

Introduction

The number of individuals with chronic kidney disease (CKD) is steadily increasing worldwide [1–3]. As a human economic activity, medical practice consumes various resources and impacts the environment and is estimated to account for 3–10% of all economic activity [4–8]. With the progression of CKD, increases are seen in medical expenses for medication, visits to doctors, and hospitalization [9], naturally resulting in greater greenhouse gas emissions (GHGE). In particular, dialysis treatment that is essential for prolonging the life of individuals with end-stage kidney disease uses vast amounts of electricity, water, and plastics and is estimated to have about ten times the environmental impact of the average per-person medical activities [10]. The burden on the global environment, primarily from GHGE, further exacerbates global warming and produces various health problems, such as cardiovascular complications, respiratory disease, and mental disorders [11, 12]. Global warming may result in the onset or progression of CKD through a variety of mechanisms [13]. As a direct cause, repeated acute kidney injury due to heat stress may result in chronicity of renal impairment, or trigger rhabdomyolysis or urolithiasis involve in development of CKD. Possible indirect causes are dehydration due to water shortages, tubular damage from contamination by nephrotoxic pesticides, insecticides, or heavy metals, and vector-borne illnesses such as malaria and dengue fever [14]. Combined with typical causes of CKD, such as chronic glomerulonephritis, hypertension and diabetes, global warming has been suggested to potentially lead to an increase in the prevalence of CKD.

According to a Japan-wide statistical survey conducted at the end of 2019, diabetes and hypertensive nephropathy (nephrosclerosis) were the top one and two most common primary diseases, respectively, for

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newly starting dialysis therapy [15]. Chronic glomerulonephritis was previously the most common and is not a lifestyle disease, and moved to third most common [15]. This indicates a change in disease structure among renal diseases, such as an increase in lifestyle-related diseases. This is consistent with the current situation that in recent years, food habits around the world have been becoming more westernized [16], resulting in increased intake of animal protein as well as cardiovascular complications [17, 18]. Empirically, limiting salt and protein intake has been shown to help prevent the onset of uremia [19]. While randomized controlled trials (RCTs) on educational interventions such as diet management and nutritional counseling are relatively difficult to conduct, limiting the possibility of accumulating high-quality evidence, experience leaves little doubt that nutritional counseling is an important part of CKD treatment.

If there is indeed an effect of global warming from the increase in GHGE caused by CKD treatment, as suggested above, food supply problems could result due to issues such as smaller crop yield, declining livestock production, and declining fish catch rates. However, most of current studies have not been able to directly quantify how much climate change will affect food yields, because it was forecasted by various uncertain anthropogenic factors [20]. Environmental issues stemming from medical practices are therefore linked to diet and nutritional problems, as well as renal health problems, with interactions among the three types of problems likely. This diet-environment-health trilemma [20] should be addressed at the global level (Fig. 1). From a nephrology perspective, the environmental impact of dialysis treatment plays a strong role in this trilemma. Japan is the 5th highest producer of GHGE in the world [21] and has 344,000 patients on maintenance dialysis [15] and so has a great responsibility to combat the problem. In this review, we discuss how to achieve nutritional treatment that effectively prevents the onset and progression of CKD and a diet with less environmental impact in Japan.

Diet-environment axis: temporal changes in Japanese diets and GHGE

Dining tables in modern Japan are covered with foods made using various ingredients and methods. Ingredients can be broadly categorized as animal- or plant-based, with the former considered to produce far higher GHGE [20, 22–24]. Cows, sheep, and other ruminant species produce methane (CH_4) and release particularly high GHGE [20, 22]. The food industry accounts for a high ratio of GHGE, so choosing a plant-based diet is a plausible way to improve the global environment [24, 25]. While the traditional Japanese diet (washoku) is plant-based and less processed food [26], intake of animal-based foods has increased from 114.9 g/day in 1955 to 338.7 g/day in 2019 and the processed food consumption ratio was 43.0% in 1990 and 50.5% in 2010, predicted to increase to 58.9% in 2035 [27]. This diversification of diets in modern Japan, and especially the westernization of diet and overconsumption of processed foods, is expected to have impacts

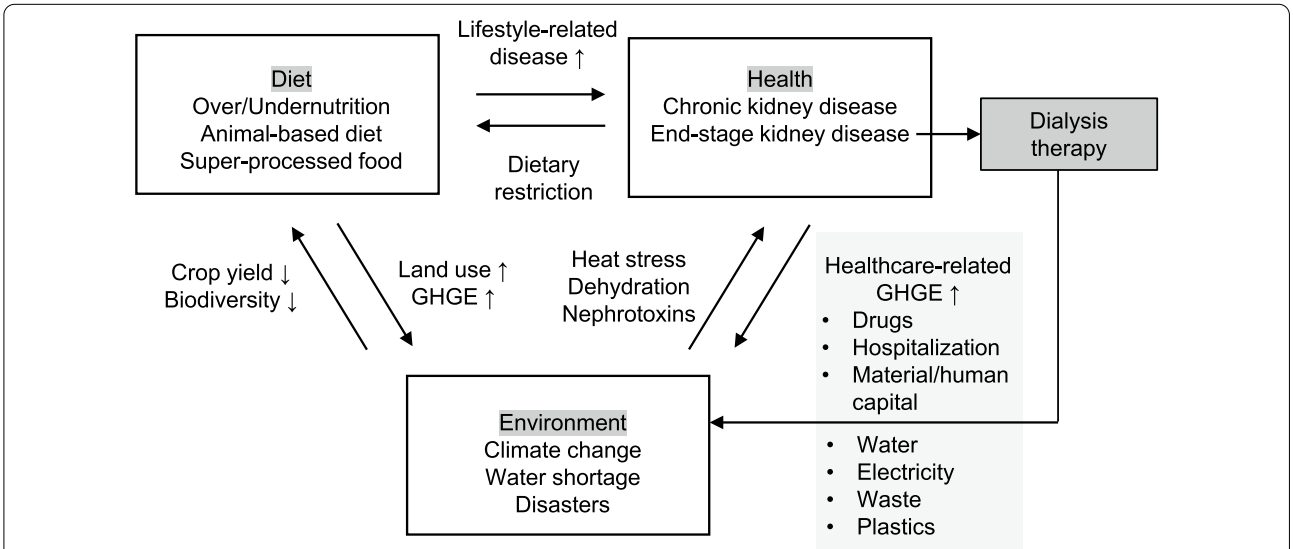

Fig. 1 The diet-environment-health trilemma is superimposed by dialysis therapy for patients with end-stage kenal disease. Diet and nutrition, health, and the environment all mutually interact. When focusing on kidney health, maintenance dialysis is essential for individuals with end-stage kenal disease and generates health care-related greenhouse gas emissions (GHGE). Drugs, hospitalization, capital investment, labor costs, water, electricity, waste, and plastics should all be recognized as having environmental impacts

on both health and the environment. Furthermore, in addition to food production activities such as crop and livestock farming, Japan's unique situation as a country with a low food self-sufficiency rate must be considered. Life cycle assessment (LCA) is a method for calculating various human economic activities (Fig. 2) [23, 24, 28]. For example, following a diet requires producing ingredients, transporting those ingredients, processing them into food products, and preparing them for meals. This entire process has environmental impacts, most notably from GHGE. The GHGE from importing and domestic transport processes cannot be overlooked [23, 29]. For this reason, evidence on LCA from other countries does not fit Japan as is, and making calculations and resolutions based on the specific characteristics of Japan, including diet, is important.

In LCA research comparing modern Japanese-style, Chinese-style, and Western-style cuisines in Japan, ingredient procurement and preparation calculations have shown that Japanese-style meals have the lowest GHGE, although the differences are not dramatic (Table 1) [30]. This may be partially attributable to the use of many imported products and processed foods in modernized Japanese foods. Traditional Japanese diets are shown in Table 2. Unfortunately, no LCA studies on these traditional diets have been conducted. Japanese-style cuisine (washoku) is high in fish and soybean consumption and low in animal fat and meat consumption. In Okinawa, which used to have the longest lifespan, people ate a sweet potato-heavy diet with small amounts of pork (a monogastric animal) that likely had low GHGE. In Japan and other countries in Asia

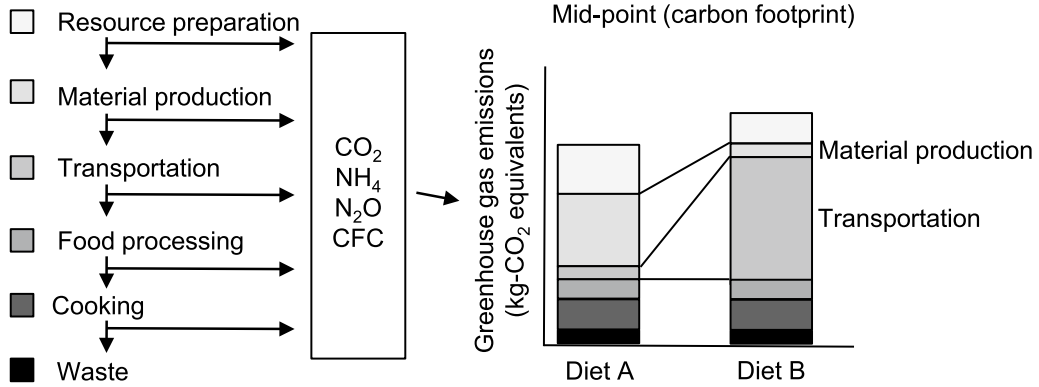

Fig. 2 Life cycle assessment in actual food production. In dietary life, greenhouse gases include gases like CO_2, methane (CH_4), nitric oxide (N_2O), and chlorofluorocarbons (CFCs) and are produced in various processes (called the "life cycle"). Greenhouse gas emissions (GHGE) produced in resource preparation, material production and transportation, food processing, cooking, and waste disposal are calculated as stacked CO_2-equivalents impacting global warming. For example, Diet A has an environmental impact from material production but a far lower impact from transportation than Diet B. As a result, Diet A is a better diet from an environmental preservation perspective when considering the entire life cycle. The carbon footprint that is used as a scale is called a midpoint indicator as it does not directly affect humankind

Table 1 Environmental impact of the modern diet

Dinner, four people	Japanese style	Chinese style	Western style
Model menu	Rice, grilled fish, steamed egg custard, boiled spinach in soy sauce, hearty miso soup, dessert (fruit), beer	Rice, zha cai and pork, deep-fried chicken, chop suey, dessert (fruit), beer	Rice, hamburger steak, potato salad, corn potage, dessert (fruit), beer
Ingredients	Rice, mackerel, salt, daikon radish, egg, chicken breast, shiba shrimp, shiitake mushroom, bonito stock, soy sauce, mirin (sweet sake), spinach, boiled-dried sardines, konjac, deep-fried tofu, tofu, carrot, burdock root, green onion, soybean paste, apple, orange, strawberry, beer	Rice, carrot, cucumber, pork, sake, soy sauce, potato starch, sesame oil, zha cai, bamboo shoot, shiitake mushroom, salt, chicken, ginger, lettuce, frying oil, squid, Chinese white shrimp, quail egg, Chinese cabbage, green pepper, green onion, podded pea, chicken soup, apple, orange, strawberry, beer	Rice, beef, panko, milk, onion, vegetable oil, salt, nutmeg, pepper, egg, butter, tomato puree, bouillon, bay leaf, parsley, green bean, carrot, sugar, salt, potato, lettuce, tomato, cucumber, mayonnaise, canned sweet corn, croutons, apple, orange, strawberry, beer
Food procurement costs	2060 g-CO_2e	2600 g-CO_2e	2720 g-CO_2e
Food preparation costs	673 g-CO_2e	374 g-CO_2e	503 g-CO_2e
Total GHGE	2733 g-CO_2e	2974 g-CO_2e	3223 g-CO_2e

Table 2 Nutritional comparison of the average diet of a modern Japanese person and traditional Japanese diets

	Average modern diet in Japan	Traditional Japanese style	Okinawa style	Traditional Buddhist diet (strict)
Characteristics	More processed foods Higher animal-based content high fat	High fiber High carbohydrate high salt	High fiber High carbohydrate low protein high potassium	All plant-based (High grain, mushroom, and seaweed content) Low energy supplemented as needed
Model menu: Breakfast	Bread Boiled egg Vegetables, mayonnaise dressing Yogurt Fruit Coffee	Boiled barley and rice Miso soup with tofu Braised Burdock root Pickles	Rice porridge with vegetables Simmered papaya Abura miso	Unflavored rice porridge Umeboshi, salt with sesame, pickles
Lunch	Rice Deep-fried chicken Simmered vegetables Pickles Japanese confectionery Black tea Coffee	Boiled barley and rice Miso soup with noodles Simmered chicken and vegetables Pickles Betayaki (savory pancake topped with vegetables)	Baked sweet potato Tofu champuru (stir-fry) Okinawan yellow cucumber with dressing Miso soup with sea lettuce	Barley rice Miso soup Dried daikon radish strips Pickles
Dinner	Rice Salt-grilled horse mackerel Braised burdock root Potato salad Miso soup with tofu, seaweed, and mushrooms Boiled spinach with crushed sesame Fruit Beer	Boiled barley and rice Whole dried sardines Simmered vegetables Fruit	Rice with sweet potato Okinawan miso soup Stir-fried kelp	Rice with seaweed Clear soup Simmered yam, pumpkin, and dried kelp Vinegared cucumber and wheat bran
Energy	1903 kcal/day	2104 kcal/day	1787 kcal/day	1119 kcal/day
Carbohydrates	248.3 g/day	411.2 g/day	382.0 g/day	218.0 g/day
Carbohydrate/energy ratio	56.3%	78.2%	85.5%	77.9%
Protein intake	71.4 g/day	69.7 g/day	39.0 g/day	27.3 g/day
Fat intake	61.3 g/day	20.3 g/day	12.0 g/day	13.1 g/day
Salt intake	9.4 g/day	15.0 g/day	8.2 g/day	6.4 g/day
Potassium intake	2.3 g/day	2.6 g/day	4.7 g/day	1.6 g/day
Phosphorus intake	1.0 g/day	1.4 g/day	0.8 g/day	0.4 g/day
Dietary fiber	18.4 g/day	22.3 g/day	27.5 g/day	12.1 g/day

where Mahayana Buddhism spread, a certain proportion of the population was vegan and people followed a traditional Buddhist diet that likely produced very low GHGE [31]. However, as shown in the data for a strict traditional Buddhist diet in Table 2, energy and nutrients are supplemented as needed. Based on the above, when considering how to reduce GHGE, using washoku with domestically produced plant-based ingredients and incorporating a traditional Japanese diet may make rational sense from an LCA perspective.

Adapted and modified from Toshie Tsuda et al. Life cycle CO2 assessment associated with model menu in Japanese household. Journal of Life Cycle Assessment Japan. 2007;3(3):157–67 [31] with permission. Abbreviations: GHGE, greenhouse gas emissions.

Diet-health axis: role of diets in chronic kidney disease

The importance of dietary treatment in renal disease has long been debated [32]. A low-salt diet not only can help prevent the onset or exacerbation of hypertension and the onset of cardiovascular complications, but also may mitigate renal dysfunction and reduce urinary protein [33]. Excessive protein intake leads to uremic symptoms, and a protein-restricted diet is believed to have preventive effect on CKD [19]. Though it has been still clinically controversial that low-protein diets prevent or attenuate the progression of CKD, a general population-based observational study demonstrated people who consumed more protein from red and processed meats were at

an increased risk of developing CKD [34] and end-stage kidney disease [35]. On the other hand, CKD risk was significantly lower among those who had a higher consumption of nuts and legumes suggesting plant protein offers advantages over animal protein in patients with CKD [36]. In the case of mild CKD, active intake of potassium can help prevent the development of cardiovascular complications and hypertension [37, 38]. Examples of typical diets for implementing such dietary treatment are traditional diets such as the Mediterranean diet and the Okinawa diet [38] and diets based on clinical research and/or academic society recommendations, such as the Dietary Approaches to Stop Hypertension [39] or a protein-restricted diet [40]. Common points for all these diets are the plant-based nature with low salt and protein contents, and high potassium content. A search of the literature regarding the relationship between progression of CKD and nutritional education interventions gives 494 hits, including 22 RCTs. As expected, most interventions involved restriction of protein or salt, but evidence on the Mediterranean diet was also included [41–43] (Fig. 3). Among all races, the Japanese, both men and women, have long life expectancies, and evidence suggests that traditional Japanese diets can prolong life and reduce the risks of cardiovascular complications [44, 45]. However, scientific evidence is currently lacking on progression of CKD as an outcome of intervention with a traditional Japanese diet (Fig. 3). Conversely, as increased potassium intake in advanced renal disease can carry a risk of cardiac death from hyperkalemia, nutritional treatment requires considerations by specialists. In recent years, CKD patients have become older, so careful nutritional guidance is also required. For older adults, excessive salt or protein restriction can lead to frailty and may aggravate prognosis.

To summarize, while a number of issues require caution, plant-based diets generally offer clear benefits in preventing the onset and progression of CKD [38]. Although following a vegan diet is difficult in modern Japan, increasing the proportion of plant-based foods in a diet is possible with nutritional counseling. Moreover, traditional Japanese diets also have several problems, which are listed as caloric deficiencies, excessive salt content (Table 2) and reduced satisfaction and quality of life due to unfitting modern society. Therefore, the traditional diets may need to be modified into diets balancing environmental sustainability and renal health based on recent nutritional science in CKD. However, the effects of a traditional Japanese diet on CKD have not been tested, and epidemiological and clinical evidence is needed.

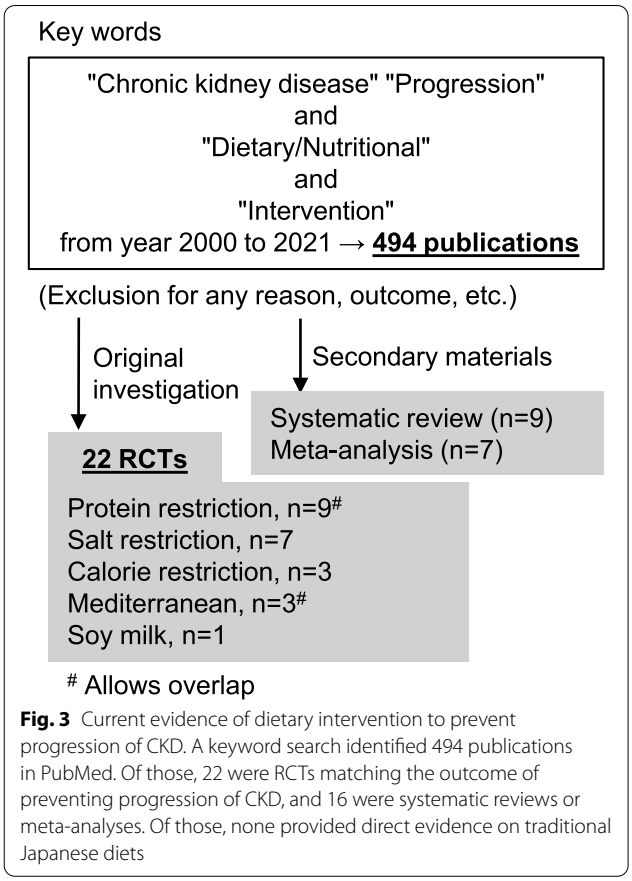

Fig. 3 Current evidence of dietary intervention to prevent progression of CKD. A keyword search identified 494 publications in PubMed. Of those, 22 were RCTs matching the outcome of preventing progression of CKD, and 16 were systematic reviews or meta-analyses. Of those, none provided direct evidence on traditional Japanese diets

Environment-health axis: life cycle impact assessment for better understanding of environmental issues by health care providers

Of the axes in the trilemma, we discussed the effects of diet on health in the previous section. In contrast, it is more difficult for medical professionals to understand the effects of the environment on health. The GHGE often used to assess environmental impact do not directly affect humans and are therefore called a midpoint indicator. Medical professionals have very few opportunities to imagine the effects of GHGE on the patients they are seeing in daily practice. On the other hand, end point environmental indicators in LCA include "monetary cost" and "health" that affect people [46]. These are areas of interest in medical economics and public health science and can be easily understood by medical professionals. As LCA research has progressed in recent years, various methods of assessment have been established, such as Life cycle Impact assessment Method based on End point modeling (LIME), which can assess damage to health and economic impact [47]. Carbon footprint research into dialysis for end-stage kidney disease has been ongoing since around 2010 and has shown the production of massive amounts of GHGE due to the use of a vast quantity

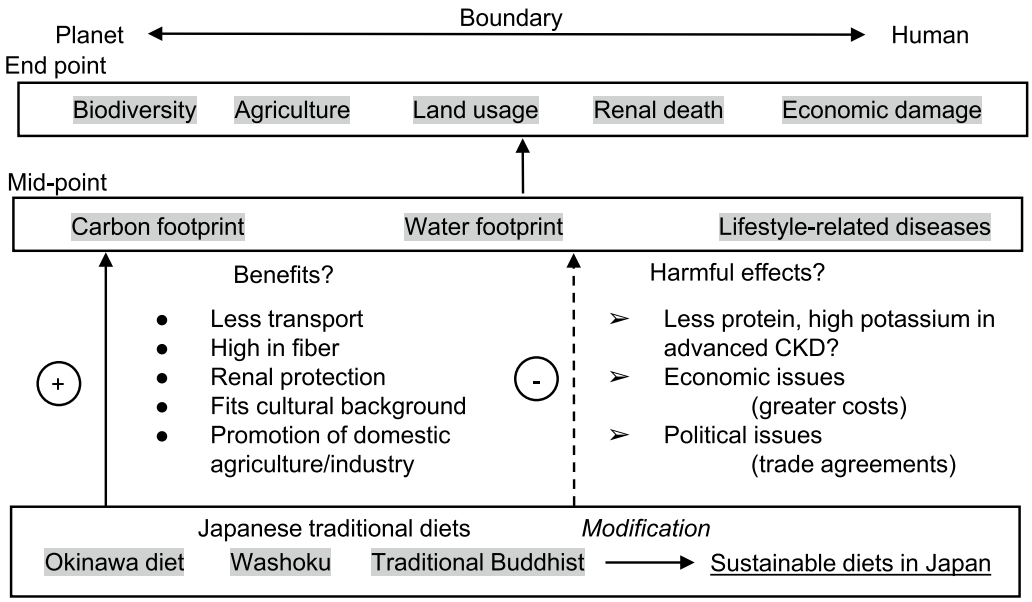

Fig. 4 Putative effects of Japanese traditional diets on end point over midpoint in planetary and human boundaries. Plant-based, low-protein diets as the traditional washoku diet, the Okinawa diet, and the traditional Buddhist diet. Using domestically produced foods reduces the need for transport, preserves links to ancient life history and culture, and may boost agriculture and the food industry in Japan. However, excessive food restrictions can cause frailty in older adults due to inadequate protein intake or trigger hyperkalemia among individuals with end-stage kidney disease due to potassium loading. Therefore, traditional diets should be modified toward co-benefit of renal health and environment. Traditional Japanese diets and sustainable diets in Japan may reduce the carbon footprint and reduce the prevalence of lifestyle diseases as midpoints. As end points, these diets may benefit the global environment or help prevent the progression of end-stage kidney disease

of resources, including drugs, electricity, water, and plastics [10, 48–50]. We recently used LIME to measure the monetary loss and health damage of resource consumption with a dialysis treatment model as an end point environmental indicator that surpasses midpoint indicators [51]. Considering a treatment model in which one patient on maintenance hemodialysis visits the hospital three times a week for 4 h of a dialysis session, we calculated a health damage of 2.4×10^{-3} disability-adjusted life years and environmental load equivalent to the monetary loss of 85.6 USD per year. Based on this result, 1 year of treatment for 418 patients on maintenance hemodialysis was equivalent to the loss of 1 year of healthy life for 1 person on earth. Importantly, this result ignores the health gained by the person on dialysis and therefore we never intend to deny dialysis treatment itself. The basic data used in the calculations were data used in other industries and agriculture, and the results are merely theoretical figures under a treatment model, and not actual measurements. The result may therefore be an under- or overestimation. That said, this is the first example showing that consumption of vast resources in medical practice damages human health.

Co-benefits of Japanese traditional diets on environment preservation and renal health

Resolving the diet-environment-health trilemma posed for renal health care requires the procurement and preparation of ingredients with a low environmental impact, nutritional treatments that effectively protect renal function, and wide acceptance of both in Japan as the dietary culture. In addition, reducing the number of people with CKD and the number of people on maintenance dialysis requires modification of patients, health care professionals, and the society that supports them. One useful method may be to scientifically determine what would be most effective for achieving both environmental and health benefits using quantitative LCA results [22, 23, 52–54]. We are currently speculating on whether a plant-based diet centered around domestically produced ingredients can improve both GHGE and CKD in Japan. However, it needs the environmental impact of domestic production must not exceed that of imports. To examine the possibilities, further development of LCA-based calculation methods is necessary.

Some specific plant-based diets are the traditional washoku diet, the Okinawa diet, and the traditional

Table 3 Initiative for mitigating the Diet-Environment-Renal Health trilemma in Japan

	Initiatives	Promoters and Inhibitors	Reported scientific evidence
Diet-environment axis	Local production for local consumption to reduce GHGE (reduce transport costs) Switch to plant-based diet Prevent overconsumption of processed foods Prevent energy loss from food processing and food preparation processes Prevent food waste Green agricultural management and land use	Requires changes to the food industry Considerations for import/export industries and existing industries (e.g., food processing industry, dairy farming) Policy incentives for going carbon free	Diet → Environment: Conclusive Plant-based diets have a far lower environmental impact than animal-based diets Environment → Diet: Conclusive Global warming reduces crop, livestock, and fishery yield
Renal health-diet axis	Switch to plant-based diet Protect renal glomerular function with low-salt, low-protein diet Avoid excessive consumption of processed foods and prevent hyperphosphatemia Avoid inappropriate nutritional treatment in advanced renal disease (overconsumption of potassium, over-restriction of protein)	Promotes appropriate intervention by dietitians for CKD Rethinking and popularization of traditional Japanese diets Promotes understanding of vegetarianism in Japan	Renal health → Diet: Conclusive Renal dysfunction requires food restriction Diet → Renal health: Partly inconclusive Plant-based diets are mostly effective for early-stage CKD. some guideline recommends for patients with CKD that at least half of their daily protein intake from animal sources. Caution is required for advanced CKD. Salt reduction is effective. Low protein may be effective, but the mechanism is partially unclear. The epidemiology of vegetarianism in Japan and effects on the kidneys are unclear
Environment-renal health axis	Reduce the need for necessary treatment by preventing aggravation of CKD Popularize green medical practices and behavior modification of patients Avoid drug waste Avoid over-prescription (including for dialysis) Pharmaceutical production with low environmental impact Establish and popularize non-drug treatment to protect renal function	Improvement of preventive medicine and people's health literacy Considerations for existing pharmaceutical companies and production lines People's understanding of the ethical question of intentionally changing prescriptions for environmental benefits	Environment → Renal health: Mostly conclusive CKD caused by global warming Loss of healthy life expectancy due to global warming in various ways Renal health → Environment: Indirect, inconclusive Increased prevalence of CKD and end-stage kidney disease has a monetary impact (but no direct quantifiable effects on the environment). environmental impact of dialysis treatment is larger than that of general medical care. lack of evidence on effects of non-drug treatment on renal function protection

Buddhist diet. Using domestically produced foods reduces the need for transport, preserves links to ancient life history and culture, and may boost agriculture and the food industry in Japan. The low food self-sufficiency rate in Japan is related to the high cost of domestically produced food and policy issues related to trade. Unfortunately, for us, it has not been possible to estimate that food self-sufficiency in Japan would reliably reduce the environmental burden. Even though maintaining domestic food production may be more expensive than imported agricultural products in the short term, the long-term cost of maintaining domestic production is actually lower when the cost of the contingency of "not being able to buy food with your money" should be also taken into account. On the negative side, inadequate nutritional controls can cause frailty in older adults due to low protein intake or may trigger hyperkalemia in people with end-stage kidney disease. Furthermore, excessive salt content of traditional Japanese diet and lack of energy in traditional Buddhist diet are not acceptable levels. Nevertheless, if some issues and problems can be overcome and modified as "sustainable diets in Japan," traditional Japanese diets may reduce both the carbon footprint and the prevalence of lifestyle-related diseases as midpoints. In advance of this, our team had started promotion of Japanese diets in new era, that is summarized by reducing the amount of salt by using dashi (Japanese soup stock). The achievement was released by the International Society of Renal Nutrition and Metabolism [55].

Conceivable end points are protection of biodiversity, improvements in land use with structural changes to agriculture, suppression of increases in the prevalence of end-stage kidney disease, reductions in medical costs, and improvements in both the global environment and human health (Fig. 4).

Table 3 summarizes the relationship between diet and environment, between diet and renal health, and between the environment that is far removed from medical professionals and renal health. We consider resolving this trilemma for renal health could possibly improve the prognosis for people with CKD. Hopefully, this debate about renal health will have ripple effects on other medical fields and bring us closer to resolving the diet-environment-health trilemma in Japan.

Conclusion

As global warming progresses, renal health sector, without exception from other industries, will require effort to reduce GHGE. Doctors, other health care specialists must work together to try to prevent the progression of CKD for reducing the need of resource-hungry therapy for end-stage kidney disease. Traditional Japanese diets may offer a rational solution to the diet-environment-health trilemma. However, traditional Japanese diets also have several problems, such as excessive salt content, and need to be modified and incorporated into the current lifestyle as sustainable diets in Japan.

Abbreviations

CKD: Chronic kidney disease; GHGE: Greenhouse gas emission; RCT: Randomized control trial; LCA: Life cycle assessment.

Acknowledgements

We would like to thank Rieko Uchima for helping us to determine the contents of the traditional Okinawa diet as a nutrition specialist.

Author contributions

KN wrote the manuscript. KS and YK contributed to construct tables and figures and reviewed the manuscript. NI supervised the descriptions regarding life cycle assessment and reviewed the manuscript. All authors edited and approved the final manuscript.

Funding

This article was supported, in part, by Japan Society for the Promotion of Science Grant Nos. 18KK0431 and 19K17729 and by the Japanese Association of Dialysis Physicians Grant No. 2019-1.

Availability of data and materials

Not applicable.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

No consent was required for publication.

Competing interests

The author declares that the review work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Received: 31 January 2022 Accepted: 24 May 2022
Published online: 31 May 2022

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