Kanauchi *et al. BMC Nephrology (2024) 25:274*
https://doi.org/10.1186/s12882-024-03707-7

BMC Nephrology

RESEARCH Open Access

Effective method for life-style modifications focused on dietary sodium intake in chronic kidney disease: sub-analysis of the FROM-J study

Noriko Kanauchi[1,2], Chie Saito[3], Kei Nagai[3], Kohsuke Yamada[4], Hirayasu Kai[5,6], Tsuyoshi Watanabe[7], Ichiei Narita[8], Seiichi Matsuo[9], Hirofumi Makino[10], Akira Hishida[11] and Kunihiro Yamagata[3*]

Abstract

Background Lifestyle modifications by educational sessions are an important component of multidisciplinary treatment for chronic kidney disease (CKD). We attempted to identify the best method to teach these modifications in order to ensure their acceptance by patients and investigated its effectiveness in CKD practice.

Methods This study is a post-hoc analysis of the FROM-J study. Subjects were 876 CKD patients in the advanced care group of the FROM-J study who had received lifestyle modification sessions every 3 months for 3.5 years. Two-hundred and ten males (32.6%) and 89 females (38.2%) showed success in sodium restriction. In this study, we examined factors affecting sodium restriction in these subjects.

Results Subjects received three or more consecutive educational sessions about improvement of salt intake. The median salt-intake improvement maintenance period was 407 days. The number of dietary counseling sessions (OR 1.090, 95%CI: 1.012–1.174) in males and the number of dietary counseling sessions (OR 1.159, 95%CI: 1.019–1.318), CKD stage progression (OR 1.658, 95%CI: 1.177–2.335), and collaboration with a nephrologist (OR 2.060, 95%CI: 1.073–3.956) in females were identified as significant factors improving salt intake. The only factor contributing to the maintenance of improved salt intake was the continuation of dietary counseling ($p = 0.013$).

Conclusion An increased number of educational sessions was the only successful approach for males to implement and maintain an improved salt intake. Providing the resources for continuous counseling is beneficial for lifestyle modifications and their maintenance in the long-term management of CKD. Continuous counseling for lifestyle modifications is highly cost-effective.

Trial registration The FROM-J study was registered in UMIN000001159 on 16/05/2008.

Keywords Sodium restriction, Behavior modification, Sex difference, Continuous dietary intervention

*Correspondence:
Kunihiro Yamagata
k-yamaga@md.tsukuba.ac.jp
Full list of author information is available at the end of the article

Background

The number of patients newly receiving kidney replacement therapy (KRT) has recently increased [1]. One of the reasons for this is the faster rate of deterioration of renal function in men with lifestyle-related chronic kidney disease (CKD), such as diabetic kidney disease (DKD) and hypertensive nephropathy as the underlying cause of renal disease [2, 3]. Efforts to prevent the progression and severity of CKD are of great significance for limiting the development of end-stage kidney disease (ESKD) and cardiovascular disease (CVD) [4, 5]. Therefore, it is very important to improve the lifestyles of patients with CKD and to take measures that will maintain the good habits acquired [6]. Lifestyle modifications represent the most effective approach to treat lifestyle-related CKD.

Dietary sodium restriction may slow the progression of renal disease and albuminuria [7–9]. Previous studies demonstrated that a low sodium diet potentiated the effects of renin–angiotensin–aldosterone system (RAAS) blockers and, thus, attenuated proteinuria and reduced blood pressure (BP) [10]. While several reviews and meta-analyses suggested the lack of clear evidence for dietary sodium restriction reducing the rate of the decline in eGFR, proteinuria, the incidence of all-cause mortality, and CV events, it was shown to decrease the risk of renal composite outcome events in patients with CKD [11].

We conducted the Frontier of Renal Outcome Modifications in Japan (FROM-J) study [12, 13], a cluster randomized trial in which each local medical association served as a cluster and the medical support system for multidisciplinary care by primary care physicians (PCPs) effectively promotes cooperation with nephrologists and improves CKD outcomes. This trial included 489 PCPs and 2417 CKD patients. Clusters were randomly assigned to the standard intervention group or the advanced intervention group. The standard intervention group received regular medical care in accordance with the CKD treatment guidelines, while the advanced intervention group was given the same medical care based on the CKD treatment guidelines and dietary counseling sessions by dieticians every 3 months. In the FROM-J study, a 50% reduction in the estimated glomerular filtration rate (eGFR) was significantly attenuated in the advanced intervention group at 3.5 years [13]. Furthermore, we followed up CKD patients for 10 years and found a significant decrease in CVD in the advanced intervention group [14].

Lifestyle modifications effectively improve the life and renal outcomes of CKD patients, particularly those with lifestyle-related CKD, which has been increasing in recent years, and trials have been conducted to prove their effectiveness. The establishment of effective lifestyle modification methods is important for preventing lifestyle-related renal diseases in males, which is the main cause of the recent increase in the number of ESKD patients worldwide.

In the present study, we focused on diet, particularly sodium restriction, as one indicator of lifestyle modifications, and attempted to identify factors that improve the effectiveness of lifestyle guidance.

Methods

Study patients

This study is a post-hoc analysis of the FROM-J study. This study is a detailed analysis of the advanced intervention group in the FROM-J study. The FROM-J study was a 3.5-year (Oct. 2008 to Mar. 2012) cluster randomized intervention study of CKD patients treated by general physicians in Japan. Details on the methods used and findings obtained in the FROM-J study have already been reported [12–14]. The advanced intervention group that received continuous dietary counseling in the FROM-J study consisted of 1,184 patients (Fig. 1). In the advanced intervention group, 206 patients who received less than 3 dietary education sessions and 102 patients whose salt intake was less than 6 g/day at the first session were excluded.

In this study, we analyzed 876 subjects, which included 643 males and 233 females (Fig. 1). Informed consent was obtained from all subjects and/or their legal guardians.

Assessment of salt intake

Dietary counseling on salt intake was provided based on the Japanese CKD Guidelines, with the goal of achieving and maintaining a salt intake < 6 g per day [15]. Patients brought their dietary records to each visit, and the dietitian calculated their salt intake and provided feedback. Salt intake per day was rated by the dietitian-in-charge into three categories: > 12 g, 6–12 g, and < 6 g. Each patient's salt intake was monitored every 3 months throughout the intervention period. The validation study on the accuracy of the categorical assessment of salt intake employed in the FROM-J study was done [16].

Outcomes

We defined "salt-intake improvement" as a change in a patient's salt-intake category to a lower intake category than that observed in the first session, plus the confirmation of this improved state for two consecutive sessions. We defined the "salt-intake improvement maintenance period" as the longest period during which the salt-intake category had changed to a lower intake category than that observed in the first session with a continuously confirmed improvement. We examined the extent to which dietary counseling interventions improved patients'

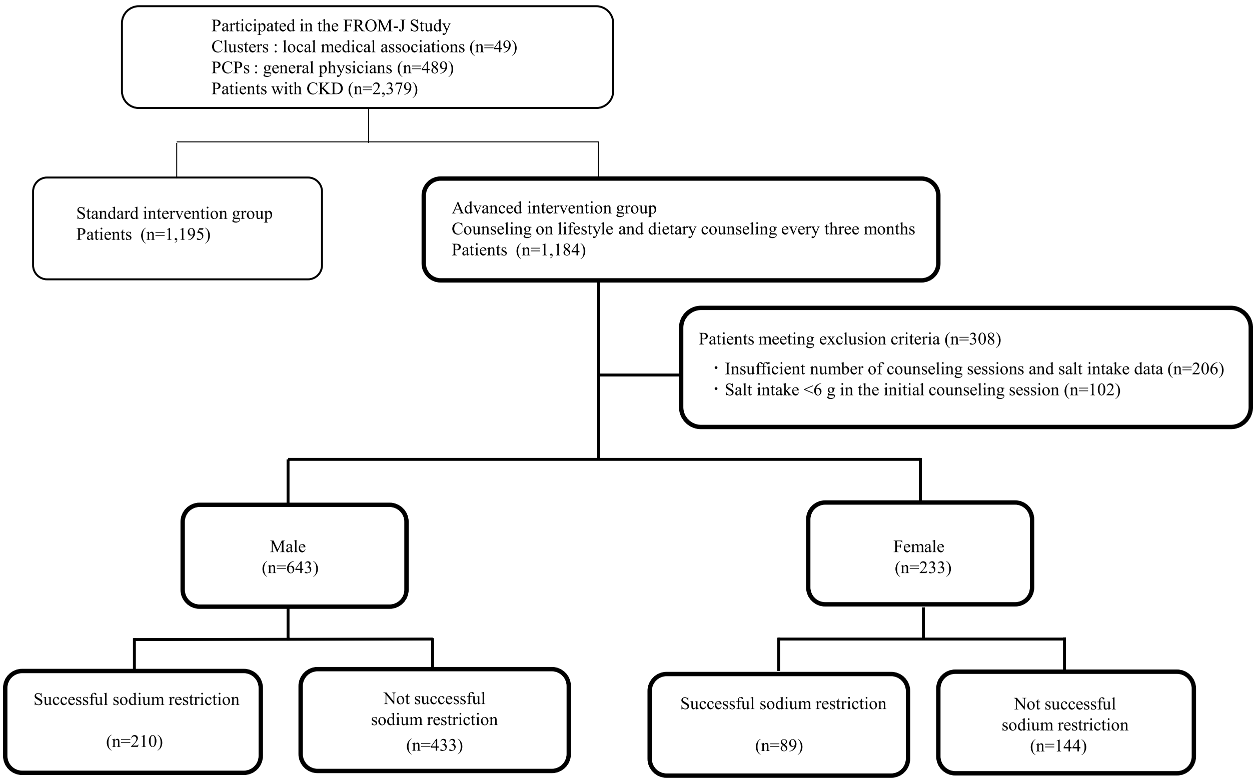

Fig. 1 Flow diagram of the present study

The subjects were the advanced intervention group of the FROM-J study (indicated by *bold lines* in the flowchart). Of the 1,184 participants enrolled in the advanced-intervention arm of the FROM-J study, 876 (male 643, female 233) were included in the present study, excluding 308 participants who met the study's exclusion criteria

salt-intake behavior, how long the improved behavior was maintained, and the number of dietary counseling sessions required to change salt-intake behavior. The intervention items evaluated included the presence or absence of collaborative care with a nephrologist, the number of counseling sessions, and whether subjects regularly measured BP at home as an indicator of lifestyle modification monitoring. We examined factors affecting salt-intake improvement and the salt-intake improvement maintenance period using these intervention conditions and patient characteristics as variables.

Statistical analyses

Descriptive statistics for continuous variables were expressed as the mean and standard deviation (SD) and categorical variables as frequencies (%). The significance of differences in means for categories were examined using Levene's test if equal variances were confirmed by the F-test, otherwise Welch's test was used. The χ^2-test was employed for categorical data. We performed a multiple logistic regression analysis to examine factors contributing to salt-intake improvement with results expressed as odds ratios (ORs) and 95% confidence intervals (CIs). A multiple regression analysis was also used as a factorial analysis of the salt-intake improvement maintenance period. Statistical analyses were performed using SPSS Statistics ver. 28 (IBM, Armonk, NY), and p-values < 0.05 were considered to be significant.

Results

Baseline characteristics of patients

The mean age of the CKD patients examined ($n = 876$) was 62.2 ± 8.0 years. The body mass index (BMI) was 25.7 ± 3.9 kg/m^2, eGFR was 59.1 ± 21.6 mL/min/1.73 m^2, and 84.1% of patients were in CKD stage 2 or 3. In addition, 53.0% of patients were obese (BMI ≥ 25 kg/m^2), 60.4% had diabetes mellitus, and 91.1% had hypertension. Regarding sex, 73.4% of subjects were male, significantly more females had CKD stages 4 and 5, and diabetes mellitus was significantly more common in males (Table 1).

Dietary consulting and salt-intake changes

In comparisons of patients with and without salt-intake improvement, the former had significantly lower eGFR

Table 1 Baseline characteristics of patients

Variable	Overall $n=876$	Male $n=643$	Female $n=233$	p-value
Age, yrs[a]	62.2 (8.0)	62.0 (8.0)	62.6 (8.1)	0.351
eGFR, mL/min/1.73m[2,a]	59.1 (21.6)	59.9 (20.7)	57.0 (23.7)	0.075
Proteinuria, g/gcr[a]	0.76 (1.77)	0.72 (1.90)	0.87 (1.33)	0.237
BMI, kg/m[2a]	25.7 (3.9)	25.7 (3.7)	25.6 (4.3)	0.694
SBP, mmHg[a]	137.0 (15.4)	137.0 (15.6)	137.1 (14.9)	0.924
DBP, mmHg[a]	78.9 (10.6)	79.3 (10.8)	78.0 (9.9)	0.115
CKD stage:[b]				0.003*
1[b]	70 (8.0%)	47 (7.3%)	23 (9.9%)	0.217
2[b]	327 (37.3%)	249 (38.7%)	78 (33.5%)	0.156
3[b]	410 (46.8%)	307 (47.7%)	103 (44.2%)	0.354
3a[b]	253 (28.9%)	199 (30.9%)	54 (23.2%)	0.025*
3b[b]	157 (17.9%)	108 (16.8%)	49 (21.0%)	0.149
4[b]	61 (7.0%)	37 (5.8%)	24 (10.3%)	0.020*
5[b]	8 (0.9%)	3 (0.5%)	5 (2.1%)	0.021*
Complications:				
Obesity[b]	462 / 872 (53.0%)	339 / 639 (53.1%)	123 / 233 (52.8%)	0.945
Diabetes[b]	527 / 873 (60.4%)	407 / 640 (63.6%)	120 / 233 (51.5%)	0.001*
Hypertension[b]	795 / 873 (91.1%)	582 / 640 (90.9%)	213 / 233 (91.4%)	0.826

eGFR estimated glomerular filtration rate, *BMI* body mass index, *CKD* chronic kidney disease, *SBP* systolic blood pressure, *DBP* diastolic blood pressure

[a] Mean (standard deviation [SD]) unless otherwise specified

[b] No. of individuals (%). *P*—values: male vs. female

Table 2 Clinical characteristics of patients with successful and not successful sodium restriction

Variable	Success in sodium restriction $n=299$	Not success in sodium restriction $n=577$	p-value
Age, yrs[a]	62.2 (7.4)	62.1 (8.3)	0.971
eGFR, mL/min/1.73m[2,a]	56.6 (20.8)	60.4 (21.9)	0.014*
Proteinuria, g/gcr[a]	0.90 (2.73)	0.69 (0.94)	0.236
BMI, kg/m[2a]	25.5 (3.7)	25.7 (4.0)	0.464
SBP, mmHg[a]	137.1 (14.6)	137.0 (15.8)	0.874
DBP, mmHg[a]	79.9 (9.9)	78.4 (10.9)	0.046*
Complications:			
Obesity[b]	153 / 298 (51.3%)	309 / 574 (53.8%)	0.727
Diabetes[b]	173 / 298 (58.1%)	354 / 575 (61.6%)	0.603
Hypertension[b]	277 / 298 (93.0%)	518 / 575 (90.1%)	0.371

[a] Mean (standard deviation [SD]) unless otherwise specified

[b] No. of individuals (%). *P*—values: Success in sodium restriction vs. not success

and significantly higher diastolic BP (Table 2). During the intervention period, subjects received dietary counseling an average of 11.7 ± 2.5 times (males 11.7 times, females 11.7 times, $p=0.938$). Home BP measurements were regularly performed by 75.7% of patients (males 74.8%, females 78.1%, $p=0.314$). Furthermore, 23.1% of patients (males 22.7%, females 24.0%, $p=0.680$) received medical care in collaboration with a nephrologist. Salt-intake improvement was observed in 34.1% of patients (males 32.7%, females 38.2%, $p=0.127$) (Fig. 1 and Table 3).

Factors affecting behavior modifications

The number of counseling sessions required for salt-intake improvement was 3.2 ± 2.4 (males 3.1, females 3.4, $p=0.259$). Based on patient background characteristics and intervention methods, multivariate variables were sex, age, CKD stage progression, obesity, diabetes, hypertension, frequency of dietary counseling, BP self-monitoring, and collaboration with a nephrologist. In all patients, the significant factor for salt-intake improvement was the number of dietary counseling sessions (OR 1.110, 95%CI: 1.041–1.183, $p=0.001$). Among females, the following factors significantly improved salt-intake behavior: the number of dietary counseling sessions (OR 1.159, 95%CI: 1.019–1.318, $p=0.025$), CKD stage progression (OR 1.658, 95%CI: 1.177–2.335, $p=0.004$), and collaboration with a nephrologist (OR 2.060, 95%CI: 1.073–3.956, $p=0.030$). The only factor that significantly improved salt intake in males was the number of dietary counseling sessions (OR 1.090, 95%CI: 1.012–1.174, $p=0.022$) (Table 4).

The median salt-intake improvement maintenance period was 407.3 days (males 407.1 days, females 407.9 days, $p=0.984$). The multiple regression analysis also showed that the salt-intake improvement maintenance period was dependent on the number of dietary counseling sessions ($p=0.013$) (Table 5).

Table 3 Educational Intervention and behavior change

Variable	Overall	Male	Female	*p*-value
Number of counseling sessions[a]	11.7 (2.5)	11.7 (2.5)	11.7 (2.5)	0.938
Self-monitoring of BP implementation > 50%[b]	663 (75.7%)	481 (74.8%)	182 (78.1%)	0.314
Collaboration with nephrologists[b]	202 (23.1%)	146 (22.7%)	56 (24.0%)	0.680
Salt-intake improvement[b]	299 (34.1%)	210 (32.7%)	89 (38.2%)	0.127

[a] Mean (standard deviation [SD]) unless otherwise specified

[b] No. of individuals (%). *P*—values: male vs. female

Table 4 Factors contributing to salt-intake improvement

Variable	Overall			Male			Female		
	OR	95%CI	*p-value*	OR	95%CI	*p-value*	OR	95%CI	*p-value*
Male sex	0.807	0.586–1.110	0.187						
Age	0.992	0.974–1.011	0.399	0.995	0.973–1.017	0.643	0.989	0.955–1.025	0.550
CKD stage	1.202	0.985–1.467	0.070	1,036	0.802–1.338	0.785	1.658	1.177–2.335	0.004*
Obesity	0.941	0.705–1.255	0.677	0.950	0.676–1.334	0.767	0.833	0.468–1.482	0.534
Diabetes	0.957	0.709–1.291	0.773	0.943	0.659–1.348	0.746	0.989	0.556–1.758	0.970
Hypertension	1.418	0.830–2.423	0.202	1.182	0.643–2.172	0.590	2.811	0.851–9.284	0.090
Number of counseling sessions	1.110	1.041–1.183	0.001*	1.090	1.012–1.174	0.022*	1.159	1.019–1.318	0.025*
Self-monitoring of BP implementation > 50%	1.330	0.937–1.888	0.111	1.370	0.909–2.065	0.133	1.214	0.603–2.443	0.588
Collaboration with nephrologists	1.301	0.929–1.822	0.125	1.078	0.719–1.616	0.716	2.060	1.073–3.956	0.030*

The odds ratios (ORs), 95%confidence intervals (CIs), and*p* —values are from multiple logistic regression analysis using the variables shown

Table 5 Factors contributing to the salt-intake improvement maintenance period

Variable	Overall		Male		Female	
	β	*p-value*	β	*p-value*	β	*p-value*
Male sex	0.000	0.992				
Age	0.028	0.428	−0.001	0.977	0.109	0.105
CKD stage	−0.018	0.630	−0.017	0.699	−0.010	0.883
Obesity	0.045	0.191	0.037	0.356	0.078	0.249
Diabetes	−0.004	0.917	0.005	0.904	−0.020	0.764
Hypertension	−0.020	0.565	−0.017	0.668	−0.021	0.755
Number of Counseling sessions	0.085	0.013*	0.074	0.064	0.121	0.077
Self-monitoring of BP implementation > 50%	0.016	0.642	0.008	0.845	0.051	0.448
Collaboration with nephrologists	0.006	0.869	0.021	0.603	−0.039	0.569

Standardized partial regression coefficients (β) and *p*—values from the multiple regression analysis using these variables are shown

Effect of improved salt intake improvement on blood pressure and proteinuria

Changes in blood pressure in those who successfully reduced salt, and change in proteinuria in those who had proteinuria were confirmed. Regarding blood pressure, both groups with successful and unsuccessful salt restriction showed a decrease in blood pressure after dietary guidance, but the percentage change in systolic blood pressure before and after dietary intervention was not different between the successful salt restriction and unsuccessful salt restriction groups (-3.2 ± 12.1% and -2.2 ± 12.7, $P = 0.251$, respectively). Diastolic blood pressure, on the other hand, decreased slightly more in the successful salt restriction group (-5.6 ± 13.3 and -3.6 ± 14.5, $P = 0.041$). And there was no significant change in proteinuria between the successful salt restriction and unsuccessful salt restriction groups.

Multiple regression analysis for effect on final blood pressure, there was no significant factor including salt-intake improvement (Supplement Table 1).

Discussion

The objectives of global CKD countermeasures is to prevent the deterioration of renal function in CKD patients and reduce not only the physical burden associated with ESKD and CVD, but also the social burden caused by an increase in the number of patients receiving KRT [17]. Furthermore, recent global prevalence and incidence of ESKD due to DKD or hypertensive nephropathy, such as lifestyle-related diseases, are increasing, and the main reason for the larger number of male ESKD patients was found to be a more rapid decline in renal function in male patients with DKD or hypertensive nephropathy [2, 3]. Lifestyle modifications are the best approach for improving lifestyle-related diseases. In the FROM-J study, dietary education sessions to implement lifestyle modifications were offered every 3 months for 3.5 years. A novel CKD evaluation checklist was used to select appropriate educational sessions. The most frequently provided instructions were those related to BP control (46%), followed by BMI control (28%), and potassium control (9%) [16]. Consequently, the most frequent educational sessions were those to restrict salt intake. One of the main challenges encountered in the treatment of CKD is how to achieve and sustain lifestyle modifications. Dietary intervention studies evaluated clinical indicators and nutrient intakes at several defined time points, such as at the baseline and endpoints, using averages and other measures. Improvements in salt-intake behavior in individuals due to an intervention are difficult to discern in a collective evaluation; it has been not clear when and by what factors CKD patients improve their salt intake with interventions and for how long they maintain it.

The present study is the first to focus on changes in salt intake among individual CKD patients and evaluate improvements in salt-intake behavior over time through dietary counseling interventions. The Transtheoretical Model, which proposes a stepwise process for a behavior change, showed a transition from the implementation phase to the maintenance phase approximately 6 months after a behavior change [18]. Health psychology research on the maintenance of changed behaviors has indicated that latent and newly adopted behaviors change in dominance depending on the environment and conditions [19]. The present study used patient backgrounds and intervention conditions as variables to examine factors contributing to improved salt intake behavior.

For this salt intake category classification, we have conducted a validation study on the accuracy of the categorical assessment of salt intake employed in the FROM-J study: less than 6 g, 6–12 g, and 12 g or more. To confirm the accuracy of the survey method in the FROM-J study, we compared the actual measured salt and protein intakes with the survey method in the FROM-J study. Compared to the accuracy of the salt intake, the agreement between the dietitian's estimate of salt intake and the objective assessment was 78.5%, and Cohen's k coefficients was 0.616, indicating a high degree of accuracy [16].

No sex differences were observed in the degree of improvement or the duration of the maintenance period of improved salt intake due to the dietary counseling intervention; however, sex differences were noted in factors that promoted salt-intake improvement. We observed that the progression of the CKD stage and collaborative care with a nephrologist promoted better salt-intake behavior in females, while only persistent and continuous counseling was important for males. An average of three dietary counseling sessions with a dietitian was required to improve salt intake by CKD patients, which was then maintained for an average of 407 days.

Few studies have examined health behavior changes and sex differences due to interventions based on clinical data assessments. The Modification of Diet in Renal Disease study reported no sex differences in compliance with a low-protein diet among CKD patients [20]. In contrast, in the Diabetes Care in General Practice examination of 6 years of structured personal care for patients with type 2 diabetes, males were more active in exercise therapy and females in diet therapy [21]. The present study found no sex differences in the degree of improvement or the duration of the maintenance of improved salt intake in patients with CKD; however, sex differences were observed in factors leading to improved salt intake. Factors improving salt intake in females were the number of counseling sessions, progression of the CKD stage, and collaboration with a nephrologist, whereas only the number of counseling sessions was a significant factor for improving salt intake in males.

Self-monitoring is a fundamental technique of cognitive behavioral therapy that is used to improve health behaviors. We examined the self-monitoring of BP measurements and observed no significant effect of this monitoring on improvements in salt intake. Improved salt-intake behavior is not always directly reflected in daily BP values, and this may have affected the results obtained. The present results also inferred the greater difficulties experienced by older patients to accept lifestyle modifications and by patients with comorbidities, such as obesity and diabetes, to self-manage, whereas patients with comorbid hypertension were more receptive to improvements in salt-intake behavior. Females were motivated to change their salt intake behavior by the progression of their CKD stage and by the explanations and advice of their nephrologists. Despite reports of disadvantaged healthcare delivery for females, the opportunity to consult with a nephrologist was confirmed to be meaningful for salt reduction in female patients in the present study. Regarding male patients with CKD, our results indicate that the optimal approach to improve salt intake is through sustained and continuous interventions by a dietitian. Previous studies reported that the threshold for a salty taste, which affects salt intake, increases with age and is higher in males than in females [22, 23]. It remains unclear whether this hinders males from improving their salt intake; therefore, further research is necessary to identify the factors affecting male behavior.

A health economic analysis using a Markov model based on the findings of the FROM-J study demonstrated that the incremental cost-effectiveness ratio (the additional cost required to extend the healthy life expectancy of one citizen by one year) of a dietetic intervention provided every 3 months was only 145,593 Japanese yen (1,324 USD) per year (i.e., quality-adjusted life year [QALY]) [24]. Since the threshold for one QALY in a medical intervention in Japan is 5 million yen (45,455 USD), continuous counseling by a dietitian is very cost-effective [24]. A budget impact analysis also confirmed that the continuation of this system of care, including lifestyle modification counseling, will reduce the number of patients with end-stage kidney disease in Japan by approx. 5,000 per year, with decreases in public healthcare costs being achieved from the 10th year [25]. Continuous dietary counseling for patients with chronic diseases, such as CKD, in Japan is often provided at a more advanced stage under the supervision of a specialist at a local base hospital, and general physicians often do not have a dietitian on staff. The FROM-J study verified that the health economic benefits of interventions were high despite a dietitian from each regional Nutrition Care Station being sent to all registered general physicians participating in that study.

Salt intake restriction was not a significant factor for blood pressure reduction or proteinuria reduction in this study. While salt intake was classified in three categories in this study, more accurate salt intake assessment is needed to assess the impact of improved salt intake on blood pressure and proteinuria. In the FROM-J study, dietary counseling was provided once every 3 months, during which the patients were examined by their attending physicians once every 2 to 4 weeks, and blood pressure was measured as needed while the prescription of antihypertensive medication was changed, and if sufficient reduction in blood pressure was achieved, the dose of antihypertensive medication was reduced. This may be the reason why the difference in antihypertensive effect between the salt intake improvement group and the non-improvement group is less pronounced. Adjustment of antihypertensive drug prescriptions in the dietary counseling group was also a factor that led to the high effectiveness of the cost-effectiveness analysis in the FROM-J study. [24].

There were several limitations in this study. Firstly, the assessment of salt intake was calculated based on dietary records with semi-quantitatively, which is inferior to 24-h urine excretion in terms of accuracy, but was considered to be capable of reflecting salt-intake behavior changes, which were the focus of this study. Secondly, the short observation period did not allow for an evaluation of lifestyle modification and adequate renal prognosis. Thirdly, to confirm the impact of sodium restriction on BP and proteinuria, long-term studies with more accurate assessment of sodium intake are needed.

Conclusions

The provision of continuous dietary counseling is beneficial for both improving salt intake and maintaining a reduced salt intake in the long-term management of CKD in both sexes. To implement these lifestyle modifications, dietary education sessions every 3 months were required, and these sessions were effective for 1 year. Continuous counseling for lifestyle modifications is highly cost-effective.

Abbreviations

CKD	Chronic kidney disease
KRT	Kidney replacement therapy
DKD	Diabetic kidney disease
ESKD	End-stage kidney disease
CVD	Cardiovascular disease
RAAS	Renin–angiotensin–aldosterone system
BP	Blood pressure

FROM-J	The Frontier of Renal Outcome Modifications in Japan
PCPs	Primary care physicians
eGFR	Estimated glomerular filtration rate
SD	Standard deviation
ORs	Odds ratios
Cis	Confidence intervals
BMI	Body mass index
QALY	Quality-adjusted life year

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12882-024-03707-7.

Supplementary Material 1.

Acknowledgements

We thank the physicians and dietitians who participated in this study and the members of the Japanese Society of Nephrology, the Japanese Dietetic Association, and the Japanese Medical Association for their continued support. We also thank Dr. Mariko Doi, Dr. Hideo Takahashi, Dr. Kunitoshi Iseki, Dr. Chiho Iseki, Dr. Masahide Kondo, and Dr. Reiko Okubo for their validation and data curation in the FROM-J study, and Dr. Yuichi Ishikawa and Dr. Atsuko Sakai for preparing the checklist.

Author's contributions

NK: Conceptualization, methodology, formal analysis, data curation, writing – original draft, visualization. CS: Conceptualization, methodology, resources, data curation, writing – review & editing, supervision. KN: Methodology, formal analysis, validation, supervision. KY: Methodology, resources. HK: Resources, data curation. TW: Resources, writing – review & editing. IN: resources, writing – review & editing. SM: Resources, writing – review & editing. HM: Resources, writing – review & editing. AH: Resources, writing – review & editing. KY: Conceptualization, writing – review & editing, supervision, project administration.

Funding

This study was supported by a grant for a Strategic Outcome Study Project from the Ministry of Health, Labour and Welfare of Japan. The study was also supported in part by a Grant-in-Aid for Research on Advanced Chronic Kidney Disease (REACH-J), the Practical Research Project for Renal Diseases, Japan Agency for Medical Research and Development (AMED) (no. JP20ek0310005) and the Japan Society for the Promotion of Science (JSPS) KAKENHI (no. JP21K08220).

Availability of data and materials

The data underlying this article will be shared on reasonable request to the corresponding author.

Declarations

Ethics approval and consent to participate

This study was conducted according to the guideline laid down in the Declaration of Helsinki after obtaining approval from the Medical Ethical Medical Ethical Committee of the Faculty of Medicine, University of Tsukuba (No.88). Informed consent was obtained from all participates and/or their legal guardians.

Consent for publication

Not applicable.

Competing interest

The authors declare that they have no relevant financial interests.

Author details

[1]Comprehensive Human Sciences Doctoral Program in Medical Sciences, University of Tsukuba, Tsukuba, Japan. [2]Tohto University, Chiba, Japan. [3]Department of Nephrology, Faculty of Medicine, University of Tsukuba, Tsukuba, Japan. [4]Kamakura Women's University, Kamakura, Japan. [5]Ibaraki Clinical Education and Training Center, Institute of Medicine, University of Tsukuba, Tsukuba, Japan. [6]Ibaraki Prefectural Central Hospital, Kasama, Japan. [7]Tokyo-Kita Medical Center, Tokyo, Japan. [8]Division of Clinical Nephrology and Rheumatology, Niigata Institute for Health and Sports Medicine, Niigata, Japan. [9]Tokai National Higher Education and Research System, Nagoya, Japan. [10]Okayama University, Okayama, Japan. [11]Yaizu City Hospital, Yaizu, Japan.

Received: 3 March 2024 Accepted: 13 August 2024
Published online: 26 August 2024

References

1. Liyanage T, Ninomiya T, Jha V, Neal B, Patrice HM, Okpechi I, et al. Worldwide access to treatment for end-stage kidney disease: a systematic review. Lancet. 2015;385(9981):1975–82.
2. Huijben JA, Kramer A, Kerschbaum J, de Meester J, Collart F, Arevalo OLR, et al. Increasing numbers and improved overall survival of patients on kidney replacement therapy over the last decade in Europe: an ERA Registry study. Nephrol Dial Transplant. 2023;38(4):1027–40.
3. Bairey Merz CN, Dember LM, Ingelfinger JR, Vinson A, Neugarten J, Sandberg KL, et al. Sex and the kidneys: current understanding and research opportunities. Nat Rev Nephrol. 2019;15(12):776–83.
4. Go AS, Chertow GM, Fan D, McCulloch CE, Hsu CY. Chronic kidney disease and the risks of death, cardiovascular events, and hospitalization. N Engl J Med. 2004;351(13):1296–305.
5. Tanaka K, Watanabe T, Takeuchi A, Ohashi Y, Nitta K, Akizawa T, et al. Cardiovascular events and death in Japanese patients with chronic kidney disease. Kidney Int. 2017;91(1):227–34.
6. Gaede P, Lund-Andersen H, Parving HH, Pedersen O. Effect of a multifactorial intervention on mortality in type 2 diabetes. N Engl J Med. 2008;358(6):580–91.
7. Kanauchi N, Ookawara S, Ito K, Mogi S, Yoshida I, Kakei M, et al. Factors affecting the progression of renal dysfunction and the importance of salt restriction in patients with type 2 diabetic kidney disease. Clin Exp Nephrol. 2015;19(6):1120–6.
8. Heerspink HL, Ritz E. Sodium chloride intake: Is lower always better? J Am Soc Nephrol. 2012;23(7):1136–9.
9. Rodríguez-Iturbe B, Vaziri ND, Herrera-Acosta J, Johnson RJ. Oxidative stress, renal infiltration of immune cells, and salt-sensitive hypertension: all for one and one for all. American Journal of Physiology-Renal Physiology. 2004;286(4):F606–16.
10. Vogt L, Waanders F, Boomsma F, de Zeeuw D, Navis G. Effects of dietary sodium and hydrochlorothiazide on the antiproteinuric efficacy of losartan. J Am Soc Nephrol. 2008;19(5):999–1007.
11. Shi H, Su X, Li C, Guo W, Wang L. Effect of a low-salt diet on chronic kidney disease outcomes: a systematic review and meta-analysis. BMJ Open. 2022;12(1): e050843.
12. Yamagata K, Makino H, Akizawa T, Iseki K, Itoh S, Kimura K, et al. Design and methods of a strategic outcome study for chronic kidney disease: Frontier of Renal Outcome Modifications in Japan. Clin Exp Nephrol. 2010;14(2):144–51.
13. Yamagata K, Makino H, Iseki K, Ito S, Kimura K, Kusano E, et al. Effect of Behavior Modification on Outcome in Early- to Moderate-Stage Chronic Kidney Disease: A Cluster-Randomized Trial. PLoS ONE. 2016;11(3): e0151422.
14. Imasawa T, Saito C, Kai H, Iseki K, Kazama JJ, Shibagaki Y, et al. Long-term effectiveness of a primary care practice facilitation program for chronic kidney disease management: an extended follow-up of a cluster-randomized FROM-J study. Nephrol Dial Transplant. 2023;38(1):158–66.
15. Iseki K, Yamagata K. A practical approach of salt and protein restriction for CKD patients in Japan. BMC Nephrol. 2016;17:87. https://doi.org/10.1186/s12882-016-0298-3.
16. Kai H, Doi M, Okada M, Yamada K, Iwabe H, Saito C, Yamagata K. Evaluation of the validity of a Novel CKD assessment checklist used in the frontier of renal outcome modifications in Japan study. J Ren Nutr. 2016;26(5):334–40.
17. Yamagata K. Trends in the incidence of kidney replacement therapy: comparisons of ERA, USRDS and Japan registries. Nephrol Dial Transplant. 2023;38(4):797–9.
18. Prochaska JO, Velicer WF. The transtheoretical model of health behavior change. Am J Health Promot. 1997;12(1):38–48.

19. Kwasnicka D, Dombrowski SU, White M, Sniehotta F. Theoretical explanations for maintenance of behaviour change: a systematic review of behaviour theories. Health Psychol Rev. 2016;10(3):277–96.
20. Coggins CH, Breyer Lewis J, Caggiula AW, Castaldo LS, Klahr S, Wang SR. Differences between women and men with chronic renal disease. Nephrol Dial Transplant. 1998;13(6):1430–7.
21. Nielsen AB, de Fine ON, Gannik D, Hindsberger C, Hollnagel H. Structured personal diabetes care in primary health care affects only women's HbA1c. Diabetes Care. 2006;29(5):963–9.
22. Yoshinaka M, Ikebe K, Uota M, Ogawa T, Okada T, Inomata C, et al. Age and sex differences in the taste sensitivity of young adult, young-old and old-old Japanese. Geriatr Gerontol Int. 2016;16(12):1281–8.
23. Barragan R, Coltell O, Portoles O, Asensio EM, Sorli JV, Ortega-Azorin C, et al. Bitter, sweet, salty, sour and umami taste perception decreases with age: sex-specific analysis, modulation by genetic variants and taste-preference associations in 18 to 80 year-old subjects. Nutrients. 2018;10(10):1539.
24. Okubo R, Kondo M, Hoshi SL, Okada M, Doi M, Takahashi H, et al. Cost-effectiveness of behavior modification intervention for patients with chronic kidney disease in the FROM-J study. J Ren Nutr. 2021;31(5):484–93.
25. Okubo R, Kondo M, Hoshi SL, Kai H, Saito C, Iseki K, et al. Behaviour modification intervention for patients with chronic kidney disease could provide a mid- to long-term reduction in public health care expenditure: budget impact analysis. Clin Exp Nephrol. 2022;26(6):601–11.

Publisher's Note