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EXAMINING WATER INSECURITY AS A DRIVER OF THE NUTRITION TRANSITION AMONG TSIMANE' ADULTS IN LOWLAND BOLIVIA

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ABSTRACT

Water insecurity has emerged as an additional driver of food insecurity, overnutrition, and nutrition transition because sugary beverages may serve as an alternative to consuming contaminated water. This study examined how water insecurity is associated with hydration strategies in response to water insecurity. We analyzed data collected in summer 2019 among Tsimane' forager-horticulturalists (n=455) living in hot-humid, lowland Bolivia. Using logistic regression with robust standard errors clustered by community residence, we found that higher water insecurity in adults was associated with increased odds of consuming non-water beverages. For men and women, each point higher water insecurity score (using the Household Water Insecurity Experiences (HWISE) scale) was associated with 24% (OR=1.24; 95% CI=1.01-1.51; P=0.037) and 27% (OR=1.27; 95% CI=1.06-1.52; $p < 0.01$) higher odds of consuming a sugar-sweetened beverage, respectively. Consumption of traditional beverages chicha dulce (a sweet manioc-based drink) and chicha fuerte (fermented manioc-based drink), in addition to liquor, were also studied. For men, each point higher HWISE score was associated with 13% (OR=1.13; 95% CI=1.11-1.16; $P<0.001$) higher odds of drinking chicha fuerte. Each point higher HWISE score was also associated with 16% (OR=1.16; 95% CI=1.02-1.32; P=0.022) higher odds of consuming liquor in the past week. Household income in the past month was also strongly associated with consumption of sugary drinks, but was inversely associated with chicha fuerte for men. These findings suggest that higher water insecurity is associated with consumption of sugar-sweetened beverages and chicha. Consumption of non-water beverages is a coping strategy to water insecurity that may have unintended nutritional consequences of excess calorie consumption, cardiometabolic risk, changes in body composition, which accelerates nutrition transition.

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Introduction

The Nutrition Transition

The nutrition transition is a global phenomenon characterized by large shifts in the composition of diet, resulting in shifted nutritional outcomes such as larger body size and greater adiposity (Popkin, 1994). With the processes of globalization, many societies are converging on a "Western" diet, which consists of high saturated fats, sugar, refined foods, and a low-fiber diet (Azzam, 2021; Hawkes, 2006). The Western diet has not driven overweight/obesity in only high-income nations, but also in low- and middle-income countries at the crux of urbanization and market integration (Templin, Cravo Oliveira Hashiguchi, Thomson, Dieleman, & Bendavid, 2019). The nutrition transition presents a significant challenge to nutritional outcomes, cardiometabolic health, and global health.

Increased global affordability of edible oils has been one driver of nutrition transition; more cost-effective production has created cheap vegetable oils that allow people in low/middle income countries to increase their energy intake even when subsisting at very low-income levels (Popkin, 1994). Processed, packaged convenience foods which contain high fat, salt, or sugar designed to be hyper-palatable have become nearly ubiquitous around the globe (Kelly, 2016). Furthermore, sugar-sweetened beverages, including sodas and juices, provide additional sugar intake and further increase carbohydrate consumption (Albala et al., 2008). The introduction of calorie-dense foods has helped mitigate undernutrition worldwide: the proportion of the world's hungry has declined from 18.6% in 1990-2002 to under 11% in 2014-16 (Webb et al., 2018).

However, national dietary programs traditionally focused on micronutrient deficiency and food insecurity, but have failed to acknowledge that staple corn, soy, and high-carbohydrate dietary intakes risk development of overweight/obesity (Ronto, Wu, & Singh, 2018). Paradoxically, the previously undernourished populations are now at risk of overweight/obesity. Combined with increased sedentary lifestyles, health consequences of this diet such as obesity, cardiovascular disease, and type 2 diabetes pose an increasing threat to global public health (Owen, Sparling, Healy, Dunstan, & Matthews, 2010).

Bolivia, a culturally and geographically diverse nation in South America, is one of many low-middle income countries undergoing nutrition transition. In a 2019 study, researchers found a 35.84% prevalence of overweight and 20.49% prevalence of abdominal obesity in Cochabamba, Bolivia (Mamani-Ortiz et al., 2019). Health behaviors associated with obesity were also measured; researchers determined 76.73% of participants had low consumption of fruits and vegetables while 64.77% exhibited a low level of physical activity. However, in a majority of the evaluated risk factors, Indigenous and Andean populations exhibited lower prevalence (Mamani-Ortiz et al., 2019). Indigenous and Andean populations comprise a large percentage of Bolivia's population and their health must be considered within context of traditional food systems and lifestyles (Lipus, Leon, Calle, & Andes, 2018).

The Tsimane' forager-horticulturalist population of lowland Amazon Bolivia is experiencing the early stages of nutrition transition. Traditionally, Tsimane' rely on a subsistence-based, labor-intensive diet based on cultivated starchy crops (plantain, rice, manioc, and maize) in addition to hunting lean game, freshwater fish, the occasional fruit and honey. Their diet is characterized by high carbohydrates, high protein, high fiber, and low fat content (Bethancourt, Leonard, Tanner, Schultz, & Rosinger, 2019). This diet has been protective to

Tsimane' health, especially against non-communicable disease; Tsimane' have enjoyed the lowest rates of coronary artery disease ever recorded, a minimal presence of hypertension and type II diabetes, even with a relatively high average Body Mass Index (BMI) (Kraft et al., 2018). Recently, population growth, encroachments on land, reductions in game and fish, loss of traditional ecological knowledge, and increasing opportunities for wage labor have resulted in lifestyle and diet changes for Tsimane' forager-horticulturalists (Bethancourt et al., 2019).

Traditional diets within Tsimane' are characterized by high energy (2422–2736 kcal/d), high carbohydrate (376–423 g/d), high protein (119-139 g/d), and low-fat intake (40-46 g/d), and have been linked to robust cardiometabolic health (Kraft et al., 2018). In recent years (between 2010-2015), researchers have found that residents of villages (especially near market towns) have increased their total energy intake, especially their total carbohydrate intake (Kraft et al., 2018). In particular, there has been increased consumption of food additives such as lard, salt, oil (4.9 mL $\cdot$ person^{-1} $\cdot$ d^{-1}), and sugar (15.8 g $\cdot$ person^{-1} $\cdot$ d^{-1}) (Kraft et al., 2018). The transition in diet has markedly affected body weight metrics; in 2002, 22.6% and 2.4% of Tsimane' women were overweight and obese (respectfully) but in 2010, 28.8% and 8.9% of women were overweight and obese (Bethancourt et al., 2019). Based on nutritional changes and anthropometric shifts, it can be concluded that Bolivians are experiencing the early stages of the nutrition transition.

Water Insecurity As a Nutritional Driver

Water insecurity is defined as "insufficient or uncertain access to adequate water for an active and healthy lifestyle" (Hadley & Wutich, 2009). Water insecurity can embody several dimensions of inadequacy – lack of water supply, insufficient water infrastructure, and inadequate water quality to support a healthy lifestyle (Stevenson et al., 2012). Water scarcity in particular (defined as the volumetric abundance, or lack thereof, of clean water) has emerged as a global “silent emergency” (Li, Hai, Han, Mao, & Tian, 2020; Moszynski, 2006). According to the United Nations Development Programme, it presents a greater threat to low-middle-income countries than violent conflict (Moszynski, 2006). Without access to clean water, people must walk kilometers to fetch clean water, or they may drink contaminated water from drains, ditches, and streams (Kangmennaang, Bisung, & Elliott, 2020). Additionally, the global water crisis prevents economic growth; sub-Saharan Africa loses 5% of its gross domestic product yearly to this crisis (Moszynski, 2006). Nearly four billion people worldwide experience freshwater scarcity each year due to water being insufficient or polluted (Mekonnen & Hoekstra, 2016).

The water crisis is driven by human activity and climate change. Globally, 70% of freshwater resources are utilized for agriculture, while another 19% is used for industry – leaving just 11% of freshwater for domestic water uses, including drinking (Ritchie & Roser, 2020). In urban settings, population growth, development, and socioeconomic development are expected to increase water demand by 50-80% in the following three decades (He et al., 2021). In parallel, climate change has also emerged as a key driver of water insecurity particularly near the equator. Recent modeling has determined that climate patterns will trend towards increasing hydrological extremes; the dry seasons will become dryer and the wet seasons will become wetter worldwide (Konapala, Mishra, Wada, & Mann, 2020). As a result, droughts and flooding are dually becoming increasingly common, exacerbating water scarcity in agriculture and for household water usage (Huang, Yuan, & Liu, 2021). Weather patterns such as the El Nino Southern Oscillation (ENSO), also exacerbated by climate change, impact Bolivia by causing droughts and flooding in different geographical areas (Rangecroft et al., 2013). In the most recent severe ENSO event (2014-2016), Bolivia's Lake Titicaca dried out entirely and drought severity has been shown to substantially increase during ENSO years (Canedo-Rosso, Hochrainer-Stigler, Pflug, Condori, & Berndtsson, 2021).

Water insecurity has clear health consequences; dehydration, diarrheal prevalence, psychosocial stress, adverse health outcomes, lower cognitive function, hypertension and chronic kidney disease (Rosinger & Young, 2020). Recent research has also determined that water insecurity is a driver of food insecurity (Boateng et al., 2020; Brewis et al., 2020). The link between water and food insecurity can certainly be biological; research has shown that children from households with poor water quality exhibit less gut microbiome diversity in comparison to children from households with better water quality (Piperata et al., 2020). Consequently, dysregulation of the gut microbiome can result in malnutrition, manifested by diarrheal disease, stunting, and obesity later in life (Daily, Zhang, Wu, & Park, 2019; Guerrant, DeBoer, Moore, Scharf, & Lima, 2013).

Water insecurity can also influence nutritional decisions. Distrust in water sources can give rise to several alternative hydration strategies, one of which is substitution with another beverage (Wutich & Brewis, 2014). Consumption of sugary beverages can be one such hydration strategy. In the United States, perception of tap water as unsafe led households to commonly substitute drinking water with sugary beverages (Onufrak, Park, Sharkey, & Sherry, 2014). Consumption of excess calories from sugary drinks increases risk of weight gain, diabetes, obesity, and dental disease and presents an urgent global health challenge accelerating the nutrition transition (Malik et al., 2010).

Tsimane' in lowland Bolivia experience a scarcity of clean water (Rufener, Mäusezahl, Mosler, & Weingartner, 2010). Water is mostly obtained from untreated surface water sources (such as rivers, ponds, and streams) which are often turbid and contaminated (Rosinger, 2018). Furthermore, water must often be hauled long distances, sometimes over rugged terrain (Rosinger, Bethancourt, Young, & Schultz, 2021). Additionally, due to an increased livestock population and increased use of motorized transport and toxic detergents, water quality has further worsened (Gurven, Kaplan, & Supa, 2007). Testing of 47 water sources among the Tsimane' community found that 40% of unprotected spring samples tested positive for fecal contamination, while 86% of open uncovered wells tested positive (Rosinger et al., 2021). However, perception of "bad water" among Tsimane' is largely based on organoleptic properties including turbidity or clarity, taste, smell, or presence of dead animals or trash in water. 15.6% of surveyed Tsimane' perceived drinking "bad water" in the past month (Rosinger et al., 2021).

Members in all Bolivian lowland communities present with high levels of parasitism, with prevalence near 100% in some communities (Gurven et al., 2007). Attempts to alleviate water insecurity by creating ground wells and providing clean water to Tsimane' residing near San Borja have been largely unsuccessful; in one community, even a new handpump produced turbid, metallic-tasting, contaminated water so community members resorted to fetching water from the river because it was perceived to be safer (Rosinger et al., 2021). The majority of Tsimane' communities experience water insecurity because they lack access to clean water (Dinkel et al., 2020; Rosinger & Tanner, 2015).

With the processes of urbanization and increasing market integration on Tsimane' lands, Tsimane' have increasing options available for alternative hydration strategies. Tsimane' traditionally make chicha, a manioc-based beverage which can be sweet (chicha dulce) or fermented and mildly alcoholic (chicha fuerte) (Asher Rosinger & Bethancourt, 2020). However, with commercial “Western” products introduced to the region, some Tsimane’ may also purchase sugary sodas, juices, flavored drinks, or liquor.

Research Gap and Hypothesis

A growing body of research has established that Tsimane’, among other groups in Bolivia, are experiencing several dimensions of water insecurity which is deleterious to population health. Several consequences of water insecurity have been explored, such as diarrheal disease, dehydration, cognitive decline, gut microbiome dysregulation, mental health, but the impacts of water insecurity on nutrition are under researched (Daily et al., 2019; Guerrant et al., 2013; Piperata et al., 2020; Rosinger & Young, 2020). A recent study in the Galapagos Islands determined that water insecurity, when examined alongside food insecurity, can predict a dual burden of undernutrition and infectious disease alongside overnutrition and non-communicable disease (Thompson, Nicholas, Watson, Terán, & Bentley, 2020). Water (or lack thereof) is deeply intertwined with nutrition, so it is surprising that the association of water insecurity with overnutrition and nutrition transition are understudied. Rosinger and Young recently emphasized the need for future studies to assess how water insecurity may be associated with the full suite of nutrition outcomes in low-, middle-, and high-income countries (Rosinger & Young, 2020). Tsimane’ are an appropriate population to study because they are experiencing transition from a forager-horticulturalist lifestyle to increasing market integration, which allows for a consideration of anthropogenic development on nutrition transition.

This honors thesis will present quantitative evidence and propose a linkage between water insecurity and the consumption of sugar-sweetened beverages (SSBs) as a driver of the nutrition transition among Bolivian Tsimane'. A comprehensive survey collecting information on water insecurity, health, and nutrition was administered for a larger study. Within a sample of 239 men and 216 women in five Tsimane' communities, consumption of sugary drinks, chicha dulce, chicha fuerte, and liquor was assessed alongside water insecurity and demographic characteristics. This thesis tests the overarching research questions of

How does water insecurity influence what people drink when they lack access to clean water? And, how are hydration strategies affected?

Specifically, it tests:

1: Does water insecurity relate to consumption of water alternatives, like SSBs, chicha, and alcohol, among Tsimane'?

2: Does community distance to market, as a proxy for market integration and the nutrition transition, influence reliance on SSB, chicha, or alcohol?

Methods

Research Site

The present study collected data from April to May of 2019 in Beni, Bolivia among the Tsimane' forager-horticulturalists. The Tsimane' population numbers approximately 16,000, and the nearest commercial town is San Borja, Bolivia (Rosinger et al., 2021). A few communities are experiencing early stages of urbanization and lifestyle changes, providing access to electricity, wells, and protected handpumps via efforts from governmental and non-governmental agencies (Rosinger, 2018). Tsimane' are also experiencing increasing market integration, which has resulted in increased availability of market food and beverages to Tsimane' (Rosinger, Tanner, & Leonard, 2013). However, most Tsimane' experience water insecurity since a majority of communities lack access to clean and safe drinking water (Dinkel et al., 2020; Rosinger & Tanner, 2015).

Participant Recruitment

Five out of ~100 communities were selected for data collection. They were selected to represent variation in distance to the market (San Borja) and in access to clean water. One community was accessible by car, while four were only accessible by canoe; travel to the communities required between two and ten hours in transit. In each village, >90% of households were recruited to complete the survey. Both male and female household heads were invited to complete the survey on their household's behalf; if both were available, they were interviewed together. Data were collected from 239 men and 216 women over 16 years of age (Rosinger et al., 2021).

Ethical Approval

The present study was conducted in accordance with the Principles of Helsinki. The study was approved by the Institutional Review Board of the Pennsylvania State University and by the Universidad Autónoma de Beni José Ballivián in Bolivia. Permission was also granted by the Gran Consejo Tsimane' in San Borja, Bolivia to conduct research among Tsimane'. Lastly, permission was also obtained by the community leaders of each village where data were collected, and each participant provided oral consent (Rosinger, Bethancourt, Young, & Schultz, 2021).

Water Environment

In this study, the primary metric used to measure water insecurity was the Household Water Insecurity Experiences (HWISE) Scale which has been validated for use in low- to middle-income countries (Young et al., 2019). We asked participants 12 questions about their water access and water fetching strategies within the last four weeks; based on their responses, an HWISE score ranging from 0 to 36 was calculated. For example, we asked, "In the last four weeks, how frequently did you or anyone in your household worry you would not have water for all of your water needs?". Responses range from never (0), rarely (1), sometimes (2), and often (3). The rest of the questions were asked in a similar format.

To benchmark quality of water sources, households were also classified on a Joint Monitoring Programme (JMP) ladder for drinking water services (World Health Organization, 2019). Households were categorized as drinking surface water if they drank from streams, ponds/lagunas, or the nearby Maniqui River. They were considered to drink unimproved water if unprotected springs or open wells served as their primary water source. If participants used protected handpumps or boreholes within a 30 minute round trip, they were considered to have basic access to water. If these handpumps/boreholes were further than 30 minutes away, they had limited access. Lastly, households were classified as drinking improved water if the water was accessible on premises, available when necessary, and free from fecal or chemical contamination. No households in the study met the criteria for receiving improved water. All households in the study fell within criteria for surface, unimproved, or basic water access (Rosinger et al., 2021).

Outcome - Hydration Strategies

To assess hydration strategies in response to water insecurity, survey participants were asked the number of days in the previous week they consumed a non-water beverage. Participants were asked about consumption of sugary drinks, which can include soda, water with added sugar or flavored powder, or beverages with fresh fruits. Participants were also surveyed on consumption of chicha dulce and chicha fuerte. Additionally, liquor is consumed among Tsimane’ to supplement chicha fuerte during celebrations, so liquor consumption in the past seven days was also assessed (Rosinger & Bethancourt, 2020). In analysis, a binary variable was also created to quantify whether any sugary drinks, chicha, or liquor was consumed in the past seven days or not.

Covariates

To distinguish the role of water insecurity on consumption of sugary beverages, we controlled for individual and household characteristics which can influence water insecurity and hydration strategies. We collected data on age, height and weight to calculate body mass index (BMI), gender, income (raw value and log-transformed), and household size adjusted for water needs (Rosinger et al., 2021).

Statistical Analysis

All analyses were performed in Stata software V.15.1 (College Station, TX). We natural log-transformed the household income value since the raw distribution was left-skewed. After natural log-transformation the income variable had a normal distribution (Rosinger et al., 2021).

To determine results for the first aim, we created a descriptive table to present characteristics of water insecurity and hydration strategy experienced by Tsimane'. Then, to determine the influence of water insecurity on hydration strategies, we used multiple logistic regression models to estimate the odds of SSB, chicha dulce, chicha fuerte, and liquor consumption by household-level water insecurity (HWISE score) adjusted for covariates. Data were considered weakly significant if $p<0.1$, moderately significant if $p<0.05$, and highly significant if $p<0.01$. Then, a sensitivity analysis was conducted via Poisson regression to re-estimate the association between water insecurity score and incidence of beverage intake.

For the second aim, we analyzed the fixed effects of community distance from market on patterns of SSB, chicha dulce, chicha fuerte, and liquor consumption from the logistic regression models. The five communities included in the present study were labeled numbers 1 through 5; community 1 being accessible by car and closest to market, while community 5 was furthest and required 10 hours of travel by canoe. Based on the multiple logistic regression, we estimated an adjusted predicted probability of consuming each beverage for each community rank. To visualize these data, we used the margins plot Stata application to generate graphs.

Results

The descriptive characteristics of the study population are depicted in **Table 1 (Appendix)**. The analysis was conducted separately for men and women. The mean (SD) age of male participants was 39 (17) years, while it was 36 (17) years for women. The mean BMI for men was 24 (2.2), while it was 24 (3.7) for women. We also determined the mean (SD) for the following predictor variables: HWISE score, JMP Ladder (Unimproved and Basic), Household (HH) Size Adjusted for Water Needs, Household Income, and Log-transformed Household Income. The data were similar for both sexes. The dependent variables (any sugary drinks, sugar drinks, any chicha dulce, chicha dulce, any chicha fuerte, chicha fuerte, any liquor and liquor) were also measured. Consumption of sugary drinks and chicha dulce was even across the sexes, but men consumed significantly more chicha fuerte. Women did not report consumption of liquor, so analysis for liquor was conducted using only data from men.

Tables 2 and 3 show the multiple logistic regression of the dependence of sugary drink, chicha dulce, and chicha fuerte consumption on the predictor variable HWISE score, with covariates of JMP ladder score, age, HH size adjusted for water needs, and HH income (log-transformed) included. The data are divided by sex.

Among men, each point higher HWISE score was associated with 24% greater odds of sugary drink consumption (Odds Ratio (OR) = 1.24, 95% CI = 1.01 – 1.51, $p = 0.037$). Similarly, among women, every 1-point increase in HWISE score was associated with 27% higher odds of consuming sugary drinks (OR = 1.27, 95% CI = 1.06 – 1.52, $p < 0.01$). Household income was also significantly associated with sugary drink consumption in both sexes; in men, we found 18% greater odds with each log-transformed income unit (OR = 1.18, 95% CI = 1.06 – 1.33, p

<0.01), while 21% greater odds with each unit were found in women (OR = 1.21, 95% CI = 1.15 – 1.27, p < 0.01).

As for chicha consumption, among men a weakly significant association was present between HWISE score and chicha dulce consumption (OR = 1.08, 95% CI = 0.99 – 1.18, p = 0.072). However, each point increase in HWISE score was associated with a 13% increase in the odds of chicha fuerte consumption (OR = 1.13, 95% CI = 1.10 – 1.16, p < 0.01). Household income was inversely associated with chicha fuerte consumption in men. Additionally, each point higher HWISE score was associated with 16% higher odds of liquor consumption in men (OR = 1.16, 95% CI = 1.02 - 1.32, p = 0.016). No significant results for chicha consumption were found in women.

Tables 4 and 5 show results of the sensitivity analysis conducted by Poisson regression. Among both men and women consuming sugary drink, there was a 4% greater incidence risk ratio of additional sugar drink drinking event with each point increase in the HWISE score (Incidence Risk Ratio = 1.04, 95% CI = 1.02 - 1.06, p < 0.01). Among men, an 11% increase in chance of a chicha fuerte drinking event occurred with each additional HWISE point (IRR = 1.11, 95% CI = 1.07 - 1.15, p < 0.01). Lastly, for liquor a similar incidence risk ratio was determined (IRR = 1.09, 95% CI = 1.06 - 1.12, p < 0.01).

Table 6 depicts the adjusted predicted probability of drink consumption by community distance to market (categorized as community rank). All results for sugary drink consumption were highly significant. As seen in **Figure** 1, in communities 1-3, there was a high probability of sugar drink consumption (for community 3, probability = 0.95, 95% CI = 0.87 - 1.02, p < 0.01). However, in the farther communities 4 and 5, sugar drink consumption dropped off sharply (in community 4, probability = 0.75, 95 % CI = 0.65 -1.86, p < 0.01). For both chicha fuerte and chicha dulce, the trend was less clear **(Figures 2 and 3)**, but for chicha fuerte the predicted probability of consumption doubled in comparison of community 1 (probability = 0.31, 95% CI = 0.15 - 0.46, $p < 0.01$) to community 2 (probability = 0.70, 95 % CI = 0.59 -0.82, $p < 0.01$). For chicha dulce (**Figure 3)**, a similar jump in consumption was observed from community 1 to 2 (probability = 0.02 to 0.10). In liquor consumption among men (**Figure 4),** no trend was observed across communities but communities 2 (probability = 0.22, 95% CI = 0.11 - 0.33, $p < 0.01$) and 4 (probability = 0.53, 95% CI = 0.40 - 0.66, $p < 0.01$) had a marked increase in liquor consumption.

Discussion

In the present study, we investigated how water insecurity was associated with hydration strategies of Tsimane' adults. For the first aim, we determined that water insecurity is indeed associated with increased consumption of sugary drinks, chicha, and liquor. When results were analyzed separately for each sex, both men and women consistently demonstrated higher odds of sugary drink consumption with increased HWISE water insecurity. Among men, increased consumption of chicha fuerte and liquor were also associated with water insecurity, while no significant trend was observed for women. As for chicha dulce a weakly significant association was found between water insecurity and chicha dulce consumption only in men. Results were consistent in the sensitivity analyses.

In investigation of the second aim, our results indicated clear trends in the predicted probability of sugar drink and chicha dulce consumption in relation to community distance from market. The probability of sugary drink consumption remained consistently high for the closest three communities, and decreased sharply for the farthest two communities. We also found a significant pattern in chicha dulce consumption; as community distance to market increases, the probability chicha dulce consumption is also predicted to increase. Chicha fuerte and liquor consumption patterns did not yield significant trends; however, the probability of chicha fuerte or liquor consumption in farther communities from market (rank 2 and 4) was greater than the probability of consumption in the closest community (rank 1).

Consuming Sugary Drinks As Alternative to Water

Our results support the paradigm that water insecurity influences greater sugary drink consumption, thus driving the nutrition transition (Rosinger & Young, 2020). This makes sense because Tsimane' adults have been documented to seek hydration from alternative sources if they distrust their local water source (Rosinger et al., 2021). Distrust may arise from organoleptic perception of water's color, taste, turbidity, or smell (Rosinger, 2018). Additionally, the process of water fetching can be strenuous and sometimes dangerous, so Tsimane' may turn to alternate hydration strategies when this is the case (Rosinger et al., 2021).

Rosinger and Tanner found that Tsimane' obtain up to 50% of their water from water-rich foods, such as fruit (2015). Additionally, Tsimane' have a long history of making chicha from grains or starchy vegetables, where the fermentation process generates a modest amount of alcohol and lactic acid which destroys pathogenic bacteria in contaminated water (Arthur, 2014; La Barre, 1938; Zycherman, 2015). Thus, water from food and chicha serve as important hydration sources and as a key alternatives to consumption of contaminated water (Rosinger & Bethancourt, 2020).

With market introduction of commercial sugary drinks and liquor, Tsimane' now have additional hydration strategies available to them (Rosinger et al., 2013). Additionally, in a water environment where a majority of water sources provide unimproved or basic access to clean water, distrust of water sources can certainly lead Tsimane' to reach for market sugary drinks, chicha, or liquor (Rosinger et al., 2021). Individuals may prefer SSB consumption due to increased palatability, lower cost, or convenience of SSBs; however, water insecurity emerges as a clear driving force (Onufrak et al., 2014). In the United States, those who perceive their tap water as unsafe are increasingly likely to rely on bottled water and sugary beverages for hydration (Rosinger, 2022). Among indigenous communities in Canada, parents provide sugary beverages such as Kool-Aid or soda to their children, despite reservations about the health implications, because high-sugar beverages are less expensive and more consistently available than bottled water in Northern Canada (Sarkar, Hanrahan, & Hudson, 2015). In fact, sugary beverages were consumed more frequently than tap water among Canadian indigenous communities (Sarkar et al., 2015). Furthermore, among Indigenous peoples in Australia, half of children in early life (ages 0-3) were fed SSBs, particularly by families in remote settings with lower socio-economic position (Thurber, Long, Salmon, Cuevas, & Lovett, 2020). With market availability of sugary drinks, Tsimane' are exhibiting similar precautions when experiencing water insecurity and rely more heavily on sugary beverages. This finding highlights a paradox of nutrition transition; when subsistence-based or low-income communities are market integrated into a Western economy where obesogenic drinks are more readily accessible than clean water, the communities begin to experience the consequences of nutrition transition (obesity, metabolic disease) while simultaneously experiencing the burden of food and water insecurity. This paradox has damaging implications for nutrition and cardiometabolic health.

Implications for Cardiometabolic Health and Nutrition Transition

Increased consumption of sugary beverages increases caloric intake, which can cause weight gain, increase risk of obesity, diabetes, and heart disease, and accelerate the nutrition transition (Hu & Malik, 2010; Malik & Hu, 2019; Malik, Pan, Willett, & Hu, 2013; Popkin, 1994). In the United States, Rosinger et. al. found that consumption of sugar-sweetened beverages adds empty calories to diets (2019). In fact, consumption of SSBs resulted in doubled caloric intake in comparison to those who primarily consumed plain water, and the subjects exceeded 10% of the daily recommended calories due to the added sugar (Rosinger et al., 2019). Furthermore, interventions to replace SSBs with plain water resulted in decreased body mass index (Rosinger et al., 2019). This provides evidence that consumption of SSBs as a hydration strategy increases risk of overweight and obesity due to excess calories.

In the Tsimane' context, where the traditional diet has supported the robust cardiometabolic health of adults, the increased empty calories from sugary drinks threaten to cause overweight and obesity in Tsimane'. Obesity places humans at greater risk of developing diabetes, hypertension, heart disease, and other manifestations of metabolic syndrome (Haffner & Taegtmeyer, 2003). In India, researchers found that each unit increase in body mass index (BMI) places an individual at 1.5% increased risk of type 2 diabetes in overweight and obese individuals (Gupta & Bansal, 2020). Additionally, overweight can increase risk of metabolic syndrome (insulin resistance, elevated triglycerides, and hypertension), which is linked with development of cardiovascular disease (Grundy et al., 2005). On a population level, the increased risk of obesity due to SSB consumption accelerates the nutrition transition and increases the burden of disease from cardiometabolic disease (Malik & Hu, 2019; Malik et al., 2013; Popkin, Adair, & Ng, 2012).

Tsimane' are already experiencing increasing rates of overweight and obesity; from 2002 to 2010, obesity rates more than tripled among Tsimane', leading Bethancourt et. al. to conclude that even small increases in caloric intake from market foods contribute to gains in adiposity among the moderately active, subsistence-based Tsimane' (Bethancourt et al., 2019). Thus, even a modest increase in caloric intake from market sugary beverages has potential to cause long-term adiposity gains and accelerate the nutrition transition among Tsimane'. This suggests increased risk of cardiometabolic disease among Tsimane' if they continue along the path of nutrition transition.

The Influence of Community Distance to Market on Sugary Drink Consumption

In the present study, we found a strong association between community distance to market and sugary drink consumption. Community distance to market serves as a proxy to understanding the level of market integration experienced by a community; the closest communities may frequently visit the market to purchase sugary drinks and high-fat, high-carbohydrate "Western" foods, while the farthest communities will largely rely on traditional subsistence methods for food and hydration (Rosinger et al., 2013). If proximity to market dictates lifestyle, then the closest communities will stray from traditional lifestyles that have maintained Tsimane' health and instead rely on market sugary beverages for hydration, driving the nutrition transition as a result and increasing the burden of health from metabolic disease. Meanwhile, farther communities follow traditional lifestyles more closely and may be at lower risk for weight gain and nutrition transition (Houck et al., 2013). In the study, we also determined that likelihood of chicha dulce increases as level of market integration decreases; this follows the assertion that Tsimane' are more likely to follow traditional lifestyles in farther communities and use more traditional methods of hydration (Rosinger & Bethancourt, 2020). The level of market integration has great influence over choice of hydration strategy by Tsimane', and must be considered within context of increasing urbanization, development, and lifestyle changes among indigenous populations.

Health Implications of Water Intervention

To address the reliance on sugary drinks for hydration, officials must recognize the role of water insecurity. As previously mentioned, most Tsimane' lack access to improved water sources that are safe, clean, and readily accessible (Rosinger & Tanner, 2015). This results in community-wide distrust of plain water and in the replacement of water with sugary beverages (Rosinger et al., 2021; Rosinger & Young, 2020). If future attempts to establish water infrastructure and introduce clean water sources to Tsimane' communities are successful, ideally Tsimane' should revert to consumption of plain water and decrease their reliance on sugary beverages for hydration. In these efforts, officials should take care to address perceptions of plain water and emphasize the nutritional value of consuming plain water instead of sugary beverages.

Limitations and Future Work

There are a few key limitations to this study. First, participants were surveyed only once because the study utilized a cross-sectional design. With data from one point in time, we cannot observe longitudinal changes or assert causality; we can only present associations. Another limitation is that we did not collect health data on weight gain, nutritional status, or cardiometabolic disease, so we are unable to make direct associations between the sugary beverage consumption in this study and health outcomes; we can only consider the implications of increased sugary drink consumption. Additionally, the administered survey required participants to recall beverage consumption patterns in the last seven days and experiences in the last four weeks; some data may be inaccurate or omitted due to recall bias. Lastly, the results may have been influenced by some unmeasured variable, which could also partially explain our findings.

In the future, researchers should conduct studies with longitudinal design in Tsimane' communities to determine whether sugary beverage consumption, driven by water insecurity, directly causes weight gain. Additionally, researchers could collect anthropometric data on weight gain, body fat percentage, and determine blood glucose/A1C levels to more directly measure associations between sugary drink consumption and nutritional status. The results of this study also raise additional questions about the influence of traditional lifestyles, perception of market integration, and culture on sugary drink consumption; future studies should explore these factors to gain a full understanding of the complex processes behind market integration and nutrition transition.

Conclusions

Overall, this honors thesis advances the water insecurity and nutritional research in two important ways. First, we utilized empirical data to relate water insecurity with frequency of sugary beverage consumption and presented a clear association between water insecurity and nutrition. We determined that increased water insecurity is associated with increased odds of sugary drink, chicha fuerte, and liquor consumption. Second, we examined association between level of market integration and sugary drink consumption, finding that the degree of market integration influences the range of available hydration strategies and has implications on nutritional outcomes. Increased level of market integration increases probability of sugary drink consumption, while lower levels of market integration predict increased reliance on chicha dulce. Our findings suggest that water insecurity can accelerate the nutrition transition due to reliance on sugary beverages, which implies increased risk of obesity and cardiometabolic disease. Future efforts to reduce water insecurity may decrease reliance on sugary beverages for hydration.

Appendix

Table 1. Descriptive Table of Tsimane' Characteristics, Separated by Sex.

VARIABLES	**Men (n=239)** Mean ± Standard Deviation	**Women (n=216)** Mean ± Standard Deviation
HWISE score	2.1 ± 2.8	2.0 ± 2.9
Any Sugar Drinks (%)	84 ± 36	83 ± 37
Sugar Drinks (days/wk)	3.6 ± 2.6	3.5 ± 2.6
Any Chicha Fuerte (%)	18 ± 38	3.5 ± 19
Chicha Fuerte (days/wk)	0.22 ± 0.53	0.036 ± 0.19
Any Chicha Dulce (%)	64 ± 48	62 ± 49
Chicha Dulce (days/wk)	1.2 ± 1.4	1.2 ± 1.4
Any Liquor (%)	20 ± 40	-
Liquor (days/wk)	0.26 ± 0.63	-
JMP Ladder		
Surface(base)	1	1
Unimproved(%)	0.46 ± 0.50	0.46 ± 0.50
Basic(%)	0.32 ± 0.47	0.31 ± 0.46
Age(years)	39 ± 17	36 ± 17
BMI (kg/m^2)	24 ± 2.2	24 ± 3.7
HH size adjusted for water needs	4.1 ± 1.7	4.1 ± 1.7
HH income (bolivianos)	595 ± 830	583 ± 903
HH Income (log-transformed)	4.9 ± 2.6	4.6 ± 2.8

Legend: JMP = Joint Monitoring Programme; BMI = Body Mass Index; HH = Household

Table 2. Multiple logistic regression examining how HWISE water insecurity score is associated with hydration strategies among Tsimane' men.

	1	2	3	4
VARIABLES	Men [2]Sugary drink OR (95% CI)	Men Chicha dulce OR (95% CI)	[1]Men Chicha fuerte OR (95% CI)	[2]Men Liquor OR (95% CI)
HWISE score (1 point)	1.24**	1.08*	1.13***	1.16**
	(1.01 – 1.51)	(0.99 – 1.18)	(1.11 – 1.16)	(1.03 – 1.32)
JMP Drinking Water Access:				
Surface (Ref)	1	1	1	1
Unimproved source	0.57	1.63	1.79	0.66
	(0.11 – 2.96)	(0.84 - 3.14)	(0.59 - 5.49)	(0.32 - 1.36)
Basic access	1.17	0.76	4.74***	2.76***
	(0.63 - 2.16)	(0.22 - 2.64)	(1.57 – 14.29)	(1.32 - 5.76)
Individual's age (years)	0.99	0.99**	0.99***	0.99
	(0.96 - 1.02)	(0.98 - 1.00)	(0.98 - 0.99)	(0.98 - 1.01)
HH size adjusted for water needs	0.98	1.10	0.95	0.97
	(0.79 - 1.21)	(0.87- 1.39)	(0.84 - 1.07)	(0.89 - 1.05)
HH Income (log-transformed)	1.20***	0.95	0.89**	1.01
	(1.09 - 1.32)	(0.84 - 1.09)	(0.79 – 1.00)	(0.93 - 1.09)
Observations	239	239	239	239

Legend: OR = Odds Ratio; Robust standard errors clustered by community. Models adjusted for community fixed effects

*** p<0.01, ** p<0.05, * p<0.1

[1]No community fixed effects due to lack of observations in 1-2 communities; [2]Insufficient observations to test among women; [2]sugary drink: any soda, water mixed with raw sugar, or water mixed with a kool-aide like sweetener

Table 3. Multiple Logistic regression examining how HWISE water insecurity score is associated with hydration strategies among Tsimane' women.

	1	2	3
VARIABLES	Women [2]Sugary drink OR (95% CI)	Women Chicha dulce OR (95% CI)	[1]Women Chicha fuerte OR (95% CI)
HWISE score (1 point)	1.27*	1.07	0.99
	(1.00- 1.61)	(0.93 - 1.23)	(0.92 - 1.07)
JMP Drinking Water Access:			
Surface (Ref)	1	1	1
Unimproved source	1.46	1.00	0.69
	(0.31 – 6.87)	(0.66 – 1.53)	(0.12 – 4.14)
Basic access	2.05***	1.40	1.31
	(1.40 – 3.00)	(0.32 - 6.08)	(0.15 – 11.29)
Individual's age (years)	0.99	0.99	1.03***
	(0.96 - 1.02)	(0.97 - 1.01)	(1.02 - 1.04)
HH size adjusted for water needs	0.91	1.05	0.89
	(0.77 - 1.09)	(0.83 - 1.32)	(0.60 - 1.34)
HH Income (log-transformed)	1.20***	0.93	0.99
	(1.12 - 1.28)	(0.83 - 1.04)	(0.84 - 1.17)
Observations	216	216	216

Legend: OR = Odds Ratio; Robust standard errors clustered by community. Models adjusted for community fixed effects

*** p<0.01, ** p<0.05, * p<0.1

[1]No community fixed effects due to lack of observations in 1-2 communities; [2]Insufficient observations to test among women; [2]sugary drink: any soda, water mixed with raw sugar, or water mixed with a kool-aide like sweetener

Table 4. Multiple Poisson regression examining how HWISE water insecurity score is associated with the incident rate ratios of hydration strategies among Tsimane' men.

	1	2	3	4
VARIABLES	Men [2]Sugary drink IRR (95% CI)	Men Chicha dulce IRR (95% CI)	[1]Men Chicha fuerte IRR (95% CI)	[2]Men Liquor IRR (95% CI)
HWISE score (1 point)	1.04***	1.02	1.11***	1.09***
	(1.02 - 1.06)	(0.99 - 1.05)	(1.07 - 1.15)	(1.06 - 1.12)
JMP Drinking Water Access:				
Surface (Ref)	1	1	1	1
Unimproved source	0.94	1.38*	1.33	0.52
	(0.82 - 1.08)	(0.97 - 1.97)	(0.37 - 4.79)	(0.23 - 1.15)
Basic access	1.12	1.44*	3.38**	1.23
	(0.97 - 1.30)	(0.99 - 2.10)	(1.21 - 9.48)	(0.71 - 2.11)
Individual's age (years)	1.00	1.00	0.99***	1.00
	(1.00 - 1.00)	(0.99 - 1.00)	(0.99 - 0.99)	(0.99 - 1.00)
HH size adjusted for water needs	1.01	1.02	1.00	0.95**
	(0.99 - 1.02)	(0.92 - 1.14)	(0.91 - 1.11)	(0.90 - 0.99)
HH Income (log-transformed)	1.06***	0.98	0.94	1.05*
	(1.05 - 1.08)	(0.91 - 1.05)	(0.87 - 1.02)	(0.99 - 1.12)
Observations	239	239	239	239

Robust standard errors clustered by community. Models adjusted for community fixed effects
*** p<0.01, ** p<0.05, * p<0.1

Legend: IRR = Incidence Risk Ratio

Table 5. Multiple Poisson regression examining how HWISE water insecurity score is associated with the incident rate ratios of hydration strategies among Tsimane' women.

	1	2	3
VARIABLES	Women [2]Sugary drink OR (95% CI)	Women Chicha dulce OR (95% CI)	[1]Women Chicha fuerte OR (95% CI)
HWISE score (1 point)	1.04***	1.05*	0.99
	(1.02 - 1.06)	(0.99 - 1.10)	(0.93 - 1.07)
JMP Drinking Water Access:			
Surface (Ref)	1	1	1
Unimproved source	1.06	1.18***	0.70
	(0.96 - 1.17)	(1.10 - 1.27)	(0.13 - 3.87)
Basic access	1.10	1.44	1.28
	(0.94 - 1.29)	(0.72 - 2.88)	(0.17 - 9.76)
Individual's age (years)	1.00	1.00	1.03***
	(1.00 - 1.00)	(0.98 - 1.01)	(1.02 - 1.04)
HH size adjusted for water needs	0.99	1.00	0.90
	(0.97 - 1.00)	(0.92 - 1.09)	(1.02 - 1.04)
HH Income (log-transformed)	1.06***	0.97	0.99
	(1.05 - 1.08)	(0.90 - 1.05)	(0.84 - 1.16)
Observations	216	216	216

Robust standard errors clustered by community. Models adjusted for community fixed effects
*** p<0.01, ** p<0.05, * p<0.1

Legend: IRR = Incidence Risk Ratio

Table 6. Predicted probability of hydration strategies by community distance to the market.

	1	2	3	4
COMMUNITY RANK	[2]Sugary drink Adjusted Predicted Probability (95% CI)	Chicha dulce Adjusted Predicted Probability (95% CI)	Chicha fuerte Adjusted Predicted Pro & bability (95% CI)	Liquor Adjusted Predicted Probability (95% CI)
1	0.92***	0.31***	0.02	0.09*
	(0.84 - 1.01)	(0.15 – 0.46)	(-0.01 – 0.05)	(-0.01 – 0.19)
2	0.94***	0.70***	0.10***	0.22***
	(0.88 – 1.01)	(0.59 – 0.82)	(0.03 – 0.16)	(0.11 – 0.33)
3	0.95***	0.53***	-	0.03
	(0.87 – 1.02)	(0.36 – 0.71)		(-0.03 – 0.09)
4	0.75***	0.78***	0.31***	0.53***
	(0.65 – 0.86)	(0.68 – 0.89)	(0.23 – 0.40)	(0.40 – 0.66)
5	0.74***	0.64***	0.05**	0.03
	(0.63 – 0.84)	(0.53 – 0.75)	(0.005 - 0.10)	(-0.01 – 0.07)
Observations	470	470	411	241

Community Rank 1 refers to community closest to market, while community 5 refers to community furthest from market. Men and women combined for models 1-3 & 5; model 4 is only men.

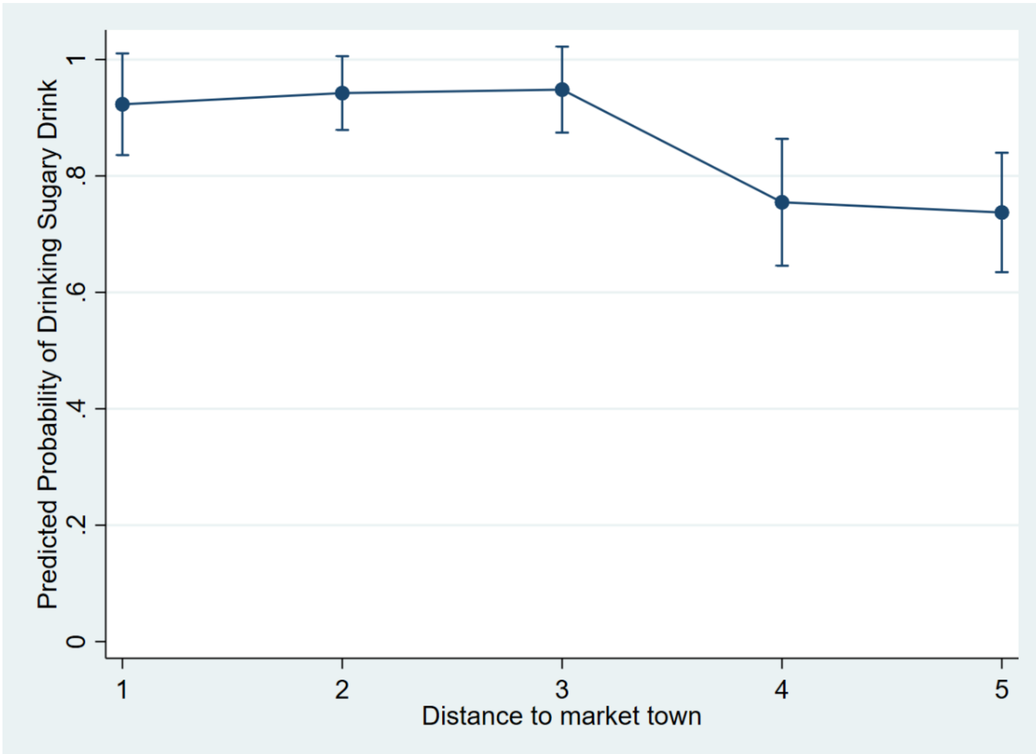

Figure 1. Predicted probability of sugary drink consumption in relation to community rank, with 95% confidence intervals included.

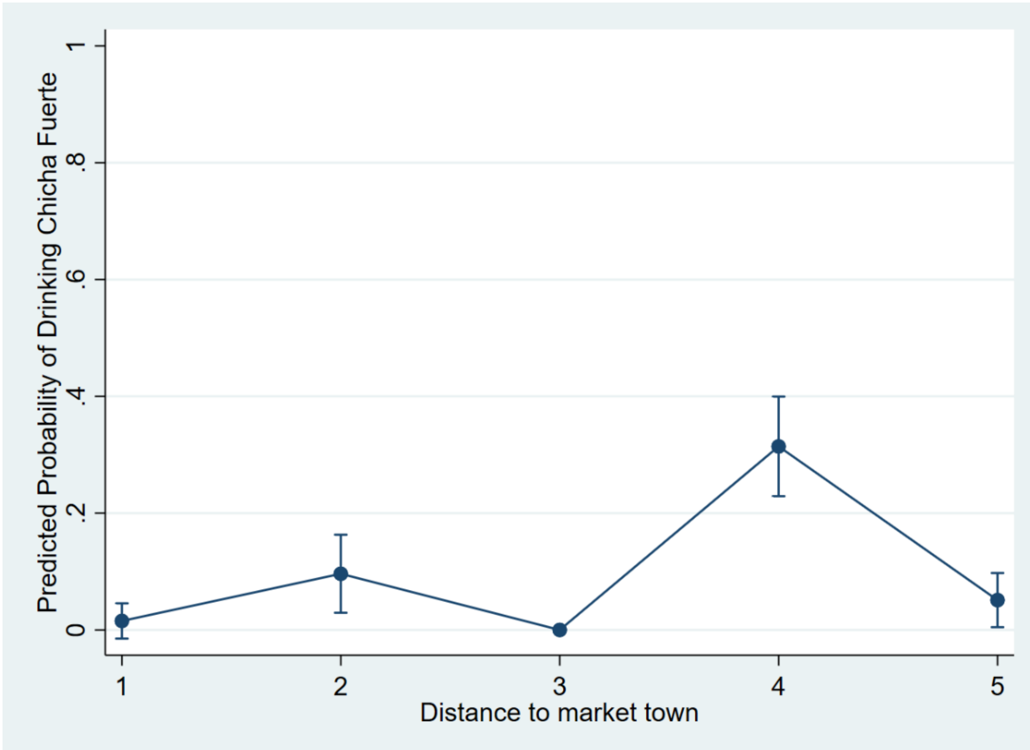

Figure 2. Predicted probability of chicha fuerte consumption in relation to community distance to market, with 95% confidence intervals included. Note: community 3 was excluded from this analysis because no one reported chicha fuerte consumption.

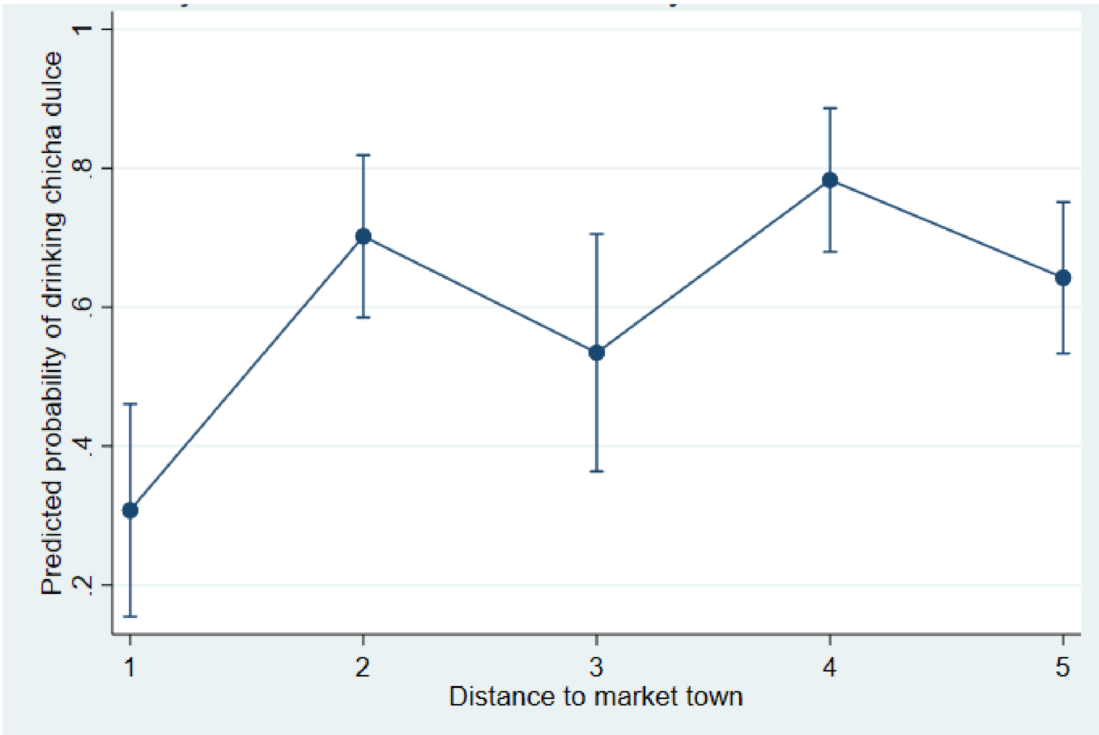

Figure 3. Predicted probability of chicha dulce consumption based on community distance from market, with 95% confidence intervals.

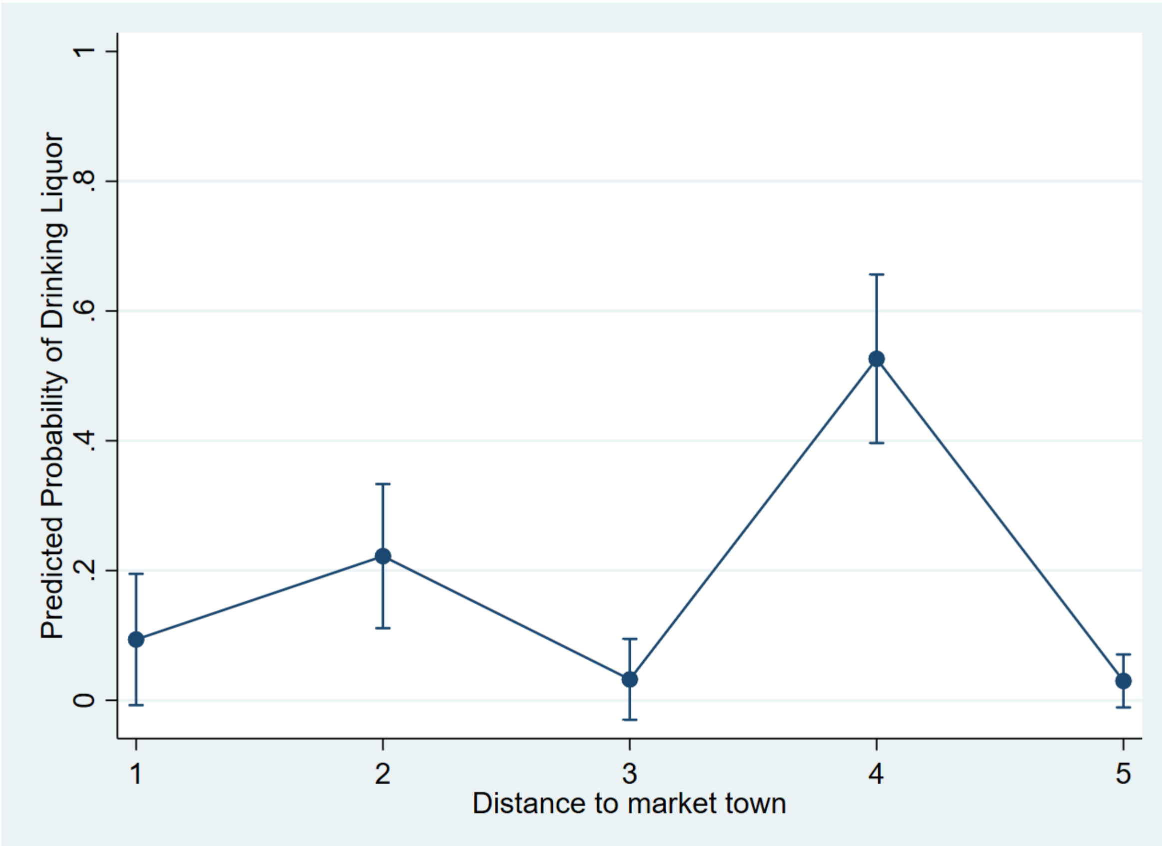

Figure 4. Predicted probability of liquor consumption in relation to community distance to market, with 95% confidence intervals included.

BIBLIOGRAPHY

1. Albala, C., Ebbeling, C. B., Cifuentes, M., Lera, L., Bustos, N., & Ludwig, D. S. (2008). Effects of replacing the habitual consumption of sugar-sweetened beverages with milk in Chilean children. *Am J Clin Nutr, 88*(3), 605-611. doi:10.1093/ajcn/88.3.605
2. Arthur, J. W. (2014). Beer through the Ages. *Anthropology Now, 6*(2), 1-11. doi:10.1080/19492901.2014.11728428
3. Azzam, A. (2021). Is the world converging to a 'Western diet'? *Public Health Nutrition, 24*(2), 309-317. doi:10.1017/S136898002000350X
4. Bethancourt, H. J., Leonard, W. R., Tanner, S., Schultz, A. F., & Rosinger, A. Y. (2019). Longitudinal Changes in Measures of Body Fat and Diet Among Adult Tsimane' Forager-Horticulturalists of Bolivia, 2002-2010. *Obesity (Silver Spring), 27*(8), 1347-1359. doi:10.1002/oby.22556
5. Boateng, G. O., Workman, C. L., Miller, J. D., Onono, M., Neilands, T. B., & Young, S. L. (2020). The syndemic effects of food insecurity, water insecurity, and HIV on depressive symptomatology among Kenyan women. *Social Science & Medicine*, 113043. doi:https://doi.org/10.1016/j.socscimed.2020.113043
6. Brewis, A., Workman, C., Wutich, A., Jepson, W., Young, S., & Household Water Insecurity Experiences – Research Coordination, N. (2020). Household water insecurity is strongly associated with food insecurity: Evidence from 27 sites in low- and middle-income countries. *American Journal of Human Biology, 32*(1), e23309. doi:https://doi.org/10.1002/ajhb.23309
7. Canedo-Rosso, C., Hochrainer-Stigler, S., Pflug, G., Condori, B., & Berndtsson, R. (2021). Drought impact in the Bolivian Altiplano agriculture associated with the El Niño–Southern Oscillation using satellite imagery data. *Nat. Hazards Earth Syst. Sci., 21*(3), 995-1010. doi:10.5194/nhess-21-995-2021
8. Daily, J. W., Zhang, T., Wu, X., & Park, S. (2019). Chronic water insufficiency induced kidney damage and energy dysregulation despite reduced food intake, which improved gut microbiota in female rats. *J Physiol Sci, 69*(4), 599-612. doi:10.1007/s12576-019-00668-7
9. Dinkel, K. A., Costa, M. E., Kraft, T. S., Stieglitz, J., Cummings, D. K., Gurven, M., . . . Trumble, B. C. (2020). Relationship of sanitation, water boiling, and mosquito nets to health biomarkers in a rural subsistence population. *Am J Hum Biol, 32*(1), e23356.
10. Grundy, S. M., Cleeman, J. I., Daniels, S. R., Donato, K. A., Eckel, R. H., Franklin, B. A., . . . Costa, F. (2005). Diagnosis and Management of the Metabolic Syndrome. *Circulation, 112*(17), 2735-2752. doi:10.1161/CIRCULATIONAHA.105.169404
11. Guerrant, R. L., DeBoer, M. D., Moore, S. R., Scharf, R. J., & Lima, A. A. (2013). The impoverished gut--a triple burden of diarrhoea, stunting and chronic disease. *Nat Rev Gastroenterol Hepatol, 10*(4), 220-229. doi:10.1038/nrgastro.2012.239
12. Gupta, S., & Bansal, S. (2020). Does a rise in BMI cause an increased risk of diabetes?: Evidence from India. *PLoS One, 15*(4), e0229716.
13. Gurven, M., Kaplan, H., & Supa, A. Z. (2007). Mortality experience of Tsimane Amerindians of Bolivia: Regional variation and temporal trends. *American Journal of Human Biology, 19*(3), 376-398. doi:https://doi.org/10.1002/ajhb.20600
14. Hadley, C., & Wutich, A. (2009). Experience-based Measures of Food and Water Security: Biocultural Approaches to Grounded Measures of Insecurity. *Human Organization, 68*(4), 451-460. doi:10.17730/humo.68.4.932w421317680w5x

15. Haffner, S., & Taegtmeyer, H. (2003). Epidemic Obesity and the Metabolic Syndrome. *Circulation, 108*(13), 1541-1545. doi:10.1161/01.CIR.0000088845.17586.EC
16. Hawkes, C. (2006). Uneven dietary development: linking the policies and processes of globalization with the nutrition transition, obesity and diet-related chronic diseases. *Globalization and Health, 2*(1), 4. doi:10.1186/1744-8603-2-4
17. He, C., Liu, Z., Wu, J., Pan, X., Fang, Z., Li, J., & Bryan, B. A. (2021). Future global urban water scarcity and potential solutions. *Nature Communications, 12*(1), 4667. doi:10.1038/s41467-021-25026-3
18. Houck, K., Sorensen, M. V., Lu, F., Alban, D., Alvarez, K., Hidobro, D., . . . Ona, A. I. (2013). The effects of market integration on childhood growth and nutritional status: The dual burden of under- and over-nutrition in the Northern Ecuadorian Amazon. *American Journal of Human Biology, 25*(4), 524-533. doi:https://doi.org/10.1002/ajhb.22404
19. Hu, F. B., & Malik, V. S. (2010). Sugar-sweetened beverages and risk of obesity and type 2 diabetes: Epidemiologic evidence. *Physiology & Behavior, 100*(1), 47-54. doi:https://doi.org/10.1016/j.physbeh.2010.01.036
20. Huang, Z., Yuan, X., & Liu, X. (2021). The key drivers for the changes in global water scarcity: Water withdrawal versus water availability. *Journal of Hydrology, 601*, 126658. doi:https://doi.org/10.1016/j.jhydrol.2021.126658
21. Kangmennaang, J., Bisung, E., & Elliott, S. J. (2020). 'We Are Drinking Diseases': Perception of Water Insecurity and Emotional Distress in Urban Slums in Accra, Ghana. *Int J Environ Res Public Health, 17*(3).
22. Kelly, M. (2016). The Nutrition Transition in Developing Asia: Dietary Change, Drivers and Health Impacts. In P. Jackson, W. E. L. Spiess, & F. Sultana (Eds.), *Eating, Drinking: Surviving: The International Year of Global Understanding - IYGU* (pp. 83-90). Cham: Springer International Publishing.
23. Konapala, G., Mishra, A. K., Wada, Y., & Mann, M. E. (2020). Climate change will affect global water availability through compounding changes in seasonal precipitation and evaporation. *Nature Communications, 11*(1), 3044. doi:10.1038/s41467-020-16757-w
24. Kraft, T. S., Stieglitz, J., Trumble, B. C., Martin, M., Kaplan, H., & Gurven, M. (2018). Nutrition transition in 2 lowland Bolivian subsistence populations. *Am J Clin Nutr, 108*(6), 1183-1195.
25. La Barre, W. (1938). Native American Beers. *American Anthropologist, 40*(2), 224-234. Retrieved from http://www.jstor.org/stable/661862
26. Li, W., Hai, X., Han, L., Mao, J., & Tian, M. (2020). Does urbanization intensify regional water scarcity? Evidence and implications from a megaregion of China. *Journal of Cleaner Production, 244*, 118592. doi:https://doi.org/10.1016/j.jclepro.2019.118592
27. Lipus, A. C., Leon, J. S., Calle, S. C., & Andes, K. L. (2018). "It Is Not Natural Anymore": Nutrition, Urbanization, and Indigenous Identity on Bolivia's Andean Plateau. *Qualitative Health Research, 28*(11), 1802-1812. doi:10.1177/1049732318761862
28. Malik, V. S., & Hu, F. B. (2019). Sugar-Sweetened Beverages and Cardiometabolic Health: An Update of the Evidence. *Nutrients, 11*(8).
29. Malik, V. S., Pan, A., Willett, W. C., & Hu, F. B. (2013). Sugar-sweetened beverages and weight gain in children and adults: a systematic review and meta-analysis. *The American Journal of Clinical Nutrition, 98*(4), 1084-1102. doi:10.3945/ajcn.113.058362
30. Malik, V. S., Popkin, B. M., Bray, G. A., Després, J. P., Willett, W. C., & Hu, F. B. (2010). Sugar-sweetened beverages and risk of metabolic syndrome and type 2 diabetes: a meta-analysis. *Diabetes Care, 33*(11), 2477-2483.
31. Mamani-Ortiz, Y., San Sebastián, M., Armaza, A. X., Luizaga, J. M., Illanes, D. E., Ferrel, M., & Mosquera, P. A. (2019). Prevalence and determinants of cardiovascular disease risk factors using the WHO STEPS approach in Cochabamba, Bolivia. *BMC Public Health, 19*(1), 786.

32. Mekonnen Mesfin, M., & Hoekstra Arjen, Y. (2016). Four billion people facing severe water scarcity. *Science Advances, 2*(2), e1500323. doi:10.1126/sciadv.1500323
33. Moszynski, P. (2006). Worldwide water crisis is a "silent emergency," UN agency says. *BMJ (Clinical research ed.), 333*(7576), 986-986. doi:10.1136/bmj.333.7576.986-a
34. Onufrak, S. J., Park, S., Sharkey, J. R., & Sherry, B. (2014). The relationship of perceptions of tap water safety with intake of sugar-sweetened beverages and plain water among US adults. *Public Health Nutrition, 17*(1), 179-185. doi:10.1017/S1368980012004600
35. Owen, N., Sparling, P. B., Healy, G. N., Dunstan, D. W., & Matthews, C. E. (2010). Sedentary behavior: emerging evidence for a new health risk. *Mayo Clin Proc, 85*(12), 1138-1141. doi:10.4065/mcp.2010.0444
36. Piperata, B. A., Lee, S., Mayta Apaza, A. C., Cary, A., Vilchez, S., Oruganti, P., . . . Lee, J. (2020). Characterization of the gut microbiota of Nicaraguan children in a water insecure context. *Am J Hum Biol, 32*(1), e23371. doi:10.1002/ajhb.23371
37. Popkin, B. M. (1994). The nutrition transition in low-income countries: an emerging crisis. *Nutr Rev, 52*(9), 285-298. doi:10.1111/j.1753-4887.1994.tb01460.x
38. Popkin, B. M., Adair, L. S., & Ng, S. W. (2012). Global nutrition transition and the pandemic of obesity in developing countries. *Nutr Rev, 70*(1), 3-21.
39. Rangecroft, S., Harrison, S., Anderson, K., Magrath, J., Castel, A. P., & Pacheco, P. (2013). Climate change and water resources in arid mountains: an example from the Bolivian Andes. *Ambio, 42*(7), 852-863.
40. Ritchie, H., & Roser, M. (2020). CO_2 and Greenhouse Gas Emissions.
41. Ronto, R., Wu, J. H., & Singh, G. M. (2018). The global nutrition transition: trends, disease burdens and policy interventions. *Public Health Nutr, 21*(12), 2267-2270. doi:10.1017/s1368980018000423
42. Rosinger, A., & Bethancourt, H. (2020). Chicha as Water: Traditional Fermented Beer Consumption Among Forager-Horticulturalists in the Bolivian Amazon. In (pp. 147-162).
43. Rosinger, A., Bethancourt, H., Young, S., & Schultz, A. (2021). The embodiment of water insecurity: Injuries and chronic stress in lowland Bolivia. *Social Science & Medicine, 291*, 114490. doi:10.1016/j.socscimed.2021.114490
44. Rosinger, A., & Tanner, S. (2015). Water from fruit or the river? Examining hydration strategies and gastrointestinal illness among Tsimane' adults in the Bolivian Amazon. *Public Health Nutr, 18*(6), 1098-1108. doi:10.1017/s1368980014002158
45. Rosinger, A., Tanner, S., & Leonard, W. R. (2013). Precursors to overnutrition: the effects of household market food expenditures on measures of body composition among Tsimane' adults in lowland Bolivia. *Soc Sci Med, 92*, 53-60. doi:10.1016/j.socscimed.2013.05.022
46. Rosinger, A. Y. (2018). Household water insecurity after a historic flood: Diarrhea and dehydration in the Bolivian Amazon. *Soc Sci Med, 197*, 192-202. doi:10.1016/j.socscimed.2017.12.016
47. Rosinger, A. Y. (2022). Using Water Intake Dietary Recall Data to Provide a Window into US Water Insecurity. *The Journal of Nutrition*. doi:10.1093/jn/nxac017
48. Rosinger, A. Y., Bethancourt, H., & Francis, L. A. (2019). Association of Caloric Intake From Sugar-Sweetened Beverages With Water Intake Among US Children and Young Adults in the 2011-2016 National Health and Nutrition Examination Survey. *JAMA Pediatrics, 173*(6), 602-604. doi:10.1001/jamapediatrics.2019.0693
49. Rosinger, A. Y., Bethancourt, H. J., Young, S. L., & Schultz, A. F. (2021). The embodiment of water insecurity: Injuries and chronic stress in lowland Bolivia. *Social Science & Medicine, 291*, 114490. doi:https://doi.org/10.1016/j.socscimed.2021.114490
50. Rosinger, A. Y., & Young, S. L. (2020). The toll of household water insecurity on health and human biology: Current understandings and future directions. *WIREs Water, 7*(6), e1468. doi:https://doi.org/10.1002/wat2.1468

51. Rufener, S., Mäusezahl, D., Mosler, H. J., & Weingartner, R. (2010). Quality of drinking-water at source and point-of-consumption--drinking cup as a high potential recontamination risk: a field study in Bolivia. *J Health Popul Nutr, 28*(1), 34-41.
52. Sarkar, A., Hanrahan, M., & Hudson, A. (2015). Water insecurity in Canadian Indigenous communities: some inconvenient truths. *Rural Remote Health, 15*(4), 3354.
53. Stevenson, E. G. J., Greene, L. E., Maes, K. C., Ambelu, A., Tesfaye, Y. A., Rheingans, R., & Hadley, C. (2012). Water insecurity in 3 dimensions: An anthropological perspective on water and women's psychosocial distress in Ethiopia. *Social Science & Medicine, 75*(2), 392-400. doi:https://doi.org/10.1016/j.socscimed.2012.03.022
54. Stoler, J., Pearson, A. L., Staddon, C., Wutich, A., Mack, E., Brewis, A., . . . Zinab, H. (2020). Cash water expenditures are associated with household water insecurity, food insecurity, and perceived stress in study sites across 20 low- and middle-income countries. *Science of The Total Environment, 716*, 135881. doi:https://doi.org/10.1016/j.scitotenv.2019.135881
55. Templin, T., Cravo Oliveira Hashiguchi, T., Thomson, B., Dieleman, J., & Bendavid, E. (2019). The overweight and obesity transition from the wealthy to the poor in low- and middle-income countries: A survey of household data from 103 countries. *PLOS Medicine, 16*(11), e1002968. doi:10.1371/journal.pmed.1002968
56. Thompson, A. L., Nicholas, K. M., Watson, E., Terán, E., & Bentley, M. E. (2020). Water, food, and the dual burden of disease in Galápagos, Ecuador. *Am J Hum Biol, 32*(1), e23344.
57. Thurber, K. A., Long, J., Salmon, M., Cuevas, A. G., & Lovett, R. (2020). Sugar-sweetened beverage consumption among Indigenous Australian children aged 0-3 years and association with sociodemographic, life circumstances and health factors. *Public Health Nutr, 23*(2), 295-308. doi:10.1017/s1368980019001812
58. Webb, P., Stordalen, G. A., Singh, S., Wijesinha-Bettoni, R., Shetty, P., & Lartey, A. (2018). Hunger and malnutrition in the 21st century. *Bmj, 361*, k2238. doi:10.1136/bmj.k2238
59. Wutich, A., & Brewis, A. (2014). Food, Water, and Scarcity: Toward a Broader Anthropology of Resource Insecurity. *Current Anthropology, 55*(4), 444-468. doi:10.1086/677311
60. Young, S. L., Boateng, G. O., Jamaluddine, Z., Miller, J. D., Frongillo, E. A., Neilands, T. B., . . . Stoler, J. (2019). The Household Water InSecurity Experiences (HWISE) Scale: development and validation of a household water insecurity measure for low-income and middle-income countries. *BMJ Global Health, 4*(5), e001750. doi:10.1136/bmjgh-2019-001750
61. Zycherman, A. (2015). Shocdye' as World. *Food, Culture & Society, 18*(1), 51-69. doi:10.2752/175174415X14101814953684

ACADEMIC VITA

Siddhi M. Deshpande

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EDUCATION

The Pennsylvania State University, Schreyer Honors College

- Neurobiology (B.S.), World Literature & Global Health (minors) Graduation: May 2022

RELEVANT EXPERIENCE

Neurobiology Teaching Assistant, Penn State University; August - December 2021

- Served as sole teaching assistant for a lecture course of 80+ students; assisted in classroom operations, held weekly office hours, exam review sessions, created study materials, and assisted students on 1:1 basis (10 hrs/wk).
- Synthesized and presented complex subject matter to students to aid their understanding of neurobiology

Undergraduate Research Assistant, Penn State University; Jan 2020 - present

- I work in the Water, Health, and Nutrition lab with Dr. Asher Rosinger (6 hrs/wk) to study the effect of water quality and availability on human health.
- Contributed to an interdisciplinary PA Water project to study water insecurity among private water users and effects on human health.
- Currently writing honors thesis studying nutrition transition and consumption of sugar-sweetened beverages as a hydration strategy among Bolivian Tsimane'.

STEER Summer Intern, Perelman School of Medicine at the University of Pennsylvania*;* June - August 2021

- Selected for a paid summer internship program (40 hrs/wk) at the Center of Excellence for Environmental Toxicology (CEET).
- Under mentorship of Dr. Jeffrey Field, conducted an investigation of the impact of PM 2.5 air quality on asthma hospitalization rates in Pennsylvania, in association with hydraulic fracturing. Presented findings virtually upon completion.

At-Large Representative, University Park Undergraduate Association at Penn State; September 2020-April 2021.

- One of 20 At-Large representatives for the Penn State student body (5-10 hrs/wk)
- Sat on the committee of Justice and Equity, where I worked on initiatives to create a student health equity fund (starting at $10,000) and writing climate legislation for divestment.

Undergraduate Research Assistant, Warren Alpert Medical School of Brown University; June - August 2019

- with Dr. Euy-Myong Jeong in the Olin Liang lab; conducted CRISPR/Cas 9 knockout of *Runx1* and *Sox17* genes regulating Pulmonary Hypertension. For 40 hrs/wk, led student project of designing oligomers for KO and learned foundational wet lab techniques such as Western blotting. Presented a poster at the Brown Undergraduate Research Symposium.

CLINICAL & SERVICE EXPERIENCE

Emergency Medical Technician, Centre Lifelink EMS and Penn State EMS; State College, PA; 650 hours

- On Penn State's student-run University Ambulance Service, have responded to 100+ 911 calls on campus and provided BLS assessment, treatment, and transport to patients for 40 hrs/wk. Also participate in training of volunteer EMTs to prepare them for promotion.

Classroom Aide & Junior Camp Counselor at Dorcas International Institute of RI, Providence, RI; 2017 & 2019

- In 2017, I worked at Camp Newcomer run by Dorcas International as a camp counselor to help acclimate refugee children to the United States (250 hrs). Duties ranged from giving English and Math help to providing social support and mentorship. In 2019, returned to Dorcas to provide 1:1 GED exam tutoring to adults 18-70 of refugee/underserved backgrounds (30 hrs).

LEADERSHIP EXPERIENCE

Sunrise Movement State College, Hub Co-founder and Leader; State College, PA; August 2019 - present

- Cultivated my passion for environmental activism by bringing Sunrise Movement to State College; Sunrise advocates for systemic action against the climate crisis. As lead, I planned 10+ local climate events, forged partnerships with local politicians and organizations, led meetings and most importantly motivated Hub members to continue their advocacy.

Schreyer Honors College Medical Career Development Team; Team Lead, Spring 2019 - present

- Work with a small committee to host 10 career-oriented trips/events per year for honors pre-medical students.

Scholar Ambassador; Spring 2019-present

- Acting as a tour guide and representative for the Schreyer Honors College to prospective students and alumni.

HONORS

Semifinalist, Fulbright Fellowship	**2022**
Member, Phi Beta Kappa	**2021**
Dean's List, all semesters	**2020**
National Merit Foundation, Letter of Commendation	**2017**