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Hydration, water intake and beverage consumption habits among adults

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Summary

Total water intake is seldom reported in dietary surveys and hydration status is rarely measured. Although adequate intake (AI) levels have been suggested by the European Food Safety Authority, the World Health Organization and the Institute of Medicine, uncertainties and confused messages abound regarding optimum intake. This paper reviews data on water intake internationally and examines associations with beverage consumption habits of adults in the UK, as determined from secondary analysis of individual diet records. On average, total water intake among British adults was equivalent to the European AI (2 l/day for women, 2.5 l/day for men) and 75% of this was derived from beverages. Factors that correlated with high total water intake included the consumption of a variety of beverages and drinking in the evening. Total water intake (and the contribution from soft drinks) is markedly higher in the USA than in Europe.

Beverage consumption habits and trends were also reviewed. In the past 10 years, water beverages have become more popular and as such the overall energy contribution from beverages has declined slightly. Most people could be encouraged to drink a variety of beverages to maintain adequate hydration and to balance the energy content according to their needs. However, further work is needed to refine recommendations for water intake, as basing these on observational epidemiological data is essentially a circular argument. A standardized measurement tool, validated against biomarkers of hydration status, would be a step forward in assessing the adequacy of water intakes at a population level. Research may also be warranted to explore the context of drinking occasions (including time of day, weekdays weekends, lifestyle and meal patterns) as these may have an impact on water intake, hydration and also energy balance.

Keywords: beverage consumption, dietary recommendations, hydration, survey, trends, water intake

Introduction

Water is arguably the most vital nutrient of all, as the absence of intake is usually lethal within just a few days (Jequier & Constant 2010). It is essential for all bodily functions, including temperature regulation, nerve conduction and many chemical reactions. Disturbances of hydration status result in changes in tissue osmolality and in cell volume, leading to alterations in cell and tissue function (Lang 2011). The primary regulated variables are the osmolality and volume of the vascularspace, though the distribution of water within the

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Table 1 Recommendations for total water intake from various authorities (l/day)

Table 1	Age group	EFSA (2010) dietary reference value		IOM (2005) adequate intake		WHO (2003) requirement	
		Male	Female	Male	Female	Male	Female
Children	12–24 months	1.1	1.1	1.3	1.3	1.0	1.0
	2–3 years	1.3	1.3	1.3	1.3	1.0	1.0
	4–8 years	1.6	1.6	1.7	1.7		
	9–13 years	2.1	1.9	2.4	2.1		
	14–18 years	2.5	2.0	3.3	2.3		
Adults	19–50 years	2.5	2.0	3.7	2.7	2.9	2.2
	51+ years	2.5	2.0	3.7	2.7	2.9	2.2
	Pregnancy		2.3		3		4.8
	Lactation		2.7		3.8		5.5

EFSA, European Food Safety Authority; IOM, Institute of Medicine; WHO, World Health Organization.

various body compartments is also tightly regulated. Euhydration (*i.e.* a normal state of hydration) is maintained primarily by control of both water intake and loss.

In spite of the importance of water, data on total water intake are seldom reported in dietary surveys, and hydration status of participants is rarely measured. It has been suggested that further research in this area would help to clarify whether the UK population is optimally hydrated (Benelam & Wyness 2010) as this is an area of uncertainty and confused messages. The purpose of this paper is to review observational data on water intake in the UK compared with other countries, and associations with beverage consumption habits, using published data from the National Diet and Nutrition Survey (NDNS) rolling programme (DH) and secondary analysis of 7-day dietary records from the previous adult survey in 2001. Data files for NDNS surveys were obtained from the UK Data Archive (www.data-archive.ac.uk).

As with requirements for many other nutrients, water requirements vary according to the individual's age, gender and body size, as well as their activity level and physical environment. Homeostatic mechanisms strive to maintain water balance within certain limits, but thirst is not a particularly sensitive indicator of mild dehydration and is normally felt only when around 1–2% body mass loss has already occurred (Armstrong 2005). Hypohydration (*i.e.* excessive loss of body fluid) of this order can lead to headaches and impaired cognitive and physical performance (Shirreffs *et al.* 2004). Because of the mounting evidence of both short- and long-term detrimental effects of hypohydration on health and well-being (Jequier & Constant 2010), guidelines have been established to determine how much water humans require (on average) to avoid dehydration and to optimize physical and psychological function. Such 'daily reference values' (DRVs) or 'adequate intakes' (AIs) range from 2 l/day for women and 2.5 l/day for men from the European Food Safety Authority (EFSA), up to 2.7 l/day for women and 3.7 l/day for men from the Institute of Medicine (IOM) (Table 1). Most estimates of adequacy are based on mean or median intake of water from observational epidemiological studies of apparently healthy people (IOM 2005), or intakes in combination with urine osmolarity (EFSA Panel on Dietetic Products, Nutrition and Allergies 2010), or from reviews of relevant data (WHO 2003). They are at best a guideline against which to measure the fluid intake of populations, but the coefficient of variation or range of acceptable intakes is not well specified and individuals may require much more or much less than these values.

Daily water intake

Recent data on water intake from both food and beverages are shown in Table 2. In the UK, total water intake is not currently quoted in the published NDNS reports but the mean value has been calculated as 2494 g/day among adults aged 19–64 years in 2008/2009 (Ng *et al.* 2011) and 2418 g/day from analysis of 2 years of data for 2008/2010 (S Gibson, unpublished data). Average water intakes in other European countries appear to be broadly similar to those in the UK [*e.g.* mean 2461 ml/day in Sweden (Becker & Pearson 2002)], or else lower than the UK [*e.g.* mean intake 1984 ml/day in France (Volatier 2000); 2039 ml/day in Germany (Manz & Wentz 2005); 2222 ml/day in The Netherlands (TNO 1998)]. However, differing data

Table 2 Total water intake and beverage consumption among adults in different countries

Country	UK (2000/2001)	UK 2008/2010	UK 2008/2009	France	Germany	Sweden	The Netherlands	USA	USA
Units	Mean g/day	Mean g/day	Mean ml/day	Mean ml/day	Mean (ml/day)	Mean ml/day	Mean ml/day	Mean g/day	Mean ml/day
Total Water (M + F)	2396†	2418*	2494	1984	2039‡	2461‡	2222	3179	
Total Water (M)	2533	2604*	N/A	N/A	2259	2467	2622	3467	2595–3189§
Total Water (F)	2059	2234*	N/A	N/A	1875	2455	2402	2897	2219–2513§
Total beverages (M + F)	1727	1886	1970	1183‡	1500	1903	N/A	2594¶	2793
Total beverages (M)	1918	2052	N/A	1236	1530	1911	1708–2018§	2827¶	N/A
Total beverages (F)	1536	1725	N/A	1130	1469	1895	1762–1941§	2377¶	N/A
Reference	(S Gibson & S Shirreffs unpublished data)	(Bates *et al.* 2011)	(Ng *et al.* 2011)	†(Volatier 2000)	†(Manz and Wentz 2005)	†(Becker and Pearson 2002)	†(TNO 1998) (water); National Institute for Public Health and the Environment, 2011 (beverages)	(Kant *et al.* 2009)	(Popkin 2010)
Data source	NDNS 2000/1 raw	NDNS report Table 5.1	Fig 4; Table A2	INCA (AFFSA)	VERA	Riksmaten 1997–1998	Dutch Food Consumption Survey TNO 1998	NHANES 2005/2006	NHANES 2005/2006

Notes:

*Calculated from raw data (S Gibson, unpublished results).

†Data taken from European Food Safety Authority (EFSA) Table 2 [EFSA Panel on Dietetic Products, Nutrition and Allergies (NDA) 2010 #40] except for Germany where data are from original paper (Manz and Wentz 2005) as values in EFSA report are incorrect.

‡Average for both men and women.

§Range for age groups 19–30, 31–50 and 51–70 years.

¶Water content of beverages.

AFFSA, Agence Française de Sécurité Sanitaire des Aliments; F, female; INCA, Enquête individuelle et nationale sur les consommations alimentaires; M, male; N/A, not available; NDNS, National Diet and Nutrition Survey; NHANES, National Health and Nutrition Examination Survey; TNO, Toegepast Natuurwetenschappelijk Onderzoek; VERA, Cooperative Study: Nutrition Survey and Risk factor Analysis, a subsample of the First National Food Consumption Survey (1986–1988) in Germany.

collection methods and survey dates mean these values are not necessarily comparable. Reported intakes of total water in North America are considerably higher than in Britain and Europe. In 2005–2006, American adults participating in the National Health and Nutrition Examination Survey (NHANES) reported consuming 3.18 l of total water within the previous 24 hours (Kant *et al.* 2009), slightly less than the 3.35 l reported in 1999–2004.

Sources of water intake

Beverages account for 70–80% of total water intake in most populations (Kant *et al.* 2009) and among UK adults the mean proportion is around 78% (Table 2), with the remainder coming from moisture in foods, notably fruits and vegetables and other foods with a high water content. This ratio is clearly not fixed, but varies depending on food and beverage choices. The popularity of different beverages varies by population, age group and gender. Table 3 summarizes consumption in a selection of countries where data are available (*i.e.* the UK, USA, Canada, France, Italy and Sweden). Comparison is hampered by the different classifications used, especially for water added to hot drinks and for milk (*i.e.* whether included with tea and coffee and whether milk on cereal is included). In addition, the US and Italian studies and that by Ng *et al.* (2011) on UK data quote volumes rather than weights, which gives a slight underestimate for the amounts of sugar-sweetened soft drinks and fruit juices, owing to their higher density (typically 1.03–1.05 g/ml).

Water as a beverage

Plain water from the tap or bottle is possibly the most difficult beverage to measure accurately (Popkin *et al.* 2010). Indeed, until 1999 there was no attempt to capture tap water consumption accurately in the US NHANES study. In Britain, consumption of plain water (bottled and tap, excluding use in tea and coffee) rose from 268 g/day in 2000/2001 to 432 g/day in 2008/2009 (Ng *et al.* 2011). Plain water consumption in the UK remains lower than in France (564 g/day for adults aged 20–54 years) and much lower than among Canadian adults aged 19–70 years (range from 705 to 1065 g/day, depending on age group) (Garriguet 2008) or American adults (mean 1134–1147 ml/day in older and younger adults, respectively) (Popkin 2010). Values for Italy are not comparable as they include water used to make tea and coffee (Turrini *et al.* 2001). In most studies, women consumed more plain water than men.

Hot beverages

Hot beverages (chiefly tea and coffee) are the most popular drinks in the UK. In the 2000/2001 survey of British adults, they were consumed on >90% of all days (S Gibson & SM Shirreffs, unpublished data). Mean *per capita* consumption was 737 g/day, men drinking more than women (774 vs. 708 g/day) and consumption increased with age, such that both men and women in the 50+ age group drank around 320 g/day more than the under 35s. Published data from the NDNS rolling programme report only a single value for tea, coffee and water (mean 1106 g/day) (Bates *et al.* 2011), while Ng *et al.* (2011) quote only the volume of unsweetened tea and coffee in 2008/2009 (mean 451 ml/day). Within the limits of the available data for other countries, it appears that consumption among UK adults is similar to that in Sweden, but higher than elsewhere in Europe, USA or Canada. Age-related increases in consumption were also observed in some of these countries (Garriguet 2008; Popkin *et al.* 2010).

Milk

Milk consumption in the UK (including milk with tea and coffee and on breakfast cereal) averaged 152 g/day among adults aged 19–64 years in 2008/2010 (Bates *et al.* 2011). Published data for other countries are difficult to compare because of differences in classification, but consumption in Italy would appear to be lower than the UK. Consumption levels in France (144–164 ml/day for younger and older adults, respectively) and the USA (136–161 ml/day) were similar to the UK, while consumption in Canada was higher than the UK, even though it excluded milk on cereals. Scandinavian adults also tend to consume more milk than British adults. Interestingly, younger Canadian adults (19–30 years) consumed more than other age groups, whereas in Britain, younger women tend to consume less milk than older women (data not shown).

Fruit juice

Fruit juice consumption was modest among British adults aged 19–64 years (mean 65 g/day for men and 49 g/day for women in the NDNS 2008/2010). This was lower than in Sweden (88 g/day), similar to that in France (33–54 ml/day across age groups) and higher than in Italy (mean 21 ml/day in 1994). American adults (76–92 ml across age groups) and especially Canadian adults (118–186 ml for men and 93–146 ml among women) had higher intakes.

Table 3 Types and amounts of beverages consumed in different countries

Country	Year	Age(yrs)	Sex	Tap water	Bottled water	Hot beverages	Milk	Caloric soft drinks	Diet soft drinks	Fruit juice	Alcoholic beverages	Reference
UK (g/day)	2000/2001	19–64	Total	218	60	737	215	110	88	49	301	(S Gibson & S Shirreffs, unpublished data)
		19–64	Male	187	55	774	232	129	82	52	501	
		19–64	Female	243	63	708*	202*	95*	93*	47	141*	
UK (g/day)	2008/2010	19–64	Total	N/A	N/A	1106[†]	152	141	101	57	329	(Bates *et al.* 2011)
		19–64	Male	N/A	N/A	1175[†]	166	173	107	65	501	
		19–64	Female	N/A	N/A	1040[†]	138	110	95	49	158	
UK (ml/day)	2008/2009	19–64	Total	432*		451[‡]	84	139	102	55	405	(Ng *et al.* 2011)
Canada (g/day)	2004	19–70	Male	705–1045	N/A	332–648[‡‡]	148–243[††]	115–304[††]	32–61[‡‡]	118–186[††]	234–327[††]	(Garriguet 2008)
		19–70	Female	840–1065	N/A	319–591[‡‡]	146–216[††]	62–142[††]	44–69[‡‡]	93–146[††]	72–91	
France (ml/day)	2002/2003	20–54	Total	564*	N/A	266	144	93	N/A	54	184	(Bellisle *et al.* 2010)
		55 years+	Total	547*	N/A	250	164	17	N/A	33	186	
Italy (ml/day)	1994–1996	19 years+	Total	348	312	8[¶]	130	35	N/A	21	112	(Turrini *et al.* 2001)
		19 years+	Male	347	305	8	132	41	N/A	24	169	
		19 years+	Female	349	317	8	128	31	N/A	19	63	
Sweden (ml/day)	1997/1998	17–80	Male	N/A	N/A	980[†]	376**	206[§]	N/A	87	254	(Becker 2002)
		17–80	Female	N/A	N/A	1230[†]	311**	138[§]	N/A	88	129	
USA (ml/day)	2005/2006	19–59	Total	1134–1147	N/A	133–320[‡]	136–161	307–520	151–290	76–92	267–296	(Popkin 2010)

*Where 'tap' and 'bottled' water were not given separately, values given under 'tap'.
[†]Sum of water, tea and coffee.
[‡]Only unsweetened hot beverages reported.
[§]All soft drinks and syrups (including diet soft drinks) exclude milk on cereal (mean 45 g).
¶Dry ingredients only.
**Milk and yogurt.
[††]Higher values for younger adults 19–30 years.
[‡‡]Lower values for younger adults 19–30 years.
N/A, not available.

Energy-containing soft drinks

Energy-containing soft drinks include fizzy drinks, squashes and cordials, and 'less than 100%' fruit juice drinks. Among British adults aged 19–64 years, mean consumption of regular (non-diet) soft drinks was 141 g/day in 2008/2010, higher among men than women and among younger adults compared with older adults. Average *per capita* consumption equates to around 2–3 cans per week.

Limited data from other European countries (France and Italy) suggests that there is low consumption (<100 g/day). By contrast, soft drinks are more widely consumed and in greater quantities in the USA (mean 520 ml/day in 19–39 year-old adults) (Popkin 2010), and in Canada (439 and 249 g/day among young men and women, respectively).

Diet soft drinks

These were less popular than energy-containing soft drinks among British adults in 2000/2001 (mean 88 g/day) but consumption had risen slightly to 102 g/day by 2008/2009 (Ng *et al.* 2011). Younger adults consumed significantly greater amounts than older adults. As with other soft drinks, consumption levels were much higher in the USA (mean 220 ml/day) than in the UK or Europe.

Alcohol

In Britain, alcoholic drinks (including beer, wine, spirits and alcopops) were consumed on 43% of all days among men and 30% of all days among women in 2000/2001. Total consumption averaged 501 g/day among men and 141 g/day among women, contributing 8% of energy intake. This is slightly higher than observed in other countries, although differences in beverage popularity mean that no inferences can be made regarding consumption of pure alcohol from these data. In addition, it is recognized that alcohol consumption is commonly under-reported, possibly more so than other beverages.

Trends over time

Data on both beverage purchases (at the household level) and consumption (at the individual level) have been collected in the UK and USA for the last 25 years and beyond, allowing some insight into the changing trends of beverage choice. However, direct comparisons between the two estimates are not possible because of the varying size and age distributions of households.

Purchase/availability data

UK purchases of energy-containing soft drinks, diet soft drinks and fruit juice increased substantially between 1975 and 2000/2001, since when they have been broadly static (Fig. 1). For example, household purchases of energy-containing soft drinks rose from 512 to 1142 ml/week between 1975 and 2007, peaking at 1195 ml/*capita*/week in 2001 (Ng *et al.* 2011). Similarly, supplies of regular soft drinks in the USA peaked at approximately 3 l/*capita*/week in 1998 and have since declined. Both countries have seen large declines in total supplies of milk and a dramatic switch from whole milk to reduced fat milks. However, the decline in milk

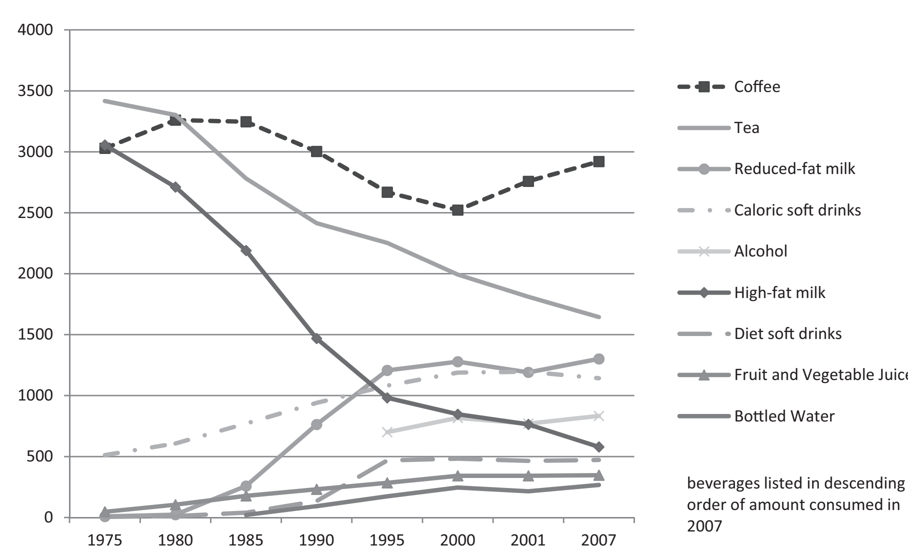

Figure 1 Trends in purchases of beverages in the UK (Source: DEFRA Expenditure and Food Survey)

availability in the USA started in 1944, long before the rise in soft drink consumption (Popkin 2010). Tea and coffee remain much more popular in the UK than in the USA, but tea purchases in the UK have dropped by more than 50% since 1975, whereas coffee has shown a rise in popularity since 2000, in line with the 'café culture'. Tea and coffee consumption has remained largely stable in the USA. Alcohol purchases were added to the UK expenditure survey only in the 1990s and appear to show a slight upward trend.

Contribution to energy intake (data on individuals)

There have been significant trends in the types of beverages consumed since the first NDNS of British adults in 1987. Consumption of plain water, alcohol, fruit juice and energy-containing soft drinks has all increased, while milk and tea have declined. The contribution of beverages to energy intake has remained at approximately 18% of energy overall, declining in absolute terms in line with total energy intake (411 kJ/day in 1986–1987 to 376 kJ/day in 2008–2009) (Ng *et al.* 2011). This proportion is higher than in France, where beverages have been estimated to contribute only around 10% of energy in 2002/2003 (Bellisle *et al.* 2010). In the USA, the energy contribution of beverages reportedly rose from 264 kcal/day (1105 kJ/day) (14% of energy) in 1977 to 458 kcal/day (1916 kJ/day) (21% of energy) in 2002 (Duffey & Popkin 2007), but in 2005/2006 it was estimated at 411 kcal/day (1719 kJ/day) (19% of energy) (Popkin 2010).

Both the UK and the USA witnessed a rise in energy from soft drinks and fruit juice in the past 25 years, offset by the substitution of reduced-fat milk in place of full-fat milk. Consumption of non-energy-containing drinks (i.e. diet soft drinks and water) increased markedly in the UK between 1987 and 2009; diet soft drinks from a mere 17 to 102 ml/day and water as a beverage from 75 to 432 ml/day in the UK (Ng *et al.* 2011). Hence, the increase in total volume of beverages was not accompanied by an increase in the total energy contribution from all beverages, notwithstanding a small increase in the energy contribution from alcohol. This probably reflects shifting consumption from beer to wine and an increase in the alcohol content of these products. Finally, it should be noted that beverages make a higher contribution to total energy intake among younger adults than in older adults. In Canada, for example, beverages contributed 20% of energy for young men under 30 years but only 12% of energy for men over 70 years (comparative values for women 18% vs. 11% energy) (Garriguet 2008). Similar differences were observed in further analysis of data from UK adults (see below).

Patterns over 24 hours and day of the week

Secondary analysis of NDNS data from 2000/2001, the last survey capturing weighed intakes over 7 days in full, shows that beverage consumption varied by time of day and also by the day of the week. For both men and women, milk and hot beverages were mainly consumed in the morning (especially among women), while alcohol dominated evening consumption (especially among men: Fig. 2a,b). Timing of beverage consumption was also influenced by age. Older people consumed more beverages in the morning, while younger people had higher evening consumption, possibly reflecting age-related differences in the time of rising and retiring to bed. Interestingly, a high proportional consumption in the evening was positively associated with high total water intake (Fig. 3). This was mainly due to the large amount of alcohol consumed in the evenings, as the association was attenuated for alcohol-free days.

Over the week, beverage consumption and total water intakes were highest on Fridays and Saturdays, due mainly to a large increase in alcohol consumption at the expense of a small reduction in hot beverages and water, compared with weekdays. This day-to-day difference in consumption habits has implications for surveys conducted over less than 1 week, particularly if there is not an equal distribution of days of the week, and for data analysed at the individual level. Although studies have estimated the number of days needed to assess 'usual' nutrient intakes, there is relatively little published research on the variability of beverage intake within individuals.

Comparison with adequate intakes (AI) from EFSA

The EFSA recommends a total water intake of 2 l/day for women and 2.5 l/day for men, values close to current mean intakes in the UK. However, this cannot be taken to imply that the needs of all adults are being met, even less so that half of the population has an inadequate water intake, because the needs of individuals vary greatly with age, diet, environmental and physical factors. It has been proposed that the variety of beverages offered may be a predictor of adequate hydration and in the secondary analysis of NDNS 2000/2001, this was positively correlated with total water intake ($r = 0.36$, $P < 0.0001$). Adults consuming fewer than 3 different beverages per day (out of a possible 8) were less likely to meet the AI. Variety was also correlated with energy intake ($r = 0.23$,

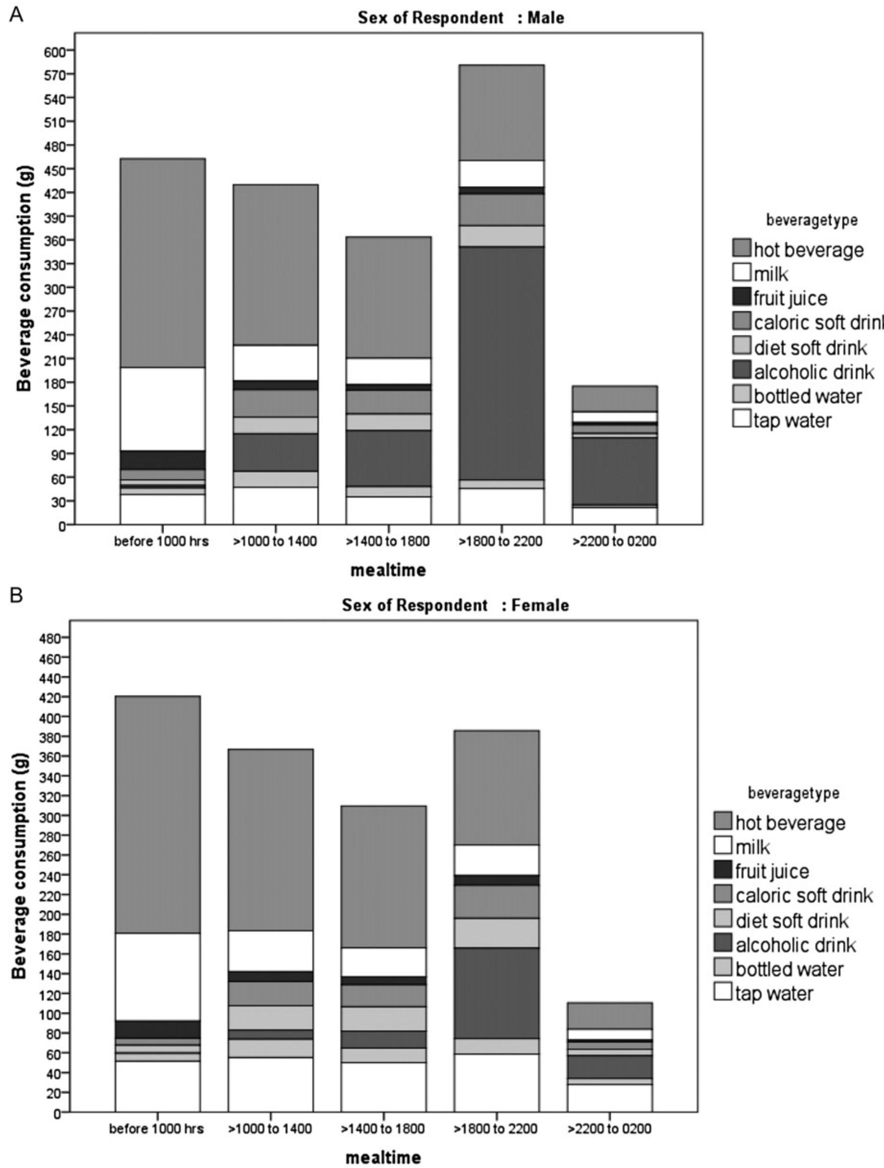

Figure 2 Beverage consumption during different time periods among adults in the National Diet and Nutrition Survey 2000/2001.

$P < 0.0001$) but not with water : energy ratio ($r = 0.005$; $P = 0.58$), suggesting it was a marker for high consumption of both food and drink.

We identified adults at the greatest and least risk of low water intake (LWI) using the EFSA AIs of 2 l for women and 2.5 l for men, *combined* with water : energy ratio (with a value of <1 ml/kcal being considered low). Those below the threshold on both criteria were classified as having LWI, while those above the threshold for both criteria were classified as having a high water intake (HWI) and the remainder were excluded from the analysis. Approximately 23% of all women and 33% of all men were classified as LWI, while 45% of men and 41% of women were in the HWI group. Men in the HWI group consumed more energy than those in the LWI group (2470 vs. 2287 kcal/day, $P < 0.0001$), largely attributable to alcohol consumption (330 vs. 99 kcal/day, $P < 0.0001$); the same trend was not evident in women (1753 vs. 1716 kcal/day, $P = 0.32$). However, the LWI group consumed a more energy-dense diet, both in terms of food and beverages. Others have also reported an inverse association between total water intake and the energy density of food (Kant *et al*. 2009), and between total water intake and both energy intake and body weight status (Stookey 2001). More research however, needs to be carried out to establish whether increased water consumption *per se* can assist weight management in the medium to long term (Dennis *et al*. 2009).

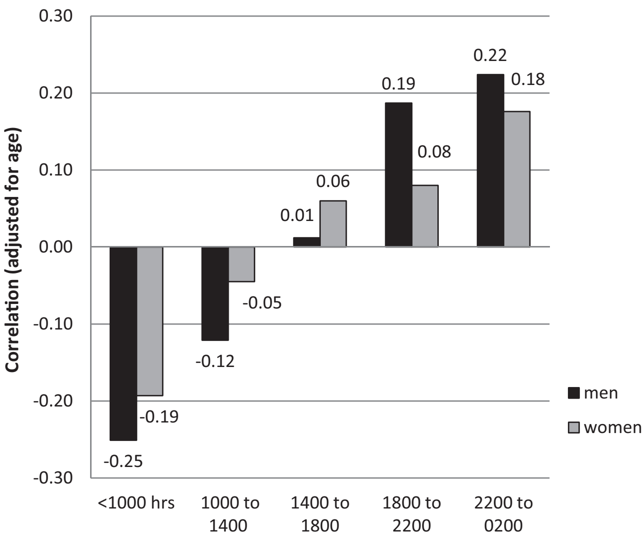

Figure 3 Correlation between the proportion of beverages consumed during each of five time periods and total water intake. (Source: Analysis of data from NDNS 2000/2001; S Gibson & S Shirreffs, unpublished data)

Discussion

In our analysis of raw data from the NDNS, factors correlated with high total water intake among adults included consuming a variety of beverages and drinking in the evening. As dietary patterns are highly complex, more sophisticated techniques might be needed to identify risk factors for hypohydration, or indeed excessive consumption, particularly of drinks with a high energy load such as alcohol. More work may be warranted to explore the context of drinking occasions (including time of day, weekdays vs. weekends, lifestyle and meal patterns) as these may have an impact on water intake and also on energy balance. Researchers in the USA have identified positive associations between evening consumption of food and total energy intake (de Castro 2004) and the UK NDNS is a rich resource to investigate such patterns because of its detailed timed records and rich contextual information on meal occasions.

The data reviewed not only illustrate the volume and depth of information about beverage intake available to researchers, but also reveal inconsistencies in the data that hamper comparison between countries. One major problem is that intake of total water as a nutrient is rarely reported, although this is almost certainly calculable or extractable from the database, as we have discovered. The result is a plethora of terms relating to water, fluids and beverages, which are not always well defined and sometimes misreported in reviews. If water is an essential nutrient, as suggested, then it should be reported in all important surveys. The contribution of moisture in food compared with water from beverages is also seldom given. Food moisture appears to have risen modestly (by about 7%) in the UK between 2000/2001 and 2008/2009 (Ng *et al*. 2011), partially helped by rising fruit and vegetable consumption. However, most of the increase in total water intake appears to be attributable to plain water consumption. The contribution of water from the oxidation of macronutrients is also generally ignored; this is proportional to energy intake but is also influenced by the composition of the diet (Maughan *et al*. 2007).

Observational data have well-known limitations in regard to under-reporting, whether by omission or incorrect estimation of the quantities consumed. Over-reporting may also occur as a result of leftovers or spillage, although most studies attempt to record these. On average, energy intakes are considered to be under-reported by 20–25% compared with doubly labelled water (Rennie *et al*. 2007), and by around 10% in the 2004 Canadian Community Health Survey data (Garriguet 2008), but the extent of beverage misreporting is not known. Ideally, biomarkers are needed that can be used in large field studies to assess hydration status and validate intake assessments.

It is also evident that recommendations for water intake vary widely, casting doubt on any attempt to assess adequacy of intake, even at the population level. There is also no clear consensus as to how AIs or DRVs might relate to optimum fluid intake, if indeed such an optimum exists. Uncertainty in this area may be one reason why there are currently no DRVs for water intake in the UK, although guidelines issued by the Department of Health (taking on responsibility from the Food Standards Agency) are that adults should consume 6–8 glasses of fluid daily, or 1.2 l/day. This is clearly much lower than other recommendations and may be intended as a minimum. Even so, water intakes among men and women in our analysis of the NDNS failed to reach 1.2 l on more than 7% and 14% of days, respectively.

Given the detrimental effects of hypohydration, the UK trend for increased total water consumption over the last 20 years, in combination with a stable energy intake and no increase in energy from beverages, is encouraging. However, as this is an average it is difficult to determine how many people remain hypohydrated in their daily lives. We estimate that up to 33% of adults aged 19–64 years may have low total water intake, although this in itself is insufficient to assess hydration status because euhydration may be achieved at high or low levels of water turnover. Given the difficulties of dietary assessment and risk of under-reporting, it has been suggested that low urine volume (low water output) may provide a better indication of hypohydration in population studies. We are currently investigating this further among adults who provided a 24-hour urine sample in the NDNS 2000/2001.

Methods to measure hydration status range from the highly objective (*e.g.* urine osmolality, urine volume and body mass) to the highly subjective (*e.g.* thirst rating). Urine volume and colour may be more relevant as body mass change loses accuracy over periods longer than 4 hours (Kavouras 2002) although colour can be influenced by dietary factors (Armstrong 2005). Even if hydration status can be accurately determined, the problem of how to translate this to a recommended average water intake persists. A recent analysis of German adults, which combined dietary records with non-renal water losses, urine volume and obligatory urine volume data, calculated an AI of 2910 and 2265 ml/day for men and women, respectively (Manz *et al*. 2012). More research combining these methods in other countries may help to develop a consensus for AI in Western cultures.

Conclusion

UK dietary intake data for adults show a slight trend for increasing total water intake since 2000, with stable or decreasing energy content of beverages, and this may aid good hydration. Total water intake in the UK and Europe appears to be significantly lower than in the USA and energy-containing soft drink consumption is markedly lower. However, beverage choices and amounts vary widely between subgroups and individuals. Although AI levels have been established the question of optimal intake is unresolved. Most people could be encouraged to drink a variety of beverages to maintain adequate hydration and to balance the energy content according to their needs. However, further work is needed to refine recommendations for water intake, as basing these on observational epidemiological data is essentially a circular argument. A standardized measurement tool combining dietary and urinary data, validated against biochemical measures, would be a step forward in assessing hydration status in the population.

Conflict of interest

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