Water intake from foods and beverages and risk of mortality from CVD: the Japan Collaborative Cohort (JACC) Study

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Abstract

Objective: To examine the association of water intake with risk of mortality from CVD.

Design: Prospective cohort study.

Setting/Subjects: A total of 22 939 men and 35 362 women aged 40–79 years enrolled in the Japan Collaborative Cohort (JACC) Study with available data regarding water intake from foods and beverages. The underlying causes of death were determined based on the International Classification of Diseases.

Results: During the median 19·1 years of follow-up, 1637 men and 1707 women died from CVD. There was an inverse trend between high water intake and risk of CVD in both sexes. Compared with participants in the lowest quintile of water intake, the multivariable-adjusted hazard ratios (95 % CI) for mortality from total CVD in the highest quintile of water intake were 0·88 (0·72, 1·07; P for trend = 0·03) in men and 0·79 (0·66, 0·95; P for trend = 0·10) in women. Those for CHD were 0·81 (0·54, 1·21; P for trend = 0·06) in men and 0·60 (0·39, 0·93; P for trend = 0·20) in women. Reduced risk of mortality from ischaemic stroke was also observed among women in the highest water intake quintile: 0·70 (0·47, 0·99; P for trend = 0·19). There was no association between water intake and mortality from haemorrhagic stroke in either sex.

Conclusions: Higher intake of fluids from foods and beverages was associated with reduced risk of cardiovascular mortality in both sexes and reduced risk of ischaemic stroke in women in Japan.

No one can deny how essential water is for life. The human body comprises about 60–75 % water by weight[1]. The biological importance of water in man includes its roles in skin moisture[2], thermoregulation[3], cognition enhancement[4], gastrointestinal function and nutrient absorption[5], renal filtration and urinary excretion of blood wastes[6] and cellular homeostasis via maintaining balanced water/mineral content in different body fluids[1].

The human consumption of fluids comes not only from plain water to quench thirst, but also some portion of our daily water intake comes from the moisture in foods and beverages. The proportion of plain water intake to total water intake differs among populations, depending on various factors such as sex, age, weight and climate[7–11]. However, the WHO recommends a daily water intake of 2·9 litres for men and 2·2 litres for women under standard conditions[12].

Evidence has been ranked from weak to strong regarding the association of good hydration with reduced risks of different chronic diseases including chronic kidney disease[13], CHD[14] and total mortality[15], and it was estimated that a 20 % loss of the body's water content can lead to death[16]. A specific importance of water is its impact on the cardiovascular system because water input/output regulates blood volume, which correlates with blood pressure and heart rate[6,17]. Moreover, it was shown in both normotensive and hypertensive individuals that water intake acutely increases the blood pressure while reducing the heart rate[17]. Those effects are caused by enhancing the sympathetic nervous system and

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preventing vasovagal reaction rather than changing the blood volume[18,19].

Therefore, the aim of the present study was to examine the association between water intake from foods and beverages and risk of cardiovascular mortality. We gave specific attention to the association with cardiovascular mortality because the water level in the body is associated with vascular contractility via controlling arginine vaso-pressin hormone[20]. Yet, current evidence on the water intake–cardiovascular mortality association is inconclusive. Some studies reported an inverse association between water intake and mortality from CVD[14,21], while other studies showed no association[13,15,22,23].

We hypothesized that higher water intake from foods and beverages is associated with lower risk of mortality from CVD and tested this hypothesis in a large cohort study of Japanese men and women who participated in the Japan Collaborative Cohort (JACC) Study.

Participants and methods

Study population

The JACC Study is a large prospective study started in 1988–1990 and included a total of 110 792 participants (46 465 men and 64 327 women) aged 40–79 years from forty-five Japanese communities. Informed consent was obtained from participants or community leaders, and the ethics committees of Hokkaido University and Osaka University approved the protocol of this study. The sampling methods and protocols of the JACC Study are described in detail elsewhere[24].

A total of 24 366 men and 37 421 women completed a self-administered questionnaire about their lifestyles and medical histories that included a forty-food-item FFQ at baseline[24]. We excluded 1427 men and 2059 women who had a self-reported history of CVD or cancer, as well as history of chronic kidney disease. Therefore, 22 939 men and 35 362 women were enrolled in the present study.

Dietary assessment

The FFQ asked about the usual food intake frequency over the past year, without specifying portion size. The five possible frequency responses offered for each food item were: rarely, 1–2 times/month, 1–2 times/week, 3–4 times/week and almost every day[24]. The consumption of each food item was calculated by multiplying the frequency score of consumption by 0, 0·38, 1·5, 3·5 and 7·0/week, respectively. Water intake was estimated from all consumed foods and beverages (beef, pork, ham or sausage, chicken, liver, eggs, milk, yoghurt, cheese, butter, margarine, deep-fried foods or tempura, fresh fish, kamaboko (fish paste), dried fish or salted fish, fried vegetables, spinach or garland chrysanthemum, carrots or pumpkins, tomatoes, cabbage or head lettuce, Chinese

cabbage, edible wild plants, fungi, potatoes, algae, pickles, preserved foods using soya sauce, boiled beans, tofu, citrus fruits, fruits excluding citrus varieties, sweets, fresh fruit juice, coffee, tea (green tea, Japanese tea and Chinese tea) and alcoholic drinks). We did not have data on plain water intake. Intakes of water and other nutrients were calculated by multiplying the participant's frequency scores by the water and nutrient contents of each food, which were determined via the Japan Food Composition Tables, fifth edition, followed by summing the content of all the food items. The portion size for each food was estimated by a validation study[24]. Water intake was adjusted for total energy intake by means of a sex-specific residual method to reduce the influence of energy intake[25]. The FFQ was validated by four seasonal 3 d dietary records for energy-adjusted values and its reproducibility was tested by applying the same FFQ after one year in a sub-sample of eighty-five participants[26]. The Spearman rank-correlation coefficient for the validity of the FFQ-estimated water intake from foods and beverages with reference to the dietary-record water intake from foods and beverages was 0·41 and 0·71 for the two FFQ. The estimated mean water intake was 1317 ml/d according to the FFQ and 1318 ml/d according to the four seasonal 3 d dietary records.

Mortality surveillance

Investigators conducted a systematic review of death certificates as part of the mortality surveillance in each community. Mortality data were forwarded to the public health departments of the respective areas before being centralized at the Ministry of Health and Welfare, and the underlying causes of death were coded in accordance with the International Classification for Diseases, 10th revision (ICD-10). Participants who died after moving out of their original communities were treated as censored cases. The primary end points for the current analysis were deaths from stroke (ICD-10 codes I60–I69), hae-morrhagic stroke (ICD-10 codes I60–I61), ischaemic stroke (ICD-10 code I63), CHD (ICD-10 codes I20–I25) and total CVD (ICD-10 codes I01–I99).

Statistical analysis

Age-adjusted mean values and proportions of mortality risk factors and participants' characteristics across sex-specific quintiles of water intake (<1053, 1053–1250, 1251–1442, 1443–1690 and ≥1691 ml/d for men; <1036, 1036–1220, 1221–1393, 1394–1606 and ≥1606 ml/d for women) were calculated and the differences in those variables across the increasing quintiles of intake were tested by ANCOVA and the χ^2 test. Statistical analyses were based on mortality during the follow-up period and the person-years of follow-up was defined as the period from submission of the initial baseline questionnaire to death, departure of a participant from his/her original

community or termination of follow-up at the end of 2009, whichever came first.

Using the lowest quintile of water intake (<1053 ml/d for men; <1036 ml/d for women) as the reference category, the sex-specific hazard ratios (HR) and their 95 % CI for mortality outcomes were calculated by Cox proportional hazards modelling after adjustment for age. The multivariable model was further adjusted for sex-specific quintiles of BMI, smoking status (never, ex-smoker, current smokers of 1–19 and ≥20 cigarettes/d), alcohol intake category (never, ex-drinker, current drinkers of 1–22, 23–45, 46–68 and ≥69 g ethanol/d), history of hypertension and diabetes (yes or no), hours of exercise (almost never, 1–2, 3–4 and ≥5 h/week), hours of walking (almost never, 1–2, 3–4 and ≥5 h/d), hours of sleep (<6, 6–7 and ≥8 h/d continuous), education levels (primary school, junior high school, high school, college or more), perceived mental stress (low, medium, high), dietary sugar and fibre intakes (g/d, sex-specific quintiles); as well as intake frequencies of fresh fish, vegetables and fruits (almost never, 1–2 times/month, 1–2 times/week, 3–4 times/week, almost every day), green tea (almost never, 1–4 times/week, 1–2, 3–9 and ≥10 times/d) and coffee (almost never, 1–2 times/month, 1–2 and 3–4 times/week, 1–2 and ≥3 times/d). We conducted tests for trends across quintiles of water intake by assigning median values for each quintile and testing the significance of this variable. We further analysed the data after exclusion of persons who died within the first 5 years of follow-up to examine a potential effect of as-yet-undiagnosed diseases at baseline. Another sensitivity analysis was conducted by excluding participants with a history of diabetes mellitus at the study baseline. We also tested if the associations between the reported water intake and the risk of mortality from CVD varied by the season when the participants responded to the questionnaire. Probability values for statistical tests were two-tailed and $P < 0.05$ was regarded as statistically significant. The SAS statistical software package version 9.4 was used for the analyses.

Results

During the 19·1-year median follow-up for 22 939 men, there were 1637 deaths from total CVD that included 720 deaths from total strokes (234 haemorrhagic strokes and 425 ischaemic strokes) and 390 from CHD. The respective numbers of deaths among 35 362 women were 1707, 777 (315 and 384) and 305.

Compared with participants in the lowest quintile of water intake, men in the highest quintile were slightly older and consumed more sugar, while women with the highest quintile were slightly younger, more likely to smoke and to practise sports, but less likely to be diabetic and consumed less sugar (Table 1). Water intake was positively associated with intakes of coffee, green tea,

fresh fish, vegetables, fruits and fibre and with education levels for both men and women; while it was inversely associated with alcohol consumption, hours of sleep and history of hypertension in men and women. There was no association between water intake and BMI in either sex.

Tables 2 shows age- and multivariable-adjusted HR (and 95 % CI) of mortality from CVD according to quintile of water intake from foods and beverages. Compared with participants in the lowest quintile of water intake, both men and women in the highest quintile of intake had lower risks of mortality from CHD and total CVD. In men, the multivariable-adjusted HR (95 % CI) were 0·81 (0·54, 1·21; P for trend = 0·06) for CHD and 0·88 (0·72, 1·07; P for trend = 0·03) for total CVD. The respective values in women were 0·60 (0·39, 0·93; P for trend = 0·20) and 0·79 (0·66, 0·95; P for trend = 0·10). Reduced risk of mortality from ischaemic stroke was also observed for women in the highest quintile of intake: 0·70 (0·47, 0·99; P for trend = 0·19); but not in men: 0·89 (0·60, 1·31; P for trend = 0·68). Excluding early deaths within 5 years from baseline or participants with diabetes at baseline did not change the associations materially (see online supplementary material, Supplemental Tables 1 and 2). There were no differences in the reported association between participants who returned the questionnaire in summer, autumn, winter and spring. There was no association between water intake and mortality from haemorrhagic stroke in either sex.

Discussion

In the present large prospective cohort study, water intake from foods and beverages was associated with reduced risk of mortality from CHD and total CVD in Japanese men and women; moreover, higher water intake was associated with reduced risk of mortality from ischaemic stroke among women but not men. These associations were independent of age, BMI, intakes of coffee, tea, vegetables, fruits and alcohol, total energy intake and other mortality risk factors.

To the best of our knowledge, the present study is the first to show that higher water intake from foods and beverages is associated with reduced risk of mortality from CHD and ischaemic stroke in the Japanese population. Among 120 852 men and women aged 55–69 years of the Netherlands Cohort Study during the 10 years of follow-up, higher total fluid intake (plain water plus moisture from foods and beverages: > 2·0 v. <1·0 litres/d) tended to be associated with reduced risk of mortality from total stroke but not from CHD. The multivariable-adjusted HR (95 % CI) for mortality from total stroke were 0·77 (0·45, 1·30) in men and 0·60 (0·31, 1·15) in women, and those for CHD mortality were 1·03 (0·73, 1·47) and 1·04 (0·67, 1·61), respectively[21]. The Blue Mountains Eye Study of 3858 men and women aged 49 years or older showed that fluid

Table 1 Age-adjusted baseline risk characteristics according to water intake from foods and beverages among 22 939 men and 35 362 women aged 40–79 years, Japan Collaborative Cohort (JACC) Study

| | Quintiles of energy-adjusted water intake | | | | | |
	1 (low)	2	3	4	5 (high)	P for trend
Men						
Range of water intake (ml/d)	< 1053	1053–1250	1251–1442	1443–1690	≥ 1691	
No. of subjects	4587	4588	4588	4588	4588	
Age (years)	55·5	55·6	55·7	56·0	56·8	<0·001
BMI (kg/m²)	22·8	22·7	22·6	22·7	22·8	0·754
Alcohol consumption (g/d)	43·2	34·4	32·7	29·1	27·5	<0·001
Current smoker (%)	55·2	53·4	51·3	54·5	56·7	0·067
History of hypertension (%)	21·8	20·2	19·2	17·0	16·2	<0·001
Diabetes (%)	6·5	6·6	5·9	5·9	5·8	0·036
Coffee intake, ≥1 time/d (%)	32·4	52·6	60·2	67·5	66·5	<0·001
Green tea intake, ≥1 time/d (%)	50·1	79·5	92·1	96·9	98·3	<0·001
Vegetable intake (times/week)	2·1	2·6	2·7	3·0	3·2	<0·001
Fruit intake (times/week)	1·6	2·4	2·7	3·0	3·4	<0·001
Fresh fish intake (times/week)	3·3	3·5	3·4	3·5	3·8	<0·001
Walk, ≥3 h/week (%)	6·7	6·8	6·9	7·0	7·2	<0·001
Sports, ≥5 h/week (%)	6·6	5·9	7·1	7·9	7·4	0·002
Sleep (h/d)	7·5	7·4	7·4	7·4	7·4	<0·001
Fibre intake (g/d)	8·3	8·7	8·9	9·4	10·1	<0·001
Sugar intake (g/d)	220	218	222	227	239	<0·001
College or higher education (%)	14·2	17·8	20·2	20·1	19·6	<0·001
Women						
Range of water intake (ml/d)	< 1036	1036–1220	1221–1393	1394–1606	≥ 1607	
No. of subjects	7072	7073	7072	7073	7072	
Age (years)	56·9	56·1	55·7	56·1	56·5	0·001
BMI (kg/m²)	23·1	22·8	22·9	22·9	23·0	0·844
Alcohol consumption (g/d)	14·6	9·4	8·7	8·7	8·4	<0·001
Current smoker (%)	5·0	4·1	4·1	4·6	6·4	<0·001
History of hypertension (%)	22·0	20·4	20·4	20·5	19·0	<0·001
Diabetes (%)	4·0	3·2	3·3	3·2	3·2	0·031
Coffee intake, ≥1 time/d (%)	30·2	51·3	55·0	62·0	63·6	<0·001
Green tea intake, ≥1 time/d (%)	44·5	76·6	92·3	96·0	97·0	<0·001
Vegetable intake (times/week)	2·6	3·1	3·2	3·4	3·7	<0·001
Fruit intake (times/week)	2·4	3·1	3·3	3·6	3·9	<0·001
Fresh fish intake (times/week)	3·3	3·5	3·5	3·6	3·8	<0·001
Walk, ≥3 h/week (%)	7·0	7·1	7·3	7·3	7·4	<0·001
Sports, ≥5 h/week (%)	3·8	3·9	4·5	4·8	4·7	<0·001
Sleep (h/d)	7·1	7·1	7·1	7·0	7·0	<0·001
Fibre intake (g/d)	8·5	8·6	8·7	9·0	9·4	<0·001
Sugar intake (g/d)	209	197	198	198	200	<0·001
College or higher education (%)	7·6	9·4	11·1	11·8	13·0	<0·001

intake from foods and beverages was not associated with cardiovascular mortality; the multivariable-adjusted HR (95 % CI) in the highest v. lowest quartile of water intake (≥3 v. <2 litres/d) was 0·91 (0·70, 1·19)[22]. Similarly, the third National Health and Nutrition Examination Survey (NHANES III) indicated that higher total fluid intake (plain water plus moisture from foods and beverages) was not associated with mortality from CVD; the multivariable-adjusted HR (95 % CI) in the highest v. lowest quartile (≥3·6 v. < 2·1 litres/d) of total fluid intake was 0·99 (0·75, 1·29)[15].

Regarding plain water intake, on the other hand, during the 6-year follow-up of 20 297 American men and women aged 38–100 years of the Adventist Health Study, higher plain water intake was associated with a reduced risk of mortality from CHD; the multivariable-adjusted HR (95 % CI) for the highest plain water intake (≥5 v. ≤2 glasses/d) was 0·39 (0·22, 0·67; P for trend = 0·0003) in men and 0·52 (0·27, 1·03; P for trend = 0·17) in women[14]. In addition,

during the 10-year follow-up of 120 852 men and women aged 55–69 years of the Netherlands Cohort Study, high plain water intake (>500 ml/d v. zero) tended to be associated with a reduced risk of mortality from total stroke; the multivariable-adjusted HR (95 % CI) was 0·85 (0·31, 2·29) in men and 0·49 (0·19, 1·24) in women[21].

Many factors interact to determine the amount of fluid intake; one of which is the season. A previous Japanese study reported that water intake was highest in summer (2331 g/d) and lowest in winter (2134 g/d), and the intake of water from beverages including plain water increased by 8·4 g/d while that from foods decreased by 3·1 g/d with each 1°C increase in mean outdoor air temperature[10]. In our study, we could not find any effect modification by the season when the questionnaire was administered on the association of water intake from foods and beverages with cardiovascular mortality. The FFQ in our study inquired about the intake over the last 12 months; therefore, the collected dietary intakes including water from foods and

Table 2 Hazard ratio (HR) and 95 % CI of mortality from CHD, total stroke, stroke type and total CVD, according to quintile of water intake from foods and beverages, among 22 939 men and 35 362 women aged 40–79 years, Japan Collaborative Cohort (JACC) Study

| | Quintiles of energy-adjusted water intake | | | | | | | | | |
| | 1 (low) | 2 | | 3 | | 4 | | 5 (high) | | |
	Ref.	HR	95 % CI	HR	95 % CI	HR	95 % CI	HR	95 % CI	P for trend
Men										
Range of water intake (ml/d)	<1053	1053–1250		1251–144		1443–1690		≥1691		
Person-years	73 524	72 515		73 750		74 627		75 973		
Total CVD, n	348	328		319		299		343		
Age-adjusted	1·00	0·97	0·86, 1·09	0·95	0·85, 1·07	0·79	0·70, 0·89***	0·83	0·74, 0·93**	<0·001
Multivariable-adjusted†	1·00	1·00	0·86, 1·18	1·01	0·85, 1·20	0·86	0·72, 1·03	0·88	0·72, 1·07	0·03
CHD, n	88	82		79		65		76		
Age-adjusted	1·00	1·00	0·80, 1·27	0·97	0·76, 1·23	0·72	0·55, 0·93*	0·77	0·60, 0·98*	0·007
Multivariable-adjusted†	1·00	1·02	0·74, 1·40	1·05	0·75, 1·49	0·81	0·55, 1·18	0·81	0·54, 1·21	0·06
Total stroke, n	158	138		137		148		139		
Age-adjusted	1·00	0·97	0·81, 1·16	0·97	0·81, 1·16	0·93	0·78, 1·11	0·80	0·67, 0·96*	0·005
Multivariable-adjusted†	1·00	0·97	0·76, 1·23	1·02	0·79, 1·32	1·04	0·79, 1·36	0·86	0·64, 1·16	0·32
Haemorrhagic stroke, n	59	42		46		48		39		
Age-adjusted	1·00	0·85	0·62, 1·18	0·92	0·68, 1·26	0·90	0·67, 1·22	0·68	0·49, 0·95*	0·02
Multivariable-adjusted†	1·00	0·84	0·55, 1·28	0·97	0·62, 1·50	1·00	0·63, 1·60	0·81	0·47, 1·39	0·43
Ischaemic stroke, n	82	85		81		89		88		
Age-adjusted	1·00	1·04	0·82, 1·31	1·02	0·81, 1·29	0·96	0·77, 1·20	0·87	0·70, 1·09	0·19
Multivariable-adjusted†	1·00	1·09	0·79, 1·50	1·13	0·80, 1·59	1·10	0·77, 1·58	0·89	0·60, 1·31	0·68
Women										
Range of water intake (ml/d)	<1036	1036, 1220		1201, 1393		1394, 1606		≥1607		
Person-years	116 789	116 678		117 231		118 529		122 256		
Total CVD, n	426	321		283		333		344		
Age-adjusted	1·00	0·91	0·81, 1·03	0·82	0·73, 0·93**	0·93	0·83, 1·05	0·85	0·76, 0·95**	0·001
Multivariable-adjusted†	1·00	0·88	0·76, 1·03	0·79	0·67, 0·94*	0·88	0·74, 1·05	0·79	0·66, 0·95*	0·10
CHD, n	88	53		52		60		52		
Age-adjusted	1·00	0·77	0·58, 1·03	0·78	0·58, 1·03	0·86	0·66, 1·13	0·66	0·49, 0·88**	0·005
Multivariable-adjusted†	1·00	0·71	0·49, 1·02	0·70	0·47, 1·03	0·75	0·50, 1·12	0·60	0·39, 0·93*	0·20
Total stroke, n	190	160		138		142		147		
Age-adjusted	1·00	1·06	0·90, 1·25	0·93	0·78, 1·12	0·93	0·78, 1·10	0·85	0·71, 1·01	0·003
Multivariable-adjusted†	1·00	0·99	0·79, 1·24	0·91	0·71, 1·17	0·90	0·69, 1·17	0·80	0·60, 1·06	0·23
Haemorrhagic stroke, n	66	62		64		58		65		
Age-adjusted	1·00	1·05	0·80, 1·37	1·10	0·84, 1·44	0·96	0·73, 1·27	0·98	0·75, 1·28	0·60
Multivariable-adjusted†	1·00	1·09	0·75, 1·57	1·19	0·80, 1·77	1·08	0·71, 1·66	1·10	0·70, 1·73	0·44
Ischaemic stroke, n	99	80		62		71		72		
Age-adjusted	1·00	1·02	0·80, 1·29	0·80	0·61, 1·04	0·89	0·69, 1·14	0·78	0·61, 1·00*	0·01
Multivariable-adjusted†	1·00	0·95	0·70, 1·31	0·79	0·55, 1·14	0·85	0·59, 1·22	0·70	0·47, 0·99*	0·19

Ref., reference category.
*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$.
†Adjusted for age, BMI (quintile), smoking, alcohol consumption, intakes of coffee, green tea, fresh fish, vegetables, fruits, fibre, sugar and energy, hours of sleep, walking and sports, education level and history of hypertension and diabetes mellitus.

beverages were not confined to a specific season but were the overall intakes over one year.

The proportion of plain water intake out of total fluid intake has been shown to be variable among populations[7–11]. For example, this proportion was 33 % in US participants in the NHANES 2005–2006[7], 54 % in Korean participants in the National Health and Nutrition Examination Survey (KNHANES) 2008–2012[8] and 53 % in adult dwellers of four cities in China[9]. Unfortunately, we do not have data on the consumption of plain water in our study to state what percentage is accounted for by plain water. Even the Japan National Health and Nutrition Survey, a survey conducted annually by the Japanese Ministry of Health, Labour, and Welfare to understand the status of people's health, nutritional intake and lifestyle habits, has not published any data about the proportions of plain water and water from foods and beverages. Thus, we were unable to discern any potential differences described in

previous studies regarding the associations of water intake from foods and beverages as opposed to plain water intake with cardiovascular mortality. However, small Japanese studies have reported the proportions of water intake from different sources. For example, in a study conducted in four areas in Japan with a total of 121 women aged 30–69 years and 121 men aged 30–76 years who completed 16 d diet records, the mean total water intake was 2230 g/d and almost half of the water was derived from foods (1130 g/d), the remaining half coming from beverages including plain water (1130 g/d)[10]. In another study among 3835 female Japanese dietetic students aged 18–20 years from fifty-three institutions in Japan, the mean total daily water intake (g/4186 kJ) was 1028 g; 654 g from fluids including plain water and 374 g from foods[5]. A report from thirteen countries that collected 7 d fluid-specific records showed a total fluid intake from beverages of 1·5 litres/d in 1318 Japanese men and

women aged 18 years or older, and 18 % of this amount was consumed as plain water[11].

Mechanisms by which water intake is associated with reduced risk of mortality from CVD are not well known. However, the vasopressin system might play a role. Post myocardial infarction activation of the vasopressin system was reported in an observational study of 980 patients. Copeptin, the C-terminal part of the vasopressin pro-hormone, and N-terminal pro-B-type natriuretic peptide (NTproBNP), an established marker for left ventricular function and the prognosis of myocardial infarction, were at highest levels at admission then plateaued within 3–5 d; moreover, their levels were higher in patients who died or were readmitted for heart failure than in survivors[20]. Another mechanism was shown in a clinical trial of 293 healthy men and women aged 20–95 years which demonstrated that hypo-hydration leads to high blood viscosity[27], which was positively associated with 8-year risk of CHD among 933 men aged 45–64 years of the MONICA-Augsburg cohort study[28]. Among 4112 men and women aged ≥20 years in NHANES 1999–2006, individuals with high water intakes either from plain water or from foods and beverages had healthier lifestyles, such as high physical activity, high education and high fibre intake, and lower sugar intake, than individuals with low water intakes[29]. In the present study, however, the reduced risk of mortality from CVD associated with high fluid intake remained statistically significant after adjustment for education level, fibre and sugar intakes.

The strengths of our study include its prospective design, the use of a validated FFQ, the consistent way of end-point determination and its large sample size from community residents. In addition, the exclusion of persons with known chronic diseases at baseline reduced bias arising from dietary changes due to known morbidity. We even took account of the possibility that preclinical diseases may affect water intake or that prevalent diabetes may increase water intake due to thirst, and we examined the association after excluding early deaths within 5 years from baseline and participants with diabetes at baseline; there was, however, no material change in the findings.

Limitations of the current study include the above-discussed lack of estimation of total fluid consumption including plain water intake. Unfortunately, none of the previous studies that assessed the associations of intakes of both plain water and water from foods and beverages with risk of CVD[14,15,21,22] have reported the correlations between plain water intake and that from foods and beverages in their samples. However, among 2691 US adults aged ≥20 years from the NHANES 2005–2006, plain water was positively associated with moisture in foods and inversely associated with moisture in beverages. Moreover, it was suggested that outdoor temperature can affect the proportions of water intake from foods, beverages and plain water[10]. Although we found no effect modification by the season when the questionnaire was administered on the association of water intake from foods and beverages with cardiovascular mortality, further studies are needed to investigate the associations between water intakes from various sources and risk of CVD.

Conclusion

In conclusion, high intake of water from foods and beverages was associated with reduced risk of cardiovascular mortality for both sexes and reduced risk of ischaemic stroke for women in Japan.

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Supplementary material

To view supplementary material for this article, please visit https://doi.org/10.1017/S1368980018001386

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