Effect of potassium-enriched salt on cardiovascular mortality and medical expenses of elderly men^{1-3}

Hsing-Yi Chang, Yu-Whuei Hu, Ching-Syang Jack Yue, Yu-Wen Wen, Wen-Ting Yeh, Li-San Hsu, Shin-Yin Tsai, and Wen-Harn Pan

ABSTRACT

Background: The beneficial effects of potassium-enriched salt on blood pressure have been reported in a few short-term trials. The long-term effects of potassium-enriched salt on cardiovascular mortality have not been carefully studied.

Objective: The objective was to examine the effects of potassiumenriched salt on cardiovascular disease (CVD) mortality and medical expenditures in elderly veterans.

Design: Five kitchens of a veteran retirement home were randomized into 2 groups (experimental or control) and veterans assigned to those kitchens were given either potassium-enriched salt (experimental group) or regular salt (control group) for ≈ 31 mo. Information on death, health insurance claims, and dates that veterans moved in or out of the home was gathered.

Results: Altogether, 1981 veterans, 768 in the experimental $[\bar{x} (\pm SD) \text{ age: } 74.8 \pm 7.1 \text{ y}]$ and 1213 in the control (age: 74.9 ± 6.7 y) groups, were included in the analysis. The experimental group had better CVD survivorship than did the control group. The incidence of CVD-related deaths was 13.1 per 1000 persons (27 deaths in 2057 person-years) and 20.5 per 1000 (66 deaths in 3218 person-years) for the experimental and control groups, respectively. A significant reduction in CVD mortality (age-adjusted hazard ratio: 0.59; 95% CI: 0.37, 0.95) was observed in the experimental group. Persons in the experimental group lived 0.3–0.90 y longer and spent significantly less (\approx US \$426/y) in inpatient care for CVD than did the control group, after control for age and previous hospitalization expenditures.

Conclusions: This study showed a long-term beneficial effect on CVD mortality and medical expenditure associated with a switch from regular salt to potassium-enriched salt in a group of elderly veterans. The effect was likely due to a major increase in potassium and a moderate reduction in sodium intakes. *Am J Clin Nutr* 2006;83:1289–96.

KEY WORDS Potassium-enriched salt, elderly, cardiovascular mortality, health expenditure, Taiwan

INTRODUCTION

Hypertension is one of the major risk factors for cardiovascular disease (CVD) and atherosclerosis. The strong associations between blood pressure and the occurrence of stroke and coronary artery disease have been well established (1-4). Dietary sodium, potassium, calcium, and fatty acid composition and obesity are considered among the contributing factors for the development of hypertension (5). Both observational and experimental studies have repeatedly shown that the level of sodium intake is positively associated with blood pressure (6–9). Although there were many contradictory findings, they were primarily due to the limitations of the study designs and methods such as not measuring confounders, low statistical power of withinpopulation studies, and regression dilution bias caused by large within-person variations in sodium intake.

The Nutrition and Health Survey in Taiwan found that the average (\pm SE) sodium intake of the general elderly male population of Taiwan was 5.0 \pm 0.3 g (10). In Taiwan or China, where salt intake is high and the intake range is large, the relation between the amount of dietary salt and blood pressure was often evident (11–13). Examples include findings from the Chinese sample of the World Health Organization Cardiovascular Diseases and Alimentary Comparison (12) study and those from the Government Employee Health Examination study (13) in Taiwan. A strong evidence of the sodium-blood pressure theory came from the difference in the degree of blood pressure elevation with aging. In societies where salt is not commonly used, people's blood pressures do not increase as they age. On the other hand, in societies with high-salt diets, people's blood pressures increase tremendously as they age (6, 7).

Sodium reduction trials showed blood pressure–lowing effects of a low-sodium diet (8, 9). The Trial of Nonpharmacological Intervention in the Elderly showed that the incidence of hypertension in the low-sodium group was significantly lower than that of the control group (9). Even with such strong evidence of

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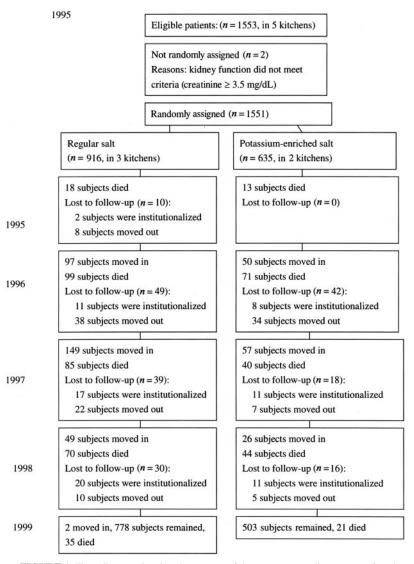


FIGURE 1. Flow diagram showing the process of the consort according to year of study.

the benefits of sodium reduction (14), some researchers have recently argued against it (15, 16). Alderman's observational findings on low-sodium intakes and increased mortality (15) has rejuvenated the discussions (17, 18).

Many researchers have established negative associations between dietary potassium intake and blood pressure. In the early 1970s, Meneely et al (19, 20) showed the vascular protective effects of potassium chloride. In a prospective study, Khaw and Barett-Connors (21) followed 859 elderly residing in southern California and found that a 10-mmol increment in potassium intake reduced stroke mortality by 40%. Therefore, the use of potassium-enriched salt has the combined advantages of sodium reduction and potassium increase. Several short-term studies have shown a blood pressure-reducing effect of potassium or other mineral-enriched salts (21-24). The present study was the first study to examine the long-term effects of potassiumenriched salt on total mortality and cardiovascular mortality in a group of elderly men. Furthermore, information on direct cost for hospitalization or clinic visits was used to show the degree of reduction in medical expenses by simply shifting into potassiumenriched salt.

SUBJECTS AND METHODS

In the present study, we randomized 5 kitchens of a veteran's retired home in northern Taiwan into experimental and control groups (Figure 1). When a veteran registered into the retired home, he was assigned into one of 11 squads; each squad was composed of ≈ 200 people, and 2 squads shared one kitchen. Of 5 kitchens (corresponding to 10 squads), 2 kitchens (corresponding to 4 squads) were randomly assigned to use potassiumenriched salt. The other 3 kitchens (6 squads) were randomly assigned to use regular salt. The simplest randomization method, ie, drawing lots, was used. Bed-ridden veterans were either assigned to squad 12 or transferred to the veteran's home located in northeast Taiwan. Because the veterans in squad 11 shared the kitchen with those in squad 12, they were excluded from the study. The residents' kidney function was examined before the study. Persons with high serum creatinine concentrations (ie, \geq 3.5 mg/dL) were asked to cook their meals separately and were excluded from the study. The rest of the veterans ate food prepared by the cook of the kitchen to which they were assigned. The salt, which was manufactured by Taiwan Salt Work (Tainan, Taiwan, China), was weighed and delivered to the kitchens by a research staff. The veterans were informed about the trial, but were not told to which salt they were assigned. The study was approved by reviewers from the National Science Council in Taiwan.

The potassium-enriched salt was composed of 49% sodium chloride, 49% potassium chloride, and 2% other additives, whereas regular salt was composed of 99.6% sodium chloride and 0.4% other additives. The potassium-enriched salt replaced regular salt in the selected kitchens in a gradual manner. The potassium-enriched salt was mixed with regular salt in a 1 to 3 ratio for the first week. Then, the ratio of potassium-enriched salt to regular salt was increased to 1:1 and 3:1 during the second and third weeks, respectively. At the fourth week, the cooks in the selected kitchens used solely the potassium-enriched salt. The other kitchens used regular salt at all times. The total amount of salt used in each kitchen was recorded monthly. The trial started on 17 October 1995 and ended 30 June 1999. The average amount of potassium-enriched salt was $\approx 1-2$ kg per day per kitchen [\bar{x} (\pm SD): 1.41 \pm 0.22 kg/d]. Each kitchen served \approx 400 persons per meal. Other condiments and spices such as soy sauce and monosodium glutamate were not limited, because reasonably priced low-sodium soy sauce and monosodium glutamate were not available at the time of the trial. The average consumption of monosodium glutamate, soysauce, vinegar, hot sauce, ketchup, and pickled vegetables during the first 3 mo of the trial were 560 mg, 389 mg, 91 mg, 84 mg, 10 mg, and 225 mg per person per day, respectively, for the experimental group. The respective values for the control group were 536 mg, 394 mg, 88 mg, 55 mg, 10 mg, and 224 mg. Intakes of sodium were 3.8 g and 5.2 g for the experimental and control groups, respectively (25). Salt was the major source of sodium added in the cooking process, whereas other sauces accounted for $\approx 30\%$ of total sodium.

Information on dates of birth and dates of entry into the study was collected when the veterans entered the study. Some measures, such as blood pressure, weight, and height, were taken from a subgroup of volunteers at the beginning of the study in October 1995 and 3 mo after the intervention in February 1996. Informed consent was obtained from the veterans who participated in these measurements. The intervention started in October 1995. Records of moving in and out of the home, and reasons for moving out, were obtained monthly from the veterans until June 1999. Most veterans stayed in the veterans' home until the end of their lives, because most of them came from mainland China after World War II and had no families in Taiwan. Death certificates of the deceased veterans were also obtained monthly throughout the entire study period. The International Classification of Diseases 9th revision (ICD-9) code for cause of death was assigned by official coders of the Department of Health. The agreement in assigning the underlying cause of death between official coders and 4 physicians were evaluated (26). The proportion physicians who completely agreed with the official coders was 69% when sufficient information was available. The proportion of physicians and official coders who agreed was higher (>90%) when 3 of 4 physicians agreed with the cause of death (10). Therefore, the ICD-9 codes assigned by the official coders were used in this study. CVD-related deaths were caused by hypertension (ICD-9: 401-405), ischemic heart disease (ICD-9: 410-414), cerebrovascular disease (ICD-9: 430-438), heart failure (ICD-9:428), or diabetes (ICD-9:250).

The National Health Insurance in Taiwan was implemented in March 1995. Information of health claims for clinic visits and hospitalizations was extracted for veterans who provided identification. Only 6 veterans did not provide us with their identification. Items extracted from the insurance data were admission and discharge dates, medical expenditures for each visit, and the reasons for clinical visits or hospitalization. The medical expenditures of both treatment groups were compared by using the Tobit Censored model (27) to account for dependent variables censored at zero. CVD-related expenditures in inpatient and outpatient care were compared between the treatment groups, with control for age and previous use of medical care, which were proxies of previous health conditions. Because death events are often associated with an elevated hospitalization charge, they were also controlled for in the model.

SAS version 8.0 (SAS Inc, Cary, NC) was used for data analyses. Descriptive statistics such as means, SDs, and frequencies were used to describe the baseline characteristics of veterans according to the 5 kitchens or 2 treatment groups. Survival curves for each of the 5 kitchens were estimated by Bayesian hierarchical method with control for the age of entry. Cluster effects were accounted for in the model as well. The models assumed the survival time T_i followed a parametric Weibull distribution as follows:

$$f(t_i) = \gamma \mu_i t_i^{\gamma - 1} \exp(-\mu_i t_i^{\gamma}), i = 1, 2, \dots, 2195 \quad (1)$$

where γ is an unknown shape parameter and μ_i is the mean hazard. The mean hazard model included an additive random effect b_j , where $j = 1, 2, \dots 5$ for each kitchen. This can be expressed as follows:

$$\log(\mu_i) = \beta_0 + \beta_1 \times (\text{age}_i - \text{mean age}) + b_j \times I(i \in j)$$
(2)

where age_i was a continuous covariate, mean age was the sample mean of age, $\beta^T = [\beta_0 \beta_1]$ was the regression coefficient, $b^T = [b_1 \ b_2 \dots b_5]$ was assumed to follow a multivariate normal distribution with zero mean, and the covariate matrix Σ and I ($i \in j$) was a dummy variable representing that whether the i^{th} observation belonged to the j^{th} kitchen.

In the Bayesian framework, the unknown parameters were assumed to be random and had a prior distribution. The regression coefficients β were given a noninformative prior distribution, namely $\beta \approx N(0, 100 \times I)$, where *I* was an identity matrix. The shape parameter of the survival distribution γ was given a γ (1, 0.01) prior. The covariate matrix Ó was assumed to follow an inverse Wishart distribution [IW (5, 100 × 1)]. The Markov chain Monte Carlo method, an iterative tool to sample from posterior distribution to estimate characteristics of the distribution of interest was applied to the above model. We used WINBUGS package to obtain model estimation and fitted our model by single chain for 30 000 iterations. The results from running 20 000 burn-in samples followed by a production run of 10 000 samples for posterior estimations were plotted.

To test the intervention effect of the potassium-enriched salt, the Cox proportional hazard model was used with each person as the unit of analysis. We assumed subjects assigned to the 5 kitchens were homogeneous and carried out the survival analysis by combining the subjects in kitchens 2 and 3 into the experimental group and the subjects in kitchens 1, 4, and 5 into the Baseline characteristics of the veterans and the average follow-up time by experimental and kitchen groups

	Experimental	group $(n = 768)$	(Control group $(n = 1213)$			
	Kitchen 2	Kitchen 3	Kitchen 1	Kitchen 4	Kitchen 5		
Age groups							
40–64 y [<i>n</i> (%)]	11 (2.8)	12 (3.2)	16 (4.1)	21 (5.1)	12 (2.9)		
65–74 y [n (%)]	206 (52.2)	207 (55.5)	183 (46.9)	207 (50.5)	212 (51.3)		
75–84 y [n (%)]	133 (33.7)	110 (29.5)	143 (36.78)	148 (36.1)	168 (40.7)		
≥85 y [n (%)]	45 (11.4)	44 (11.8)	48 (12.3)	34 (8.3)	21 (5.1)		
Total $[n(\%)]$	395 (100)	373 (100)	390 (100)	410 (100)	413 (100)		
Age (y)	75.6 ± 7.7^{1}	74.8 ± 7.0	74.8 ± 7.3	74.6 ± 6.7	74.6 ± 6.1		
Follow-up (mo)	30.6 ± 14.5	32.6 ± 14.9	31.5 ± 14.9	30.0 ± 15.1	30.7 ± 14.9		
Height $(cm)^2$	161.3	± 6.9		161.8 ± 6.5			
Weight $(kg)^2$	60.7	± 10.8		60.3 ± 9.8			
BMI $(kg/m^2)^2$	23.3	± 3.5		23.0 ± 3.3			
Systolic blood pressure (mm Hg)	131.3	± 19.7		130.7 ± 20.4			
Diastolic blood pressure (mm Hg)	71.2	± 10.8		71.4 ± 10.8			
Hypertension (% of subjects)	4	0.2		40.4			
Sodium-to-creatinine ratio	1.34	± 0.92	1.14 ± 0.74				
Potassium-to-creatinine ratio	0.277	± 0.143		0.284 ± 0.142			

 $^{I}\bar{x} \pm \text{SD}$ (all such values).

² Data were from reference 25 for 248 and 391 subjects in the experimental and control groups, respectively. These subjects had a physical examination before the intervention and 3 mo after the intervention. None of the comparisons were statistically significant, P > 0.05 (chi-square or *t* test, as appropriate).

control group; the age and CVD risk factor distributions were not significantly different between the subjects in the experimental and control groups. In addition, all veterans were covered by the same health insurance plan (National Health Insurance with additional coverage for veterans), which used the same health care system (mostly veteran general hospitals). The food supply and the meal plans were exactly the same for all kitchens, and the veterans were randomly assigned to each squad.

Life expectancies for both groups were also calculated. The mortality rate was calculated for each age group by dividing number of deaths by person-years. The raw mortality rate was then smoothed by Whittaker's method (28) because the raw values were not stable due to the small number of observations.

RESULTS

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Altogether, 1982 persons entered the study. One person had invalid date of birth and 15 deaths were missing the date of death. They were excluded from the survival analysis. Seven hundred sixty-eight veterans (395 from kitchen 2 and 373 from kitchen 3) were assigned to the experimental group and 1213 (390 from kitchen 1, 410 from kitchen 4, and 413 from kitchen 5) were assigned to the control group. The average follow-up period was \approx 31 mo (\approx 2.6 y) with a maximum follow-up of 1352 d (ie, 3.7 y) (Table 1). The ages of persons in different kitchens were not significantly at entry (P = 0.24; Table 1). The results also indicated that weight, height, body mass index, blood pressure, and electrolytes for a subsample of persons in the experimental and control groups were not significantly different at baseline (25). Persons in kitchens 2 and 3 had slightly longer follow-up times than did their counterparts in kitchens 1, 4, and 5; however, the difference did not reach statistical significance (P = 0.11).

The urine electrolyte data were available for $\approx 25\%$ of the subjects. In the experimental groups, the average (\pm SD) urinary sodium-to-creatinine ratio decreased from 1.34 ± 0.92 to $1.22 \pm$

0.73 and the potassium-to-creatinine ratio increased from 0.28 \pm 0.14 to 0.48 \pm 0.23 for the initial 3 mo of the study, whereas the sodium-to-creatinine ratio increased from 1.14 \pm 0.74 to 1.23 \pm 0.76 and the potassium-to-creatinine ratio did not change significantly in the control groups (from 0.28 \pm 0.14 to 0.27 \pm 0.12) (25).

Because the death registry of Department of Health in Taiwan is fairly complete, all information regarding deaths was obtained. A few veterans went back to mainland China and died there. Their death certificates were also available; however, $\approx 8\%$ of death certificates from mainland China did not provide a cause of death (Table 2). A total of 504 deaths occurred during the study period. About 15% of the deceased veterans died of cancer and 9% died of pneumonia. Although the overall distributions of the causes of death were not significantly different in the 2 groups $(\chi^2 = 23.45, P = 0.267; \text{Table 2})$, there was smaller proportion (P = 0.005) of subjects who died of CVD in the experimental group (27 died; 1310.0 per 100 000 person-years) than in the control group (66 died; 2140.0 per 100 000 person-years). The difference was -828.7 per 100 000 person-years (95% CI: -1424.5, -232.9). The non-CVD deaths were not significantly different between the groups (P = 0.479). The non-CVD incidence was 8030.0 and 7990.0 per 100 000 person-years for the experimental and control groups, respectively. The differences in the incidence of mortality from cerebral vascular diseases (389.4 compared with 779.2 per 100 000 person-years for the experimental and control groups, respectively, P = 0.041) and from heart failure (97.3 compared with 324.6 per 100 000 person-years, P = 0.049) between the 2 groups were particularly apparent.

The Bayesian method–derived survival curves of the 5 kitchens for CVD deaths are shown in **Figure 2**. The subjects assigned to kitchens 2 and 3 (the experimental group) showed better survivorship in terms of CVD-related deaths than did persons assigned to kitchens 1, 4, and 5 (the control group), especially after

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TABLE 2

Distribution of causes of deaths and the cause-specific incidence of death per 100 000 person-years in the experimental and control groups¹

Cause of death	Experimental group		Control group			Relative	Total	
	Deaths	Incidence	Deaths	Incidence	Absolute risk reduction (95% CI) ²	risk reduction ³	Deaths	Incidence
	n (%)	n	n (%)	n		%	n (%)	п
Cancer	32 (16.7)	1557.5	42 (13.5)	1363.5	194.0 (-454.7, 842.7)	14.2	74 (14.7)	1441.1
Cardiovascular disease	27 (14.1)	1310.0	66 (21.3)	2140.0	$-828.7 (-1424.5, -232.9)^4$	-38.8	93 (18.5)	1810.0
Ischemic heart disease	9 (4.7)	438.0	20 (6.4)	649.3	-256.3(-600.3, 87.7)	-32.5	29 (5.8)	564.8
Hypertensive disease	4 (2.1)	194.7	4(1.3)	129.9	64.8 (-164.5, 294.1)	49.9	8 (1.6)	155.8
Diabetes mellitus	4 (2.1)	194.7	8 (2.6)	259.7	-65.0(-294.3, 164.3)	-25.0	12 (2.4)	233.7
Heart failure	2(1.0)	97.3	10 (3.2)	324.6	$-227.3(-389.5, -65.1)^4$	-70.0	12 (2.4)	233.7
Cerebrovascular disease	8 (4.2)	389.4	24 (7.7)	779.2	$-389.8(-741.1, -65.5)^4$	-50.0	32 (6.4)	623.2
Infectious disease								
Pneumonia	20 (10.4)	973.4	28 (7.2)	811.6	125.8 (-387.0, 638.6)	20.0	48 (9.5)	930.0
Infection	7 (3.7)	340.7	16(5.1)	519.4	-178.7(-482.1, 124.7)	-34.4	23 (4.6)	447.9
Others	, (517)	0.000	10 (011)	01)11	1,01,(10211,1211))	0	20 (110)	
Senility ⁵	20 (10.4)	973.4	36 (11.5)	1168.7	-195.3 (-708.1, 317.5)	-16.7	56 (11.1)	1090.6
COPD	12 (6.3)	584.1	26 (8.3)	844.1	-260.0(-657.2, 137.2)	-30.8	38 (7.5)	740.0
Digestive system	17 (8.9)	827.4	18 (5.8)	584.4	243.0 (-229.8, 715.8)	41.6	35 (6.9)	681.6
Genital diseases	8 (4.2)	389.4	9 (2.9)	292.2	97.2 (-227.1, 421.5)	33.2	17 (3.4)	331.1
Other heart problems ⁶	8 (4.2)	389.4	4 (1.3)	129.9	259.5 (-64.8, 583.8)	33.2	12 (2.4)	233.7
Renal failure	5 (2.6)	243.4	5(1.6)	162.3	81.1 (-175.3, 337.5)	50.0	10 (2.0)	194.7
Liver diseases	1(0.5)	48.7	3 (1.0)	97.4	-48.7 (-163.4, 66.0)	-50.0	4 (0.8)	77.9
Rheumatic heart disease	0		1 (0.3)	32.5	-32.5		1 (0.2)	19.5
Suicide	3 (1.6)	146.0	5(1.6)	162.3	-16.3(-214.9, 182.3)	-10.0	8 (1.6)	155.8
Injury	1(0.5)	48.7	6 (1.9)	194.8	-16.3(-260.8, -31.4)	-75.0	7 (1.4)	136.3
Missing ICD-9 code ⁷	16 (8.3)	778.7	26 (8.5)	844.1	-65.4 (-524.1, 393.3)	-7.7	42 (8.3)	817.9
Total	192 (100.0)	9344.8	312 (100.0)	10129.1	-784.3 (-2373.2, 804.6)	-7.7	504 (100.0)	9815.3

¹ COPD, chronic obstructive pulmonary disease; ICD, International Classification of Diseases.

² Number of deaths per 100 000 person-years.

³ Calculated as (rate of experimental - rate of control)/(rate of control) \times 100.

⁴ The absolute incidence was significantly different between the 2 groups (chi-square test), P < 0.05.

⁵ ICD-9 between 797 and 799.

⁶ Other heart problems included ICD-9: 415 (acute pulmonary heart disease), 426 (conduction disorders), 429 (III-defined descriptions and complications of heart disease), 440 (atherosclerosis), and 427 (cardiac dysrhythmia).

⁷ Most subjects in this group of people died in mainland China. Their death certificates did not provide detailed information on the cause of death.

 ≈ 100 d. No significant interaction between survivorship and kitchen assignment was observed. The cumulative hazard ratio of deaths due to all causes and CVD are shown in **Figure 3** and **Figure 4**, respectively. The group who received the potassiumenriched salt had a lower overall death hazard ratio after 1.5 y than did the control group. The difference in the risk of CVD appeared early in the study. Age was positively and significantly associated with death in all cases and was controlled for in the models.

Potassium-enriched salt reduced the CVD mortality hazard ratio to $\approx 60\%$ that of the control group (hazard ratio: 0.59; 95% CI: 0.37, 0.95). In all-cause mortality, potassium-enriched salt also showed protective effects (hazard ratio: 0.90), but the effect was not statistically significant. The experimental group had a longer life expectancy than did the control group (**Table 3**). The age-specific differences ranged from 0.2 to 0.9 y for those aged between 65 and 75 y. Results of economic analyses also showed that the treatment group had significantly lower expenditures on CVD-related inpatient care than did the control group (**Table 4**) after control for the amount of medical expenditure for CVD before the study. During the study period, the experimental group spent, on average, 39 071.78 New Taiwanese Dollars (NTD) less on inpatient care for CVD-related diseases than did the control group, given the same age, observation days, previous use of medical care, and other factors. This resulted in 14 913 NTD [39 071.78 NTD/(958.7 total days of study/365 days per year)] less spent per person per year. A similar pattern was found in expenditures for outpatient care and in total expenditures, although the treatment effect was not statistically significant (Table 4). Other factors such as death and previous use of medical care for CVD were also significantly associated with medical expenditures.

DISCUSSION

The present study showed a long-term effect on CVD mortality and medical expenditure associated with lowering the sodium-to-potassium ratio in a group of veterans in northern

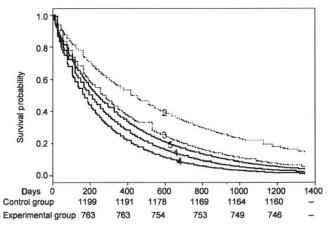


FIGURE 2. Cardiovascular disease (CVD) survivorship of veterans according to kitchen assignment. The numbers on the lines indicate the kitchen number. The control groups were assigned to kitchens 1, 4, and 5; the experimental groups were assigned to kitchens 2 and 3.

Taiwan. The effect may primarily be due to the increase in potassium intake, because the sodium reduction achieved was moderate. The present study examined the effects from several angles. Survivorship in the experimental group (kitchens 2 and 3) was better than that in the control group (kitchens 1, 4, and 5), as shown by the Bayesian method–derived survival curve. Cox proportional hazard models confirmed the results: the effect in CVD mortality reduction was statistically significant. Compared with the control group, the estimated life expectancy was increased, whereas the medical expenditure was reduced, in the experimental group. The age at entry into the study and the average baseline measurements on height, weight, and blood pressure were not significantly different between the 2 groups (Table 1). The only difference between the experimental and control groups was the cooking salt (25).

The average amount of sodium consumed during the trial was estimated to be ≈ 3.8 g per person per day for the experimental group and 5.2 g per person per day for the control group. A 17% reduction was observed for the urinary sodium-to-creatinine ratio in the experimental group, but a 76% increase was observed

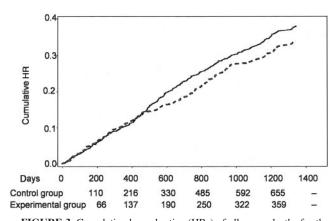


FIGURE 3. Cumulative hazard ratios (HRs) of all-cause deaths for the treatment and control groups. The incidence rate of the experimental group (dash line) was 9344.8 per 100 000 person-years and that of the control group (solid line) was 10 129.1 per 100 000 person-years. HR: 0.90; 95% CI: (0.79, 1.06).

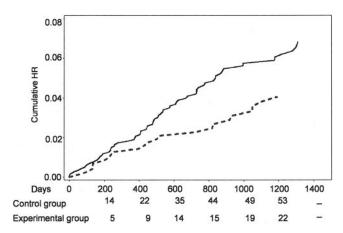


FIGURE 4. Cumulative hazard ratios (HRs) of cardiovascular diseaserelated deaths for the treatment and control groups. The incidence rate was 1310.0 per 100 000 person-years for the experimental group (dash line) and 2140.0 per 100 000 person-years for the control group (solid line). HR: 0.59; 95% CI: (0.37, 0.95).

in the potassium-to-creatinine ratio. The urinary potassium-tocreatinine ratio of the veterans was low at baseline (0.28). Three months into the experiment, the mean (\pm SD) urinary potassium concentration remained $\approx 0.28 \pm 0.12$ for the control group, whereas it increased to 0.48 ± 0.23 in the experimental group. We speculated that potassium from the enriched salt contributed to the prevention of CVD-related deaths in this group of veterans with poor potassium status. The increase in potassium intake may have an effect on general health and on the reduction of overall mortality, although the relative risk of all-cause mortality did not reach statistical significance.

The estimated life expectancy for the group of veterans aged 70 y could be used to show how potassium-enriched salt substantially reduces mortality risks. In Taiwan, the average male life expectancy at age 70 y improved 0.05 y naturally in the past 20 y (29). The life expectancy difference at age 70 y between the 2 groups (0.90 y) is equivalent to that which would have naturally occurred in 14 y.

Many researchers have provided strong evidence on the relation between sodium and blood pressure (17, 18, 30) to contradict the arguments by Alderman (15) and Freeman (16). However, most of these studies were observational epidemiologic studies. In addition, most sodium reduction trials were short-term and used blood pressure reduction as the primary endpoint. Recently, Cook et al (31) presented the long-term effects of sodium reduction on CVD based on the data from the Trials of Hypertension Prevention. By providing evidence of the protective effects of potassium-enriched salt against CVD mortality, our results add strong support for the promotion of lowering sodium and increasing potassium intakes.

The present study showed the potential beneficial effects of potassium-enriched salt in the elderly, a great proportion of whom may be sodium-sensitive (32, 33). Reduction of sodium intake was suggested for the treatment of geriatric hypertension before beginning pharmacologic therapy (34). In recent findings of the Dietary Approaches to Stop Hypertension–sodium trial, Bray et al (33) observed a stronger reduction in blood pressure in older age groups than that in the younger age groups given the same type sodium-reduction diet. From the data on causes of death, we observed an apparent difference in mortality from Life expectancies for the experimental and control groups

Age (y)	Experimental group		Contro	D:00	
	Mortality rate ¹	Life expectancy	Mortality rate ¹	Life expectancy	Differences in life expectancy
		у		у	
65	0.0670	9.97	0.0566	9.41	0.56
66	0.0597	9.54	0.0698	9.05	0.49
67	0.0667	9.22	0.0751	8.59	0.63
68	0.0791	8.92	0.0813	8.17	0.76
69	0.0929	8.67	0.0897	7.82	0.84
70	0.1029	8.47	0.0899	7.58	0.90
71	0.1050	8.26	0.0779	7.39	0.87
72	0.1005	7.92	0.0625	7.195	0.72
73	0.0894	7.41	0.0574	6.94	0.47
74	0.0825	6.83	0.0663	6.58	0.26
75	0.0884	6.28	0.0800	6.12	0.16

¹ Smoothed by using Whittaker's method (28).

cerebrovascular disease and heart failure between the experimental and the control groups in this group of elderly veterans, for whom the prevalence of hypertension was 40% at baseline.

The benefit of using potassium-enriched salt on CVD mortality can be translated into dollars saved. On average, veterans in the experimental group spent 14 913 NTD (\approx \$426 USD) less in inpatient care for CVD than did the control group, given the same age, survival status, previous clinic visits, and hospital stay. Compared with the average CVD inpatient medical expenditure before the trial (ie, 24 817 NTD), the dollar benefit of replacing regular salt with potassium-enriched salt was a reduction in the CVD impatient expenditure of \approx 40%. The benefit was also observed in total medical expenditures, even though it did not reach statistical significance. The findings had the same implication as those of Daviglus et al (34) who used data from the Chicago Heart Association Detection Project in Industry to evaluate the late life medical expenditure of persons who had low risk of CVD in middle age. They found that the average annual charges of persons in late life with a low risk of CVD were much lower than those of persons in middle age with a high risk of CVD. Our results showed that slight modifications in sodium and potassium intakes reduced medical expenses, especially for CVDrelated hospitalizations.

In conclusion, the present follow-up study showed that switching from regular salt to potassium-enriched salt reduced cardiovascular mortality, improved longevity, and cut down medical expenditures for CVD-related inpatient care in a group of elderly men in northern Taiwan. Additional studies are encouraged to demonstrate the beneficial effects of a reduction in dietary sodium and an increase in potassium intake in the general population and to clarify whether the effect comes from lower sodium intake or from higher potassium intake.

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TABLE 4

Medical expenditure related to cardiovascular disease (CVD) during the trial

	Inpatient care		Outpatient care		Total ¹	
Variable	Estimate of coefficient	SE	Estimate of coefficient	SE	Estimate of coefficient	SE
Treatment	-39071.8^2	19 539.5	-1237.3	1229.3	-9081.2	7484.3
Age at entry	722.0	1388.6	-312.8^{2}	90.5	79.4	545.4
Days observed during trial	229.9^{2}	30.4	22.4^{2}	1.75	106.4^{2}	10.5
Death occurred during the trial	$206\ 120.7^2$	27 319.4	-6042.0^{2}	1730.7	$34\ 208.4^2$	10 318.0
Inpatient care for CVD before trial ³	1.32^{2}	0.20	0.03^{2}	0.01	0.71^{2}	0.09
Outpatient care for CVD before trial ³	8.87^{2}	3.48	1.98^{2}	0.21	6.44	1.33
Inpatient care for non-CVD before trial ³	-0.02	0.17	0.01	0.01	-0.06	0.06
Outpatient care for non-CVD before trial ³	1.08	1.55	-0.03	0.11	0.29	0.62
Intercept ⁴	-612553.0^2		952.37	7026.97	-141 318.2	42 498.07
Log likelihood	-6580.88		-14 401.89			
χ^2	123.60^2		411.06			

¹ Sum of the inpatient and outpatient care.

² Significantly different from zero, P < 0.05 (*t* test).

³ Before the study.

⁴ Intercept of the model; expected value of the dependent variable when independent variables are set to zero.

H-YC contributed to the managing and cleaning the data bank, analyzing the data, providing statistical consulting, coordinating the analyses and writing, and drafting of the manuscript. Y-WH contributed to the economical analysis of the study. C-SJY contributed to the estimation of life expectancy. Y-WW contributed to the Bayesian analysis of kitchen effect. W-TY communicated with the veteran's retired home, collected urine samples for the study, and helped in the weighing of the salt for the veteran's home, collecting in and out, death information. L-SH helped to collect and analyze death information and help to develop a data collection and entry system. S-YT was in charge of the measurements at baseline and at 3 mo, assessed the condiments and spices used in the cooking, and generated descriptive statistics. W-HP was the primary investigator, initiated and designed the study, contacted the veteran home and negotiated with the veterans to get their permission to carry out the study in their home, contributed to the intellectual discussion of the data analysis, and wrote many sections of the manuscript. None of the authors had any conflict of interest or any financial relations with the funding agent (Taiwan Salt Work; Tainan, Taiwan, ROC).

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