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Impact of a nudge-based food environment intervention in a hospital convenience store on staff's food intake and Na/K

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Abstract

Background A food environment intervention using nudge tactics was implemented at a hospital convenience store (CVS) in Tokyo to improve employees' eating habits. The objective of this study was to evaluate its effects on the urinary sodium-to-potassium ratio (Na/K), food intake, eating attitude, and behavior.

Methods Using a pre–post design; the intervention incorporated nudge tactics, healthier options, easy-to-pick food placement, and eye-catching information. We also used price incentives. The primary outcomes included changes in Na/K and sodium and potassium excretion assessed using spot urine samples at health checkups. Secondary outcomes were changes in staff food intake, eating attitude, and behavior which were assessed using questionnaire surveys. All outcomes were evaluated statistically. Furthermore, we investigated how the intervention led to outcomes using path analysis.

Results A total of 140 participant (52men and 88women) were analyzed. Significant changes were observed in Na/K (3.16 to 2.98 in median, $p = 0.02$) and potassium excretion (43.4 to 45.2 mmol/day in mean, $p = 0.03$). However, sodium excretion did not change significantly. The intake of fruits and dairy products increased with improved self-efficacy. The most influential factor for lowering Na/K and increasing potassium excretion was information from the CVS; purchasing "balanced meals" to lower Na/K and salads to increase potassium excretion were second.

Conclusions Food environment intervention using nudge tactics can improve staff's food intake and lower Na/K.

Trial registration Registration number: UMIN000049444 (UMIN-CTR).

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Keywords Food environment, Convenience store, Intervention study, Nudge, Sodium-to-potassium ratio, Food intake, Medical staff

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Background

Protecting the health and well-being of healthcare workers is crucial for providing sustainable healthcare. Nutrition and dietary habits are among the most important factors, and it is of great significance for healthcare organizations to take initiatives to improve the food environment of their facilities.

Recent studies showed the effects of nudge tactics in improving the food environment [1–13]. Nudge is a strategy based on behavioral economics that uses small cues to influence people's decisions and encourage behavioral change without drastically changing economic incentives or coercing behavior through penalties or rules [14]. Nudges can encourage undesirable decisions, depending on how they are used, therefore it is important to be transparent about how they are implemented [14].

Many studies have reported the effects of nudges such as price incentives and increasing healthier selections at school and worksite cafeterias, restaurants, shops, and vending machines [1–13]. Among studies in hospital settings [15–20], some showed positive effects with increased sales of healthier products, healthier menu selections, and reduced staff energy intake [16–20]. However, none of these studies examined changes in the staff's food intake.

There are no reports showing the pathways by which nudges stimulate medical staff to change their eating behaviors. Glanz, et al. presented a conceptual model of nutritional environments, indicating that there were two ways in which the environment influences eating patterns [21]. One directly influences eating patterns, and the other is via individual factors, such as knowledge, attitude, belief, and self-efficacy. Environmental factors include access to food, healthy options, placement, price promotions, and access to information. Our hypothesis was that the nudge-based food environment intervention also influences staff eating patterns both directly and indirectly, by changing their attitude and self-efficacy. It is important to clarify the pathways for building the next strategy to improve staff food intake and prevent non-communicable diseases.

Furthermore, most previous studies have focused on weight control [3, 6, 8, 15–20]. However, hypertension is the most preventable risk factor for mortality in Japan [22]. The prevalence of hypertension among Japanese adults is 29.5% [23], and the number of people with cardiovascular disease is estimated at 1,732,000 [24]. The salt intake of the population remains high [23], and reducing salt intake is urgently needed to prevent non-communicable diseases [25]. Recent findings indicate that sufficient potassium (K) intake can help decrease blood pressure [26], and that a higher dietary sodium-to-potassium ratio (Na/K) increases cardiovascular mortality risk [27]. Some studies have aimed to reduce salt consumption using nudges in hospitals [28, 29]. However, no study has evaluated the changes in biomarkers, which are more objective than self-reported dietary surveys, for dietary sodium and potassium intake among hospital staff. Thus, in this study, we used nudges to help medical staff, who were not very health-conscious or too busy to put knowledge into practice, make better food choices for themselves. We assessed the effect of food environment interventions in a hospital convenience store on the staff's urinary Na/K levels and food intake.

Method

Study design, features of the hospital, and staff dietary issues

A pre-post-comparison design was used for this study. The intervention site was the Taito Municipal Hospital convenience store (CVS) in Tokyo. The sales floor is approx. 62.5 m^2, and the opening hours are 7:45 AM–7:00 PM during the week and 11:00 AM–6:00 PM during weekends.

According to sales data, the average number of visitors per day was approximately 250, of which 75% were staff, as counted by investigators in September–October 2019. The hospital has no cafeteria and about 30% of its staff use the CVS daily to buy meals at work. Most others bring light meals, such as rice balls or bowl noodles, from home and nearby supermarkets, according to the preliminary survey we conducted in November 2018.

The baseline survey was conducted with all staff ($N = 273$) from April1 to May31 2018. 222 staff participated (participation rate: 81.3%). 9.5% of the participants had hypertension. The prevalence of hypertension among the staff was lower than that in the national data [22]; however, the survey revealed dietary problems among the staff. Of all participants, 90.1% lacked vegetables (< 350 g/day) and 92.3% lacked fruits (< 200 g/day) in their diet based on the Japanese Food Guide recommendation [30], 97.3% exceeded salt intake limit (males: > 8.0 g, females: > 7.0 g per day) set by the Dietary Reference Intake for Japanese, 2015 [31], and only 15.8% consumed a "balanced meal" consisting of staple food, main dish, and side dish more than twice a day, as recommended by Health Japan 21 (second term) [32].

Procedure

The study procedure and subject selection process are shown in Fig. 1. A baseline survey was conducted in April 2018, and a post-survey was conducted in April 2020 for all employees.

The preparation period was from April 2018 to March 2019, during which consensus building with hospital managers for conducting research, recruiting project

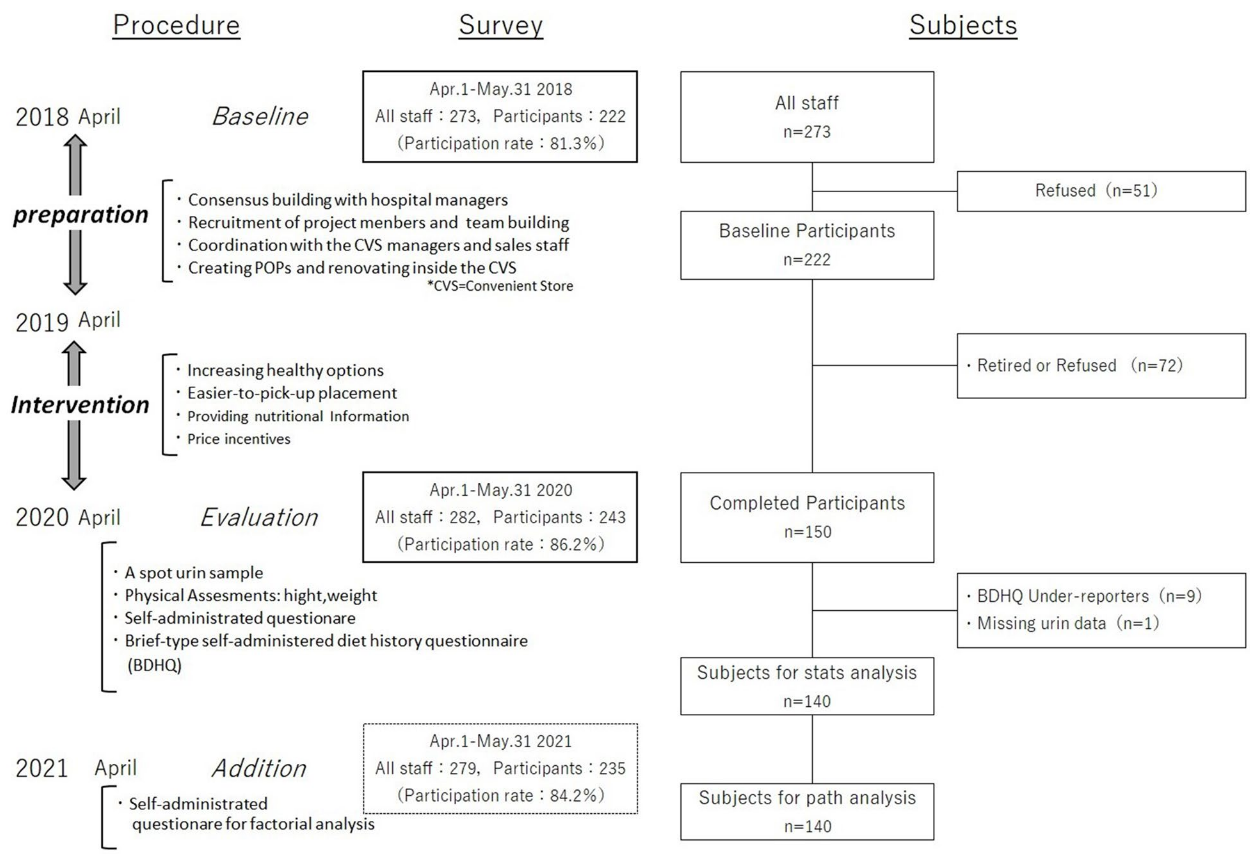

Fig. 1 Procedure of the study and the subject selection

members, coordinating with CVS managers and sales staff, creating display pops, and renovating the inside of CVS were conducted.

The intervention was from April 2019 to March 2020. An additional survey was conducted in April 2021 to obtain the variables for the factorial analysis.

Written informed consent was obtained from all the participants. This study was approved by the Ethics Committee of Japan Association for Development of Community Medicine.

Intervention contents

The contents of the interventions are shown in Table 1. The intervention was based on the Hospital Nutrition Environmental Scan (HNES) by Winston et al. [33] and incorporated one of the nudge frameworks, EAST, advocated by the Behavioural Insight Team (BIT) [34]. The EAST framework focuses on four simple principles to encourage a behavior: making it Easy, Attractive, Social, and Timely [34].

HNES is widely used as a hospital food environment evaluation index in the United States [35–37]. It is divided into three venue sections: cafeterias, vending machines, and gift shops, each further divided into subsection questions [33]. We designed the intervention by referring to the subsection questions and, dividing them into four categories: healthy options, placement, information, and pricing, each incorporating nudge tactics.

The main contents were 1) offering a "healthy set" (Supplementary File 1) with a discount at grab-and-go; 2) increasing and improving the placement of healthy options (e.g., salads, yogurt, sugar-free drinks, low-salt bowl noodles); 3) providing nutrition information in the CVS and monthly newsletters.

Data collection and outcome measures

Data were collected during the annual staff health checkups in 2018 and 2020. Two types of questionnaire were used in this study. One was Brief-type self-administered diet history questionnaire (BDHQ) developed by Sasaki et al. [38, 39] to evaluate food intake and the other was an original self-administered questionnaire developed for this study to evaluate diet-related attitudes and behaviors (Supplementary Files 2 and 3). They were distributed to staff, with information about their health checkups. During the check-up, the researchers collected and examined

Table 1 Intervention contents

HNES	EAST	contents
healthy options	E・T	Providing "healthy set" combining existing products e.g. packed lunch, salad, fruit, yogurt
	E	Increasing sugar-free soft drinks from 30% to over 60% of total
		Increasing the low salt bowl noodles with salt amount of 4g or less from20% to over 50% of total
placement	E	Placing "healthy sets" at Grab-and-Go next to point-of-purchase
		Placing sugar-free softdrinks at "Golden zone" where easy-to-pick-up
		Placing the less salt bowl noodles at the easier-to-pick-up level
information	A・S	Posting Attractive and social information e.g. "best-selling" on healthier foods
	A・E	Posting attractive mascots on bowl noodles with salt amount using real salt
		Posting information of energy/salt content with price cards of all foods and drinks
		Posting "healthy set" menu with encouraging tips to take "balanced meal"twice a day
		Providing easy monthly newsletter with attractivequiz and information e.g. how to make quick "balanced meal", healty recipes, tips to reduce salt
pricing	A	Discounting "Healthy sets" approx.10% for visitors and 20% for staff

HNES: Hospital Nutrition Environment Scan

EAST: E=Easy, A=Attractive, S=Social, T=Timely

"Healthy sets": Comprising of grain dishes, fish and meat dishes, Vegetable dishes, and salt content 3.5g or less

"balanced meal":consisting of staple food, main dish and side dish

the questionnaires and resurveyed or corrected missing or illogical responses. Residual urine after the health checkups (spot urine at fasting) was used in this survey.

Measurements

Urinary Na/K ratio and sodium (Na) and potassium(K) excretion

The primary outcomes were changes in urinary Na/K molar ratio and Na and K excretion. The collected specimens were sent to a laboratory company (BML, Inc.) immediately after the checkup was performed in the morning and analyzed for Na (mEq/L), K (mEq/L), and creatinine (mg/dL). Generally, 24-h urine collection is considered the most reliable method for evaluating Na and K intake [40]. As with other alternatives, it has been reported that six random daytime urine samples collected on different days are sufficient compared to 7-day and 24-h urine collections [41]. However, we decided to use spot urine samples during the health checkups to minimize the burden on the participants.

The estimated 24-h Na and K excretion (E24HNaV and E24HKV, respectively; mmol/day) was calculated using the formula of Tanaka et al. [42], and the Na/K was calculated using the results. The required information and values for calculation, including sex, age, height, and weight (measured in a medical check-up-gown) were collected during the health checkup.

Food group intake and BMI as an energy-intake evaluation index

The secondary outcomes were changes in the intake of five potassium-excretion-related foods: vegetables, fruits, fish, meat, and dairy products [23, 43]. The BDHQ was used for the evaluation [38, 39]. The nutrient and food group intakes obtained from the BDHQ were validated using energy-adjusted values [38, 39].

Additionally, changes in energy intake were evaluated using the body mass index (BMI: kg/m^2) calculated using height and weight measured during health checkup.

Diet-related attitudes and behavior

We also evaluated attitudes and behavior toward having a "balanced meal" by asking about its frequency, beliefs, and participants' self-efficacy to do it. As for awareness, we asked the participants to answer yes or no to each of the following: taking sufficient vegetables, adequate energy intake, reducing salt intake, taking a "balanced meal", taking sufficient dairy products, and taking fruits every day, using an original self-administered questionnaire (Supplementary File 2).

Factors contributing to outcomes

After evaluating the primary outcomes, we conducted an additional survey to investigate the factors contributing to the results using an original self-administered questionnaire (Supplementary File 3) in April 2021. The variables collected were the frequency of using the CVS, the information provided by the CVS, and purchasing a “healthy set” salad and yogurt at the CVS.

As confounders, occupation, work shift, living alone, and frequency of referring to nutrition labells were also collected using the same self-administered questionnaire.

Analyses

Subjects

The subject selection procedure is shown in Fig. 1. As reported by Sasaki, energy intake values that were likely severely under- or over-reported were excluded from statistical analyses [44]. This included nine participants with an estimated energy intake calculated using the BDHQ less than half the energy requirements for the lowest physical activity level (PAL: I). There were no over-reporters with more than or equal to 1.5 times the energy requirement of the highest physical activity (PAL: III).

We also excluded one subject with missing urine data, resulting in 140 staff members meeting the inclusion criteria.

Statistical analyses

(1) Pre-post comparison

Preliminary analyses showed no significant difference in the indicators by sex, age group, work shift, or living alone; therefore, we decided to compare them as a whole. Wilcoxon’s signed rank-sum test was used for changes in the Na/K, and paired t-tests were used for changes in E24HNaV, E24HKV, nutrient and food group intake, and BMI.

Changes in dietary consciousness were analyzed using the McNemar test, and dietary attitudes, behaviors, and BMI categories were analyzed using the McNemar-Bowker test.

All statistical analyses were performed using the Statistical Package for the Social Sciences Statistics (SPSS) 25 made by International Business Machines Corporation (IBM), and the significance level was set at 5%.

(2) Path analysis

First, we hypothesized that there were two ways to change staff’s food intake following the model of Glanz, et al. [21]. One is that the exposure to the intervention (using CVS, using information from the CVS, frequency of purchasing “healthy set”, salad, and yogurt) directly influenced their food intake, the other is the intervention change their attitude and behavior (awareness of taking "balanced meal", taking sufficient vegetable, taking fruits every day, reducing salt, self-efficacy to take "balanced meal", frequency of taking "balanced meal") which influenced their food intake. Under this hypothesis we performed a multiple regression analysis (stepwise method) to predict the change in Na/K and E24HKV based on the intervention factors, dietary attitudes and behavior as the outputs of the intervention. Age, sex, occupation, and dietary attitude/behavior at baseline were adjusted for confounding factors.

Subsequently, we created a causal model based on the results and performed path analysis. The path diagram was laid out, confirming the standardized partial regression coefficient (β) of the multiple regression analysis. The model fit indices the goodness-of-fit index (GFI), adjusted GFI (AGFI), comparative fit index (CFI), root mean square error of approximation (RMSEA), and chi-squared/degree of freedom (CMIN/DF). GFI, AGFI, and CFI values are recommended to be above 0.9 [45, 46] and RMSEA is considered to be perfect fit if it’s less than 0.05 and acceptable if it’s less than 0.08. CMIN/DF is suggested to be 5 or less and desirable not to be significant [46]. Thus, we set these as the cut-off values. SPSS Amos 25 Graphics (IBM) was used for the statistical analyses. The significance level was set at 5%, and variance inflation factor (VIF) values for the level of collinearity were set at 3 [47].

Results

Baseline characteristics of subjects (Table 2)

The age [mean (standard deviation: SD)] was 41.6 (10.9) years; females constituted 62.9%. Occupations were nursing/care workers: 61.4%; technicians (therapists, dietitians, pharmacists): 20.7%; clerical workers: 13.6%; and doctors: 3.6%. Staff who had night shifts comprised 35.0%, and those who lived alone were 23.6%.

Na/K, E24HNaV, and E24HKV (Table 3)

The Na/K [median (25–75 percentile)] decreased significantly from 3.16 [2.69–3.78] to 2.98 [2.63–3.48] ($p=0.015$). E24HNaV (mean (SD) mmol/day) decreased from 137.7 (39.4) to 135.9 (34.3) but was not significant ($p=0.63$). E24HKV increased significantly from 43.4 (8.1) to 45.2 (10.2) ($p=0.03$).

Food group intake and BMI as energy-intake evaluation indices (Table 3)

Significant increases were shown in fruit and dairy product intake (mean (SD) g/1000 kcal); fruits: 46.5 (40.8) to 51.7 (44.9) ($p=0.002$); and dairy products: 72.2 (56.6) to 84.4 (68.7) ($p=0.01$). Significant decreases were shown

Table 2 Subject characteristics at baseline

	category	n=140 n (%) mean (SD)
sex	female	88 (62.9)
age (years)		41.6 (10.9)
age groups	20 or less	23 (16.4)
	30–49	80 (57.1)
	50–69	35 (25.0)
	70 or over	2 (1.4)
occupation	medical doctor	5 (3.6)
	technician	29 (20.7)
	nurse/care worker	86 (61.4)
	clerical worker	19 (13.6)
	others	1 (0.7)
night shift	yes	49 (35.0)
living alone	yes	33 (23.6)

Table 3 Change of Na/Ka, E24HNaV, E24HKV, and nutrients and food groups intake

data source	outcomes		unit	n=140		p-Value
				before(2018)	after(2020)	
				median (25–75%ile) / mean (SD)		
urin	Na/K ratio			3.16 (2.69–3.78)	2.98 (2.63–3.48)	0.02 ↓
	E24HNaV		mmol/day	137.7 (39.4)	135.9 (34.3)	0.63
			g/day	3.2 (0.9)	3.1 (0.8)	
		salt equivalent	g/day	8.1 (2.3)	8.0 (2.0)	
	E24HKV		mmol/day	43.4 (8.1)	45.2 (10.2)	0.03 ↑
			mg/day	1696.9 (316.7)	1767.3 (398.8)	
measured BW/H	energy	BMI	kg/m^2	22.0 (19.9–24.5)	22.5 (19.9–24.6)	0.002 ↑
	BMI Category	<18.5	%	10.0	4.3	0.04
		18.5–<25.0		67.9	72.9	
		≧25.0		22.1	22.8	
BDHQ	nutrients	protein	%E	15.1 (3.1)	15.2 (3.1)	0.51
		lipids	%E	27.8 (5.1)	27.4 (5.2)	0.43
		carbohydrate	%E	51.5 (8.6)	51.3 (9.1)	0.77
	food groups	G/Y vegetables	g/1000kcal	55.1 (41.3)	55.9 (34.0)	0.81
		other vegetables	g/1000kcal	84.3 (54.9)	83.9 (42.7)	0.28
		fruit	g/1000kcal	46.5 (40.8)	51.7 (44.9)	0.002 ↑
		fish	g/1000kcal	36.6 (23.3)	38.4 (26.7)	0.29
		meat	g/1000kcal	43.2 (20.2)	45.8 (20.6)	0.19
		dairy product	g/1000kcal	72.2 (56.6)	84.4 (68.7)	0.01 ↑
		snack	g/1000kcal	29.1 (18.2)	25.5 (17.9)	0.01 ↓
		beverage	g/1000kcal	433.1 (211.9)	392.2 (221.0)	0.02 ↓
		sugar added soft drink	g/1000kcal	39.1 (57.2)	29.4 (52.2)	0.03 ↓
		alcohol	g/1000kcal	4.5 (7.2)	3.0 (7.6)	0.01 ↓

p-Value: Wilcoxon's signed rank sum test for Na/K ratio and BMI, McNemar-Bowker test for BMI Category, Paired t-test for others

E24HNaV=estimated 24h Na excretion value / E24HKV: estimated 24h K excretion value (by the formula of Tanaka et al[35])

BW=body weight, H=height, BMI=Body Mass Index, G/Y=Green and Yellow

BDHQ=Brief-type self-administered Diet History Questionnaire in snacks and beverages; snacks: 29.1(18.2) to 25.5 (17.9) ($p=0.01$); beverages, including alcohol: 433.1 (211.9) to 392.2 (221.0) ($p=0.02$); and sweetened soft drinks: 39.1 (57.2) to 29.4 (52.2) ($p=0.03$). The other parameters showed no significant changes.

BMI increased significantly; however, the proportion of the underweight decreased from 10.0% to 4.3%, and that of normal weight participants increased from 67.9% to 72.9%. 9 of 14 underweight participants at baseline were women, among whom five were classified under normal weight.

Attitude and behavior (Table 4)

The percentage of staff who were conscious of taking a "balanced meal" increased significantly ($p=0.02$), and the staff's SE to do so was also significantly improved ($p<0.001$). Other variables showed no significant changes.

Factors contributing to changes in Na/K and E24HKV

The results of the multiple regression analysis showed that the frequency of taking a "balanced meal" and using information from the CVS were most influential to the change in the Na/K. Regarding the change in E24HKV, using information from the CVS, the frequency of purchasing salads at the CVS and the awareness of taking sufficient vegetables were the most influential (Table 5).

The preparatory stages of these variables were investigated. For the change in Na/K, the frequency of taking a "balanced meal" was influenced by self-efficacy to take a "balanced meal" and the awareness of taking sufficient vegetables. Regarding the change in E24HKV, the awareness of taking sufficient vegetables was influenced by the frequency of purchasing salads at the CVS and using information from the CVS, and the frequency of purchasing salads at the CVS was influenced by the frequency of using information from the CVS. All variables were within the intervention period and were independent of sex, age, occupation, baseline awareness, and attitude. We also confirmed that VIF values for all independent variables were lower than 3 (range:1.1–1.6), therefore we considered no multicollinearity existed.

The desirable number of samples for building a reliable model is said to be 10 for 1 independent variable [48]. In this analysis, 140 samples were used for 11 independent variables, therefore we considered the sample size to be adequate.

Based on the results, a path diagram was created (Fig. 2). We confirmed that all path coefficients were significant and the goodness-of-fit indices were GFI=0.972, AGFI=0.929, CFI=0.973, RMSEA=0.047, and CMIN/DF=1.3 ($p=0.22$). Thus, we considered the model to be a good fit.

Table 4 Change of diet-related attitude and behavior

category			answer	n=140 2018 n (%)	n=140 2020 n (%)	p value
toward taking "balanced meal" twice a day	behavior	frequency	almost every day	22 (15.7)	29 (20.7)	0.07
			4-5days/week	56 (40.0)	58 (41.4)	
			2-3days/week	47 (33.6)	39 (27.9)	
			seldom	15 (10.7)	14 (10.0)	
	attitude	self efficacy	very high	6 (4.3)	11 (7.9)	<0.001 ↑
			high	22 (15.7)	29 (20.7)	
			middle	56 (40.0)	62 (44.3)	
			low	36 (25.7)	34 (24.3)	
			very low	20 (14.3)	4 (2.9)	
		beliefs	very important	53 (37.9)	55 (39.3)	0.33
			important	55 (39.3)	56 (40.0)	
			middle	20 (14.3)	20 (14.3)	
			not very important	8 (5.7)	7 (5.0)	
			not at all important	4 (2.9)	2 (1.4)	
taking sufficient vegetable		awareness	yes	65 (46.4)	81 (57.9)	0.39
adequate energy intake				42 (30.0)	44 (31.4)	0.89
reducing salt intake				41 (29.3)	46 (32.9)	0.42
taking a "balanced meal"				32 (22.9)	52 (37.1)	0.02 ↑
taking sufficient dairy product				31 (22.1)	37 (26.4)	0.77
taking fruits every day				10 (7.1)	16 (11.4)	0.48

P Value : McNemar–Bowker test for frequency, self efficacy, beliefs. McNemar test for awareness

"balanced meal":consisting of staple food(grain), main dish(mainly fish and meat) and side dish(mainly vegetables)

Table 5 Prediction the change in the Na/K ratio and E24HKV based on the outputs of the intervention by multiple regression analysis

Dependent variable	Na/K ratio				E24HKV			
	Model1		Final Model**		Model1		Final Model**	
Independent variable	β	p-Value	β	p-Value	β	p-Value	β	p-Value
Outputs of the intervention								
Intervention factor								
frequency of using the CVS			-				-	
frequency of using information from the CVS			0.287	<0.001			0.495	<0.001
frequency of purchasing "healthy set" at the CVS			-				-	
frequency of purchasing salads at the CVS			-				0.202	0.001
frequency of purchasing yogurt at the CVS			-				-	
Dietary behavior (at post)								
frequency of taking "balanced meal"			0.381	<0.001			-	
Dietary attitude (at post)								
self-efficacy to take "balanced meal"			-				-	
awareness of taking "balanced meal"			-				-	
awareness of taking sufficient vegetables			-				0.257	0.002
awareness of taking fruits every day			-				-	
awareness of reducing salt intake			-				-	
Adjusted R2	0.017		0.247		0.023		0.323	
Confounders								
Attributes								
age	0.066	0.38	0.041	0.68	0.041	0.61	0.023	0.73
sex	0.034	0.63	0.045	0.73	0.073	0.49	0.031	0.37
occupation	0.068	0.86	0.041	0.58	0.028	0.66	0.010	0.85
Dietary behavior(at baseline)								
frequency of taking "balanced meal"	0.039	0.69	0.044	0.71	0.044	0.49	0.047	0.48
frequency of referencing nutrition labeling	0.059	0.70	0.027	0.78	0.141	0.09	0.157	0.08
Dietary attitude(at baseline)								
self efficacy to take "balanced meal"	0.069	0.45	0.071	0.46	0.035	0.38	0.047	0.56
awareness of taking "balanced meal"	0.039	0.65	0.061	0.75	0.034	0.53	0.070	0.40
awareness of taking sufficient vegetables	0.043	0.29	0.045	0.19	0.020	0.71	0.032	0.76
awareness of taking fruits every day	0.021	0.82	0.026	0.82	0.020	0.74	0.040	0.65
awareness of reducing salt intake	0.086	0.58	0.086	0.55	0.111	0.27	0.038	0.79

Entered variables:

Model 1=all confounders (forced entry)

Final Model=all confounders (forced entry) and all independent variables(stepwise)

"-" = Variables excluded automatically during the stepwise procedure

Final Model=adjusted for sex, age, occupation, and dietary attitude/behaviour at baseline.

Multicollinearity was not observed between the independent variables.

Na/K ratio= the change in the urinary sodium to pottasium molar ratio. E24HKV=the change in the estimated 24-h sodiun excretion value.

**p<0.001. β =the standardized partial regression coefficient, adjusted R2=adjusted coefficient of determination

balanced meal=consisting of staple food(grain), main dish(mainly fish and meat) and side dish(mainly vegetables). CVS=Convenient Store.

Discussion

Changes in Na/K, E24HNaV, and E24HKV

In this study, Na/K decreased from 3.16 to 2.98 and E24HKV increased from 43.4 to 45.2 mmol/day significantly. In previous studies, Vanderlee, et al. reported that improving nutritional information on menus in hospital cafeterias led to reduced salt intake among staff [29]. Some reports have indicated that improving the placement of foods in school and hospital cafeterias nudged children and staff into choosing fruits and vegetables [6, 7, 22, 23]. Sakaguchi, et al. reported that providing low-salt, well-balanced lunches in a company cafeteria lowered employees' Na/K [49]. The results of this study also support these findings, showing the effects of food environment improvements.

No significant changes were observed in E24HNaV in this study. Considering that meals at home also affect E24HNaV and that the main source of salt intake in Japan is cooking seasonings such as soy sauce and miso [50], it might have been necessary to encourage salt

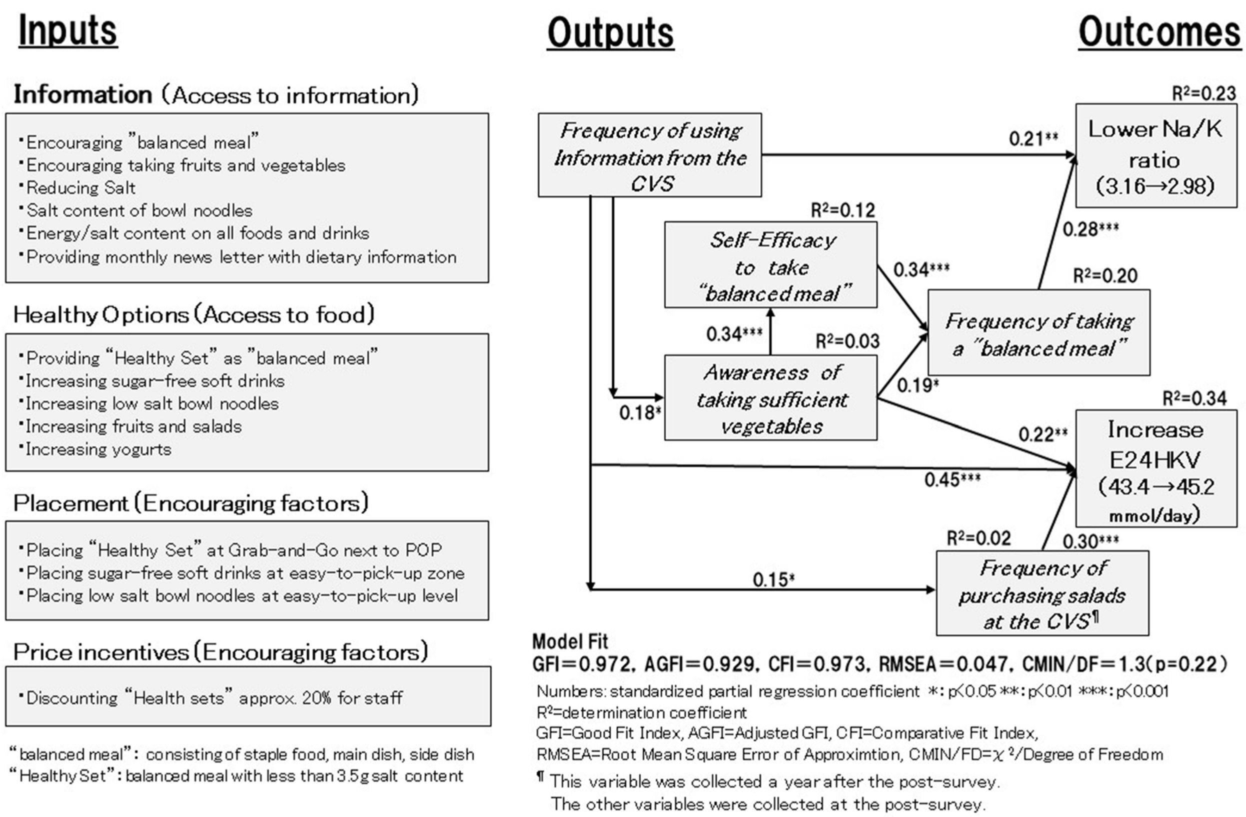

Fig. 2 Intervention outline and the pass diagram from intervention to outcome

reduction in home cooking, besides food selection at the CVS.

Changes in food intake

Of the five K-increasing food groups examined in this study, the intake of fruits and dairy products increased significantly, but not for other types of food.

For the increase in fruit and dairy products, it could be assumed that increasing attractive fruits and yogurts in the CVS and placing them in a grab-and-go lane with a price-promoted "healthy set" contributed to a certain extent. Previous studies indicated the effectiveness of price promotion and using grab-and-go to improve dietary consumption [11–14], and this result supported the finding. Also, the sales of these items during the study period increased—plain yogurt: 136%; fruits in yogurt: 340%, compared to average year-on-year sales from April to December 2019 [51].

The BDHQ, a fixed-portion food frequency questionnaire, was a possible reason for the lack of changes in vegetable intake [38, 39]. The intake was estimated from a standardized single-dose intake and frequency; therefore, the change in the amount per meal was not considered.

For the significant decrease in the intake of snacks and sweetened soft drinks, the improvement in planogram allocation in the beverage corner (Easy-to-pick-up, Social normative change) and the energy and salt-amount indication next to the price cards (Easily-recognizable, Attractive-and-Timely indication) might have nudged the staff's purchasing behavior.

Changes in BMI and other lifestyle-related factors

Underweight is a significant issue among young women in Japan [32, 52]. In this study, the proportion of the underweights significantly decreased. This result can be considered a desirable change.

Decreased physical activity during the COVID-19 pandemic [53] may have led to increased BMI. We confirmed this using the results of a standard health checkup questionnaire; however, but no such changes were observed. In addition, 6 of 10 who improved underweight increased their frequency of "balanced meal" intake, and 4 of the 6 were CVS users. Thus, it could be assumed that the food environment improvement in the CVS certainly contributed to the result.

Diet-related attitude and behavior

The percentage of staff conscious of taking a “balanced meal” significantly increased, but no other variables. The message to take a “balanced meal” twice daily with good examples was disseminated through monthly newsletters and the “healthy set” menus more frequently than any other information from the CVS. Repeated exposure to the information may have helped raise awareness.

Furthermore, a recent systematic review revealed that short-term interventions were more effective than those implemented over a longer period [54]. This suggests that the above success was achieved by providing different menus and related information in the short term but repeatedly maintaining a consistent key message of eating a “balanced meal” more than twice a day.

Self-efficacy for taking a “balanced meal” also improved significantly. The environment in which the staff could get “balanced meals” in their workplace at reasonable prices was thought to have contributed to the results.

Many studies showed the effect of providing information along with the targeted food to replace in an effective way [6, 8, 10, 13, 20, 54], and so did this study. This suggests that providing not only information, but also targeted food in appropriate places with price incentives could lead to successful results.

Factors that contributed to changes in Na/K and E24HKV

The frequency of using information from the CVS was the most influential factor for both outcomes. It was widely disseminated to the staff so that even those not using the CVS were exposed to the information, which may have been a reason for the result.

The preparation of attractive salads and a “healthy set” in the CVS was also considered to have contributed to the result since the frequency of taking a “balanced meal” and the frequency of purchasing salads at the CVS were secondly influential.

Vermote, et al. reported that the combination of eat-well posters and an attractive green-heart icon above fruit stands resulted in significant increases in fruit consumption, whereas substitution and social norm messages had limited effects [55]. Almeida, et al. also reported that the placement position and information were the two most effective types of nudges [54]. Consequently, the strategy of presenting specific examples in an appropriate place, combined with related information, was found to be effective in this population.

These results indicated that the environment in which the desirable food, such as price-promoted “healthy set” and attractive salads, prepared in a timely manner at easy-to-pick-up places along with the encouraging information, enhanced awareness and strengthened purchasing behavior, which led to increasing E24HKV and lowering the Na/K.

Strengths and weaknesses

To our knowledge, this is the first study to show positive changes in Na/K and K intake among healthcare workers' by improving the food environment using nudge tactics in a hospital CVS.

However, this study had some limitations. First, we were unable to set a control in this study. Further controlled trials are required to examine its effectiveness and reliability. Second, this study was conducted at a single hospital. The sample size was also limited, which makes it difficult to generalize. However, the result of examining the statistical power for Na/K, E24HKV and all food groups was 0.9, exceeding the 0.8 recommended by Cohen [56]. Therefore, we believe that our results are adequate. Third, we needed one year to start the food environment intervention after the baseline survey, and the state of the staff immediately before the intervention could not be investigated. Therefore, the possibility that some factors during the preparation period affected the results could not be ruled out. Finally, an additional survey on purchasing behavior before the COVID-19 pandemic, which were used as variables for the multiple regression analysis, was conducted a year after the post-survey; thus, recall bias was inevitable.

Despite these limitations, the method used in this study, which minimized the burden on participants, and led their food intake in a desirable direction, is highly recommended, even for hospitals without cafeterias.

Conclusion

This study showed that nudge-based food environment improvement providing both information and food, as a good example at a hospital CVS, can lead the staff's food intake toward desirable directions, increasing K intake and lowering the Na/K. Further consideration is needed to reduce salt intake while preserving the K intake.

Abbreviations

Na	Sodium
K	Potassium
Na/K	Sodium-to-Potassium ratio
CVS	Convenience Store
HNES	Hospital Nutrition Environmental Scan
E24HNaV	Estimated 24-h Na Value
E24HKV	Estimated 24-h K Value
BDHQ	Brief-type self-administered Diet History Questionnaires
BMI	Body Mass Index
PAL	Physical Activity Level
SPSS	Statistical Package for the Social Sciences Statistics
IBM	International Business Machines Corporation
GFI	Good Fit Index
AGFI	Adjusted Good Fit Index
CFI	Comparative Fit Index
RMSEA	Root Mean Square Error of Approximation (RMSEA)
CMIN/DF	Chi-squared/Degree of Freedom

SD Standard Deviation
COVID-19 Coronavirus Disease 2019

Supplementary Information

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Supplementary Material 1
Supplementary Material 2
Supplementary Material 3

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Authors' contributions
T.K, M.N, Y.T, and F.H designed the study. T.K and T.Y conducted the experiment. T.Y contributed to data acquisition. T.K, Y.T, and F.H analysed and interpreted the data. T.K drafted the manuscript. All the authors critically revised and approved the final manuscript.

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Availability of data and materials
The datasets generated and analysed during the current study can not to be shared due to ethical restrictions, but are available from the corresponding author on reasonable request.

Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
We confirm that all methods in this study were carried out in accordance with the ethical standards of the declaration of Helsinki. Written informed consent was obtained from each participant. This study was approved by the Ethical Committee of the Japan Association for Development of Community Medicine (approval number: 18–032).

Consent for publication
Not applicable.

Competing interests
Teruko Kawabata is a researcher of Japan Association for Development of Community Medicine (JADECOM), which runs Taito Municipal Hospital and was the franchise owner and operator of the convenience store during the study period.
Masakazu Nakamura is a board member of JADECOM.
Takashi Yamada is the executive vice president of JADECOM, also the administrator of Taito Municipal Hospital.
Other authors declare no competing interests.

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