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Food labeling requirements may explain lower autism and ADHD prevalence in the United Kingdom

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Improvements in child nutrition lead to advancements in child neurodevelopment and learning. Countries all over the world initiate programs to ensure pregnant women and their children have adequate nutrition to enhance child health and learning outcomes. In the United States (U.S.), women of lesser means with low-income are provided with supplemental foods, nutrition education, and health care referrals through the Women, Infants and Children (WIC) program funded by the U.S. Department of Agriculture [1]. Healthy diet early in a child's life is a predictor for later academic achievement [2]. Yet the free market economy in the U.S. often allows families to unknowingly buy unhealthy foods that can adversely impact student cognition, learning and academic achievement.

Two of the most common neurodevelopmental learning disorders associated with nutritional deficits in the U.S. are autism and attention-deficit-hyperactivity disorder (ADHD) [3,4]. According to the U.S. Centers for Disease Control and Prevention (CDC), approximately 9.4% of children between the ages 2-17 years had been diagnosed with ADHD in 2016 [5] and the prevalence of autism is now 1 in 59 children [6]. These disorders are far less common in the United Kingdom (U.K.) where student academic achievement scores far surpass those of the U.S. in standardized testing [7].

In 2016, the prevalence of ADHD in the U.K. was reported by Public Health England to be only 1.5% of children between the ages 5-16 years [8]. Earlier, a side by side comparison of autism prevalence rates in the U.S. and U.K. revealed a large difference with 4 per 1000 8-year-old boys in the U.K. and 11 per 1000 8-year-old boys in the U.S. stricken [9]. So what is the U.K. doing differently with their food supply that may impact ADHD and autism prevalence and improve student learning and achievement?

In 2010, the European Union (E.U.) decided to require their food manufacturers to place a warning label on foods with ingredients found to increase hyperactivity and inattention in children [10]. Foods containing Yellow #5, Yellow #6, or Red #40 food colors in the U.K. must carry the warning "*May have an adverse effect on activity and attention in children*" on their packaging [10]. In the U.S. and the U.K., these food colors have allowable levels of lead up to 10 ppm and arsenic up to 3 ppm [11]. The yellow colors also have allowable levels of inorganic mercury up to 1 ppm [11]. Exposures to lead and inorganic mercury continue to be associated with the development of autism and ADHD [12-14]. The EU warning label may help parents avoid food products that allow these heavy metal exposures and permit the development of the learning disabilities associated with them.

The EU warning label requirement is not directly tied to the allowable heavy metal contaminants in food colors but rather a result of two separate studies conducted by researchers in the United Kingdom (U.K.) on children who consumed these food colors with and without sodium benzoate. The researchers found consumption of these food colors alone or with sodium benzoate led to hyperactivity in *all* children [15,16]. These studies confirmed the connection between exposure to these food colors and symptoms of ADHD. Average child exposures to lead and inorganic mercury from food color consumption have not yet been determined by any organization. Food color batches are certified by the U.S. Food and Drug Administration to contain no more than the allowable levels of inorganic mercury, lead, and cadmium before they are sold to food manufacturers and processors [11].

Metabolically, zinc is required to transport lead and mercury out of the body [17]. A model has been published to show how lead and inorganic mercury exposures may contribute to the development of autism and ADHD via the metabolic loss of zinc [3,4]. Children with these disorders show the accumulation of lead and mercury in their blood [12,18,19] and they also exhibit zinc deficiencies [20,21]. Ward demonstrated this positive feedback loop in two separate studies when he found consumption of yellow #5 food color led to zinc losses in hyperactive children [22,23].

When there are zinc deficits, heavy metals may accumulate in the blood of children with autism and ADHD. Kahn *et al.* analyzed foodstuffs and human blood samples collected from a population in Pakistan [24]. The heavy metal concentrations found in foodstuffs significantly correlated with the levels found in human blood [24]. Alabdali *et al.* demonstrated that blood lead and mercury levels correlate with the severity of social and cognitive impairment in children with autism [25]. To reduce zinc deficits and mitigate symptoms associated with autism and ADHD, children need to consume fewer foods with ingredients that have allowable heavy metals in them.

The warning label requirement in the U.K. allows parents to avoid purchasing products containing the food colors with allowable heavy metals that may lead to zinc losses upon consumption. This parent shopping practice likely contributes to the trend of lower autism and ADHD prevalence in the U.K. when compared to the U.S. where there is no such labelling requirement. The same warning label requirement could be adopted in the U.S. to help steer parents toward healthier food choices to bring down America's prevalence of autism and ADHD.

Another major dietary difference between the two countries is fructose consumption which is relevant because fructose and high fructose corn syrup (HFCS) consumption can also lead to reductions

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in zinc [26] and lower child cognition [27]. While Americans consume vast amounts of high fructose corn syrup in their food and beverages, up to 41.4 pounds per person in 2016 [28], citizens in the U.K. consume negligible amounts. HFCS remains severely restricted by trade barriers in the U.K. Such restriction appears beneficial for child health. Cohen *et al.* recently confirmed in a pre-birth cohort of 1,234 American mother –child pairs the inverse relationship between fructose consumption from sugar sweetened beverages during pregnancy and mid-childhood cognition scores [27]. Given this apparent toxic effect, the U.S. could place warning labels on products containing fructose or high fructose corn syrup to steer parents away from unhealthy food products that may contribute to zinc loss and impair child cognition. Alternatively, to lower autism and ADHD prevalence the U.S. could expand its WIC participation and make it available to all American women regardless of income. States with the highest WIC participation have the lowest autism rates in the U.S. [29].

The lack of HFCS consumption and the avoidance of food color intake are important elements of a healthy diet that may explain both the lower prevalence in learning disorders and the superior academic achievement scores in the U.K. compared to the U.S. Warning label requirements for foods with ingredients found to lower cognition or increase hyperactivity and inattention in children may serve to reduce autism and ADHD prevalence in the U.S. as parents will be able to make healthier food choices for their children.

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