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Trihalomethane concentrations in tap water as determinant of bottled water use in the city of Barcelona

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ABSTRACT

Background: Bottled water consumption is increasing worldwide, despite its huge economic and environmental cost. We aim to describe personal and tap water quality determinants of bottled water use in the city of Barcelona. Methods: This cross-sectional study used data from the Health Survey of Barcelona in 2006 (N = 5417 adults). The use of bottled water to drink and to cook was evaluated in relation to age, gender, educational level, district and levels of trihalomethanes (THMs), free chlorine, conductivity, chloride, sodium, pH, nitrate and aluminium in municipal tap water using Robust Poisson Regression. Results: The prevalence of bottled water use to drink and cook was 53.9% and 6.7%, respectively. Chemical parameters in water had a large variability (interquartile range of THM concentrations: 83.2–200.8 μg/L) and were correlated between them, except aluminium. Drinking bottled water increased with educational level, while cooking with bottled water was higher among men than among women and decreased with age. After adjusting by these personal determinants, a dose–response relationship was found between concentrations of all chemicals except aluminium in tap water and bottled water use. The highest association was found for THMs, with a Prevalence Ratio (PR) of 2.00 (95%CI = 1.86, 2.15) for drinking bottled water and 2.80 (95%CI = 1.72, 4.58) for cooking with bottled water, among those with >150 μg/L *vs.* <100 μg/L THMs in tap water. Conclusion: More than half of Barcelona residents regularly drank bottled water, and the main determinant was the chemical composition of tap water, particularly THM level.

Introduction

Bottled water consumption is increasing worldwide (Rodwan, 2011). However, bottled water is 240 to 10,000 times more expensive than tap water (Olson, 1999) and requires 1000 to 2000 times more energy, especially for bottle production and transportation (Gleick and Cooley, 2009). One of the main causes of the increasing bottled water consumption is the belief that it is healthier than tap water, which has been promoted by heavy marketing campaigns, but also that it has a better taste (Doria, 2006; Levallois et al., 1999; Saylor et al., 2011; Ward et al., 2009). These beliefs and willingness to buy

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bottled water vary between communities but also within them, depending on personal characteristics and socioeconomic factors (Castaño-Vinyals et al., 2011; Dupont et al., 2010; Font-Ribera et al., 2010; Hu et al., 2011; Huerta-Saenz et al., 2012).

Chemical properties and organoleptic characteristics of bottled and tap water vary across different locations and types of bottled water (Marcussen et al., 2013; Platikanov et al., 2013; Whelton et al., 2007). Although expert panels can blindly distinguish between tap and bottled water (Platikanov et al., 2013), there is little scientific evidence to support that bottled water has better sensory qualities compared to tap water (Marcussen et al., 2013) and that general population can appreciate these differences. Taste problems in tap water occur more frequently when surface water is used as source water to produce potable water (Levallois et al., 1999) and chlorination is applied (Marcussen et al., 2013). Mineral bottled water is not disinfected, and consequently, it does not contain free chlorine and chlorination by-products (Font-Ribera et al., 2010).

Spain is among the top ten countries with the highest per capita consumption of bottled water (Rodwan, 2011). Barcelona, located on the Mediterranean coast, is the second largest city of the country. Level of trihalomethanes (THMs), the most common disinfection by-product in drinking water, was reported to be high in tap water (Gómez-Gutierrez et al., 2012),. Since the city is supplied by surface water from two rivers with very different organic matter and bromide content (López-Roldán et al., 2016), chemical characteristics of tap water including THM level have a large geographical variability within the city (Gómez-Gutierrez et al., 2012).

Previous studies on bottled water consumption determinants described personal determinants and health beliefs in small and/or selected samples (Saylor et al., 2011; Huerta-Saenz et al. 2011; Merkel et al., 2012; Ward et al., 2009; van Erp et al., 2014). Although previous work has shown a high prevalence of bottled water use in areas of high THM concentrations in tap water (Villanueva et al., 2007; Villanueva et al., 2011), there are no studies describing the relationship between tap water quality and the prevalence of bottled water use. The aim of this study is to identify personal and tap water quality determinants of the prevalence of bottled water use to drink and to cook in a population-based sample in the city of Barcelona.

1. Material and methods

This is a cross-sectional study using data from the Health Survey of Barcelona in 2006 and the concentrations of chemical parameters in municipal tap water during the three years prior to the survey (2003–2006).

1.1. Health survey

The Barcelona Health Survey collected data through home-based personal interviews on a representative sample of all non-institutionalized subjects aged ≥15 years living in Barcelona in 2006. The sampling design involved stratification by the 10 districts of the city and participants were randomly selected through proportional assignments of gender and age. Non-respondents, resulting from refusal to participate or absence, were replaced by other residents with the same characteristics (20% in 2006) (Rodríguez-Sanz et al., 2008).

Prevalence of bottled water consumption was calculated with the following questions: “How often do you use bottled water to drink?” and “How often do you use bottled water to cook?”. The three possible answers “Usually”, “Occasionally” or “Never”, were categorized into two: “Yes” for usually and “No” for occasionally or never. Gender, age and educational level were collected as potential socioeconomic determinants of bottled water use. The district of residence was used to link the data with the water parameters.

1.2. Water quality parameters

We used routine monitoring data that was part of the surveillance carried out by the Public Health Agency of Barcelona between 2003 and 2006 in compliance with the Directive 98/83/EC, on the quality of water intended for human consumption. Data for the period 2003–2006 was analysed, including measurements from 109 water samples (1 L) collected in 87 public fountains selected randomly and covering all the city water distribution system. During 2003–2005, at least one water sample was collected per year and per district. Water samples were collected after flushing the fountain for about 2 min and stored refrigerated until chemical analysis. Free chlorine was determined *in situ* by means of a Lovibond Water Testing Kit and the rest of the water parameters were determined in the Laboratory of the Public Health Agency of Barcelona according to accredited standard analytical methodologies.

The following parameters were analysed in all the samples collected: free chlorine, chloroform, dibromochloromethane, bromodichloromethane, bromoform, conductivity and nitrite. A more complete analysis was conducted in a random selection of 30 water samples (including at least one sample per district in two different years). The complete analysis included nitrate, pH, lead, aluminium, chloride, copper, iron and sodium. Total THM (TTHM) was calculated summing up the levels of chloroform, dibromochloromethane, bromodichloromethane and bromoform and was expressed as μg/L. Levels below the limit of detection (LOD) were substituted by half of the LOD value.

1.3. Statistical analysis

The Barcelona Health Survey 2006 was available for 5419 subjects older than 14 years. Two subjects were excluded for having missing data in the water use question and the final analysed sample was 5417.

The normal distribution of the water chemical parameters was checked with a Skewness and Kurtosis based test for Normality and the Spearman correlation between the water parameters was calculated. The median level of the parameters during the period of study was calculated for each of the 10 districts of the city and linked to the study participants. Each water parameter was then categorized into three categories balancing the number of subjects across the categories.

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