

Is the default of 2 liters for daily per-capita water consumption appropriate? A nationwide survey reveals water intake in Japan

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ABSTRACT

Two liters per day is generally applied as the default drinking water intake rate for risk assessments, although evidence supporting this value is insufficient. This study aimed to reveal actual water intakes from tap water and other types of drinks, and to explore the relationships between these intakes. For this purpose, we conducted a nationwide Internet questionnaire survey. Tap water intake negatively correlated with bottled water and soft drink intakes, suggesting a mutually complementary relationship. We propose an index, potential Tap Water Intake (pTWI), calculated by adding soft drinks and bottled water to tap water intake. Mean per-capita tap water intake across the entire Japanese population was estimated at 1.28 L/d, whereas mean pTWI was estimated at 1.65 L/d. Two liters per day corresponds to the 88th percentile of tap water intake and to the 76th percentile of pTWI, and covers the intake of the majority of the population in Japan. This rate should continue being used as the default in the Japanese population, but the rate to cover the tap water intake of almost the entire population would be higher: it was >2.5 L/d.

Key words | community water, direct and indirect intake, drinking water, exposure assessment

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INTRODUCTION

Daily intake rates of water, drinking water, and tap water are basic factors used to assess the health risks of water contaminants and to develop regulations, policies, and guidelines. A value of 2 L/d is generally applied as the default rate of daily drinking water intake for adults for exposure assessments conducted by many countries and international organizations. In the current edition of the WHO (World Health Organization) *Guidelines for Drinking-water Quality* (WHO 2011), the 2 L/d rate is applied as a default assumption for an adult. WHO regards this value as an assumption because the volume of water consumed daily varies (WHO 2011), but does not explicitly provide background information for this assumption.

Regarding the volume of daily total water intake, which includes intrinsic water that is naturally contained in foods, detailed statistics can be found in many reports. Total water

intake varies per country depending on dietary habit, lifestyles, and environmental conditions (Athanasatou *et al.* 2016). For example, the mean total water intake (L/d) for adults is 1.6 (women) and 1.7 (men) in Spain (2,007 adults, 2013) (Nissensohn *et al.* 2016), 2.23 in four prefectures of Japan (242 adults, 2003–2004) (Tani *et al.* 2015), 2.3 (women) and 2.6 (men) in Australia (6,232 adults, 2011–2012) (Sui *et al.* 2016), 2.1 (women) and 2.5 (men) in Germany (1,528 adults, 1986–1988) (Manz *et al.* 2012), and 2.8–2.9 (women) and 3.5–3.8 (men) in the United States (15,702 adults, 2005–2012) (Drewnowski *et al.* 2013; Rosinger & Herrick 2016). The median total water intake is 1.49 L/d in four cities of China (747 adults) (Ma *et al.* 2012). Ferreira-Pego *et al.* (2015) collected original and published data for 13 countries, and reported that the median total fluid intakes for the total population (16,276) was

1.98, the highest was 2.47 for Germany and the lowest was 1.50 for Japan. Data for total drink intake, which does not include alcohol, intrinsic water, or water added in the preparation of food, are also found in some reports. The contribution of food moisture to total water intake is reported to be around 30–40% (Guelinckx *et al.* 2016; Lee *et al.* 2016; Szabo de Edelenyi *et al.* 2016). These statistics serve as fundamental data when assessing hydration and dietary status of populations (Malisova *et al.* 2016; Mora-Rodriguez *et al.* 2016).

Compared with information for total water intake, however, daily intake of tap water supplied through pipes by the public water system has not been reported for many countries. Those values of tap water intake as a beverage (i.e., plain tap water intake) that have been reported tend to be small, at 0.2 to 0.4 L/d in some European countries (Gibson & Shirreffs 2013; O'Connor *et al.* 2014; Ferreira-Pego *et al.* 2016) and around 0.6 L/d in the United States (Sebastian *et al.* 2011). This information may be valuable, but data for the direct plus indirect water intake are required for exposure assessment of contaminants in tap water. This is because exposure of contaminants in tap water comes from not only intake of tap water as a beverage (direct intake) but also from tap water indirectly ingested from prepared food and beverages (indirect intake). However, estimations of direct and indirect supplied water intake have only been made in a few countries, described below.

In reports by Kahn & Stralka (2009) and the US Environmental Protection Agency (USEPA) (2004), the estimated per-capita water ingestion in the United States was calculated by using combined data from four survey results from the Continuing Survey of Food Intakes by Individuals. For adults, the estimated direct and indirect daily per-capita intake of 'community water' – tap water from a public water supply – is 1.10 L/d. The mean estimated direct plus indirect daily per-capita intake of 'total water,' which consists of water from all supply sources such as public water supply, bottle, other, and missing sources, is 1.47 L/d (Kahn & Stralka 2009). According to recent estimates (USEPA 2011) based on 2003–2006 data from the US National Health and Nutrition Examination Survey, the mean ingestion rate for combined direct and indirect water from 'community water' for adults is estimated at 1.04 L/d, while the rate for 'total water' is 1.70 L/d. It was also reported that

the percentage of the US population ingesting 3 L/d or less was approximately 95% for 'community water' and 90% for 'total water.'

In Japan, no nationwide survey has been conducted in which tap water and commercial beverages' intakes are separately counted, and direct and indirect water intakes are separately counted. Recently, the marketing of not only carbonated beverages (e.g., sodas) but other types of drinks such as isotonic drinks, coffee, and tea (especially unsweetened bottled green tea and black tea) has been prevalent (Japan Soft Drink Association 2016). The intake of these commercial beverages can vary depending on personal drinking habits and scenarios (e.g., home, work-sites, and restaurants). Some people may be ingesting these commercial drinks as substitutes for drinking water, possibly reducing the national mean of daily tap water intake. Although these drinks may be complementary to tap water for some people, a mutually complementary relationship between their consumption and tap water has yet to be clearly revealed in statistical data. Moreover, if their consumption reduces the national mean of daily tap water intake, the risk of water contaminants based on the national mean would be underestimated for non-consumers of commercial drinks due to their tap water intake being relatively higher than that of consumers. Conversely, using the larger intake of those consuming primarily tap water may overestimate the risk for the population. However, statistical analysis exploring this possibility has not been conducted as yet.

Here, we conducted a nationwide Internet questionnaire survey of direct and indirect tap water intake and water intake via other types of drinks, including soft drinks, alcoholic drinks, and milk, in Japan. Correlation analyses revealed a mutual complementary relationship between tap water and these other intakes for hydration. Finally, we propose an index of potential Tap Water Intake (pTWI), applicable to the assessment of health risks of contaminants in drinking water.

METHODS

Development of the questionnaire

The survey questionnaire presented several sets of questions about water intake, characteristics of the respondent, and

other details. The questions related to water intake are shown in Figure S1 of the Supplementary Material (available with the online version of this paper). For easier comprehension by respondents, questions regarding intake were grouped into: (a) tap water including drinks and ice cubes made with tap water (Codes W01–06 in Figure S1); (b) commercial drinks including water and tea served free-of-charge in restaurants and presumably produced with tap water (W07–14); (c) steamed rice and soup made at home (W15,16); and (d) steamed rice and soup eaten outside the home or purchased in the market place (W17,18). W11 includes water added to non-alcoholic commercial beverages, such as tea and coffee, by manufacturers. Intrinsic and added water in commercial fruit and vegetable juices are also included in W11. W13 is alcoholic drinks. In the questionnaire sheet, intake of food other than rice and soup was not described because rice and soup are the two major sources of indirect tap water intake in Japan (MHLW (Ministry of Health, Labour and Welfare, Japan) 2016) and the inclusion of other food would make the questionnaire complicated, discouraging the respondents from answering honestly.

The questionnaire sheet mostly used the unit ‘mL’ as a measure of water volume because the unit is familiar in daily life, but it was also supplemented with illustrations and the volume of typical vessels such as a cup for respondents to make it convenient to quantify the intake amount. Respondents were asked to print out the questionnaire sheet after downloading it. They selected two work days and one non-work day in the survey periods, which were January and February for the winter survey and August and September for the summer survey. They were asked to keep records of intake according to the questions, rather than to fill in the sheet after recalling their intake during the previous period (selected days) to avoid forgetting their intake (Bardosono *et al.* 2015). After recording and completing the questionnaire sheet, respondents entered the answers on the questionnaire website.

Participant recruitment and Internet survey

In accordance with the above-mentioned questionnaire and survey plan, Internet surveys were conducted twice, in the winter and in the summer of 2012, by the consumer monitoring company Nikkei Research Inc. (Tokyo, Japan). This

company had 171,735 persons registered nationwide as of January 13, 2012. As one of the daughter companies of Nikkei Inc., which publishes a financial newspaper with nationwide circulation of about three million, this company was considered to be trustworthy. The Internet diffusion rate at 2012 was high: it was 79.5%, but it could not guarantee that those reachable for internet surveys were completely the same as the population as a whole. However, we tried to minimize sample bias in the recruitment process. We first divided the registered persons by four regions (North-east, East, Middle, and West, Figure S2, available online), two genders, and three age brackets (20 to 39, 40 to 59, and 60 to 79 years). In short, we divided the registered persons into 24 ($=4 \times 2 \times 3$) groups. From the company’s registration list, we tried to recruit 50 respondents for each group (a total of 1,200 people). Other characteristics such as occupation and annual income were not considered in the recruitment because of the difficulty, although they may indirectly affect water intake rate. Respondents were recruited through invitation emails. We allowed up to four members in the same household to participate in this survey. Respondents received an honorarium payment for their participation. Ethical review for the study was waived by the Hokkaido University Ethical Review Committee.

Tally method of questionnaire results

The items (questions) in the questionnaire (Figure S1) were categorized in terms of food/beverage type and water source into the following eight categories (Figure S3, available online). The codes W01–07 were tabulated as category C1 ‘tap water drink.’ This consisted of plain drinking water from the tap and beverages such as tea and ice cubes made with tap water. The water source of the tap water was almost always the public supply system (coverage of the public water supply system is 97.9% as of 2015 (MHLW 2017)). The category C2 ‘bottled water’ consisted of W08–10 and included not only plain bottled water but also tea, coffee, ice, and other beverages made with bottled water, and water from household water dispensers; C3 ‘water-in-rice’ was the tap water absorbed during the cooking of rice (W15 and W17); and C4 ‘soup’ was the water in soup, including broth used for noodles (W16 and W18). For these categories, participants were asked to record

only the ingested amounts. Codes W11–W14 were assigned to the following category designations: C5 ‘soft drink’ (W11), C6 ‘milk’ (W12), C7 ‘alcohol’ (W13), and C8 ‘miscellaneous’ (Misc.; W14).

We used several combined categories to represent water characteristics (Figure 1). The category designated as ‘tap + bottled drink intake’ was the sum of C1 and 2; ‘tap water intake’ was the sum of categories C1, 3, and 4; ‘tap + bottled water intake’ consisted of C1–4 and was equivalent to the sum of tap water intake and bottled water intake. The summation of the categories from C1–5 was called ‘pTWI’ (potential tap water intake). Category ‘all-water intake’ was defined as the summation of all the categories (C1–8).

Water intake in each category was summed in the unit of mL/d with the following assumptions. One ice cube

had a volume of 15 mL according to the questionnaire sheet; the proportion of tap water absorbed during cooking rice was estimated at 52.7%, based on figures for moisture in dry rice and normally steamed rice of 15.5% and 60.0%, respectively (MEXT (Ministry of Education, Culture, Sports, Science and Technology, Japan) 2010), using algorithms from USEPA (2004). Therefore, 1 kg of steamed rice intake was converted to an indirect tap water intake of 527 mL.

Statistical analysis

All statistical analyses were performed with the original water intake data without the adjustment for demographic strata described above. Mann–Whitney *U*-tests and Kendall

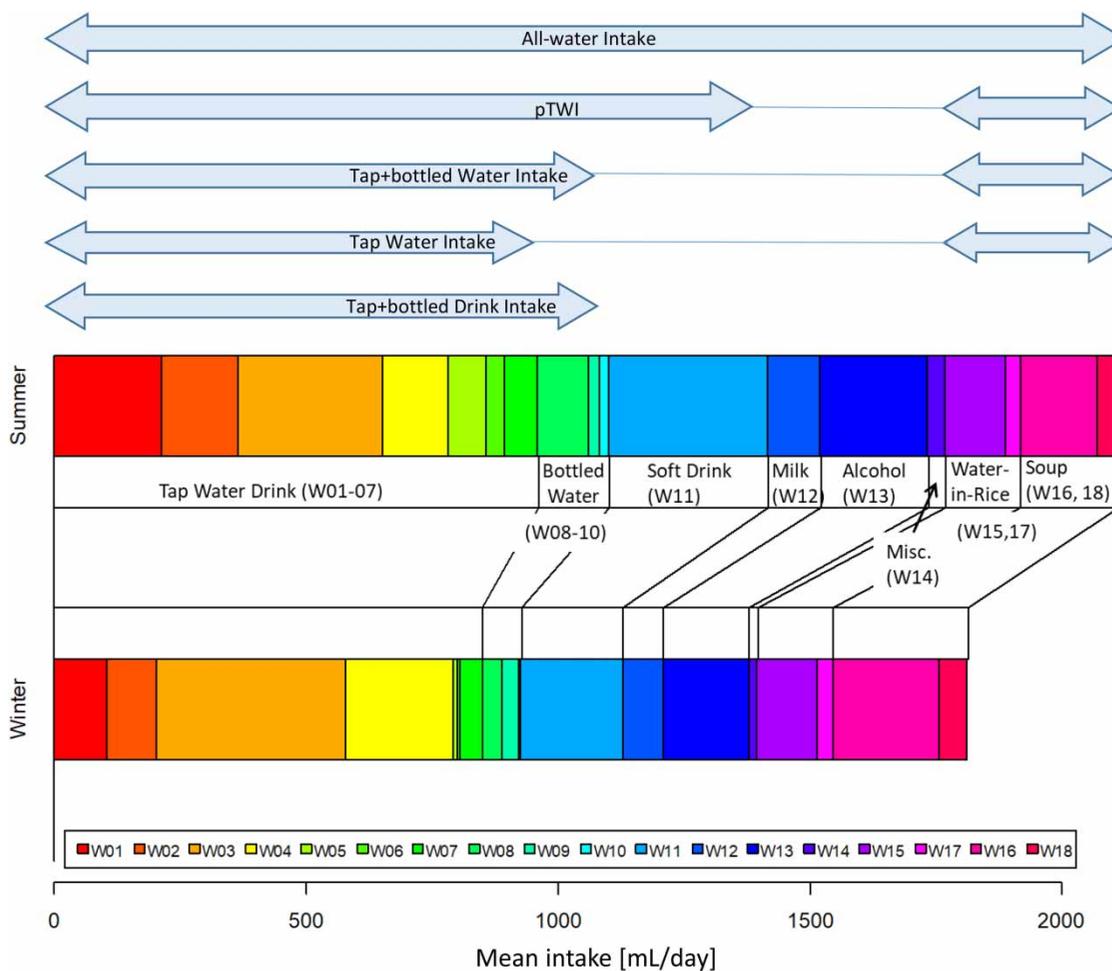


Figure 1 | Mean values of water intakes and the relationships between water codes (W01–18), water categories, and combined categories. For details of the water codes and categories see Figures S1 and S3, respectively, in the Supplementary material (available with the online version of this paper).

rank correlation tests were selected as nonparametric analyses. This was because the data included respondents with zero-volume intake, and the intake volumes were not normally distributed. The software R (R Development Core Team 2016) was used for all statistical analyses. *P*-value range of less than 0.05 was classed as statistically significant.

Adjustment for demographic strata

Water intakes representing the whole population of the country were estimated as follows. The adult population (in units of a thousand; Statistics Bureau, Japan 2011) for each of the 24 population groups (Table S1) was divided by the number of respondents recruited from the population group (Table S2). The quotients of the division were rounded to integer values. Water intake data of each respondent was replicated by factoring in the rounded figure of the corresponding population group to construct a new larger dataset (Table S3). This new adjusted dataset took into account the actual demographic structure in Japan. Percentiles and mean of estimated water intakes were calculated using this adjusted dataset. (Tables S1–S3 are available online.)

RESULTS

Internet surveys

Respondents were recruited from near evenly distributed geographical regions, ages, and gender. The number of respondents in the winter and the summer surveys were 1,190 and 1,278, respectively. We checked all the data to see whether the entered values fall extremely far outside the bounds of common sense or not. The data of two respondents in the winter survey were omitted. The data of 1,188 and 1,278 respondents in the winter and the summer surveys, respectively, were provided for statistical analyses (Table S2). Because the surveys were conducted during 2 work days and 1 non-work day, weekly-weighted average intakes were calculated for each respondent: the 2 work day intakes were each multiplied by 2.5 and the non-work day intake was multiplied by 2, before dividing the total by 7. The weekly-weighted average intakes are shown in Table 1 and Figure 1; details are shown in Tables S4–S6 (available with the online version of this paper). For simplicity, weekly-weighted average intakes are referred to as ‘uptakes’ below.

Mean per-capita intakes of Tap water drink intakes for all the respondents were 850 and 961 mL/d in winter and summer, respectively; the intake in summer was

Table 1 | Results from the questionnaire: mean water intake and number of respondents who answered zero intake during the 3-day survey for each category

Category			Mean water intake [mL/day]		Number of subjects with zero intake			
					Winter		Summer	
No.	Designation	Water code in the questionnaire	Winter	Summer	(<i>n</i> = 1,188)	(%)	(<i>n</i> = 1,278)	(%)
C1	Tap water drink	W01–07	850	961	27	2.3	27	2.1
	Cold tap water	W01, 02, 07	247	431				
	Hot tap water	W03, 04	590	416				
	Ice cubes	W05, 06	12	113				
C2	Bottled water	W08–10	77	141	870	73.2	798	62.4
C3	Water-in-rice	W15, 17	150	148	22	1.9	19	1.5
C4	Soup	W16, 18	267	195	48	4.0	144	11.3
C5	Soft drink	W11	201	316	317	26.7	259	20.3
C6	Milk	W12	82	103	546	46.0	500	39.1
C7	Alcohol	W13	169	215	633	53.3	623	48.7
C8	Misc.	W14	17	34	1,033	87.0	1,053	82.4

approximately 13% higher than that in winter. Mean per-capita intakes of tap + bottled drink (tap water drink plus bottled water) intakes were 928 and 1,102 mL/d in winter and summer, respectively; those of tap water intake were 1,266 and 1,304 mL/d for winter and summer, respectively; and those of pTWI were 1,545 and 1,761 mL/d for winter and summer, respectively.

When assessing cold and hot water separately, the cold-water intake in summer (431 mL/d) was approximately 75% higher than that in winter (247 mL/d). Consumption of bottled water and soft drinks were 83% and 57% higher in summer than in winter, respectively. Consumption of water-in-rice (tap water in the form of steamed rice) was almost equal between winter and summer. There were a few respondents (~2%) who did not drink water supplied

from the public water system (tap water drink) (Table 1). The percentages of respondents who did not drink bottled water were 73% and 62% during winter and summer, respectively.

The median value of tap water drink intakes for the respondents who did not consume any bottled water or soft drinks (tap water-only consumer) were 986 and 1,071 mL/d in winter ($n=253$, 21%) and summer ($n=185$, 14.5%), respectively (Figure 2). In contrast, the median values of tap water drink intakes for those who drank bottled water and/or soft drink as well as tap water drink (bottled-water/soft-drink consumers) was 739 and 838 mL/d in winter ($n=935$) and summer ($n=1,093$), respectively. The differences between the tap water-only and the bottled-water/soft-drink consumers were statistically

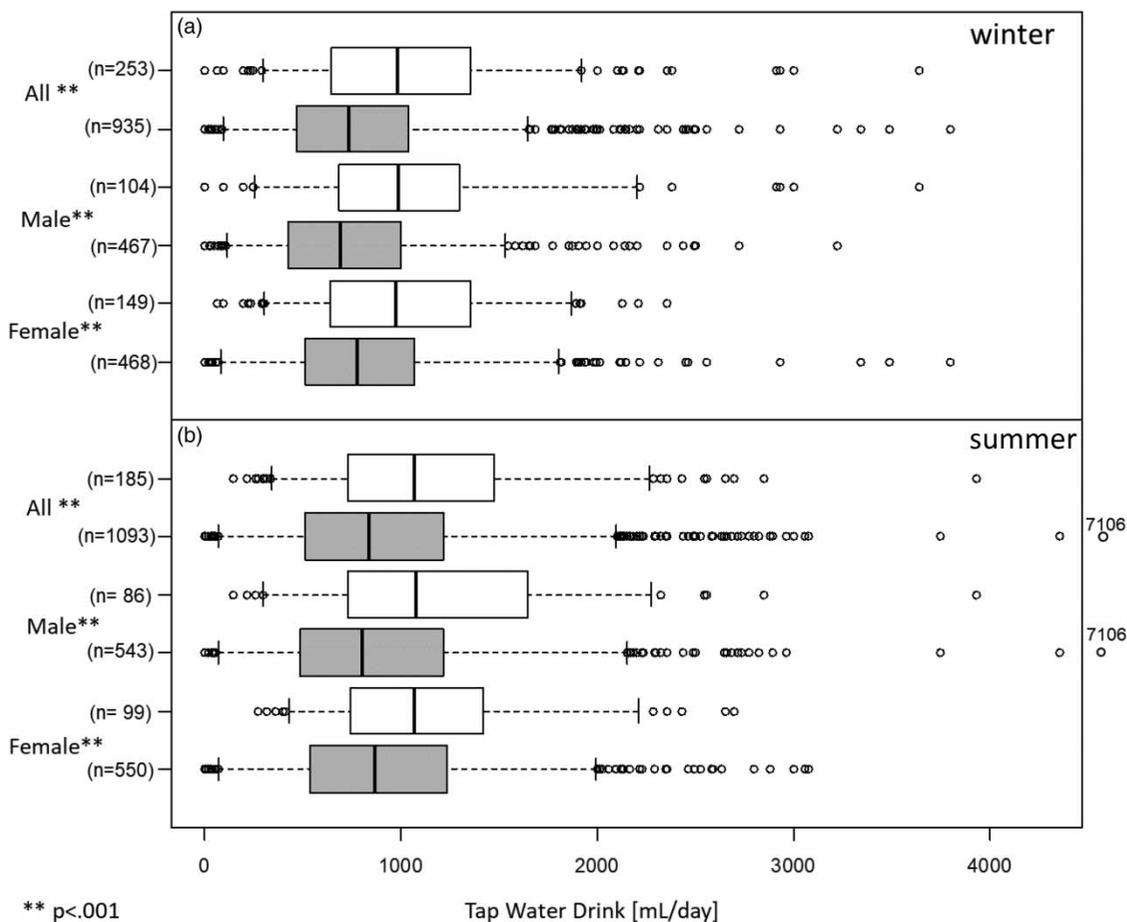


Figure 2 | Tap water drink intakes in (a) winter and (b) summer. Comparison of tap water drink intakes between people who did not drink bottled water or soft drink (tap-water-only consumer; white box) and people who drank bottled water and/or soft drink (grey box). The ends of each whisker represent the 5th and the 95th percentiles. Values outside the axis range are shown outside the frame. ** $p < 0.001$, Mann-Whitney U -test.

significant ($p < 0.001$, Mann–Whitney U -test); significant differences were also observed when tests were conducted separately for males and females.

Correlation analysis

Kendall's tau rank correlation tests were performed to examine whether tap water drink intake is associated with intakes of bottled water, soft drink, milk, alcohol, or misc., and to assess whether the intake of tap + bottled drink is associated with intakes of soft drink, milk, alcohol, or misc. The correlation coefficients are shown in Table 2 and Figure S4. We also conducted correlation analyses among all categories; the results are shown in Figures S5 and S6. (Figures S4–S6 are available online.) A significant negative correlation was found between tap water drink and bottled water ($\tau = -0.11$, $p < 0.001$). Negative correlations were also found between soft drink and tap water drink ($p < 0.001$) and between soft drink and tap + bottled drink ($p < 0.001$).

Estimation of water intakes after the demographic adjustment

After the demographic adjustment, the intake values corresponding to the <5% and >95% populations were somewhat changed (Tables S6 and S7); however, the demographic adjustment did not result in substantial changes to the mean and median values. The winter and summer datasets were merged to estimate intake distributions of the adult population, male and female. Percentiles and means are shown in Figure 3 and Table 3, and cumulative distribution curves are depicted in Figures S7 and S8. Intake

values were distributed widely: for example, the mean and 95th percentile values of tap water intake were 1,312 and 2,533 mL/d for male and 1,263 and 2,395 mL/d for female, respectively. The 5th percentile, median, mean, and 95th percentile of tap water intake for the entire population were 406, 1,202, 1,287, and 2,465 mL/d, respectively. The equivalent values for pTWI were 774, 1,546, 1,653, and 2,913 mL/d, respectively. Two liters per day corresponds to about the 95th percentile of intake of tap water drink, the 88th percentile of tap water intake, and the 76th percentile of pTWI. Details are given in Tables S8–S10. (Tables S6–S10 and Figures S7 and S8 are available online.)

DISCUSSION

Water intake for risk assessment of the public water system

For the assessment and management of health risks to human population from contaminants in public water systems, the ingestion rate of tap water is fundamental information. Here, the mean values of tap water intake (1,287 mL/d for the whole adult population) by our estimation are larger than the values of the community water intake for adults in the United States reported by Kahn & Stralka (2009). They reported that the mean community water intake, which was defined as direct and indirect intake of tap water from a community or municipal water supply, was 1,104 mL/d for 'all individuals' and 1,183 mL/d for 'consumers only,' that is, respondents that reported ingestion of tap water during their survey (Kahn & Stralka 2009). The difference between our

Table 2 | Results of Kendall's rank correlation tests

	Kendall's tau coefficient (* $p < 0.05$ and ** $p < 0.001$)				
	Bottled water	Soft drink	Milk	Alcohol	Miscellaneous
Winter ($n = 1,188$)					
Tap water drink	-0.11** ($p < 0.001$)	-0.15** ($p < 0.001$)	0.027 ($p = 0.19$)	-0.066* ($p = 0.002$)	0.0002 ($p = 0.99$)
Tap + bottled drink		-0.13** ($p < 0.001$)	0.040 ($p = 0.06$)	-0.040 ($p = 0.06$)	0.020 ($p = 0.39$)
Summer ($n = 1,278$)					
Tap water drink	-0.11** ($p < 0.001$)	-0.13** ($p < 0.001$)	0.077** ($p < 0.001$)	-0.014 ($p = 0.48$)	0.002 ($p = 0.94$)
Tap + bottled drink		-0.14** ($p < 0.001$)	0.090** ($p < 0.001$)	0.002 ($p = 0.91$)	0.049* ($p = 0.02$)

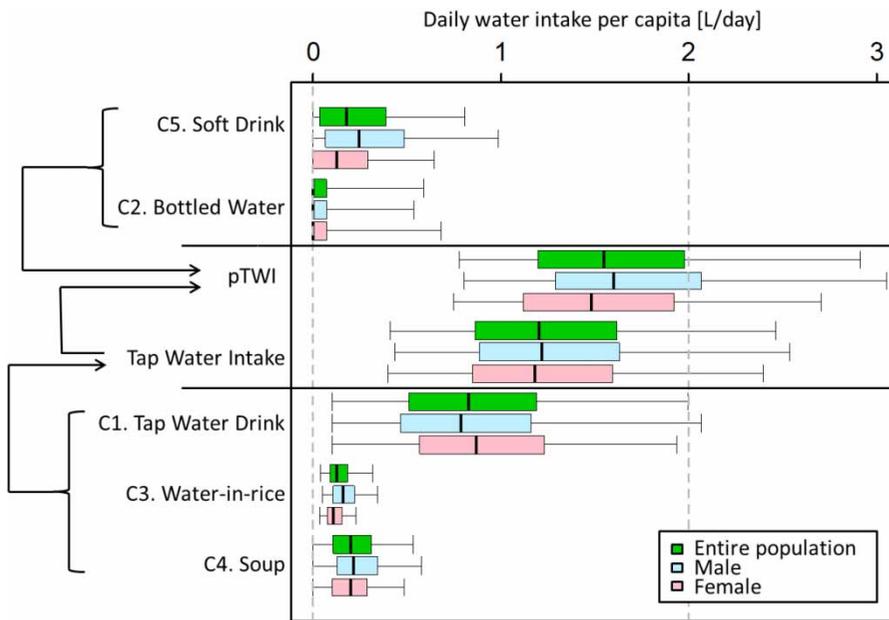


Figure 3 | Box plot of pTWI, tap water intake and categories included in pTWI. Whiskers show 1st and 99th percentiles.

Table 3 | Estimated percentiles and means of water intakes (the winter and summer data were merged)

	Percentiles (mL/day)									Mean
	1%	5%	10%	25%	50%	75%	90%	95%	99%	
For the entire population										
All-water intake	621	924	1,084	1,424	1,830	2,335	2,914	3,427	4,639	1,957
pTWI	487	774	908	1,196	1,546	1,979	2,501	2,913	3,898	1,653
Tap + bottled water intake	305	520	687	951	1,292	1,732	2,239	2,592	3,523	1,395
Tap water intake	213	406	567	861	1,202	1,614	2,103	2,465	3,145	1,287
Tap + bottled drink intake	57	243	364	616	921	1,309	1,793	2,129	3,011	1,022
For males										
All-water intake	726	1,051	1,255	1,555	1,959	2,552	3,174	3,678	4,764	2,125
pTWI	512	800	975	1,287	1,597	2,064	2,597	3,051	4,349	1,738
Tap + bottled water intake	285	495	646	967	1,313	1,724	2,312	2,692	3,533	1,416
Tap water intake	220	433	567	886	1,217	1,632	2,163	2,533	3,302	1,312
Tap + bottled drink intake	0	214	300	557	868	1,271	1,800	2,170	3,011	991
For females										
All-water intake	529	841	1,008	1,308	1,690	2,183	2,674	2,994	4,256	1,796
pTWI	468	744	867	1,120	1,482	1,920	2,364	2,705	3,806	1,572
Tap + bottled water intake	366	562	710	933	1,275	1,735	2,149	2,497	3,351	1,375
Tap water intake	203	395	563	849	1,179	1,596	2,058	2,395	3,011	1,263
Tap + bottled drink intake	98	300	436	654	954	1,364	1,786	2,071	3,057	1,051

values and their values may reflect the different rates of consumption of bottled water. In fact, the difference between studies decreased when we compared total water intake (termed tap + bottled water in our study), which was 1,466 mL/d in their data and 1,395 mL/d in our data. The difference in tap water intake (community water intake) and similarity in tap + bottled water intake (total water intake) suggests a mutually dependent relationship between tap water intake and bottled water intake.

The negative correlation between tap water drink intake and bottled water intake in our data (Table 2) supports this relationship: soft drink intake was also negatively correlated with tap water drink intake. These results clearly indicate that both soft drink and bottled water served as substitute sources for water ingestion, at least in part in place of tap water intake.

Kahn & Stralka (2009) provided water intake data for a 'consumers only' group, which excluded those who did not drink tap water during the survey period, as well as intake data for all survey respondents. In addition, they mentioned that estimates for 'consumers only' were often the primary focus in analyses of risk due to ingestion of potentially contaminated water. The consumers-only group excludes those who did not drink community water, but includes those who drink both bottled water and commercial beverages.

In our survey, the number of people who did not drink water supplied from the public water system was very small (2%), but most people (62–73%) did not drink bottled water and a substantial percentage of people (20–27%) did not consume soft drinks (Table 1). This result may be due not only to the diversity of people's preferences for types of beverage and water consumption, but also the availability and convenience of them. Tap Water Drink intake for tap water-only consumers was significantly higher than that for bottled-water and/or soft-drink consumers (Figure 2). For risk assessment of tap water, a water intake rate of 2 L/d is normally placed in the context of intake of the whole population of tap water consumers, but it should also be discussed in the context of water intake of the subpopulation who do not drink bottled water or soft drinks. The water intake of the subpopulation that does not consume bottled water or soft drinks is not easily estimated. The demographic distribution of tap water-only consumers is unknown. Even in our Internet survey, the number of

tap water-only consumers was around 200. Therefore, pTWI estimated for the entire set of respondents can be applied as a tap water intake index. Use of pTWI rather than tap water intake for risk assessment has additional merit because some commercial beverages are produced from water from public water supplies (Asami *et al.* 2009), and some contaminants (e.g., chlorate) remain in the final products of commercial beverages and foods even after water has been further purified at the production plant (Asami *et al.* 2009, 2013). Therefore, the use of tap water intake may underestimate the potential exposure to some toxic substances from tap water. On the other hand, given the assumption that bottled water and purchased foods and beverages that contain water are widely distributed and less likely to contain source- and site-specific water, the use of total water intake may overestimate the potential exposure to toxic substances present only in public water supplies (USEPA 2011). Therefore, we propose that both tap water intake and pTWI should be used for risk assessments of drinking water on a case-by-case basis. We do not recommend using either tap water intake or pTWI exclusively, but risk managers should determine which is more appropriate given their particular circumstances.

Implication of tap water intake and pTWI rates

It is common practice to use 2 L/d as a default value to represent water intake in risk assessments and for determining drinking water quality guidelines and standards. In the current study, the estimated mean intake rate of drinking water was lower than 2 L/d: for example, mean tap water intake and pTWI were 1,287 and 1,653 mL/d, respectively. Therefore 2 L/d would exceed (i.e., cover) the intake of most of the population in Japan, although the intake rate was distributed widely.

In terms of the tap water drink intake, 2 L/d exceeded the rate across almost the entire Japanese population (95.0% of total; 94.3% of males and 95.7% of females). When tap water ingested in rice and soup was added to tap water drink intake to give tap water intake, 2 L/d covered 88.0% of the population (87.8% of males and 88.1% of females). For pTWI, it covered 75.7% of the population (73.0% of males and 78.5% of females). In the United States, 2 L/d corresponds to the 85th percentile of the

cumulative distribution of community water intake for males 20 years and older and the 88th percentile for women aged 20 and older (USEPA 2004). The present study revealed that even if tap water ingested in food is added, the 2 L/d value would cover the intake of the majority (>75.7%) of the Japanese population. Two liters per day should continue being used for the default in the Japanese population, but the rate to cover the tap water intake of almost the entire population would be higher: it was >2.5 L/d according to the result that 95th percentiles of tap water intake and pTWI were 2.5 and 2.9 L/d, respectively.

CONCLUSIONS

In risk assessments and implementations for determining drinking water quality guidelines and standards, the water intake rate of 2 L/d has been used historically as a standard value worldwide, under the assumption that this value exceeds the intakes of most of the population. However, the intake of water varies depending on its definition and the population. This study has carefully specified the various intakes of water and revealed a mutual complementation between intake of tap water and other beverages.

Of the respondents, 73% and 62% did not drink bottled water during summer and winter surveys, respectively, while 21% and 14.5% did not drink bottled water or soft drinks during the same periods. Intakes of tap water drink (tap water from public water supply system, which consisted of direct intake as a drink and indirect intake via beverages) for those who did not consume bottled water or soft drinks were significantly larger than those that did consume them. Furthermore, both the correlation between soft drink and tap water drink intakes and the correlation between bottled water and tap water drink intakes were negative and significant. Therefore, soft drink and/or bottled water are complementary to tap water drink for some people. If the consumption of soft drinks and bottled water reduces the national mean tap water intake, risks assessed based on that national mean would be underestimated for non-consumers of commercial drinks due to their tap water intake being relatively high. Therefore, statistics of tap water intake (the water source is tap water from the public water

supply system) for the whole population may not be appropriate for non-consumers of bottled water and soft drinks. Considering the above-mentioned results and the fact that the source waters of some soft drinks are from public water supplies, we proposed the pTWI (water sources are tap and bottled water and soft drinks) as an alternative index.

The intake of water varied greatly among the population in Japan. Mean and 95th percentile values of tap water intake were 1,287 and 2,465 mL/d, respectively. The rate of 2 L/d covers 88% of the population in terms of tap water intake and 75.7% in terms of pTWI. Because the cohort used here is representative of the geographical regions, ages, and gender of the Japanese population, this study quantitatively demonstrates that the rate of 2 L/d covers the intake of the majority of the populations in Japan. The rate to cover the intake of almost the entire population was >2.5 L/d. These results and other statistical data presented in this study should serve as important scientific evidence for exposure assessment.

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