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# Perfluoroalkyl substances and thyroid function in older adults

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ABSTRACT

Current understanding of the thyroid disruptive properties of perfluoroalkyl substances (PFASs), particularly in aging populations, is limited. The objectives of this study were to (i) assess associations between thyroid function, as measured by serum thyrotropin (thyroid stimulating hormone, TSH), free thyroxine (fT4), total thyroxine (T4), and total triiodothyronine (T3), and serum perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA) in an aging population and (ii) determine if other persistent organic pollutants with thyroid disruptive properties including polychlorinated biphenyls (PCBs) and polybrominated diphenyl ethers (PBDEs) modify such associations. We conducted a cross-sectional study of 87 men and women 55 to 74 years of age, without clinically-diagnosed thyroid disease, who resided in upper Hudson River communities in New York. Geometric means (standard deviations) of serum PFOS and PFOA were 31.6 (1.7) ng/mL and 9.17 (1.72) ng/mL, respectively. Multivariable linear regression analyses indicated that one interquartile range difference in PFOS corresponded to 4% and 9% increases in fT4 and T4 respectively. We detected statistical interactions between PFOA and age for effects on fT4 and T4; joint increases in PFOA and age were associated with increases in fT4 and T4, of 3% and 7%, respectively. We also detected statistical interactions between PFOS and total PCBs for the effect on T3 and between PFOA and total PBDEs for the effect on TSH. Our results suggest that PFASs are associated with subtle alterations in thyroid hormone levels in this population, and that these associations are likely to vary by age, and levels of PCBs and PBDEs.



## 1. Introduction

Perfluoroalkyl substances (PFASs) have been extensively used over the last five decades in a variety of consumer products and industrial applications including textiles, fire-fighting foams, and fluoropolymers mainly due to their surfactant properties (ATSDR, 2009; Prevedouros et al., 2006). Due to extensive persistence and an ability to bioaccumulate, PFASs are widespread in the environment (Giesy and Kannan, 2001; Kato et al., 2011). Their ubiquity and potential link to human health effects led to efforts to phase out U.S. production and use of perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA), the two most predominant PFASs, in the early 2000s (ATSDR, 2009). PFASs, however, were still detected in 99% of serum samples collected from the general U.S. population during the 2007–2008 National Health and Nutrition Examination Survey, and therefore remain a potential health concern (Kato et al., 2011).

Thyroid hormones are important for proper cardiovascular and central nervous system function, including neuropsychological function (Bauer et al., 2008; Klein and Ojamaa, 2001; Yen and Brent, 2012). Rather than directly interfering with the hypothalamus–pituitary–thyroid (HPT) axis, PFASs may compete for certain thyroid hormone binding proteins (TBPs) including albumin and transthyretin (Chang et al., 2008; Han et al., 2012; Jones et al., 2003; Weiss et al., 2009). By competing for binding sites on TBPs, PFASs may displace thyroid hormone and in doing so increase the circulating levels of biologically available hormone. However, both increases and decreases in serum thyroid hormones have been demonstrated in groups occupationally exposed to high-dose PFASs (Olsen et al., 2003; Olsen and Zobel, 2007), and in adults and children exposed to high/background levels of PFOA and PFOS (Dallaire et al., 2009; Knox et al., 2011; Lopez-Espinosa et al., 2012a; Wen et al., 2013). Inconsistent findings across studies limit current understandings of PFASs' thyroid disruptive properties and the associated public health impact. Additionally, aging populations are often under-represented in the literature, with only one study illustrating

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associations in an older population (Knox et al., 2011). Aging individuals may experience increased health risks due to compromised biological capacities and higher body burdens of the chemicals (Geller and Zenick, 2005). Therefore, characterization of the associated risks in such populations is important but understudied areas.

Besides PFASs, U.S. populations are also exposed to other persistent organic pollutants (POPs) with thyroid disruptive properties, including polychlorinated biphenyls (PCBs) and polybrominated diphenyl ethers (PBDEs) (Boas et al., 2012; Centers for Disease Control Prevention, 2009). In our previous research, we reported that such POPs may interact to affect thyroid and neuropsychological function (Bloom et al., 2014; Fitzgerald et al., 2012). Similarly, there exists a likelihood for shared biological mechanisms, including interference with serum TBPs (Boas et al., 2012), and so these POPs may modify the effects of PFASs on thyroid function. However, the interaction between PFASs and other POPs has not been well addressed in other studies of human populations.

The current study is intended to further increase knowledge of the associations of PFASs with thyroid function in aging populations and the potential modifying effects of the other POPs on such associations. We assessed associations between serum PFOS and PFOA and thyroid function among older men and women residing in upper Hudson River communities. We hypothesized that PFOS and PFOA would be positively associated with free thyroxine (fT4), total thyroxine (T4), and total triiodothyronine (T3). Additionally, we examined if serum total PCBs ($\sum$ PCBs), total PBDEs ($\sum$ PBDEs), and dichlorodiphenyl trichlorethane (DDT) and its metabolite p,p-dichlorodiphenyl dichloroethene (DDE) modified such associations.

## 2. Materials and methods

### 2.1. Sample selection

The study population consisted of men and women, aged 55 to 74 years, who lived in three demographically similar communities adjacent to the Hudson River in New York State (NYS) for 25 years or more: Fort Edward, Hudson Falls, and Glens Falls (Fig. 1). The study participants were originally recruited to investigate associations between environmental PCB exposure and neuropsychological function, given the proximity to General Electric plants located in Fort Edward and

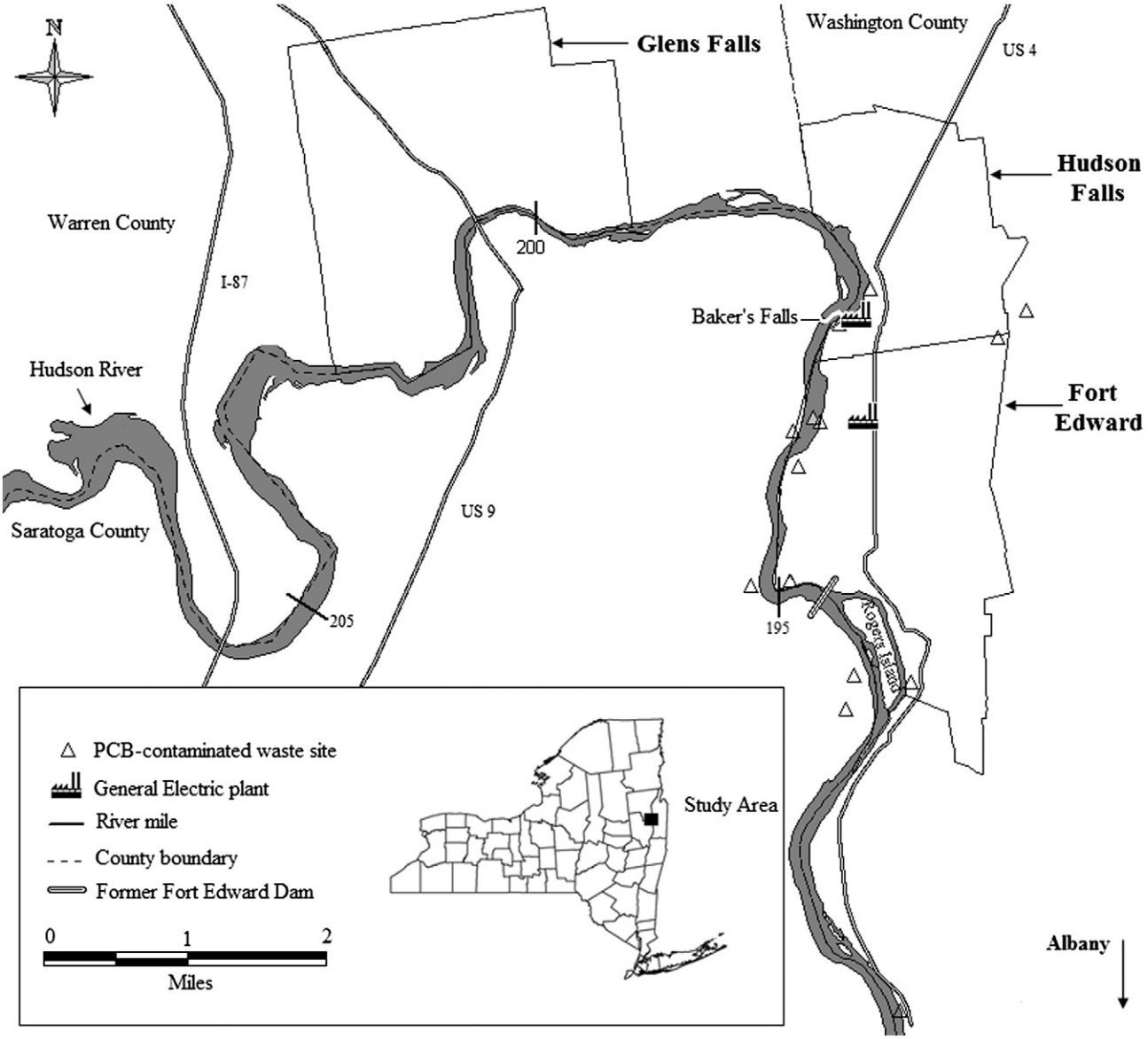


**Fig. 1.** Study areas: Glens Falls, Hudson Falls, and Fort Edward, New York.