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Reducing the Obesity Epidemic Globally

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The Sustainable Development Goal (SDG) I intend to address is goal three of ensuring healthy lives and promoting well-being for all at all ages (Johnston, 2016). Within this SDG, I want to specifically address how the consumption of high fructose corn syrup (HFCS) has caused a global obesity epidemic that has several health implications such as type two diabetes, fatty liver disease, kidney failure, oxidative stress, insulin resistance, multiple types of cancer, and pathogenesis of cardiometabolic diseases (Johnson et al., 2013; Malik and Hu, 2015; Romieu et al., 2017; Softic et al., 2016). The prevalence of obesity in the United States was evaluated by the Center for Disease Control (CDC) and reported that USA was at 39.8 percent, which is a significant risk factor for the development of type two diabetes mellitus (T2DM) (Mejia and Pearlman, 2019). Furthermore, the World Health Organization's (WHO) Global Report on Diabetes estimated that 422 million adults were living with diabetes worldwide in 2014 (Mejia and Pearlman, 2019). Inside the bounds of this data includes shocking numbers of children with obesity, 41 million under the age of five years old documented in 2014 (Romieu et al., 2017). Awareness of these statistics have placed multiple countries around the world at risk of obesity with corresponding chronic health complications. In regards to the correlations between obesity rates and how developed a country is, the frequency of obesity tends to increase generally with the income level of a country (Romieu et al., 2017). Essentially, the obesity prevalence is more pronounced in high-income and upper-middle-income countries than it is in low-income countries (Romieu et al., 2017). When addressing the goal of reducing the occurrence of obesity and fulfilling the third SDG, it's

necessary to recognize where the prevalence of this disease lies and why it is occurring in order to take measures to tackle it. Factors such as genetics, age, socioeconomic status, level of physical activity, type of behavior, and dietary patterns all contribute to the propagation of this epidemic and demonstrate the complexity of reversing it as many of these components are interrelated (Bray and Popkin, 2014; Johnson et al., 2013; Malik and Hu, 2015; Romieu et al., 2017). To combat this public health issue globally, reduction of daily intakes of sugar-sweetened beverages through adjustments in dietary patterns, policy interventions addressing consumption/advertisement of sugar-sweetened foods by agribusinesses and corporations in society, and utilization of natural sweeteners are current measures that hold potential to reduce this global obesity epidemic (Johnson et al., 2013; Malik and Hu, 2015; Mejia and Pearlman, 2019; Romieu et al., 2017). These intervention efforts focus on external factors that are instrumental in increasing obesity rates and are modifiable.

This public health issue arose quickly when the emergence of chemically engineered sweeteners such as HFCS and sucrose began being utilized in a wide variety of food items in the late 1960s due to their low cost and sweet flavor (Malik and Hu, 2015). Earl Butz, the secretary of the United States department of Agriculture (USDA), passed legislation during this time period that economically profited farmers and corporations that produced high yields of corn and converted it to decreased nutritional forms such as HFCS, feed for livestock, and erythritol (Hinrichs and Lyson). Analyzing the United States history of its consumption of sugar shows that citizens have steadily increased it, dating back to 1776 at four pounds of sugar per person each year to 20 pounds by 1850 (Bray and Popkin, 2014). After Earl Butz's role in changing policy for agribusiness, this statistic saw its most dramatic increase in 1994 when the amount of sugar consumed rose to an astounding 120 pounds per person (Bray and Popkin, 2014). In addition to

the increased volumes of HFCS in a large range of consumer products for economic profit by corporations, rapid economic growth and urbanization have also contributed to this global obesity epidemic due to changes in traditional dietary patterns (increased consumption of highly processed foods and beverages containing less nutrient dense diets, replacing or supplementing traditional plant-based diets, increasing sedentary behaviors, and reducing physical activity across all ages (Johnson et al., 2013; Malik and Hu, 2015). Some examples to give readers a perspective of how large the range of food products with these added sugars extend in the consumer market place include processed items such canned foods (e.g., soups and fruits), cereals, baked goods, desserts, sweetened dairy products, condiments, fruit-flavored noncarbonated beverages, candies, and many fast-food items (Malik and Hu, 2015).

Examining how prevalent the obesity epidemic is, lower-income countries have lower rates of obesity when compared to high-income and upper-middle-income countries (Romieu et al., 2017). However, lower-income countries additionally have undernutrition (including energy, and macro and micronutrient deficiencies) coexisting with rising obesity rates, putting the individuals residing there at a double jeopardy of malnutrition (Romieu et al., 2017). As these countries undergo economic growth and urbanization, alterations in traditional dietary patterns have resulted with alarming surges of consumption of processed foods containing HFCS (Romieu et al., 2017). The differences between countries with higher-income and obesity rates and vice versa stem from the complexity of factors that determine dietary patterns, levels of physical activity, and sedentary behaviors (Romieu et al., 2017). Diet is influenced by many aspects such as traditions, knowledge about diet, food availability, food prices, cultural acceptance, and health conditions (Romieu et al., 2017). Similarly, physical activity and sedentary behaviors are influenced by dwellings, urbanization, opportunities for safe transportation (bicycle riding and walking), recreational

facilities, employment constraints, and health conditions (Romieu et al., 2017). When evaluating individuals to determine the occurrence of obesity, several measures can be employed. These include but are not limited to, Body Mass Index (BMI), waist circumference (WC), waist-to-hip ratio (WHR), skinfold thickness, bioelectrical impedance analysis, air displacement plethysmography, underwater weighing (hydrodensitometry), dual-energy X-ray absorptiometry, ultrasound, computed tomography, and magnetic resonance imaging (Romieu et al., 2017). The use of these measurements varies on cost, scale of the study conducted, portability, and accuracy (Romieu et al., 2017). Since the majority of studies conducted so far have been large-scale, BMI is the standard measurement that has been utilized the most for its simplicity of assessment and high precision and accuracy (Romieu et al., 2017). This measurement is efficient as it quickly calculates the quotient between weight in kilograms (kg) and height in meters squared, but lacks the ability to differentiate between lean and adipose tissue (fat distribution) (Romieu et al., 2017). This limiting property can be problematic due to the variation of fat distribution for individuals belonging to specific ethnicities and ages (Romieu et al., 2017). Research so far has found that some ethnic groups are more susceptible than others to obesity, with a panel of gene loci where methylation levels in DNA significantly differ in obese and lean individuals (Romieu et al., 2017). In order for an individual to reduce body weight, energy expenditure must be greater than intake (Romieu et al., 2017). The best results incorporate physical activity and diet and ideally generate increases in fat mass loss while preserving lean body mass (Romieu et al., 2017).

The current prevalence of childhood obesity and its continuous rise resembles the onset use of Tobacco in the United States as external factors like exploitative, life-style oriented marketing creates a social norm of regular consumption of sugar-sweetened beverages and foods (Moran et al., 2020; Romieu et al., 2017). This type of marketing includes advertisements that are

strategically placed in areas of the community like grocery stores, conveniency stores, online, on television, and more to build brand loyalty from individuals at a young age and encourage increased usage of the product (Moran et al., 2020). The experiences an individual has during early life can have substantial, long-term impacts on the future of their health and emphasizes how viewing this type of marketing prematurely leads to the propagation of obesity in children (Romieu et al., 2017). Children that belong to low-income socioeconomic groups and in lower-income countries are even more susceptible to developing this disease and corresponding health complications (Romieu et al., 2017). In comparison to high-income children, low-income children have a 93 percent higher consumption of sugar-sweetened beverages (Romieu et al., 2017). Along with low-income socioeconomic status and clever marketing from corporations, other elements that encourage the obesity epidemic in children are increases in sedentary behaviors (e.g., screen time), short durations of sleep, changes in parenting and family factors, school factors, social norms, high levels of stress, community food, high consumption of fast foods and highly processed food, and prenatal/postnatal experiences (in utero exposures and infant and young child feeding) (Romieu et al., 2017). Additional aspects during a women's pregnancy such as maternal gestational weight gain (GWG), mother's overweight prior to pregnancy, smoking during pregnancy, high or low infant birth weight, rapid weight gain during the first year of life, and premature inception of complementary food all correlate to excess adiposity in children (Romieu et al., 2017)

From a biological standpoint, the reason why high fructose corn syrup and other non-nutritive sweeteners (NNS) play a role in increasing obesity and other associated chronic diseases worldwide is due to the enzymatic reactions that take place in the human body when they are metabolized (Johnson et al., 2013; Malik and Hu, 2015; Mejia and Pearlman, 2019; Softic et al.,

2016). Fructose specifically, is absorbed via portal vein and delivered to the liver in much higher concentrations as compared to other tissues and does not require insulin to metabolize like glucose does (Softic et al., 2016). This rapid delivery thus alters multiple enzymatic processes intracellularly and creates insulin resistance (Johnson et al., 2013; Softic et al., 2016). Notable enzymatic processes impacted by fructose metabolism include ATP depletion, suppression of mitochondrial fatty acid oxidation, and stimulation of lipogenesis that result in increased production of reactive oxygen species (ROS), promotion of ER stress and uric acid formation, generation of adipocyte lipolysis and production of additional insulin independent pathways that lead to hepatic de novo lipogenesis (DNL) (Softic et al., 2016). Hepatic DNL and adipocyte lipolysis are important contributors to the progression of Nonalcoholic fatty liver disease (NALFD). When these sweeteners are consumed through sugar-sweetened beverages (SSB's) in particular, increased caloric intake and lack of stimulating hormones such insulin and leptin secretion inhibit the induction of a satiety response (Bray and Popkin, 2014; Johnson et al., 2013; Malik and Hu, 2015; Mejia and Pearlman, 2019). These two effects paired together overall contribute to obesity as these beverages do not suppress the intake of other food calories to an appropriate degree to prevent weight gain (Bray and Popkin, 2014; Malik and Hu, 2015). In addition to obesity-associated deviations in molecular metabolism, these interactions also play a role in cancer cell energetics that serve as the predominant genesis of obesity-associated cancer advancement and evolution (Romieu et al., 2017).

It is important to note that so far, the scientific findings of HFCS's effects on the intracellular and extracellular metabolic mechanisms only account for vertebrate organisms with closed circulatory systems such as humans and rats (Bray and Popkin, 2014; Johnson et al., 2013; Malik and Hu, 2015; Mejia and Pearlman, 2019; Romieu et al., 2017; Softic et al., 2016).

Currently, Kimberli Pepper et al. (2021) has conducted a short-term experiment on an invertebrate organism with an open circulatory system, crayfish, to investigate if HFCS and sucrose have similar effects on the metabolic rate and weight gain of the species. The crayfish were divided into groups and injected with one ml of HFCS, sucrose, or pure water (control) with 20-gauge needles (Pepper et al., 2021). The researchers then weighed and used an oxidative technique to analyze weight gain and metabolic rate (Pepper et al., 2021). Findings so far indicate increases in both metabolic rate and weight gain, a positive correlation to vertebrate organisms with closed circulatory systems. This is a substantial finding as it is the first experiment to utilize invertebrate organisms that have an open circulatory system and supports further research to better understand the metabolic pathways effected by HFCS (Pepper et al., 2021).

Sugar substitutes such as stevia, rare sugars, sugar alcohols, and monk fruit provide alternative options for the public to utilize in their foods for reduction in overall concentrations of sugar that can subsequently reduce the global health issues of obesity and corresponding health complications (Mejia and Pearlman, 2019). However, it is important to note that not all of the sugar alternatives listed are necessarily more nutritious options over HFCS because some of them result in similar impacts on metabolic derangements and glucose homeostasis (Mejia and Pearlman, 2019). The most promising options for natural alternative sweeteners are stevia and rare sugars, as the effects studied so far have discovered that caloric over-consumption was ultimately reduced (a health issue seen frequently from sugar-sweetened beverages with HFCS) and metabolic pathways breaking down these sugars were not altered as dramatically when compared to the effects from HFCS (Mejia and Pearlman, 2019).

Policy intervention is a potential method to help reduce the obesity epidemic as excising taxes on sugar-sweetened beverages, elimination of tax deductions for advertisements of unhealthy

food to children, and establishing nutrition standards for food and beverages sold in schools can prevent childhood obesity and reduce the burden of expensive healthcare costs (Romieu et al., 2017). Top-down government policies, bottom-up community approaches, and evidence-based prevention are essential components for policy intervention (Romieu et al., 2017). An example of a community-based approach could be school-based programs that educate children on the nutrition of the foods they consume and promote non-sedentary lifestyles (Romieu et al., 2017). Previously mentioned, exploitative marketing geared towards children has proven effective in contributing to to the development of obesity at a young age as the experiences an individual has during early life are impactful and have long-term impacts on the future of their health (Romieu et al., 2017).

In addition to integration of policy interventions in the government and community and utilization of alternative types of sugar, reduction of sugar-sweetened beverages through changes in dietary patterns is the final component that holds strong potential to reduce the obesity epidemic worldwide. The Mediterranean diet is a diet that could be beneficial for long-term weight control and is characterized by higher intakes of fruits and vegetables, legumes, whole grains, nuts and seeds and unsaturated fat, and lower intakes of refined starch, red meat, trans and saturated fat, and sugar-sweetened foods and beverages (Romieu et al., 2017).

As mentioned previously, methods to combat this epidemic include reduction of daily intakes of sugar-sweetened beverages, changes in policy addressing consumption and advertisement of sugar-sweetened foods and agribusiness, utilization of alternative natural sweeteners, and adaptation of a Mediterranean style diet are current measures that hold potential to reduce this global obesity epidemic (Johnson et al., 2013; Malik and Hu, 2015; Mejia and Pearlman, 2019). Alternatives to SSBs include water, 100 percent fruit juice, coffee, tea, and

natural alternative sweeteners (NAS) (Malik and Hu, 2015; Mejia and Pearlman, 2019). Mejia and Pearlman found through extensive research over a variety of sweeteners that NAS products (stevia and rare sugars specifically) seem to have more beneficial effects on glucose metabolism, lipids, and pro-inflammatory pathways compared with AS (artificial sugar) and HFCS-containing products. With more research and analysis of additional, this thesis aims to achieve SDG three through focus on improvements in physiological health and well-being.

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“On my honor, I have not given, nor received, nor witnessed any unauthorized assistance on this work.”