Assessing the Impact of Water, Sanitation, and Hygiene (WASH) on Household Food Insecurity and Nutritional Outcomes of Women and Children in Nepal
A Three Paper Dissertation

by

Yashu Sapkota

A dissertation submitted to the Graduate Faculty of
Auburn University
in partial fulfillment of the
requirements for the Degree of
Doctor of Philosophy

Auburn, Alabama
August 9, 2025

Keywords: Body Mass Index (BMI), Demographic & Health Survey (DHS),
Food security, Stunting, Undernutrition, Wasting

Approved by

James Lindner, Chair, Alumni Professor, Curriculum and Teaching
Christopher Clemons, Associate Professor, Curriculum and Teaching
Jason McKibben, Assistant Professor, Curriculum and Teaching
Joseph Molnar, Alumni Professor, Agricultural Economics and Rural Sociology

Abstract

This study explores the relationship between Water, Sanitation, and Hygiene (WASH) conditions and three critical public health outcomes in Nepal: household food insecurity, child malnutrition, and women's nutritional status. Using data from the 2022 Nepal Demographic and Health Survey (DHS), we analyze how WASH factors influence food security, child nutrition, and women's Body Mass Index (BMI) across diverse populations.

Among the 13,786 households surveyed, 6,007 were classified as food insecure. Households relying on spring water experienced the highest levels of food insecurity, while those with on-premises drinking water, private sanitation, and handwashing resources had lower food insecurity levels. Ordinary least squares regression confirmed that the presence of soap, water treatment, and improved sanitation significantly reduced food insecurity, whereas poverty and shared sanitation facilities increased the risk.

Further analysis examined the impact of WASH on child malnutrition among children aged 0–59 months. Binary logistic regression results revealed that water on-premises was protective against stunting, while children from poor and middle-income households had higher odds of being stunted or underweight. Urban residence was associated with lower odds of stunting and underweight, but wasting was more prevalent in urban areas. Additionally, access to piped water reduced the likelihood of underweight and wasting, while a higher number of young children in a household increased the probability of stunting and being underweight.

The study also assessed the association between WASH conditions and women's BMI among 6,291 non-pregnant women aged 15–49. Multinomial logistic regression results indicated that women with access to water on premises and piped water had higher odds of being overweight or obese. Additionally, women from non-Hindu and non-Brahmin/Chhetri ethnic

groups, those with access to flush toilets, and those residing in urban areas were more likely to be overweight or obese.

These findings underscore the role of WASH infrastructure in shaping food security, child nutrition, and women's health outcomes in Nepal. Strengthening WASH infrastructure and addressing socioeconomic disparities through integrated policy interventions may thus improve food insecurity, child malnutrition, and women nutrition.

Acknowledgments

I would like to express my sincere gratitude to my advisor, Dr. James Lindner, for his mentorship, patience, and unwavering support throughout my academic journey at Auburn University. His guidance has been invaluable in shaping my research and professional growth. I am also deeply appreciative of my committee members, Dr. Christopher Clemons and Dr. Jason McKibben, as well as my university reader, Dr. Frances O'Donnell, for their thoughtful feedback and encouragement.

A special acknowledgment goes to Dr. Joseph Molnar, whose expertise, guidance, and generous support were instrumental in the completion of this dissertation. His mentorship and willingness to provide critical insights greatly enriched my research, and I am profoundly grateful for his belief in my work and dedication to my academic success.

I also extend my appreciation to Dr. George Flowers, Dean of the Graduate School, and Dr. Maria Witte, Associate Dean of the Graduate School, whose support was pivotal in the completion of this dissertation. I am also deeply grateful to the faculty, students, and staff of the Graduate School, as well as the Departments of Curriculum and Teaching and Agricultural Economics and Rural Sociology, for their support.

Finally, I want to express my deepest gratitude to my family for their unwavering love, patience, and encouragement. Their belief in me has been my greatest source of strength throughout this journey.

Table of Contents

List of Tables

List of Figures

List of Abbreviations

BMI	Body Mass Index
CDC	Centers for Disease Control and Prevention
DHS	Demographic and Health Survey
FAO	Food and Agriculture Organization
FIES	Food Insecurity Experience Scale
HAZ	Height-for-Age
UNICEF	United Nations International Children's Emergency Fund
USAID	United States Agency for International Development
WASH	Water, Sanitation, and Hygiene
WAZ	Weight-for-Age
WFP	World Food Program
WHZ	Weight-for-Height
WHO	World Health Organization

Introduction to the Dissertation

Water, Sanitation, and Hygiene (WASH)

WASH refers to the provision of safe drinking water, sanitation facilities for waste disposal, and hygiene promotion to support healthy behaviors and well-being (World Health Organization, 2025). Securing sufficient access to safe water, sanitation, and hygiene (WASH), stands as a global health and development objective owing to its enduring and significant role in diminishing morbidity and mortality rates (Food and Agriculture Organization of the United Nations et al., 2018). Unsafe WASH increases the risk of diarrhea, chronic undernutrition, and childhood stunting (Wolf et al., 2023). WASH intervention can provide benefits in addressing maternal and child malnutrition (Keats et al., 2021). A positive impact of WASH interventions was observed on linear growth in children under five years old (Dangour et al., 2013). However, other study found no association found between WASH interventions with the prevention of acute malnutrition or the improvement of its treatment outcomes among children (Patlán-Hernández et al., 2022).

In Nepal, 89% of the population has access to basic water supply services, and 62% have access to basic sanitation facilities. Nonetheless, ensuring safe water quality at the point of consumption and promoting adequate hygiene practices remain significant challenges (A. Shrestha et al., 2020). A recent estimate suggests that only 16% of the population in Nepal are using safely managed drinking water, 51% are using sanitation services, and 64% have a handwashing facility with soap and water available at home (United Nations Water, 2025). Improving WASH conditions may enhance food security and the nutritional status of children and women in Nepal. However, research exploring this association remains scarce. Therefore, this study utilizes the recently published 2022 Nepal Demographic and Health Survey (DHS) data to examine the relationship between WASH and household food security/insecurity, as well as malnutrition among children and Body Mass Index (BMI) as a measure of nutritional status among women in Nepal.

Food Security/Insecurity

According to the United States Agency for International Development (USAID), food security means having at all times, both physical and economic access to sufficient food to meet dietary needs for a productive and healthy life (United States Agency for International Development, 2023). On the other hand, the United States Department of Agriculture (USDA) defines food insecurity as a household-level economic and social condition of limited or uncertain access to adequate food (United States Agency for International Development, 2022).[1]

Nepal recognized food security as a fundamental human right for all citizens in its interim constitution (2006/07)(Singh et al., 2014). However, only half of the households in Nepal are food secure (48%) and have access to food year-round (Ministry of Health et al., 2017). Among food-insecure households (52%), 20% are mildly food insecure, 22% are moderately food insecure, and 10% are severely food insecure (Maharjan & Joshi, 2011; Ministry of Health et al., 2017). This 10% of the severely food-insecure population is neither able to meet their household food requirement nor have sufficient income to procure the deficit food (Maharjan & Joshi, 2011). According to the World Food Program (WFP), food security status in June 2022 improved slightly

---

[1] Ranges/classification of food security:
High food security (old label = Food security): no reported indications of food-access problems or limitations.
Marginal food security (old label = Food security): one or two reported indications—typically of anxiety over food sufficiency or shortage of food in the house. Little or no indication of changes in diets or food intake.
Food Insecurity
Low food security (old label = Food insecurity without hunger): reports of reduced quality, variety, or desirability of diet. Little or no indication of reduced food intake.
Very low food security (old label = Food insecurity with hunger): reports of multiple indications of disrupted eating patterns and reduced food intake (United States Department of Agriculture. (2025). Food Security in the U.S. - Definitions of Food Security. Retrieved April 7, 2025 from https://www.ers.usda.gov/topics/food-nutrition-assistance/food-security-in-the-us/definitions-of-food-security).

compared to October 2021; however, despite this improvement, approximately 3.86 million people (13.2%) in Nepal were not consuming an adequate diet (World Food Programme, 2022).

In Nepal, ensuring safe water quality at the point of consumption and promoting adequate hygiene practices remain significant challenges (A. Shrestha et al., 2020). Improving water, sanitation, and hygiene (WASH) conditions and practices could potentially prevent malnutrition-related child deaths, as intestinal parasites and diarrhea incidence among children are strongly associated with stunting and physical weakness (A. Shrestha et al., 2020). Cunninghams and colleagues observed that one of the factors for maternal and child nutritional improvements in Nepal was increased coverage and use of toilets (Cunningham et al., 2017). This indicates the linkages between water and the important determinants of food security (Young et al., 2021). However, literature has overlooked the significance of water in food security, nutrition, and overall well-being (Young et al., 2021). Acknowledging the need for a comprehensive analysis of the relationship between WASH and household food security/insecurity in Nepal, this study examines the association between household food insecurity and WASH variables, accounting for socio-demographic characteristics.

Malnutrition

The World Health Organization (WHO) defines malnutrition as “deficiencies, excesses or imbalances in a person’s intake of energy and/or nutrients” (World Health Organization, 2024a). Malnutrition encompasses two main categories of conditions. The first is undernutrition, which includes stunted growth (inadequate height for age), wasting (insufficient weight for height), being underweight (low weight for age), and deficiencies or insufficiencies of essential vitamins and minerals. The second category involves excess nutrition, including overweight and obesity.[2]

[2] Stunting

Nepal has one of the highest rates of child malnutrition in the world, with around 36% of children under five years of age being stunted (Adhikari et al., 2019). Nepal Demographic and Health Survey Report 2016 stated that the prevalence of stunting, wasting, underweight, and overweight among children younger than 5 years was 35.8%, 11%, 27%, and 1% respectively (Ministry of Health et al., 2017). The prevalence of wasting also increases with the level of food insecurity: from mild (9.4%) to moderate (10.8%) and to severe (11.3%) (Nepali et al., 2020). Children residing in households experiencing severe food insecurity exhibited a higher likelihood of being underweight or stunted in comparison to those from food-secure households (Singh et al.,

---

1) Severely stunted: Number of children age 0-59 months whose height-for-age z-score is below minus 3 (-3.0) standard deviations (SD) below the median on the WHO Child Growth Standards (hc70 < -300)
2) Moderately or severely stunted: Number of children age 0-59 months whose height-for-age z-score is below minus 2 (-2.0) standard deviations (SD) below the median on the WHO Child Growth Standards (hc70 < -200)

Mean z-score for height-for-age: Sum of the z-scores of children age 0-59 months with a non-flagged height for age score (∑ hc70/100, if hc70 < 9990)

Wasting and overweight:
1) Severely wasted: Number of children age 0-59 months whose weight-for-height z-score is below minus 3 (-3.0) standard deviations (SD) below the median on the WHO Child Growth Standards (hc72 < -300)
2) Moderately or severely wasted: Number of children age 0-59 months whose weight-for-height z-score is below minus 2 (-2.0) standard deviations (SD) below the median on the WHO Child Growth Standards (hc72 < -200)
3) Overweight: Number of children age 0-59 months whose weight-for-height z-score is above plus 2 (+2.0) standard deviations (SD) above the median on the WHO Child Growth Standards (hc72 > 200 & hc72 < 9990)

Mean z-score for weight for height: Sum of the z-scores of children age 0-59 months with a non-flagged weight for height score (∑ hc72/100, if hc72 < 9990)

Underweight and overweight for age:
1) Severely underweight: Number of children age 0-59 months whose weight-for-age z-score is below minus 3 (-3.0) standard deviations (SD) below the median on the WHO Child Growth Standards (hc71 < -300)
2) Moderately underweight: Number of children age 0-59 months whose weight-for-age z-score is below minus 2 (-2.0) standard deviations (SD) below the median on the WHO Child Growth Standards (hc71 < -200)
3) Overweight for age: Number of children whose weight-for-age z-score is above plus 2 (+2.0) standard deviations (SD) above the mean on the WHO Child Growth Standards (hc71 > 200 & hc71 < 9990) (legacy indicator)

Mean z-score for weight for age: Sum of the z-scores of children age 0-59 months with a non-flagged weight for age score (∑ hc71/100, if hc71 < 9990)

(United States Agency for International Development. (2025). Guide to DHS Statistics DHS-8: Nutritional Status. Retrieved 4/2/2025 from https://dhsprogram.com/data/Guide-to-DHS-Statistics/Nutritional_Status.htm)

2014). A previous study suggests that food insecurity and hunger can have a range of adverse health and social implications, including an increased risk of malnutrition, susceptibility to multiple infections, chronic illnesses, impaired physical health and wellbeing, hindered learning, and poor mental health (Singh et al., 2021). Additionally, malnutrition can have lifelong consequences, such as psychosocial dysfunction in children, cognitive impairment, poor physical health, socio-familial problems, and reduced productivity (Chemjong & KC, 2020). Thus, given the high burden of malnutrition among children in Nepal, there is a need to examine the association between WASH intervention and malnutrition.

Nepal has one of the highest childhood undernutrition prevalence rates in the South Asian region (United Nations Children's Fund South Asia, 2019). According to the Nepal Demographic and Health Survey (DHS) 2022, 25% of children under five were stunted, 8% were wasted, and 19% were underweight (Ministry of Health et al., 2022). Previous studies have explored the relationship between WASH practices and child nutrition. For instance, one study examined WASH practices and their impact on child health and nutritional status (Shrestha et al., 2022). Their findings indicated significant improvements in WASH practices, including increased handwashing and better water quality, which contributed to a reduction in infectious diseases such as fever, respiratory illness, and diarrhea. However, the limited geographic scope of the study restricts its generalizability to the national level.

Similarly, another study utilized data from the 2016 DHS to investigate the association between WASH variables and preschool child undernutrition, finding a positive relationship between enhanced WASH practices and improved nutritional outcomes among children under five (S. K. Shrestha et al., 2020). With the rapid advancements in WASH practices in Nepal and the availability of updated 2022 DHS data, a comprehensive investigation is needed to reassess the association between WASH conditions and childhood undernutrition at the national level. Therefore, this study examines the relationship between WASH variables and the nutritional status (stunting, wasting, and undernutrition) of children aged 0–59 months while controlling for household sociodemographic characteristics.

Body Mass Index (BMI)

BMI is a measure of weight to height and serves as a quick, cost-effective, and reliable screening tool for identifying underweight, overweight/ obese (Centers for Disease Control and Prevention, 2024). It is widely used as a population health indicator across the globe. BMI was categorized into three categories: underweight (< 18.5 kg/m^2), normal (18.5 to 24.9 kg/m^2), and overweight/obese (>= 25 kg/m^2).

Food insecurity impacted 41.5% of women of reproductive age in Nepal (Aung, 2024). As per the Nepal DHS 2016, approximately 17% of women of reproductive age (15–49 years) were underweight, with a BMI below 18.5 kg/m^2 (Ministry of Health et al., 2017). Women from severely food-insecure households in Nepal are significantly more likely to be underweight than women from food-secure households (Singh et al., 2014). Dalit women were 82%, 85%, 92% more vulnerable to food insecurity than Muslims, Brahmin/Chhetri, Terai indigenous, and hill population (Pandey & Fusaro, 2020). However, other studies suggest that household food security was not associated with underweight or overweight/obesity among reproductive age women in Nepal (Rai et al., 2019).

Previous studies have highlighted indirect links, such as reduced exposure to contaminated water through piped water systems, leading to a lower incidence of diarrheal diseases (Cunningham et al., 2016; Mehata et al., 2022; Pandey et al., 2020). Additionally, improvements in sanitation and hygiene have been associated with maternal weight gain in

Nepal from 1996 to 2011. Prior research also found that among non-pregnant women, access to piped water was positively associated with BMI (Cunningham et al., 2017) and negatively associated with low maternal BMI (Headey & Hoddinott, 2015). While access to clean water, improved sanitation, and proper hygiene are essential for overall health and nutrition, their direct impact on women's nutritional status has not been extensively studied. Therefore, this study investigates the relationship between WASH variables and the nutritional status (BMI) of non-pregnant women aged 15–49 years, while accounting for household sociodemographic characteristics using 2022 DHS data for Nepal.

Knowledge Gap/Problem Statement

There is limited understanding of the WASH along with other socio-economic factors as the household determinants of food security in Nepal (Young et al., 2021). Understanding the determinants of food security can help identify and address the root causes of food insecurity, such as poverty, access to food, and availability of food that in turn can be used by the policy makers to fulfill the basic human right and met the goal of sustainable development to end hunger by 2030 (Chemjong & KC, 2020).

Previously, attempts have been made to establish the association between WASH and food insecurity and child and maternal nutrition in Nepal. Sarkar and colleagues (2022) observed an association between sanitation and hygiene with food insecurity in the Kathmandu valley of Nepal (Sarkar et al., 2022). Studies also examined several social determinants of household food security (Chemjong & KC, 2020; Maharjan & Khatri-Chhetri, 2006; Maharjan & Joshi, 2011; Regmi et al., 2019).

WASH practices were positively associated with improved nutritional outcomes among children under five in Nepal (S. K. Shrestha et al., 2020). Households regularly washing hands and better water quality led to fewer cases of infectious diseases like fever, respiratory illness, and diarrhea among children (Shrestha et al., 2022).

Analysis from 1990 to 2011 Nepal DHS data showed, improved water source (piped water) was positively associated with improved maternal BMI (Cunningham et al., 2017; Cunningham et al., 2016). Better sanitation and hygiene contributed to the 35% change in maternal weight gain (Cunningham et al., 2016). A positive relationship was also observed between improved sanitation and the likelihood of being overweight/obese (Cunningham et al., 2016; Headey & Hoddinott, 2015).

However, the narrow focus of previous studies, primarily limited to city-level analyses, restricts their generalizability. Moreover, Nepal has undergone significant advancements in WASH interventions, maternal and child nutrition programs, and food security policies over the past decade, emphasizing the need for an updated examination. Thus, utilizing the recently available 2022 DHS data (United States Agency for International Development, 2024), this study aims to investigate the association between WASH variables and household food insecurity, childhood (0–59 months) malnutrition, and women's (15–49 years) nutritional status. The 2022 DHS dataset provides nationally representative and up-to-date information, enabling a more precise and comprehensive assessment of WASH with food insecurity and nutrition outcomes.

Purpose

The purpose of this quantitative, non-experimental, cross-sectional study was to investigate the relationship between WASH variables with household food insecurity, malnutrition among children aged 0-59 months, and women's (aged 15-49) nutrition as measured by BMI, using 2022 DHS data for Nepal. Sociodemographic variables, such as age, place of residence, religion, ethnicity, and wealth index, will be used as covariates.

Significance of Study

This study provides a comprehensive analysis of the relationship between WASH conditions and key indicators of food security and nutrition in Nepal, addressing critical gaps in the existing literature. By utilizing the most recent 2022 Nepal DHS data, this study offers updated insights into how WASH factors influence household food insecurity, child malnutrition (stunting, wasting, and underweight), and women's nutritional status as measured by BMI.

Understanding the root causes of food insecurity and the factors that influence food security can help build more stable and resilient societies, inform policy development, and support evidence-based interventions aimed at improving food security for vulnerable populations in Nepal. The findings will provide valuable insights for policymakers, enabling them to develop targeted policies and interventions that integrate WASH improvements with food security strategies. Additionally, this study will support efforts to enhance nutritional outcomes for children and women, further strengthening Nepal’s public health and development initiatives.

Three Papers

1. Water, Sanitation, and Hygiene (WASH): Impacts on Household Food Insecurity in Nepal
2. Water and Sanitation Conditions as Determinants of Stunting, Undernutrition, and Wasting Among Young Children in Nepal
3. Water, Sanitation, and Hygiene Conditions as Determinants of Body Mass Index (BMI) Among Nonpregnant Women Aged 15-49 Years in Nepal

Paper 1: Water, Sanitation, and Hygiene (WASH): Impacts on Household Food Insecurity in Nepal

Abstract

This study examines the relationship between water, sanitation, and hygiene (WASH) conditions and household food insecurity in Nepal using data from the 2022 Nepal Demographic and Health Survey (NDHS). Among the 13,786 households surveyed, 6,007 were classified as food insecure. Households relying on protected and unprotected spring water experienced the highest levels of food insecurity, while those with on-premises drinking water, private sanitation, and handwashing resources had lower food insecurity levels. Ordinary least squares regression confirmed that the presence of soap, water treatment, and improved sanitation were significantly associated with reduced food insecurity, whereas poverty and shared sanitation facilities increased the risk. These findings underscore the critical role of WASH in shaping food security outcomes in Nepalese households. Strengthening WASH infrastructure and addressing socioeconomic disparities through integrated policy interventions are essential to mitigating food insecurity in Nepal.

Keywords: Demographic Health Survey (DHS), Food Insecurity, Nepal, Water, Sanitation, and Hygiene (WASH)

Introduction

Nepal recognized food security as a fundamental human right for all citizens in its interim constitution (2006/07) (Singh et al., 2014), However, only half of the households in Nepal are food secure (48%) and have access to food year-round (Ministry of Health et al., 2017). Among food-insecure households (52%), 20% are mildly food insecure, 22% are moderately food insecure, and 10% are severely food insecure (Maharjan & Joshi, 2011; Ministry of Health et al., 2017). This 10% of the severely food-insecure population is neither able to meet their household food requirements nor have sufficient income to procure enough food (Maharjan & Joshi, 2011).

According to the World Food Program (WFP), food security status in June 2022 improved slightly compared to October 2021; however, despite this improvement, approximately 3.86 million people (13.2%) in Nepal were not consuming an adequate diet (World Food Programme, 2022). According to the Global Hunger Index 2024, Nepal ranked 68 out of 127 countries (Concern Worldwide and Welthungerhilfe, 2024). Food insecurity and hunger can have a range of negative health and social implications, including an increased risk of malnutrition, susceptibility to multiple infections, chronic illnesses, impaired physical health and well-being, hindered learning, and poor mental health (Singh et al., 2021).

Previous studies have suggested that food security in Nepal is determined by various factors such as income, unemployment, agricultural productivity, less number of livestock holdings, access to market, social protection, age of the household head, geographic locations such as households in Mountain and Hill, climate variability, gender, family size, and education levels (Chemjong & KC, 2020; Maharjan & Khatri-Chhetri, 2006; Maharjan & Joshi, 2011; Regmi et al., 2019).

Regmi and colleagues suggest the size of the family, gender, age, and education levels, as well as land ownership, household income, receipt of remittances, and improved access to markets and roads were found to be strongly correlated with food security (Regmi et al., 2019). Additionally, they also observe that food insecure is relatively more prevalent in rural areas with higher dependent on rainfed agriculture, higher dependency ratio and larger family size (Ministry of Health et al., 2017). Food insecurity is particularly common in remote and low-productive rural areas dependent on rainfed subsistence agriculture. Severe food insecurity affects about 12% of the rural population compared to 9% in urban areas and 14% in the Mountain zone compared to 9% in the Terai zone (Ministry of Health et al., 2017).

According to the Food and Agriculture Organization (FAO), there are four main dimensions of food security: 1) Physical availability of food, 2) Economic and physical access of food, 3) Food utilization, and 4) Stability (vulnerability and shocks) over time (Food and Agriculture Organization of the United Nations, 2013). This underscores that household food security status is influenced not only by factors like availability, economics, and stability but also by food utilization. Water sources and Sanitation facilities are the indicators for the utilization and thus ultimately the food security (Food and Agriculture Organization of the United Nations, 2013). Access to safe drinking water is defined as the percentage of the population having access to and using improved drinking water sources.

Basic sanitation refers to the provision of facilities enabling safe disposal of human waste (feces and urine) and the ability to uphold hygienic standards through services such as treatment and disposal of wastewater (Centers for Disease Control and Prevention, 2022b). Hygiene standards encompass practices that enhance cleanliness and promote good health, including regular handwashing, maintaining facial cleanliness, and bathing using soap and water (Centers for disease Control and Prevention, 2022a).

WASH plays a multifaceted role in addressing food insecurity. Inadequate water and sanitation lead to higher burden of enteric diseases which impair nutrient absorption and exacerbate child malnutrition thereby worsening food insecurity (Workman et al., 2022). Access to safe drinking water promotes food safety through proper sanitation practices, and enhancing nutritional outcomes through improved hygiene behaviors, thereby contributing to reduced food contamination, and better health and nutrition outcomes.

In Nepal, while 89% of the population has access to basic water supply services and 62% have access to basic sanitation facilities, ensuring safe water quality at the point of consumption and promoting adequate hygiene practices remain significant challenges (A. Shrestha et al., 2020). Improving water, sanitation, and hygiene (WASH) conditions and practices could potentially prevent malnutrition-related child deaths. Intestinal parasites and diarrhea incidence among children are strongly associated with stunting and physical weakness (A. Shrestha et al., 2020).

Cunninghams et al. (2017) observed that one of the factors in improving the nutritional status of mothers and children in Nepal is the increased coverage and use of toilets (Cunningham et al., 2017). This highlights the basic linkages between water and food security (Young et al., 2021). However, researchers seem to have downplayed the significance of water in food security, nutrition, and overall well-being (Young et al., 2021). Although previous studies have examined several determinants of household food security (Chemjong & KC, 2020; Maharjan & Khatri-Chhetri, 2006; Maharjan & Joshi, 2011; Regmi et al., 2019), few have investigated the impact of household water, sanitation, and hygiene conditions on food insecurity. Understanding the water-related determinants of food security clarifies the role of water insecurity in hygiene and food preparation. Thus, the relationship between WASH and food insecurity has not been well established in the context of Nepal.

Thus, the purpose of this quantitative, non-experimental, cross-sectional design study was to investigate the association of WASH as household factors affecting food insecurity, utilizing recent data from the 2022 Nepal Demographic and Health Survey (DHS). First, a conceptual framework is established based on the relationship between WASH and food insecurity. Second, I examine the data from the 2022 Nepal Demographic and Health Survey to explore the association of WASH as household factors influencing food insecurity. Finally, I articulate specific policy insights derived from the analysis.

Conceptual Framework

Global health experts also recognize that food security challenges cannot be met until safe drinking WASH are available in the world's poorest communities (WASH Advocates, 2013). Securing sufficient access to safe and nutritious food, along with WASH, stands as paramount global health and development objectives owing to their enduring and significant role in diminishing morbidity and mortality rates (Food and Agriculture Organization of the United Nations et al., 2018). However, in 2022, 2.2 billion people lacked access to uncontaminated water sources situated on their premises or were not readily available when required (World Health Organization, 2023). Moreover, over 1.5 billion individuals do not have access to basic sanitation facilities, such as personal toilets or latrines (World Health Organization, 2024c). In 2020, 2.3 billion people were without essential hygiene services, including handwashing facilities equipped with soap and water (World Health Organization, 2021).

This paper draws on concepts from previous studies to develop a fundamental relationship between WASH and food insecurity (Brewis et al., 2020; Tolossa & Tafesse, 2008; Workman et al., 2022; Young et al., 2021). Resilient water, sanitation, and hygiene systems are vital for water security and are strongly connected to food security and global health (Zavala et al., 2021). Likewise, effective WASH is essential for enhancing nutritional outcomes. The link between food security and WASH goes beyond clean water, highlighting the importance of safe sanitation and hygiene. Access to clean water alone is insufficient to improve nutrition; the entire WASH system plays a critical role (Gensch & Tillett, 2019). The relationship between individual WASH components and food insecurity is described below.

Role of Water in Food Insecurity

Several perspectives cite the role of water insecurity and food insecurity (Miller et al., 2024). Miller and colleagues argue that water scarcity can limit agricultural production, reduce crop yields, and diminish farm incomes, which in turn lowers the availability and affordability of nutrient-dense foods (Miller et al., 2024). Similarly, Tolossa and colleagues contend that lack of access to clean drinking water reduces production and productivity and deteriorates health, leading to increased food insecurity (Tolossa & Tafesse, 2008).

Cairncross and colleagues offer a financial perspective, suggesting that expenditures on obtaining safe drinking water take away funds allocated for food, exacerbating food insecurity (Cairncross & Kinnear, 1992). Schuster and colleagues examined water security from a nutritional perspective, suggesting that when water is scarce, individuals replace their preferred dishes with meals made from less diverse foods, further exacerbating food insecurity (Schuster et al., 2020). Similarly, Young and Boateng argue that water insecurity is detrimental to child feeding and nutrition (Young et al., 2021) and precedes food insecurity (Boateng et al., 2022).

Role of Sanitation in Food Insecurity

Similarly, previous studies have also highlighted the interplay between sanitation and food insecurity. Workman and colleagues suggested that illnesses arising from inadequate sanitation can diminish productivity and income, potentially leading to malnutrition and increased susceptibility to food insecurity (Workman et al., 2022). Miller and colleagues argued that adequate sanitation facilities are essential for ensuring proper disposal of human waste and minimizing the risk of water contamination and food insecurity (Miller et al., 2024). A position paper from WASH Advocates noted that although utilizing wastewater can lead to greater crop yields, it also poses an increased risk of exposure to microbial contamination, which negatively impacts food security (WASH Advocates, 2013). A USAID report also suggests that good sanitation practices reduce food contamination during production, processing, storage, and distribution, leading to a reduction in foodborne diseases such as diarrhea by at least 30 percent, thereby reducing food insecurity (United States Agency for International Development, 2013).

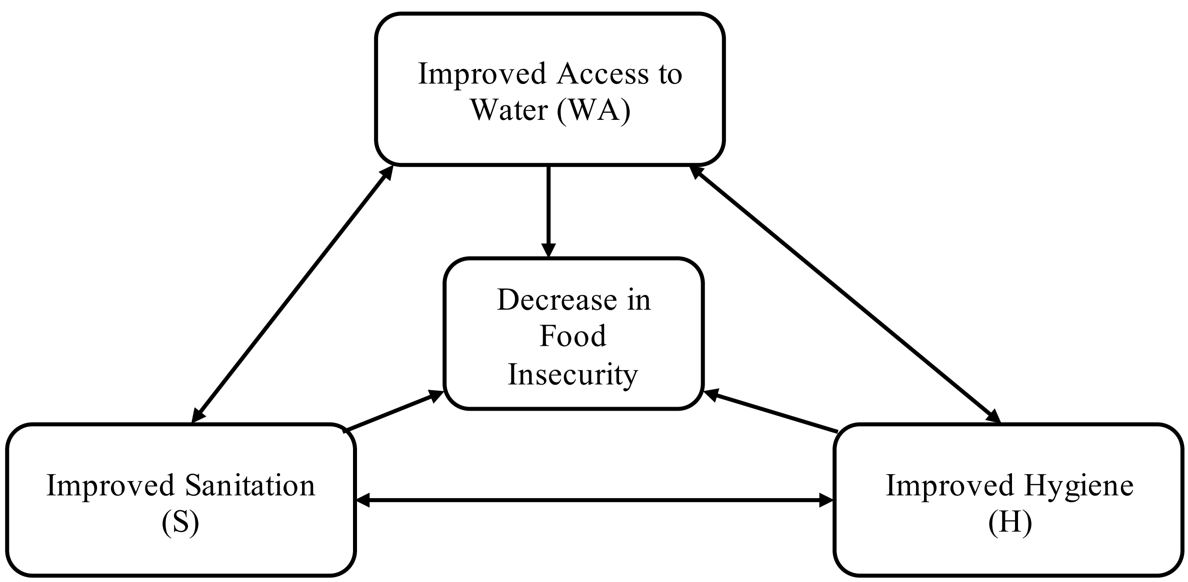

Figure 1
Nexus of WASH and Food Insecurity

Role of Hygiene in Food Insecurity

Lastly, proper hygiene behaviors have been linked to food insecurity. Shrestha and colleagues argue that handwashing and food preparation practices are critical for preventing contamination and reducing the risk of foodborne illnesses (A. Shrestha et al., 2020). Inadequate hygiene practices can lead to the transmission of pathogens, compromising food safety and deteriorating health, which contributes to food insecurity (Chemjong & KC, 2020; Food and Agriculture Organization of the United Nations et al., 2018).

Shrestha and colleagues suggest adequate hygiene behavior, such as handwashing, keeping the latrines clean, keeping the household environment free from animal feces, and assuring a reliable supply of safe water (A. Shrestha et al., 2020). Proper hygiene can make a significant difference in halting the cycle of infectious disease and undernutrition, improving sanitation, improved access to water and playing a crucial role in decreasing food insecurity.

Method

Data

This study will use the nationally representation secondary cross-sectional data, from the 2022 Nepal DHS (United States Agency for International Development, 2024). The DHS survey is conducted every five years. DHS surveys collect primary data using four types of Model Questionnaires. One such questionnaire is the Household Questionnaire, which is designed to gather details about the dwelling unit of the household, as well as the characteristics of its usual residents and visitors.

The Household Questionnaire contains information on the following topics: Household Schedule*:* For usual members of the household and visitors, information is collected about age, sex, relationship to the head of the household, education, parental survivorship and residence, and birth registration. Household characteristics: Questions inquire about the source of drinking water, toilet facilities, cooking fuel, household assets, and exposure to second-hand smoke. To capture food insecurity, a series of questions regarding household food insecurity are included in the DHS Household Questionnaire.

Measures

Dependent Variables

Food Insecurity. The main dependent variable is food insecurity. Food insecurity is assessed using the Food Insecurity Experience Scale (FIES) developed by the Food and Agriculture Organization of the United Nations (Food and Agriculture Organization of the United Nations, 2013). The FIES evaluates food insecurity on a continuous scale of severity (sum of eight question and range from 0=food secure, 1-3=mild food insecure, 4-6=moderate food insecure, 7-8=severe food insecure). In the 2022 DHS, households were asked eight questions regarding their ability to access adequate food during the preceding 12 months, and their responses were used to calculate the prevalence and severity of food insecurity experienced at the household level.

In this study, we conducted factor analysis, specifically Principal Component Analysis (PCA), on all eight questions: 1) Was there a time when you were worried you would not have enough food to eat because of a lack of money or other resources? 2) Was there a time when you were unable to eat healthy and nutritious food because of a lack of money or other resources? 3) Was there a time when you ate only a few kinds of foods because of a lack of money or other resources? 4) Was there a time when you had to skip a meal because there was not enough money or other resources to get food? 5) Was there a time when you ate less than you thought you should because of a lack of money or other resources? 6) Was there a time when your household ran out of food because of a lack of money or other resources? 7) Was there a time when you were hungry but did not eat because of a lack of money or other resources for food? 8) Was there a time when you went without eating for a whole day because of a lack of money or other resources?

The PCA results suggest that one of the eight questions, "Was there a time when you went without eating for a whole day because of a lack of money or other resources?" has a lower loading compared to the other questions. Therefore, this study utilized seven questions, effectively measuring the food insecurity status. Subsequently, we aggregated responses from these seven questions to create a new variable representing food security/insecurity status (0=food secure, >0=food insecure). Aggregate response was the sum of seven individual responses. This study included only households experiencing food insecurity (food insecurity>0).

Independent Variables

Water Access. Access to water was measured using multiple questions: "What is the main source of drinking water for members of your household?" (Piped into dwelling, piped to yard/plot, piped to neighbor, public tap/standpipe, tubewell or borehole, protected well, unprotected well, protected spring, unprotected spring, rainwater, tanker truck, cart with small tank, surface water (river/dam/lake/pond/stream/canal/irrigation channel), bottled water, others). The variable was categorized into two levels: piped water vs. others. "How long does it take to go there, get water, and come back?" (On premises, not on premises, don't know). "Do you do anything to the water to make it safer to drink?" (Yes, no, don't know). Any response of Don't Know was treated as missing.

Sanitation Access. Household sanitation was assessed using several questionnaires: What type of toilet facility do members of your household typically use? (Flush or pour flush toilet, pit latrine, composting toilet, bucket toilet, hanging toilet/hanging latrine, no facility/bush/field, others) and was recoded as Flushed vs. Others. Do you share this toilet facility with other households? (Yes, no). Where is this toilet facility located? (In own dwelling, in own yard/plot, elsewhere). Any " Don't Know " responses were treated as missing.

Hygiene. Household hygiene was assessed using multiple questionnaires: Observe the presence of water at the handwashing station (Water is available, water is not available), Observe the presence of soap or detergent (Yes, No), Items present (ash, mud, sand) (Yes, No). Any " Don't Know " responses were treated as missing.

Household Characteristics. Some of the other variables include the number of household members, the number of eligible women (ages 15-49), the number of eligible men, the number of eligible children aged 5 and under (de jure), the type of place of residence (Rural, Urban), and whether any member of this household has an account in a bank or other financial institution (Yes, No). The Wealth Index Combined (Poorest, Poorer, Middle, Richer, Richest) is recorded as Poor (Poorest and Poor), Middle, and Rich (Richer and Richest). In each case, ' Don't Know' is treated as missing.

Data Analysis

Descriptive statistics, including the mean for continuous variables and frequency for categorical variables, were used to describe the characteristics of households with food insecurity. An independent sample t-test or analysis of variance (ANOVA) was employed to determine the mean difference in food insecurity across categorical and continuous variables, respectively. Ordinary least squares regression was utilized to estimate the association between WASH household factors and food insecurity. The statistical model is:

Model 1.

Food insecurity = β0 + β1 Number of household members + β2 Place of residence (Rural vs Urban)+ β3 Wealth Index Combined (Poor) + β4 Wealth Index Combined (Middle)+ β5 Source of drinking water (piped water) + β6 Location of drinking water (On premise)+ β7 Type of toilet facility(Flush Toilet) + β8 Presence of water at hand washing place (Yes)+ β9 Soap or detergent present at wash site (Yes)+ β10 Ash, mud, sand present at wash site (Yes)+ β11 Anything done to water to make safe to drink (Yes)+ β12 Share toilet with other households (Yes)+ β13 Location of toilet facility (In own dwelling)+ β14 Location of toilet facility (In own yard/plot)+ ε

Findings

Out of 13,786 households, a total of 6007 were food insecure (with food insecurity status greater than zero based on our principal component analysis) and were included in our descriptive analysis. On average, there were 4 members in a household (with a minimum of 1 and a maximum of 26). The number of women in a household ranged from 0 to 6, the number of men ranged from 0 to 5, and the number of children aged 5 and under (de jure) ranged from 0 to 6. The majority of households were rural (53%) and had a bank account (68%). Approximately 68% of households were classified as poor or poorest in terms of the wealth index (see Appendix 1 and Appendix 2).

ANOVA results showed that mean food insecurity was highest among households with protected springs as their source of drinking water (mean=3.29, SD=2.05, n=154), followed by unprotected springs (mean=3.23, SD=1.87, n=113) and lowest among households with water piped into their dwelling (mean=1.97, SD=1.45, n=178). There was a significant difference in food insecurity across different sources of drinking water (F=10.58, p<0.01). In terms of the location of drinking water, households with drinking water not on premises were more food insecure (mean=3.13, SD=1.88, n=1490) than those with drinking water on premises (mean=2.65, SD=1.76, n=4516), showing a significant difference with F=1.069, p<0.01. Regarding toilet facilities, households with no facility/bush/field were the most food insecure (mean=3.52, SD=2.01, n=630), whereas households with biogas-attached toilets were the least food insecure (mean=1.90, SD=1.10, n=122).

There was a significant difference in food insecurity across different sources of toilet facilities (F=30.38, p<0.01). Examining the relationship between handwashing, sanitation, and food insecurity, our results showed that households with water (mean=2.61, SD=1.72, n=4924), soap or detergent (mean=2.44, SD=1.63, n=3403), or ash, mud, and sand (mean=2.66, SD=1.71, n=1453) present at the wash site were less likely to be food insecure. If a household made water safe to drink through processing, they were less likely to be food insecure (mean=2.4, SD=1.61, n=1197). Households that do not share toilets with others (mean=2.61, SD=1.7, n=3992) or have toilet facilities in their own dwelling were less food insecure than others (mean=2.11, SD=1.52, n=555) (Appendix 3).

Table 1

Association Between Food Insecurity And Water, Sanitation and Hygiene (WASH), Nepal, 2022

Variable	*B*	*SE B*	*β*	*t*	*p*
Constant	2.705	0.090		30.152	<0.001
Items present: Soap or detergent (Yes vs No (ref))	-0.315	0.055	-0.088	-5.683	<0.001
Presence of water at hand washing place (Yes vs No (ref))	-0.375	0.073	-0.078	-5.140	<0.001
Share toilet with other households (Yes vs No (ref))	0.229	0.053	0.057	4.301	<0.001

Items present: Ash, mud, sand (Yes vs No (ref))	-0.197	0.056	-0.048	-3.554	<0.001
Anything done to water to make safe to drink (Yes vs No (ref))	-0.171	0.057	-0.040	-2.978	0.003
Wealth Index Poor (Poor vs Rich (ref))	0.697	0.067	0.189	10.426	<0.001
Wealth Index Medium (Medium vs Rich (ref))	0.285	0.080	0.061	3.545	<0.001

Model fit statistics (R^2) = 0.068

The ordinary least squares regression was performed on 5353 households (missing values were removed) using the recorded independent variable (Table 1). The distribution of food insecurity status indicates that a large proportion of households experienced mild food insecurity (Figure 2).

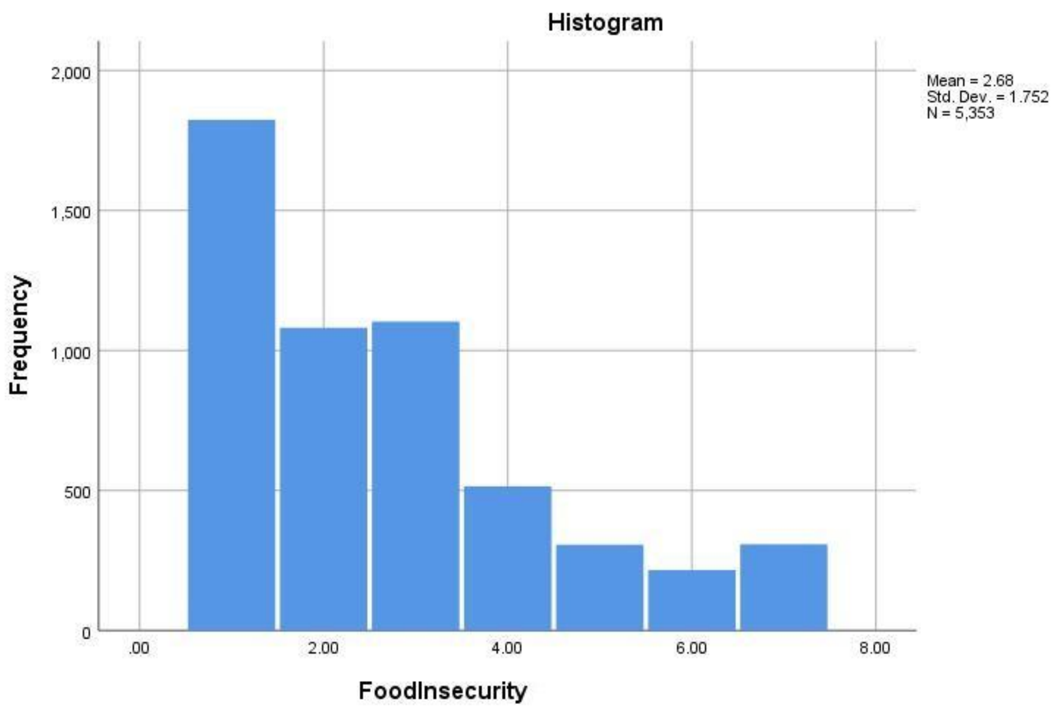

Figure 2

Distribution of food insecurity status based on FIES scores (ranging from 1 to 7): scores 1–3 indicate mild food insecurity, 4–5 indicate moderate food insecurity, and 6–7 indicate severe food insecurity.

The stepwise procedure indicated that the mean household food insecurity was 2.705 (se=0.090). WASH-related variables, such as the presence of soap or detergent (β=-0.315, se=0.055, p=0.000), ash, mud, and sand (β=-0.197, se=0.056, p=0.000), and water availability at the handwashing place (β=-0.375, se=0.073, p=0.000), were associated with a decrease in food insecurity. Similarly, any treatment of water to make it safe for drinking (β=-0.171, se=0.057, p=0.003) was linked to a reduction in food insecurity. However, an increase in household poverty level, such as a wealth index of poor (β=0.679, se=0.067, p=0.000) and medium (β=0.285, se=0.080, p=0.000), along with sharing a toilet with other households (β=0.229, se=0.053, p=0.000), were factors associated with an increase in food insecurity. Wealth Index Poor is a strong predictor of food insecurity as compared to other variables. Other predictor variables were statistically non-significant.

Discussion

This study investigated the relationship between WASH conditions and food insecurity among households in Nepal, drawing on data from 5353 out of 6007 food-insecure households. The findings reveal a strong association between WASH conditions and household food insecurity, highlighting the critical role of access to clean water, sanitation, and hygiene in mitigating food insecurity. Our findings are consistent with previous studies. For instance, Brewis and colleagues (2019) observed that household water insecurity was strongly associated with food insecurity among 27 sites in low and middle-income countries (Brewis et al., 2020). Miller and colleagues suggested that water-insecure households had 1.67 (95% CI: 1.47, 1.89) times higher odds of reporting any food insecurity (Miller et al., 2024).

Our ANOVA results indicated that households dependent on spring water sources exhibited the highest levels of food insecurity. This may be due to the additional time and financial resources required to access clean water when it is not readily available through a piped system (Gurung et al., 2019; Young et al., 2023) . Households with water sources located on their premises experienced significantly lower levels of food insecurity compared to those who had to collect water from off-premises locations. The time and effort spent collecting clean water detract from other essential activities, such as food preparation and income generation, which might worsen food insecurity (Brewis et al., 2020; Young et al., 2023; Young et al., 2021).

In terms of hygiene practices, the availability of water, soap, or detergent at handwashing stations was linked to lower levels of food insecurity. As noted earlier, this could be attributed to a decrease in preventable diseases, such as diarrhea and other infections, which often arise from poor hygiene (Shrestha et al., 2022). Fewer illnesses may result in reduced resource allocation toward healthcare and enhance dietary intake by ensuring better nutritional absorption. Additionally, food contamination is less likely when proper handwashing is observed, further supporting improved food security.

Households lacking toilet facilities, or those utilizing open areas like the bush or fields, experienced the highest levels of food insecurity. In contrast, those equipped with biogas-attached toilets demonstrated the lowest levels of food insecurity. This disparity likely reflects the broader effects of insufficient sanitation on health and financial resources, as inadequate sanitation contributes to the spread of diseases, further straining household finances and worsening food insecurity. Furthermore, households sharing toilets with others faced greater food insecurity compared to those with private facilities, likely due to overcrowding and the accompanying health risks linked to shared sanitation.

Additionally, households that treated water to make it safe for drinking were less food insecure, indicating that even in resource-limited settings, efforts to improve water safety can directly reduce food insecurity. For instance, a study by Sarkar and colleagues highlighted that in Kathmandu, a major city in Nepal, 94% of water sources tested positive for bacterial contamination, including total and fecal coliform (Sarkar et al., 2022). Furthermore, harmful metals such as aluminum, arsenic, iron, and manganese were present at unsafe levels, exceeding World Health Organization (WHO) guidelines. Treating water in such contexts likely enhances water quality and improves health and the body's ability to absorb nutrients, thereby reducing food insecurity.

The ordinary least squares regression results emphasize that efforts to ensure safe drinking water, sanitation practices (such as sharing toilets with other households), and the availability of handwashing materials (e.g., soap, ash, or mud) are all significantly associated with household food security.

These findings align with previous research on the role of sanitation and hygiene in food insecurity (Sarkar et al., 2022). Additionally, shared toilets may indicate broader socioeconomic disadvantages, highlighting the multidimensional nature of poverty that contributes to both poor sanitation and food insecurity. This point is further supported by the fact that in this study, household poverty (wealth index) level was a key sociodemographic factor strongly linked to food insecurity.

Households facing higher poverty levels experience greater food insecurity, as increased poverty restricts access to resources and results in insufficient food availability. For instance, Dhital and colleagues (2022) discovered that households with a poor wealth index had 78% lower odds of accessing an improved water source compared to wealthier households (Dhital et al., 2022). Nevertheless, it is important to note that even after adjusting for poverty, WASH factors remained independently linked to food insecurity. This highlights the importance of enhancing WASH conditions as a direct strategy to reduce food insecurity, beyond merely alleviating poverty.

Policy Implications

The findings of this study have several important policy implications. First, improving access to safe drinking water and sanitation facilities is essential for reducing food insecurity. Policymakers should prioritize interventions that ensure households have access to water sources on their premises and promote the use of safe and hygienic sanitation facilities. Second, promoting hygiene practices, such as providing soap and clean water at handwashing stations, should be integrated into broader food security programs. Lastly, targeted interventions aimed at poverty reduction will be crucial in addressing the root causes of food insecurity in Nepal, as wealth inequality continues to play a significant role in limiting access to both food and WASH resources.

Limitations and Future Research

While this study offers valuable insights into the relationship between WASH conditions and food insecurity, it is essential to recognize some limitations. The cross-sectional nature of the data restricts the ability to establish causal relationships between WASH factors and food insecurity. Therefore, future research could utilize longitudinal data to enhance understanding of the directionality of these associations. Furthermore, broadening the scope of WASH interventions alongside poverty alleviation strategies could present a more comprehensive approach to addressing food insecurity in resource-limited settings like Nepal.

In conclusion, this study emphasizes the essential role that WASH conditions play in shaping food insecurity among Nepalese households. Access to safe drinking water, improved sanitation, and proper hygiene practices correlate with lower levels of food insecurity, while poverty and inadequate sanitation worsen it. Tackling WASH challenges alongside poverty alleviation programs may provide a more comprehensive approach to reducing food insecurity in Nepal.

Paper 2: Water and Sanitation Conditions as Determinants of Stunting, Undernutrition, and Wasting Among Young Children in Nepal

Abstract

This study utilized data from the 2022 Nepal Demographic and Health Survey (DHS) to examine the association between Water, Sanitation, and Hygiene (WASH) factors and child malnutrition among children aged 0 to 59 months. Key WASH indicators included the source of drinking water, the location of water access, the type of toilet, and toilet sharing. Socioeconomic factors such as the wealth index, type of residence, and household composition were considered as covariates. Using binary logistic regression, the results revealed that having water on-premises was protective against stunting. In contrast, children from poor and middle-income households had higher odds of both stunting and being underweight. Urban residence was associated with lower odds of stunting and underweight; however, wasting was more prevalent in urban areas.

Furthermore, access to piped water decreased the likelihood of both underweight and wasting. Simultaneously, a higher number of young children in a household was associated with an increased probability of stunting and underweight. These findings highlight the significance of targeted interventions to enhance water access, sanitation, and economic conditions in vulnerable communities. Tackling these structural determinants is essential for reducing child malnutrition and fostering equitable health outcomes in Nepal.
Keywords: Undernutrition, Stunting, Wasting, Water Sanitation and Hygiene (WASH)

Introduction

Undernutrition, which encompasses stunting (low height-for-age), wasting (low weight-for-height), and underweight (low weight-for-age), is a major public health issue that significantly heightens the vulnerability of children under five years old to illness and mortality (World Health Organization, 2024a). Undernutrition among children under five remains a critical public health challenge in many low- and middle-income countries (Amare et al., 2019; Anin et al., 2020; Madiba et al., 2019). Sub-Saharan Africa and South Asia bear the highest burden of child undernutrition (Black et al., 2013) and inadequate water, sanitation, and hygiene (WASH) globally (Chase & Ngure, 2016).

Forms of Undernutrition

Low height-for-age is referred to as stunting. Among the three forms of undernutrition, stunting is the most prevalent among children under five (Said-Mohamed et al., 2015). It is defined as having a height-for-age z-score more than two standard deviations (SDs) below the World Health Organization (WHO) Child Growth Standards (Said-Mohamed et al., 2015) median. In 2022, an estimated 148.1 million children under the age of five were stunted (too short for their age) (World Health Organization et al., 2023). Children who are stunted face long-term growth failure, reflecting the cumulative impact of chronic deficiencies in food intake, inadequate care practices, and recurrent illness (Said-Mohamed et al., 2015). This study analyzes the effects of water and sanitation conditions on stunting and wasting.

Low weight-for-height is referred to as wasting. This form of malnutrition results from recent shocks, such as inadequate calories and nutrients due to famine or a sudden, severe illness. In 2022, approximately 45.0 million children under the age of five were wasted (too thin for their height) (World Health Organization et al., 2023).

Low weight for age is a third form of malnutrition. Underweight children may also be stunted or wasted. Underweight serves as a composite measure that reflects both stunting and wasting (Chase & Ngure, 2016).

Determinants of Undernutrition

Key factors contributing to the high prevalence of childhood undernutrition include insufficient food intake, frequent diarrhea, recurring infections, inadequate sanitation practices, and low levels of parental education (Amare et al., 2019; Organization, 2019; Yalew et al., 2014). However, literature suggests that undernutrition can also be indirectly influenced by factors such as food insufficiency, inadequate childcare, limited access to healthcare, maternal illiteracy, and environmental conditions, including the availability and quality of water, sanitation, and hygiene (WASH) practices (Chase & Ngure, 2016).

Numerous studies have examined the relationship between undernutrition and factors such as WASH, socioeconomic conditions, infectious diseases, and child health, particularly among children under five in low- and middle-income countries (Momberg et al., 2021; Sahiledengle et al., 2022; S. K. Shrestha et al., 2020). For example, Sahiledengle and colleagues suggest that inadequate access to WASH facilities is strongly linked to child undernutrition, particularly stunting and wasting among children under five in Ethiopia (Sahiledengle et al., 2022). The paper highlights that insufficient sanitation, the practice of open defecation, and substandard housing conditions (e.g., dirt floors) significantly raise the likelihood of stunting in Ethiopian children. However, most research investigating the relationship between WASH variables and stunting, wasting, or underweight has been conducted in Sub-Saharan Africa, where the protocol was published in PROSPERO (Momberg et al., 2021).

Nepal is among the countries with the highest levels of childhood undernutrition in the South Asian (United Nations Children's Fund South Asia, 2019). The Nepal DHS 2022 indicated that 25% of children under five were stunted, 8% were wasted, and 19% were underweight (Ministry of Health et al., 2022). Shrestha and colleagues examined WASH practices and their impact on child health and nutritional status in two specific districts (Shrestha et al., 2022). Their findings suggest significant improvements in WASH practices, with more households regularly washing their hands and experiencing better water quality. This resulted in fewer infectious diseases such as fever, respiratory illness, and diarrhea. However, this study only covered these two districts and did not represent the entire nation.

Similarly, Shrestha and co-authors examined the association and interactive effects between WASH variables and preschool child undernutrition, utilizing household data from the 2016 Nepal Demographic and Health Survey to represent child undernutrition status (S. K. Shrestha et al., 2020). They observed that WASH practices were positively associated with improved nutritional outcomes among children under five in Nepal. However, several significant events between 2016 and 2022: post-earthquake recovery, slower GDP growth and increased food prices during and after COVID-19 pandemic, severe flood in 2017 and 2021 likely influenced both WASH access and nutritional outcomes. Thus, with 2022 data recently available, there is a need to investigate the relationship between WASH variables and undernutrition. Therefore, the purpose of this quantitative, cross-sectional study is to examine how WASH variables influence various forms of childhood undernutrition in Nepal using a large representative sample from the 2022 Nepal DHS.

Hypotheses

Null Hypothesis (H_0): There is no significant association between WASH variables and various forms of childhood undernutrition (stunting, wasting, and underweight) in Nepal.

Alternative Hypothesis (H1): A significant association exists between WASH variables and various forms of childhood undernutrition (stunting, wasting, and underweight) in Nepal.

Methods

Sample and Data Collection

This study will use the nationally representative secondary cross-sectional data from the 2022 Nepal Demographic and Health Survey (United States Agency for International Development, 2024). The DHS survey is conducted every five years. A detailed description of the sampling methods and methodology is reported in the Nepal DHS (Ministry of Health et al., 2022). We used the Children's Data Sets, which include one record for every child of the interviewed women born in the five years preceding the survey. This dataset contains information about the child's pregnancy, post-natal care, immunization, and health. The unit of analysis in this dataset is the children of women who were born in the last five years (0-59 months).

Measures

Dependent Variables.

Stunting. Stunting refers to the impaired growth and development that children experience due to poor nutrition, recurrent infections, and insufficient psychosocial stimulation (World Health Organization, 2015). Our dataset classifies children aged 0-59 months as stunted if their height-for-age is more than two standard deviations below the median of the WHO Child

Growth Standards. Stunting is evaluated based on a child's height in relation to their age (World Health Organization, 2015).

Underweight. Children with low weight-for-age are referred to as underweight. In our dataset, an underweight child (0-59 months) is defined as one whose weight-for-age z score is two standard deviations below the WHO child growth standards. A child may be classified as stunted, wasted, or both (World Health Organization, 2024a).

Wasting is characterized by a low weight-for-height ratio, often reflecting recent and severe weight loss (World Health Organization, 2024a). It typically results from inadequate food quality and quantity but can persist over time. Frequent or prolonged illnesses are also common contributing factors. Our dataset defines a wasted child (0-59 months) as one whose weight-for-height z-score is two standard deviations below the WHO child growth standards.

Independent WASH Variables

Water Access. Access to water for children was measured using two questionnaires: "What is the main source of drinking water for your household members? " (Responses were categorized into two groups: piped water vs. others). "How long does it take to go there, collect water, and return?" (Responses were categorized into two groups: On-premises and off-premises).

Sanitation and Hygiene Access. Children's sanitation was assessed with two questions: What type of toilet facility does your household usually use? (Responses were categorized into two groups: Flush to safety tank toilet and others) Do you share this toilet facility with other families? [Yes, No]

Covariates

Covariates are variables used as controls in statistical analysis. Other variables, such as wealth index (categorized as poor, rich, and middle), place of residence (urban and rural), and the number of children aged five and under in the household (de jure), were also utilized as covariates.

Analysis

Descriptive statistics, including the mean for continuous variables and frequency for categorical variables, were used to describe the characteristics of children aged 0-5. An independent samples t-test or ANOVA was utilized to determine the mean differences in stunting, underweight, and wasting scores across categorical and continuous independent variables. Binary logistic regression with forward LR was conducted to estimate the association between drinking WASH and the nutritional status of children. The statistical models for stunting, underweight, and wasting are as follows:

Model 1.

Stunted Children (stunted vs not stunted) = $\beta_0 + \beta_1$ Source of Drinking Water (piped water) + β_2 Location of Drinking Water (On-premises) + β_3 Type of Toilet Facility (Flush Toilet) + $\beta 4$ Share Toilet with Other Households (no) + β_5 Type of Place of Residence (urban) + $\beta 6$ Wealth Index Combined (poor)+ β_7 Wealth Index Combined (middle) + β_8 Number of Children Five and Under in Household (de jure) +e

Model 2.

Wasted Children (wasted vs not wasted) = $\beta_0 + \beta_1$ Source of Drinking Water (piped water) + β_2 Location of Drinking Water (on-premises) + β_3 Type of Toilet Facility (flush toilet) + β_4 Share Toilet with Other Households (no) + β_5 Type of Place of Residence (urban) + β_6 Wealth

Index Combined (poor)+ β_7 Wealth Index Combined (middle) + β_8 Number of Children Five and Under in Household (de jure) +e

Model 3:

Underweight Children (underweight vs not underweight) = β_0 + β1 Source of Drinking Water (piped water) + β2 Location of Drinking Water (on-premises) + β_3 Type of Toilet Facility (flush toilet) + β_4 Share Toilet with Other Households (no) + β_5 Type of Place of Residence (urban) + β_6 Wealth Index Combined (poor)+ β_7 Wealth Index Combined (middle) + β_8 Number of Children Five and Under in Household (de jure) +e

Observations with missing data were excluded from the analysis. All analyses were performed in SPSS 25. Differences were considered statistically significant at the alpha level of 5%. Nonresponse error was not a threat in this study as a preexisting data set was used and no attempts to generalize beyond the sample were made (Lindner, 2002). Scaled attitudinal items were described using Lindner's (2024) convention.

Findings

After removing missing data, our analysis included 2202 (582 stunted and 1620 not stunted), 2208 (401 underweight and 1807 not underweight), and 2198 (154 wasted and 2044 not wasted) children aged five and under. Appendix 4 provides details about the number of children included in this study.

Socioeconomic Characteristics

Table 2 shows the socioeconomic characteristics of the study population. Our result indicates that a higher percentage of stunted children (59%) live in rural areas and are poor (65%) as compared to those who were not stunted, 46% and 49%, respectively. Similarly, a higher percentage of underweight children (55%) live in rural areas and are poor (57%) as compared to those who were not underweight, 48% and 52%, respectively. In contrast, a higher percentage of wasted children (55%) live in urban areas compared to not-wasted children (52%). A lower percentage of wasted children are poor (44%) compared to those who were not wasted (54%).

Table 2
Socioeconomic Characteristics Of Children Aged 0-5 Nepal, 2022

Characteristics	Stunted		Not stunted		Underweight		Not Underweight		Wasted		Not Wasted	
	N	Mean (SD)	N	Mean (SD)	N	Mean (SD)	N	Mean (SD)	N	Mean (SD)	N	Mean (SD)
Number of children 5 and under in household (de jure)	582	1.72 (0.83)	1620	1.52 (0.75)	401	1.68 (0.52)	1807	1.54 (0.76)	154	1.57 (0.72)	2044	1.57 (0.78)
Type of place of residence												
Rural	342	58.8	747	46.1	181	45.1	934	51.7	84	54.5	1027	50.2
Urban	240	41.2	873	53.9	220	54.9	873	48.3	70	45.5	1017	49.8
Wealth Index Combined												
Poorest	262	45	462	28.5	144	35.9	582	32.2	40	26	683	33.4
Poor	116	19.9	325	20.1	85	21.2	357	19.8	28	18.2	413	20.2
Middle	106	18.2	330	20.4	87	21.7	351	19.4	36	23.4	400	19.6
Richer	65	11.2	290	17.9	52	13	303	16.8	27	17.5	328	16
Richest	33	5.7	213	13.1	33	8.2	214	11.8	23	14.9	220	10.8

Source: Nepal Demographic and Health Survey, 2022

The Mean Difference in Nutritional Status Based on WASH Variables

Table 3 presents the mean difference in stunting scores for the included WASH variable. The t-test indicates that, except for shared toilet facilities (t=-1.3, p=0.027), there was no significant difference in mean stunting scores based on the source of drinking water, time taken to access water, and type of toilet facility among stunted children. For children who were not stunted, the mean stunting score significantly differed only by the presence of water on the premises (t=2.49, p=0.013).

Table 3
Mean Stunting Score By WASH Variables Nepal, 2022

WASH variables	Stunted			Not stunted		
	N	Mean (SD)	t	N	Mean (SD)	t
Source of drinking water						
Piped	337	-268.8 (57.86)	-0.73	896	-84.66 (80.34)	-0.83
Others	245	-265.1 (60.74)		724	-81.16 (86.16)	
Water on premises						
On-premises	435	-265.4 (57.73)	1.25	1334	-80.71 (82.89)	2.49*
Not on premises	147	-272.5 (62.75)		286	-94.2 (82.68)	
Type of toilet facility						
Flush to septic tank	539	-267.3 (59.58)	-0.21	1477	-82.69 (82.90)	0.63
Others	43	-265.4 (52.69)		143	-87.32 (83.97)	
Toilet facilities shared with other households						
Yes	161	-262.09 (57.62)	-1.30*	425	-90.72 (80.154)	2.20
No	421	-269.2 (59.56)		1195	-80.38 (83.83)	

Source: Nepal Demographic and Health Survey, 2022

Table 4 presents the mean difference in underweight scores for the included WASH variable. The t-test shows no significant difference in the mean underweight scores based on the source of drinking water, time taken to access the water, type of toilet facility, and whether toilet facilities are shared with other households among underweight children. In contrast, among children who were not underweight, the mean underweight scores differed based on the source of drinking water (t=2.488, p=0.013), time taken to fetch the water (t=2.772, p=0.006), and whether the household shared toilet facilities with others (t=-2.895, p=0.004).

Table 4
Mean Underweight Score By WASH Variables Nepal, 2022

Characteristics	**Underweight**			**Not underweight**		
	N	**Mean (SD)**	**t**	**N**	**Mean (SD)**	**t**
Source of drinking water						
Piped	198	-254.2 (49.21)	0.73	1040	-73.41 (82.66)	2.48*
Others	203	-257.86 (50)		767	-83.04 (79.38)	
Water on premises						
On-premises	316	-258.02 (48.97)	1.53	1459	-74.91 (82.29)	2.77*
Not on premises	85	-248.76 (51.42)		348	-88.35 (76.71)	
Type of toilet facility						
Flush to septic tank	378	-255.67 (50.05)	0.626	1644	-77.73 (81.68)	-.384
Others	23	-262.35 (41.52)		163	-75.17 (78.78)	
Toilet facilities shared with other households						
Yes	111	-258.13 (52.37)	-.517	476	-86.03 (71.14)	-2.89*
No	290	-255.26 (48.54)		1331	-74.45 (84.58)	

Source: Nepal Demographic and Health Survey, 2022

Table 5 presents the mean difference in wasting scores for the included WASH variable. The t-test reveals no significant difference in the mean wasting score based on the source of drinking water, time taken to fetch water, type of toilet facility, or shared toilet facilities among underweight children. In contrast, among children who were not wasted, the mean wasting score varied only by the source of drinking water (t=6.14, p=0.00).

Table 5
Mean Wasting Score By WASH Variables Nepal, 2022

Characteristics	Wasting			Not Wasting		
	N	**Mean (SD)**	**t**	**N**	**Mean (SD)**	**t**
Source of drinking water						
Piped	67	-247.19 (45.83)	-0.228	1165	-25.01 (88.02)	6.14*
Others	87	-245.45 (48.10)		879	-49.09 (87.28)	
Water on premises						
On-premises	136	-244.28 (45.24)	1.40	1630	-34.86 (90.20)	0.54
Not on premises	18	-260.78 (57.90)		414	-37.35 (81.45)	
Type of toilet facility						
Flush to septic tank	144	-246.37 (47.72)	-0.16	1868	-36.36 (88.72)	-1.66
Others	10	-243.90 (36.6)		176	-24.76 (85.57)	
Toilet facilities shared with other households						
Yes	51	-248.02	-0.33	535	-39.03 (82.58)	-1.16
No	103	-245.31		1509	-34.07 (90.47)	

Source: Nepal Demographic and Health Survey, 2022

Logistic Regression

Stunted

Table 6 presents the binary logistic regression results (Stunted vs. Not Stunted). Children living in households with water on the premises had lower odds of stunting [odds ratio (OR)=0.78, confidence interval (CI)=0.61 to 0.98] compared to those living in households without water on the premises. Children from households with a Poor wealth index [OR = 2.03, CI = 1.56 to 2.65] and those with a Middle wealth index [OR = 1.51, CI = 1.10 to 2.06] had higher odds of stunting compared to those from households with a Rich wealth index. Urban children exhibited lower odds [OR = 0.70, CI = 0.58 to 0.86] of stunting than rural children. Furthermore, with each additional child aged five and under in a household (de jure), the probability of stunting increased by 37.3%.

Table 6
Logistic Regression Results For Stunting (Stunted Vs Not Stunted) Nepal, 2022

Variables	Exp (Beta)	95% Confidence Interval	
Constant	0.189		
Time to get to a water source: on-premises vs not on-premises (ref)	0.780	0.615	0.989
Wealth index: poor vs rich (ref)	2.037	1.564	2.653
Wealth index: middle vs rich (ref)	1.510	1.103	2.066
Type of place of residence: urban vs rural (ref)	0.709	0.580	0.867
Number of children 5 and under in household (de jure)	1.373	1.220	1.546

Source: Nepal Demographic and Health Survey, 2022; Model fit statistics (Nagelkerke R^2) = 0.064

Underweight

Table 7 presents the binary logistic regression results for Underweight (Underweight vs Not Underweight). Children from households with poor [OR=1.62, CI=1.21 to 2.18] and middle [OR=1.45, CI=1.04 to 2.03] wealth indices had higher odds of being underweight compared to those from households with a rich wealth index. Children living in households with flush toilets had higher odds [OR=1.68, CI=1.06 to 2.64] of being underweight compared to those using other toilet types. Children residing in households with access to piped water [OR=0.64, CI=0.50 to 0.81] and in urban [OR=0.79, CI=0.63 to 0.99] areas had lower odds of being underweight compared to those relying on other sources of drinking water and those living in rural areas, respectively. Additionally, for each unit increase in the number of children aged 5 and under in a household (de jure), the probability of being underweight increased by 17%.

Table 7
Logistic Regression Results For Underweight (Underweight Vs Not Underweight) Nepal, 2022

Variables	Exp (Beta)	95% Confidence Interval	
Constant	0.11		
Wealth index: poor vs rich (ref)	1.62	1.21	2.18
Wealth index: middle vs rich (ref)	1.45	1.04	2.03
Type of toilet facility: flush vs others (ref)	1.68	1.06	2.64
Source of drinking water: piped water vs others (ref)	0.64	0.50	0.81
Type of place of residence: urban vs rural (ref)	0.79	0.63	0.99
Number of children 5 and under in household (de jure)	1.17	1.03	1.34

Source: Nepal Demographic and Health Survey, 2022; Model fit statistics (Nagelkerke R^2) =0.029

Wasting

Table 8 presents the binary logistic regression results for Wasting (Wasted vs Not wasted). The logistic regression analysis revealed that children in households with access to piped drinking water had lower odds of wasting [OR=0.59, CI=0.42 to 0.82] compared to those using other sources of drinking water. In contrast, children living in households with water on-premises had higher odds of wasting [OR=1.88, CI=1.14 to 3.11] than those in households without water on-premises.

Table 8
Logistic Regression Results For Wasting (Wasted vs Not Waisted) Nepal, 2022

Variables	Exp (Beta)	95% Confidence Interval	
Constant	0.06		
Source of Drinking Water: Piped water vs others (ref)	0.59	0.42	0.82
Time to get to a water source: On-premises vs not on-premises (ref)	1.88	1.14	3.11

Source: Nepal Demographic and Health Survey, 2022; Model fit statistics (Nagelkerke R^2) =0.02

Discussion

The findings of this study highlight a concerning prevalence of malnutrition among children under five, with 36% experiencing stunting, 22% being underweight, and 7.5% suffering from wasting. These figures reflect a critical public health issue, underscoring the severe burden of malnutrition faced by this population (de Onis et al., 2019). Compared to the 2016 NDHS, stunting levels have remained unchanged, while the prevalence of underweight has decreased by 5%, and wasting has declined by 2.5% (Vijay & Patel, 2024). In a similar study, Siddiqui and colleagues found that the stunting level among children under three years of age remained unchanged from 2016 to 2022, while the prevalence of underweight decreased by 13%, and wasting declined by 3% (Siddiqui et al., 2024). These trends suggest modest improvements in certain aspects of child nutrition; however, the persistent stunting rates indicate ongoing challenges in addressing chronic malnutrition.

A higher percentage of stunted (59%) and underweight (55%) children lived in rural areas and were poor (65% and 57%, respectively) compared to their urban counterparts. This pattern suggests that poverty and rural residence are significant risk factors for poor nutritional outcomes in children, likely due to limited access to nutritious food, healthcare, and improved water and sanitation infrastructure (Adhikari et al., 2019; Srinivasan et al., 2013; Tiwari et al., 2014; Vijay & Patel, 2024) . However, this trend diverged for wasting, where a higher percentage of wasted children lived in urban areas, indicating that urban children may still face significant challenges related to food insecurity or access to clean water and sanitation (Siddiqui et al., 2024). Our findings are consistent with a previous study, which reports a higher percentage of wasting among children residing in urban areas (9.9%) compared to rural areas (9.4%) of Nepal (Vijay & Patel, 2024).

For stunted children, the only notable difference in mean stunting scores was observed in households that shared toilet facilities, indicating that sanitation conditions may contribute to an environment affecting stunting among children (Adhikari et al., 2019; Headey & Hoddinott, 2015). Among non-stunted children, the time spent fetching water significantly impacted stunting scores, with lower mean stunting scores for those with water on-premises compared to those without, implying that water accessibility could decrease the probability of stunting (Adhikari et al., 2019). For underweight children, none of the WASH variables showed significant differences in underweight scores.

These findings indicate that children already classified as underweight did not vary based on WASH variables. However, among children who were not underweight, significant differences based on the source of drinking water, time spent fetching water, and shared toilet facilities were noted. This suggests a protective effect of improved sanitation and water conditions in preventing underweight status (Adhikari et al., 2017; S. K. Shrestha et al., 2020). Regarding wasting, no significant differences in mean wasting scores were found among wasted children based on WASH variables, but among those who were not wasted, the mean wasting score varied significantly by the source of drinking water, suggesting that while WASH conditions may not directly influence wasted children, the quality (purification) and accessibility of drinking water could be crucial in preventing wasting among children who are not yet affected (S. K. Shrestha et al., 2020).

Binary logistic regression reveals an intriguing pattern regarding WASH variables: children living in households with water on the premises are less likely to be stunted but more likely to be wasted. The reduced likelihood of stunting in these households may be attributed to improved hygiene practices, decreased exposure to waterborne diseases, and better caregiving due to the diminished time burden associated with water collection (United Nations Children's Fund, 2013). Consistent access to clean water likely enhances sanitation, reduces the incidence of infectious diseases, and promotes overall child health, which are key factors in lowering the risk of stunting, a condition linked to long-term nutritional deficiencies and poor health environments (Guerrant et al., 2008; United Nations Children's Fund, 2013).

The findings align with previous research showing that children living in households with access to piped water have lower odds (OR=0.72 [0.48–1.07]) of stunting in Nepal (Adhikari et al., 2019). However, the increased likelihood of wasting among children in households with water available on the premises may be due to complex, context-specific factors. Households with access to water on the premises may be located in urban areas where dietary patterns, food quality, and exposure to infectious diseases differ from rural settings, potentially heightening the risk of acute malnutrition. Previous studies also indicate a higher level of wasting in urban areas of Nepal (Siddiqui et al., 2024) and among households using tap water (Vijay & Patel, 2024). Nonetheless, no significant association between water facilities and malnutrition was noted in these studies (Tiwari et al., 2014; Vijay & Patel, 2024).

Similarly, regarding another WASH variable, children living in households where water is sourced from piped systems are less likely to be underweight and wasted compared to those using other sources of drinking water. This may be due to the more reliable and consistent access to clean water in households with piped systems, which can reduce the risk of waterborne diseases and infections that contribute to malnutrition (Adhikari et al., 2017; Headey & Hoddinott, 2015). Improved water access also promotes better hygiene and sanitation, supporting overall health and nutrition, as improved sanitation has been identified as the major driver of reduced undernutrition in Nepal (Headey & Hoddinott, 2015). In contrast, households that depend on water sources other than piped systems may face challenges in maintaining water quality and availability, which can negatively impact child health. A previous study indicated that children in households consuming untreated water had higher odds of being underweight (Adhikari et al., 2017).

Counterintuitively, we observe that children living in households with flush toilet facilities are more likely to be underweight than those with other types of toilet facilities. Several factors may influence these findings. First, households with flush toilets are often located in urban areas, where access to better sanitation may coexist with other challenges, such as higher living costs, food insecurity, or reliance on processed foods with lower nutritional value (Dave et al., 2024; Fagbamigbe et al., 2020). Furthermore, flush toilet facilities might not necessarily indicate access to improved overall sanitation practices, such as water quality, waste management, and other public health factors in these areas, which can still be suboptimal. This highlights the dual influence of urbanization and the need for a more nuanced understanding of the complex relationship between sanitation infrastructure and child nutritional outcomes, considering the broader social and environmental contexts (Fagbamigbe et al., 2020). The type of toilet remains the highest contributor to the rural-urban gap or disparities in severe acute malnutrition (Fagbamigbe et al., 2020).

We observe socioeconomic factors as significant determinants of malnutrition status. Our findings reveal that the risk of being stunted and underweight is notably higher among children from the poorest households, with the risk decreasing as the wealth index increases. Consistent with previous studies, these patterns may be attributed to limited access to adequate food, healthcare services, and other essential resources among lower-income households, contributing to the elevated risk of stunting and underweight (Adhikari et al., 2019; Li et al., 2020; United

Nations Children's Fund, 2013; Vijay & Patel, 2024). We also found that children in households located in urban areas were less likely to be stunted or underweight compared to those in rural areas. This may be attributed to better access to healthcare, improved sanitation, and more diverse food options in urban settings (Fagbamigbe et al., 2020). Additionally, urban areas often have better infrastructure, which can lead to improved nutrition and overall child health.

A higher number of children in one household is associated with increased odds of stunting and being underweight. This is consistent with a previous study that reports odds (OR=1.52 [1.22–1.90]) of stunting increasing with family size (Adhikari et al., 2019). Another study found that stunting is disproportionately concentrated in poorer households (Angdembe et al., 2019). A greater number of children may negatively impact children's nutritional status due to increased economic strain on food consumption and fewer resources available for each child's needs (Khan & Azid, 2011). Larger household sizes often lead to limited resources being stretched more thinly, which can impact the availability of adequate food, healthcare, and attention for each child. This can elevate the risk of malnutrition as the demand for household resources grows, potentially resulting in insufficient nutrition for all children.

Conclusion

Our study highlights significant associations between child malnutrition indicators (stunting, underweight, and wasting) and household socioeconomic and WASH characteristics in Nepal. Stunting and underweight were more prevalent among children from rural and economically disadvantaged households, emphasizing persistent disparities in nutritional outcomes. Logistic regression results indicate that access to water on-premises acted as a protective factor against stunting. In contrast, children from poor and middle-income households had higher odds of both stunting and underweight compared to their wealthier counterparts.

Additionally, children in households with piped drinking water exhibited lower odds of being underweight and wasted, underscoring the importance of improved water access in mitigating malnutrition risks. Interestingly, while urban residence was generally associated with lower odds of stunting and underweight.

The findings suggest that different forms of malnutrition may have distinct underlying determinants, requiring tailored interventions. Notably, an increasing number of young children in a household was linked to a higher probability of both stunting and underweight, highlighting the potential role of household structure in child nutrition. These results emphasize the need for targeted public health interventions to improve water access, sanitation, and economic conditions in vulnerable communities. Enhancing access to proper WASH facilities is crucial for reducing child malnutrition and promoting equitable health outcomes across Nepal. Future research should explore how WASH factors interact with socioeconomic conditions to influence child nutrition and identify effective intervention strategies.

Paper 3: Water, Sanitation, and Hygiene Conditions as Determinants of Body Mass Index (BMI) Among Nonpregnant Women Aged 15-49 Years in Nepal

Abstract

The objective of this study is to examine the relationship between Water, Sanitation, and Hygiene (WASH) variables and women's nutritional status, measured by Body Mass Index (BMI), in Nepal. Using data from the 2022 Nepal Demographic and Health Survey (DHS), we investigate how access to clean water, sanitation, and hygiene practices influences the BMI of non-pregnant women aged 15 to 49. BMI is categorized into underweight, normal, and overweight/obese groups. We utilize multinomial logistic regression to assess the association between WASH factors- such as piped water, water on premises, toilet facilities, and hygiene practices- and BMI while controlling for demographic variables including age, wealth index, place of residence, religion, and ethnicity. A total of 6,291 non-pregnant women are included in the study. Multinomial logistic regression indicates that women with access to water on premises and piped water have higher odds of being overweight or obese. Additionally, women from religions and ethnicities other than Hindu and Brahmin or Chhetri, those with access to flush toilets, and those living in urban areas are also more likely to be overweight or obese. Our results highlight the complex interplay of sociodemographic and environmental factors in determining women's BMI in Nepal. These findings emphasize the need for public health interventions that integrate WASH improvements with strategies promoting healthy lifestyles and equitable resource distribution to enhance women's nutritional outcomes in Nepal.

Keywords: Body Mass Index (BMI), Water, Sanitation, Hygiene (WASH)

Introduction

According to the 2024 Global Nutrition Report, approximately 390 million (20 %) of adults aged 18 and older were underweight, 2.5 billion (43%) were overweight, and 890 million (16%) were classified as living with obesity (World Health Organization, 2024b). The prevalence varied by region; for instance, the proportion of overweight adults ranged from 31% in the South-East Asia and African regions to 67% in the Americas (World Health Organization, 2024b). The overall pooled prevalence of underweight, overweight, and obesity in the South and Southeast Asian regions was estimated to be 22.9%, 21.3%, and 8.6%, respectively (Biswas et al., 2019).

Women, in particular, experience a higher prevalence of undernutrition compared to men (Phelps et al., 2024). The combined probability of underweight and obesity across 162 countries is 81% for women and 70% for men (Phelps et al., 2024). The World Health Organization (WHO) 2022 report indicates that 43% of men and 44% of women aged 18 years and older are overweight (World Health Organization, 2024b). The prevalence of obesity also surpasses that of underweight in 177 countries, affecting 89% of women and 73% of men in 2022 (Phelps et al., 2024) . In low- and middle-income countries, overweight is more common among women than men (Ford et al., 2017). Women in South Asian countries such as Nepal, Bangladesh, Pakistan, and India historically exhibit high levels of underweight (11%) and overweight/obesity (36%) (Ferdausi et al., 2022; Ford et al., 2017). A potential reason for the greater prevalence of undernutrition among women may be linked to social and economic disparities, where men are prioritized for nutritious food over women (Nubé & Van Den Boom, 2003).

In Nepal, the nutritional status of women has undergone significant changes over the years. A study analyzing 20 years of data from the Nepal DHS 2016 found a notable increase in overweight (from 6% in 1996 to 15% in 2016) and obesity (from 2% in 1996 to 1% in 2016) among women aged 15-49, with key determinants including age, marital status, wealth index, and urban residence (Rana et al., 2022). Meanwhile, the percentage of underweight women decreased from 25% to 16%, but it remained high (Rana et al., 2022).

A recent estimate suggests that the prevalence of overweight or obesity among women aged 20-49 is 35%, while it stands at 6% among adolescent girls aged 15-19 in Nepal (Ministry of Health et al., 2022). These findings highlight the dual burden of malnutrition, wherein both undernutrition and overnutrition coexist, underscoring the need for further investigation into their underlying determinants. Sociodemographic factors, such as age, educational status, marital status, religion, and wealth index, have been linked to the risk of undernutrition in Nepal (Rana et al., 2022). Having a large family, residing in rural areas, and being engaged in work are significantly associated with lower rates of overweight and obesity (Ferdausi et al., 2022).

WASH and Women's Nutrition

Research has also suggested a potential link between WASH practices and women's nutritional status (Anyanwu et al., 2022; Chattopadhyay et al., 2019; Dodos et al., 2017; Merkina et al., 2024; S. K. Shrestha et al., 2020). Unprotected drinking water sources and a lack of handwashing after toilet use were significant predictors of underweight (body mass index (BMI) <18.5 kg/m^2) among women of reproductive age in Ethiopia (Ferede et al., 2017).

The high prevalence of underweight among women in reproductive age groups is associated with various health problems, including low birth weight, preterm birth, stunting, and reduced resistance to infections among their offspring (Central Statistical Agency (CSA) [Ethiopia] & ICF, 2016). A community-based cross-sectional study in Southern Ethiopia examined the link between WASH practices and underweight status among women of reproductive age (Merkina et al., 2024). The findings revealed that 7.82% of the women were underweight, and those with access to clean latrines had 57% lower odds of being underweight compared to those using unclean or no latrine facilities (Merkina et al., 2024).

These results suggest that proper sanitation practices may play a crucial role in improving women's nutritional status, potentially by reducing infection risks and enhancing overall health. Similarly, studies conducted in Cambodia and India suggest poor sanitation is associated with lower BMI (Janmohamed et al., 2016; Nagpal et al., 2021). Specifically, improved access to sanitation was linked to better nutritional outcomes, suggesting that adequate WASH infrastructure plays a crucial role in shaping women's health (Caruso et al., 2022). In Nigeria, the type of toilet facility, source of drinking water, along with housing characteristics have shown to predict undernutrition with higher odds of undernutrition among women with unimproved toilet and drinking water facilities of reproductive age (Morakinyo et al., 2020; Rana et al., 2021; Rana et al., 2020).

WASH and Preschool Nutrition

In Nepal, previous studies have examined the association and interaction between the WASH variable and preschool children's undernutrition to suggest that improved sanitation was associated with an increase in weight-for-age (WAZ) score, and height-for-age (HAZ) score, water purification was associated with an increase in weight-for-height (WHZ) score, and handwashing practice with water and soap was associated with an increase in weight-for-age (WAZ) score (S. K. Shrestha et al., 2020). Finding from our own analysis from 2022 DHS data revealed that water on-premises was protective against stunting, while children from poor and middle-income households had higher odds of being stunted or underweight. Additionally, access to piped water reduced the likelihood of underweight and wasting. However, the relationship between women's BMI and the impact of WASH remains underexplored. Access to clean water, improved sanitation, and proper hygiene practices are critical for overall health and nutrition, yet their influence on women's nutritional status has not been extensively studied.

This study aims to fill this gap by investigating the relationship between WASH variables and women's nutritional status, measured by BMI, in Nepal, utilizing the latest available data from the 2022 Nepal DHS. The findings of this research can contribute to evidence-based policies designed to address malnutrition and promote overall well-being among Nepalese women. Therefore, this quantitative cross-sectional study seeks to examine the factors associated with WASH variables in relation to the BMI of women in Nepal, using the most recent data from the 2022 DHS. The focal sample segment is of non-pregnant (aged 15-49).

Hypotheses

Null Hypothesis (H_0): There is no significant association between WASH variables and the body mass index of women aged 15 to 49 in Nepal.

Alternative Hypothesis (H1): A significant association exists between WASH variables and the Body Mass Index of women aged 15 to 49 in Nepal.

Methods

Sample and Data Collection

This study will use the nationally representative secondary cross-sectional data from the 2022 DHS (United States Agency for International Development, 2024). The DHS survey is conducted every five years, and a detailed description of the sampling methods and methodology is available in the DHS documentation (Ministry of Health et al., 2022).

Measures

Dependent Variables

Women's BMI (aged 15-49). BMI is a measure of weight relative to height and serves as a quick, cost-effective, and reliable screening tool for identifying underweight and overweight/ obese individuals (Centers for Disease Control and Prevention, 2024). It is widely used as a population health indicator around the world. BMI is categorized into three groups: underweight (< 18.5 kg/m^2), normal (18.5 to 24.9 kg/m^2), and overweight/obese (>25 kg/m^2).

Independent Variables

Water Access. The access to water for women was evaluated using two questionnaires: "What is the main source of drinking water for your household members? (Piped water vs. others) and how long does it take to go there, collect water, and return?" (On-premises vs. not on-premises).

Sanitation and Hygiene Access. Women's sanitation was assessed using two questionnaires: What type of toilet facility does your household typically use? (Flush to safety tank toilet vs. others) and Do you share this toilet facility with other households? (Yes vs. No)

Covariates

Covariates are control variables that address competing explanations. Demographic variables, including a combined wealth index (classified as poor, middle, or rich), place of residence (urban or rural), religion (Hindu or other), ethnicity (Brahmin, Chhetri, or others), and age groups (15-19, 20-34, and 35-49), were used as covariates.

Analysis

Descriptive statistics and frequencies for categorical variables were used to outline the characteristics of non-pregnant women aged 15 to 49. An independent samples t-test assessed the mean differences in underweight, normal, and overweight/obese BMI scores across the categorical independent variables. Multinomial logistic regression evaluated the association between WASH and women's BMI. The statistical model is:

Statistical Model

The BMI category serves as the dependent variable. BMI of women (underweight, normal, and overweight/obese) = $\beta 0 + \beta 1$ Source of drinking water (piped) + $\beta 2$ Location of drinking water (on-premises) + $\beta 3$ Type of toilet facility (flush toilet) + $\beta 4$ Share of toilet with other households (no) + $\beta 5$ Type of place of residence (urban) + $\beta 6$ Wealth index combined (poor)+ $\beta 7$ Wealth index combined (middle)+ $\beta 8$ Age(15-19)+ $\beta 9$ Age (20-34) + $\beta 10$ Religion (Hindu)+ $\beta 11$ Ethnicity (Brahmin and Chettri) + ε

Findings

After excluding the missing data, our analysis included 6,291 non-pregnant women aged 15 to 49 years. Appendix 5 provides details about the number of women who participated in this study.

Sociodemographic Bivariate Analysis

Table 9 illustrates the distribution of BMI categories (underweight, normal, and overweight/obese) across various sociodemographic characteristics. Most individuals classified as underweight or normal were in the 20–34 age group, while overweight and obesity were most common among those aged 35–49. These findings suggest that younger adults are more likely to have a standard or underweight BMI, whereas older individuals tend to be overweight or obese. A higher proportion of women lived in urban areas, with overweight and obesity being significantly more prevalent among urban residents compared to their rural counterparts.

Table 9

Body Mass Index (BMI) Of Non-Pregnant Women Aged 15-49 Years Across Sociodemographic Characteristics, Nepal 2022

Characteristics	Underweight (N=831)		Normal (N=3790)		Overweight/Obese (N=1670)	
	Number	Percent	Number	Percent	Number	Percent
Age						
15-19	312	37.5	796	21.0	44.0	2.6
20-34	337	40.6	1794	47.3	727.0	43.5
35-49	182	21.9	1200	31.7	899.0	53.8
Place of residence						
Urban	438	52.7	1951	51.5	1049.0	62.8
Rural	393	47.3	1839	48.5	621.0	37.2
Religion						
Hindu	759	91.3	3291	86.8	1329.0	79.6
Others	72	8.7	499	13.2	341.0	20.4
Ethnicity						
Brahmin and Chhetri	308	37.1	1368	36.1	513.0	30.7
Others	523	62.9	2422	63.9	1157.0	69.3
Wealth index						
Poor	423	50.9	1978	52.2	505.0	30.2
Middle	319	38.4	1357	35.8	718.0	43.0
Rich	89	10.7	455	12.0	447.0	26.8

Hindu women constituted the majority across all BMI categories; however, the proportion of overweight and obese women from other religious groups was relatively higher compared to those in the underweight and normal BMI categories. Ethnicity-wise, most women belonged to groups other than Brahmin and Chhetri, and they were also more likely to fall into the overweight or obese category. Regarding the wealth index, women in the underweight and normal BMI categories predominantly came from poorer households. However, a notable shift was observed in the overweight or obese category, where middle-income women represented the largest proportion, highlighting the influence of socioeconomic status on BMI distribution.

WASH Bivariate Analysis

Table 10 shows the mean differences in BMI scores among the underweight, normal, and overweight categories based on WASH variables. A notable pattern emerges in the relationship between BMI and drinking water sources. While no significant difference is observed in the mean BMI of individuals in the underweight category regarding their drinking water source, those in the normal and overweight/obese categories exhibit significantly higher BMI when using piped water compared to other sources. This trend suggests a potential association between access to piped water and increased BMI.

Table 10
Mean BMI Score For Underweight, Normal, And Overweight/Obese By WASH Variables For Non-Pregnant Women Aged 15-49 Years, Nepal, 2022

WASH variables	**Underweight**			**Normal**			**Overweight/Obese**		
	N	M (SD)	**t**	**N**	M (Sd)	**t**	**N**	M (SD)	**t**
Source of drinking water									
Piped	39	1735 (93)	1.38	2271	2159 (173)	2.75	1087	2859 (309)	2.96
Others	43	1726 (102)		1519	2143 (181)		583	2814 (282)	
Water on premises									
On-premises	69	1727 (99)	2.17	3071	2159 (178)	4.71	1474	2846 (303)	0.94
Not on premises	13	1747 (88)		719	2125 (168)		196	2824 (281)	
Type of toilet facility									
Flush to septic tank	74	1730 (99)	0.04	3394	2154 (177)	1.55	1569	2842 (299)	0.38
Others	90	1730 (86)		396	2139 (177)		101	2854 (327)	
Toilet facilities shared with other households									

Yes	63	1732 (94)	0.88	2962	2151 (176)	0.72	1340	2847 (307)	0.94
No	19	1724 (109)		828	2156 (180)		330	2829 (275)	

Individuals with on-premises water access have significantly higher BMIs in the underweight and normal categories compared to those without on-premises water access. However, no significant difference is observed in the overweight category, indicating that while improved water access may influence BMI in lower-weight groups, its impact on overweight individuals appears minimal.

In contrast, no significant associations are found between BMI and sanitation variables. BMI scores do not significantly differ among the underweight, normal, and overweight categories based on access to a flush toilet or whether the toilet facility is shared, as all p-values exceed the 0.05 threshold. This finding suggests that, unlike water access, the type of toilet facility and sharing status may have a limited role in influencing BMI outcomes.

Multinomial Logistic Regression

Table 11 shows the multinomial logistic regression results for factors associated with BMI (underweight, normal, overweight/obese) among non-pregnant women aged 15 to 49 years in Nepal in 2022. An odds ratio is generally considered statistically significant at the corresponding confidence level (e.g., $p < 0.05$ for a 95% CI) if its confidence interval does not include 1 (the null value).

Table 11
Multinomial Regression Of Sociodemographic Variables On Weight Status, Nepal, 2022.

Variables	Weight Status (Reference category: Normal)					
	Underweight			Overweight/Obese		
	OR	CI (95%)		OR	CI (95%)	
Age of participants (15-19 years)	**2.706**	**2.203**	**3.324**	**0.069**	**0.050**	**0.095**
Age of participants (20-34 years)	**1.241**	**1.020**	**1.510**	**0.498**	**0.438**	**0.567**

Age of participants (35-49 years)	Ref	Ref	Ref	Ref	Ref	Ref
Type of place of residence (Urban)	0.970	0.826	1.140	**1.210**	**1.057**	**1.386**
Type of place of residence (Rural)	Ref	Ref	Ref	Ref	Ref	Ref
Religion (Hindu)	**1.598**	**1.218**	**2.096**	**0.602**	**0.506**	**0.716**
Religion (Others)	Ref	Ref	Ref	Ref	Ref	Ref
Ethnicity (Brahmin and Chhetri)	1.187	0.996	1.414	**0.750**	**0.648**	**0.867**
Ethnicity (Others)	Ref	Ref	Ref	Ref	Ref	Ref
Wealth index (Poor)	**1.347**	**1.025**	**1.771**	**0.252**	**0.208**	**0.305**
Wealth index (Middle)	1.209	0.922	1.584	**0.580**	**0.486**	**0.692**
Wealth index (Rich)	Ref	Ref	Ref	Ref	Ref	Ref
Source of drinking water (Piped)	**0.524**	**0.440**	**0.625**	**1.816**	**1.580**	**2.088**
Source of Drinking Water (Others)	Ref	Ref	Ref	Ref	Ref	Ref
Time to get drinking water (On premise)	**1.291**	**1.046**	**1.593**	**1.207**	**1.004**	**1.452**
Time to get drinking water (Not on premise)	Ref	Ref	Ref	Ref	Ref	Ref
Types of toilet facility (Flush)	1.010	0.788	1.295	**1.608**	**1.266**	**2.043**
Types of toilet facility (Others)	Ref	Ref	Ref	Ref	Ref	Ref

CI: Confidence Interval, OR: Odds Ratio.[3] ; Model fit statistics (Nagelkerke R^2) =0.217

The multinomial logistic regression results presented in Table 11 indicate that key demographic and WASH-related factors are associated with being underweight or overweight/obese among non-pregnant women aged 15 to 49 years. Comparing the underweight results to those of the normal BMI categories reveals that younger age, religious affiliation,

[3] In multinomial logistic regression, odds ratios represent the multiplicative change in the odds of being in a specific category of the dependent variable compared to a chosen reference category, for a one-unit increase in the independent variable, holding other variables constant. Interpretation:
OR > 1: An odds ratio greater than 1 suggests that an increase in the predictor variable is associated with increased odds of being in the specific category versus the reference category.
OR < 1: An odds ratio less than 1 indicates that an increase in the predictor variable is associated with decreased odds of being in the specific category versus the reference category.
OR = 1: An odds ratio of 1 implies no effect of the predictor variable on the odds of being in that specific category compared to the reference category.
A confidence interval (CI) provides a range within which the true population odds ratio is likely to lie.
Interpretation: 95% CI: A 95% confidence interval indicates a 95% probability that the true population odds ratio is within the calculated interval.
Statistical Significance: If the confidence interval for an odds ratio does not include 1 (the null value), the odds ratio is typically considered statistically significant at the corresponding confidence level (e.g., p < 0.05 for a 95% CI) (Google AI, 2025).

economic status, and water access play a critical role in determining BMI status. Younger women are at a higher risk of being underweight, with those aged 15 to 19 years (OR = 2.71, 95% CI: 2.20–3.32) and 20 to 34 years (OR = 1.24, 95% CI: 1.02–1.51) showing significantly greater odds of being underweight compared to women with normal weight.

Socioeconomic factors also play a role in this trend, with Hindu women (OR = 1.60, 95% CI: 1.22–2.10) and individuals from poorer households (OR = 1.35, 95% CI: 1.03–1.77) being more likely to be underweight. Access to water also affects BMI status. Women with water available on the premises face a heightened risk of being underweight (OR = 1.29, 95% CI: 1.05–1.59), while those using piped water have significantly lower odds of being underweight (OR = 0.52, 95% CI: 0.44–0.63), suggesting a potential protective effect. Meanwhile, urban residence, Brahmin/Chhetri ethnicity, and access to flush toilets demonstrate minimal or non-significant associations with underweight status.

The multinomial logistic regression analysis reveals a distinct pattern in the factors associated with overweight and obesity among non-pregnant women aged 15 to 49 years compared to those with a normal BMI. Age plays a crucial role, as younger women are significantly less likely to be overweight or obese. Women aged 15 to 19 years (OR = 0.069, 95% CI: 0.050–0.095) and those aged 20 to 34 years (OR = 0.498, 95% CI: 0.438–0.567) have markedly lower odds of being overweight or obese compared to their normal-weight counterparts, indicating an increased risk of excess weight with age. Socioeconomic status also influences BMI outcomes.

Urban women are more likely to be overweight or obese (OR = 1.21, 95% CI: 1.057–1.387), while those from poorer (OR = 0.252, 95% CI: 0.208–0.305) and middle (OR = 0.58, 95% CI: 0.486–0.692) wealth index categories have significantly lower odds, highlighting the influence of wealth on obesity risk. Additionally, Hindu women (OR = 0.602, 95% CI: 0.506–0.716) and those from Brahmin/Chhetri ethnic groups (OR = 0.75, 95% CI: 0.648–0.867) are less likely to be overweight or obese. Access to water and sanitation appears to affect weight status. Women with water on the premises (OR = 1.207, 95% CI: 1.004–1.452), those using piped water (OR = 1.816, 95% CI: 1.58–2.088), and those with flush toilets (OR = 1.608, 95% CI: 1.266–2.43) are at a higher risk of being overweight or obese. These findings suggest that improved WASH access may be associated with higher BMI, potentially reflecting lifestyle changes linked to urbanization and enhanced infrastructure.

Discussion

This study offers valuable insights into the relationships between WASH variables and BMI status among non-pregnant women aged 15 to 49 in Nepal, based on the 2022 DHS. The findings reveal significant sociological disparities in BMI distribution and highlight the potential role of water access in influencing weight status, while sanitation factors seem to have a minimal impact.

We observe that 13% of women aged 15-49 were underweight (BMI <18.5 kg/m^2), 60% were at a normal weight (BMI 18.5 to 24.9 kg/m^2), and 27% were overweight or obese (BMI >25 kg/m^2). Our estimate for the underweight category was lower than in 2016, when it was 17.5%, and higher for the overweight/obesity category, which was estimated at 22.2% in 2016 (Hasan et al., 2022). The reduction in underweight and the increase in the overweight/obese category align with the predicted changes from previous studies (Biswas et al., 2019; Hasan et al., 2022; Headey & Hoddinott, 2015). Factors such as asset accumulation, health and nutrition interventions, maternal educational gains, and improvements in sanitation may have driven these changes (Headey & Hoddinott, 2015).

The higher prevalence of overweight and obesity in urban areas (52%-62%) compared to rural regions aligns with existing literature (Bhattarai et al., 2025). Women from religious groups other than Hindus, as well as those who were not Brahmin or Chhetri, exhibited a relatively higher prevalence of overweight and obesity. This observation corresponds with previous studies of reproductive-aged (15-49) women in India, which indicated that Hindu women were approximately 1.5 times more likely to be underweight than women of other religions (Al Kibria et al., 2019).

Hindu women who are Brahmin and Chhetri are seen as belonging to a higher caste. Consequently, the lack of balanced dietary patterns (dietary diversity) and higher calorie intake among women from other groups may help explain these ethnic and religious differences (Acharya et al., 2017; Henjum et al., 2015). Furthermore, the wealth index significantly influences BMI distribution, with underweight and normal BMI categories being more common among women from poor households. In contrast, middle-income women comprise the largest proportion of the overweight and obese categories, reinforcing the link between higher economic status and overweight or obesity (Al Kibria, 2019; Bishwajit, 2017; Shariful Islam et al., 2022).

The mean difference between water access and sanitation in BMI is particularly noteworthy. Women with access to piped water are more likely to be overweight or obese. This finding was consistent with a previous study, which observed that among non-pregnant mothers, water source: piped led was positively associated with BMI (Cunningham et al., 2017) and was negatively related to low maternal BMI (Headey & Hoddinott, 2015). Households connected to a piped water supply also have a higher likelihood of treating their household water, thereby enhancing water quality (Daniel et al., 2019).

The percentage of households in Nepal using piped water in their dwelling, yards, or plots doubled from 22% to 44% between 2011 and 2022 (Ministry of Health et al., 2022), which may contribute to the increase in the overweight or obese category (Biswas et al., 2019; Hasan et al., 2022; Headey & Hoddinott, 2015). Our finding correlates with research conducted among Ethiopian women of reproductive age, which indicated that an improved source of drinking water was linked to being overweight (Ferede et al., 2017).

Women in the normal BMI category and those with on-premises water access had a higher mean BMI, whereas those in the underweight category exhibited a lower mean BMI. For the normal BMI category, the convenience of having water access on the premises may reduce the physical effort (the need to walk 30 minutes or less round trip) required for water collection (Ministry of Health et al., 2022), potentially leading to decreased energy expenditure. In contrast, for the underweight category, factors beyond water convenience, such as lower wealth and a lack of dietary diversity, might have contributed to the lower mean BMI, warranting further investigation (Al Kibria, 2019; Bishwajit, 2017; Shariful Islam et al., 2022).

In contrast, sanitation variables, including access to flush toilets and shared toilet facilities, did not show a significant difference in BMI status in our study. This finding suggests that while improved sanitation is crucial for overall health, its direct impact on BMI may be limited. This result aligns with previous meta-analyses, which indicate no effect of sanitation on weight-for-age z-scores/underweight and weight-for-height z-scores/wasting (Freeman et al., 2017). The lack of significant differences may imply that sanitation infrastructure primarily influences health outcomes related to infectious diseases rather than nutritional status and weight management.

For example, access to WASH, including access to the hygienic toilet system, reduces communicable diseases (Mehata et al., 2022; Pandey et al., 2020). However, other studies suggest a positive relationship between unimproved sanitation with low BMI (Headey & Hoddinott, 2015). In terms of maternal weight gain, better sanitation is the most important factor, indicating that increased toilet access may have significantly reduced maternal infections (Cunningham et al., 2016). Women in Ethiopia without access to toilet facilities (e.g., flush toilets) are more likely to be underweight compared to those with access to improved toilet facilities (OR = 1.32; 95% CI: 0.93, 1.88) (Ferede et al., 2017). Similarly, in Ethiopia, the odds of being underweight among those using clean latrines are 0.43 (95% CI: 0.20, 0.92) compared to those using unclean latrines or lacking toilet facilities (Merkina et al., 2024).

In Nigeria, inadequate WASH facilities have been linked to undernutrition among women of childbearing age (Morakinyo et al., 2020). A previous study indicates that poor sanitation is associated with lower BMI among pregnant Cambodian women (Janmohamed et al., 2016). One reason for this discrepancy might stem from our study design, which categorizes toilet facilities as flush versus other types, in contrast to improved versus not improved. However, the cause of this difference requires further investigation.

The multinomial logistic regression analysis further clarifies the influence of demographic and WASH factors on BMI categories. Our results indicate that younger women (aged 15-19) were more likely to be underweight, and older women (aged 35-49 years) were more likely to be overweight/obese than normal. This finding was consistent with previous studies (Bhattarai et al., 2025; Schwinger et al., 2020; Shariful Islam et al., 2022). Women in the age group of 25 to 35 years and 35 to 49 years were two to three times more likely to be overweight than the younger age (15 to < 25 years) group (Bhattarai et al., 2025; Shariful Islam et al., 2022).

Age-related hormonal changes (e.g., menopause) (Opoku et al., 2023), a slower metabolism (e.g., fewer calories consumed as one ages), and lifestyle changes (e.g., decreased physical activity with age) may have contributed to the weight gain observed in women over time. The strong inverse association between younger age and overweight or obesity emphasizes the need for early interventions to prevent excessive weight gain in adulthood.

The connection between urban residence and the increased prevalence of overweight and obesity underscores the impact of urbanization on dietary patterns and physical activity levels. This finding aligns with previous studies indicating that women living in urban areas are more likely to be obese (Bhattarai et al., 2025; Shariful Islam et al., 2022; Smith, 1998; Vaidya & Krettek, 2014). Urban women, experiencing reduced energy expenditure due to a shift toward sedentary jobs, better access to food and transportation, and increased affluence, may face a higher risk of overweight and obesity compared to their rural counterparts (Bhattarai et al., 2025; Smith, 1998).

Religious differences among non-pregnant women in Nepal also influence BMI distribution. While Hindu women comprise the majority across all BMI categories, women from other religious backgrounds show a higher likelihood of being overweight or obese. Dietary patterns, including a rice intake that can account for up to 60% of energy, alongside consumption of meat, dairy, and calorie-rich fermented foods, as well as limited access to balanced nutrition and poorer economic status among other groups, may contribute to the higher prevalence of overweight and obesity in these populations (Henjum et al., 2015). A previous study found that grain, meat, and alcohol intake, which is common among women from other religious backgrounds, was positively associated (OR 1.19, 95% CI: 1.03 – 1.39) with overweight and obesity (Shrestha, 2015). This finding aligns with another study conducted among reproductive-aged women (15-49 years) in India, which indicates that women of non-Hindu religions were more likely (OR 1.33, 95% CI 1.28-1.38) to be overweight or obese compared to their Hindu counterparts (Al Kibria et al., 2019).

Similarly, women from ethnic groups other than Brahmin and Chhetri are more likely to be overweight or obese. This aligns with previous studies that found Newar and Hill Jana Jati women had a 30% to 80% higher chance of being overweight or obese compared to those from Brahmin and Chhetri backgrounds (Bhattarai et al., 2025; Sutradhar et al., 2021). One reason for this disparity may be that women in the more advantaged ethnic group (Brahmin and Chhetri) have experienced greater dietary diversity than their less advantaged counterparts (Bhattarai et al., 2025). These differences reflect variations in dietary habits, cultural practices, and socioeconomic conditions among various religious and ethnic groups.

Economic status also plays a critical role in BMI outcomes. Consistent with previous studies in Nepal, women from poorer households are more likely to be underweight, whereas middle-income women exhibit the highest proportion of overweight and obesity (Bishwajit, 2017; Shariful Islam et al., 2022). Nepalese women were 8.54 (OR = 8.452; 95% CI = 5.228–13.663) times higher compared with those in the poorest households (Bishwajit, 2017). Similarly, Women aged 35–49 from the richest households were more likely to be overweight (OR 5.68; 95%CI 4.62–6.99) (Shariful Islam et al., 2022). This finding suggests that as household wealth improves, dietary diversity and energy intake may increase, leading to higher BMI (Bhattarai et al., 2025). However, contrary to previous studies, a lower prevalence of overweight and obesity was observed among the wealthiest group in our study (Shariful Islam et al., 2022). One reason for this may be the heightened health awareness and lifestyle modifications, such as better nutrition and exercise habits, among these groups.

Additionally, the protective effect of piped water and its availability on premises against being underweight, along with its association with an increased risk of obesity, suggests a complex relationship between water access, nutrition, and physical activity. This finding aligns with a previous study that observed among non-pregnant mothers a positive association between the source of piped water and BMI (Cunningham et al., 2017), as well as a negative relationship with low maternal BMI (Headey & Hoddinott, 2015).

Reducing exposure to contaminated water sources through piped water leads to a lower incidence of diarrheal diseases (Cunningham et al., 2016; Mehata et al., 2022; Pandey et al., 2020), improved sanitation, and enhanced hygiene. These factors have been shown to contribute to a 35% increase in maternal weight gain in Nepal from 1996 to 2011. Urban areas are more likely to utilize piped water as the drinking source, which is associated with greater wealth and either a sedentary lifestyle or physical activity to access the water (Bhattarai et al., 2025; Shariful Islam et al., 2022; Smith, 1998; Vaidya & Krettek, 2014). This may explain the protective effect observed with piped water and having water on the premises. However, we also found that women with access to water on the premises were 1.3 times more likely to be underweight compared to those without access.

This result was unexpected, as piped or easily accessible water is typically associated with better hygiene and improved nutritional intake. One explanation for our findings may be the socioeconomic disparities; for instance, women in urban areas might have access to water on the premises but still encounter economic hardship, leading to insufficient dietary intake and, as a result, a higher prevalence of underweight.

In our study, we also observed that women who use flush toilets were 1.6 times more likely to be overweight or obese compared to those with normal weight. A positive relationship between improved sanitation and the likelihood of being in the overweight or obese category aligns with prior research (Cunningham et al., 2016; Headey & Hoddinott, 2015). Future studies should explore the underlying mechanisms driving this association to inform targeted strategies aimed at mitigating obesity risks in populations experiencing enhanced living conditions.

Limitations and Future Research

While this study provides valuable insights, several limitations must be acknowledged. First, the cross-sectional design restricts causal inferences, as the relationships between WASH factors and BMI may be affected by unmeasured confounders. Longitudinal studies are essential to establish causal pathways and assess how changes in WASH access over time influence BMI trajectories.

Second, the analysis did not encompass dietary intake and physical activity data, which restricts the ability to explore the mechanisms underlying the observed associations. Future research should include these variables to provide a more comprehensive understanding of the relationship between WASH access and BMI.

Third, because of a substantial amount of missing data, only a limited number of sociodemographic and WASH variables (such as the source of drinking water and the time taken to collect it) were included to examine their relationship with BMI. Future studies should explore a broader range of WASH-related variables to investigate their association with BMI categories.

Conclusion

This study highlights the intricate relationship between WASH access, socioeconomic factors, and BMI among non-pregnant women aged 15-49 in Nepal. Our findings suggest that older age, urban residency, non-Hindu or Brahmin/Chhetri ethnic backgrounds, and higher wealth are linked to a greater BMI or an increased likelihood of being overweight or obese. Furthermore, WASH factors, such as access to piped water and water on premises, are associated with higher BMI. These results underscore the vital role of both sociodemographic and environmental determinants in shaping women's health and nutritional outcomes. To effectively improve women's nutritional status in Nepal, public health interventions should adopt a comprehensive approach that integrates WASH enhancements with strategies to promote healthy lifestyles and ensure equitable resource distribution.

Implications of Findings

Theoretical Implications

This dissertation contributes to the theoretical understanding of health and development by reinforcing the Social Determinants of Health (SDOH) framework (United States Department of Health and Human Services, Office of Disease Prevention and Health Promotion, 2025). First, this study empirically validates the SDOH framework by showing that WASH-related factors such as access to clean water, improved sanitation, and hygienic practices have significant, independent associations with household food insecurity and the nutritional status of both children and women. These results underscore how health outcomes are shaped by social and environmental conditions beyond individual behavior (Marmot et al., 2008). Specifically, households with inadequate WASH conditions had higher odds of food insecurity, stunting, underweight, and, in some cases, under- or over-nutrition among women, pointing to the multidimensional nature of nutritional status.

Second, this work aligns with the UNICEF framework for child undernutrition, which identifies enabling determinants (governance, resources, and norms), underlying determinants (food, practice and services), immediate determinants (diets and care) contributing to improved maternal and child nutrition (United Nations Children's Fund, 2020). By quantitatively linking WASH indicators to child malnutrition outcomes, this research supports the UNICEF framework's emphasis on the importance of basic environmental health conditions in improving maternal and child nutrition. Importantly, the results also highlight that while improved WASH access is generally associated with positive nutritional outcomes (especially reductions in undernutrition), it may also be linked to increases in overweight and obesity, particularly among wealthier, urban women. This duality challenges the conventional assumption that WASH improvements uniformly benefit all health outcomes. It calls for a multimodal approach to account for the double burden of malnutrition, where undernutrition and overnutrition coexist within populations, and even households (Popkin et al., 2020).

Additionally, nutritional status differed by ethnicity, religion, and wealth, suggesting future theoretical models of nutrition and food security must integrate sociocultural determinants more explicitly. For example, the influence of caste and religious dietary norms in Nepal appears to intersect with WASH access in complex ways that shape nutrition outcomes. This intersection invites a broader theoretical conversation about how ethnicity and religion interact with the social determinants of health.

Empirical Implications

This study makes important empirical contributions by offering comprehensive, nationally representative evidence on the relationships between water, sanitation, and hygiene (WASH) conditions and key nutrition-related outcomes in Nepal, including household food insecurity, childhood undernutrition, and women's BMI. This research empirically substantiates the role of WASH as a critical determinant of household food insecurity. Our study advances the literature by using detailed regression analysis and nationally representative DHS data to isolate and quantify the independent effects of WASH factors such as water source, sanitation type, and hygiene behaviors on food insecurity outcomes, controlling for key socioeconomic variables. The significant association between the location of drinking water and food insecurity highlights the time and labor burden associated with off-premises water access.

Furthermore, the findings from the child nutrition analysis provide strong empirical evidence for the protective role of improved WASH conditions against stunting, underweight, and wasting among children under five. Children living in households with piped water and toilets on the premises were less likely to be undernourished, even after adjusting for household wealth, number of children, and residence type. These results align with previous findings from multi-country analyses (Dangour et al., 2013), but our analysis deepens the empirical insights by focusing on Nepal's unique geographic and socioeconomic contexts and using the most recent nationally representative data.

Moreover, the study uncovers empirical evidence on the relationship between WASH and women's nutritional status, measured by BMI. The findings show that women in households with access to piped water and flush toilets were more likely to have higher BMI, suggesting that while WASH improvements reduce infectious disease risk and energy expenditure from water collection, they may also contribute to increased caloric retention or reduced physical activity, especially in urban or wealthier populations (Subramanian et al., 2009). These results highlight the emerging double burden of malnutrition in Nepal, where overweight and underweight coexist and may be differentially influenced by infrastructure improvements.

Additionally, this research reinforces the empirical importance of integrating sociodemographic and cultural variables such as wealth, age, religion, ethnicity, and place of residence. Across all three papers, these factors consistently modified the relationship between WASH and nutrition-related outcomes. For example, poor households and those in rural areas faced significantly higher food insecurity and undernutrition risks, while wealthier, urban households were more prone to being overweight, even with similar WASH access. This suggests that WASH interventions must be specific to cultural context.

Practical and Policy Implications

The findings from this study provide actionable insights for educators and educational institutions, policymakers, public health practitioners, and development stakeholders working to address food insecurity and malnutrition in Nepal. The strong associations observed between WASH conditions and household food insecurity, child undernutrition, and women's nutritional status highlight the need to incorporate WASH interventions into broader national strategies aimed at improving public health and nutritional outcomes.

Educators and educational institutions

The demonstrated impact of WASH conditions on food insecurity and nutritional outcomes underscores the need for integrating WASH education into school curricula, particularly in health, environmental science, and social studies programs. As emphasized by UNESCO (2020), integrating context-specific health education fosters inclusive and responsive learning environments. Furthermore, academic institutions, particularly those in or partnering with low- and middle-income countries like Nepal, have a vital role in preparing future public health professionals through interdisciplinary coursework, applied fieldwork, and community-based research. UNICEF (2012) also underscores the importance of school settings not only as learning environments but also as platforms for modeling healthy WASH practices. Institutions can lead by example by ensuring access to clean water, sanitation, and hygiene within their facilities, thereby fostering lifelong health behaviors among students and staff. Finally, universities and research centers should actively engage in collaborative research with governmental and non-governmental organizations to explore the long-term impacts of WASH interventions.

Integrating WASH into Nutrition and Food Security Programs

Evidence from this study underscores that inadequate access to clean water, basic sanitation, and hygiene contributes not only to communicable diseases but also to food insecurity and undernutrition. Therefore, integrating WASH improvements into national food security and nutrition initiatives is crucial. Programs such as the Multi-Sector Nutrition Plan (MSNP) in Nepal should continue to prioritize WASH infrastructure, particularly piped water access and improved toilet facilities, as foundational to reducing household vulnerability (National Planning Commission, 2017; World Health Organization & United Nations Children's Fund, 2023).

Targeted Interventions for Vulnerable Populations

The results indicate that rural households, poor families, and those with more children are disproportionately affected by food insecurity and malnutrition. WASH interventions should be targeted specifically toward these vulnerable groups to maximize impact. For example, expanding rural water supply schemes and community sanitation programs in underserved provinces can improve household resilience.

Addressing the Double Burden of Malnutrition

The positive association between improved WASH access and increased BMI among women in wealthier, urban areas reveals a nuanced implication: while improving WASH helps combat undernutrition, it may also inadvertently contribute to overweight and obesity through decreased physical activities and improved calorie absorption. National nutrition policies should therefore address the emerging double burden of malnutrition, ensuring that WASH programs are complemented with dietary education and promotion of physical activity in urban settings (Popkin et al., 2020; Pries et al., 2019).

Culturally and Religiously Sensitive Program Design

Given the observed variations in outcomes based on religion and ethnicity, interventions must be culturally tailored. For example, hygiene promotion efforts should consider religious norms related to cleanliness, gender roles in water collection, and dietary restrictions. Engaging local leaders and community-based organizations can enhance the cultural acceptability and effectiveness of interventions.

Overview and Conclusion

This study examines the relationship between Water, Sanitation, and Hygiene (WASH) conditions and three critical public health outcomes in Nepal: household food insecurity, child malnutrition, and women's nutritional status. Using nationally representative data from the 2022 Nepal Demographic and Health Survey (DHS) and adjusting for sociodemographic covariates, our analysis explores how WASH variables influence food insecurity, child malnutrition (stunting, wasting, undernutrition), and women's nutrition (Body Mass Index (BMI)). Among the 13,786 households surveyed, 6,007 were identified as food insecure, illustrating the widespread prevalence of food insecurity across Nepal. Households' dependent on spring water sources and shared sanitation facilities faced higher risks of food insecurity, while those with access to on-premises drinking water and private sanitation facilities experienced improved food security outcomes.

Regression analyses confirmed our findings that improved sanitation, the availability of handwashing resources, and household water treatment practices were associated with lower levels of food insecurity. In contrast, poverty and inadequate WASH conditions emerged as major contributors to food insecurity. These findings emphasize that WASH-related deprivation undermines household food resilience. Findings from our study also highlight geographic and infrastructural inequalities that disproportionately affect rural and low-income households. National food security and health strategies should therefore include targeted investments in WASH infrastructure alongside income-based interventions. Additionally, promoting water treatment and hygiene practices offers a practical and effective way to reduce food insecurity, particularly where full infrastructure development is not yet feasible.

Similarly, malnutrition outcomes among children aged 0–59 months, including stunting, wasting, and underweight, were closely linked to WASH conditions, reinforcing the critical role of basic infrastructure in early childhood health. Children in households with access to piped water and improved sanitation had significantly better nutritional outcomes, particularly lower rates of stunting. In contrast, children from lower-income households or those with multiple young siblings faced increased risks of stunting and underweight, pointing to the compounded burden of poverty and caregiving demands. Interestingly, urban residence was associated with lower stunting but higher rates of wasting, suggesting a need for context-specific interventions that address both undernutrition and acute malnutrition in different settings.

Among non-pregnant women aged 15–49 years, WASH access was also a key determinant of nutritional status. Women with access to piped water and private sanitation were more likely to be overweight or obese, particularly those in urban areas and from non-Hindu or non-Brahmin/Chhetri ethnic groups. These patterns highlight a growing double burden of malnutrition, where both undernutrition and overnutrition coexist within the same population, often shaped by social and environmental disparities. The findings underscore the need for integrated health and development strategies in Nepal that combine WASH improvements with targeted nutrition education and social equity efforts. Addressing these disparities requires not only expanding infrastructure but also tailoring interventions to the sociodemographic contexts of households, recognizing that WASH access alone does not guarantee uniform health benefits across diverse population groups.

In conclusion, this study provides compelling and comprehensive evidence that WASH conditions are associated with household food insecurity, child malnutrition, and women's nutritional status in Nepal. Inadequate access to clean water, sanitation, and hygiene resources significantly exacerbates nutritional vulnerabilities, particularly among low-income households, families with young children, and women in both rural and urban settings. The findings across all three studies underscore the intricate and reinforcing relationship between WASH infrastructure, socioeconomic disparities, and health outcomes, demonstrating that improvements in water and sanitation alone are insufficient without concurrent efforts to address poverty, education, and social inequality. These insights call for integrated, multisectoral policy solutions that position WASH as a central pillar of national strategies to reduce malnutrition and food insecurity. Targeted investments in equitable WASH access, especially for marginalized populations, have the potential to alleviate the dual burden of undernutrition and overnutrition. Future research should prioritize longitudinal and intervention-based designs to establish causal pathways and evaluate the long-term effectiveness of WASH-centered approaches in improving maternal and child health and household food resilience.

Limitations

While this dissertation provides valuable insights into the relationship between water, sanitation, and hygiene (WASH) conditions and key health and nutrition outcomes in Nepal, several limitations inherent to the use of secondary data from the 2022 Nepal Demographic and Health Survey (DHS) must be acknowledged. First, the cross-sectional design of the DHS restricts causal inference, as the data reflects a snapshot in time and cannot establish temporal relationships between WASH conditions and outcomes such as food insecurity, child malnutrition, or women's BMI. Second, the reliance on self-reported measures for key variables, such as food insecurity and hygiene practices, may introduce recall bias or social desirability bias, potentially affecting the accuracy of responses. Literacy is also a critical variable in interpreting responses to survey questions, particularly in studies involving self-reported measures of food insecurity, sanitation practices, and health behaviors. This has important implications for how respondents understood and responded to survey items, especially those related to WASH practices and food insecurity. Low literacy levels among certain respondent groups may have influenced their ability to accurately interpret survey questions, introducing potential response bias or measurement error. Finally, the available data limits the inclusion of potentially important confounding variables, such as dietary intake, environmental contamination, seasonal variability in water access, and other WASH variables which could influence the observed relationships. Despite these limitations, the DHS remains one of the most comprehensive sources of population-level health data in for Nepal and provides a strong foundation for informing policy and guiding future research.

References

Acharya, S. R., Bhatta, J., & Timilsina, D. (2017). Factors associated with nutritional status of women of reproductive age group in rural, Nepal. *Asian Pacific Journal of Health Sciences*, *4*, 19-24. https://doi.org/10.21276/apjhs.2017.4.4.6

Adhikari, D., Khatri, R. B., Paudel, Y. R., & Poudyal, A. K. (2017). Factors Associated with Underweight among Under-Five Children in Eastern Nepal: Community-Based Cross-sectional Study. *Front Public Health*, *5*, 350. https://doi.org/10.3389/fpubh.2017.00350

Adhikari, R. P., Shrestha, M. L., Acharya, A., & Upadhaya, N. (2019). Determinants of stunting among children aged 0-59 months in Nepal: findings from Nepal Demographic and health Survey, 2006, 2011, and 2016. *BMC Nutr*, *5*, 37. https://doi.org/10.1186/s40795-019-0300-0

Al Kibria, G. M. (2019). Prevalence and factors affecting underweight, overweight and obesity using Asian and World Health Organization cutoffs among adults in Nepal: Analysis of the Demographic and Health Survey 2016. *Obes Res Clin Pract*, *13*(2), 129-136. https://doi.org/10.1016/j.orcp.2019.01.006

Al Kibria, G. M., Swasey, K., Hasan, M. Z., Sharmeen, A., & Day, B. (2019). Prevalence and factors associated with underweight, overweight and obesity among women of reproductive age in India. *Glob Health Res Policy*, *4*, 24. https://doi.org/10.1186/s41256-019-0117-z

Amare, Z. Y., Ahmed, M. E., & Mehari, A. B. (2019). Determinants of nutritional status among children under age 5 in Ethiopia: further analysis of the 2016 Ethiopia demographic and health survey. *Global Health*, *15*(1), 62. https://doi.org/10.1186/s12992-019-0505-7

Angdembe, M. R., Dulal, B. P., Bhattarai, K., & Karn, S. (2019). Trends and predictors of inequality in childhood stunting in Nepal from 1996 to 2016. *International Journal for Equity in Health*, *18*(1), 42. https://doi.org/10.1186/s12939-019-0944-z

Anin, S. K., Saaka, M., Fischer, F., & Kraemer, A. (2020). Association between Infant and Young Child Feeding (IYCF) Indicators and the Nutritional Status of Children (6-23 Months) in Northern Ghana. *Nutrients*, *12*(9). https://doi.org/10.3390/nu12092565

Anyanwu, O., Ghosh, S., Kershaw, M., Cherinet, A., & Kennedy, E. (2022). Dietary Outcomes, Nutritional Status, and Household Water, Sanitation, and Hygiene (WASH) Practices. *Curr Dev Nutr*, *6*(4), nzac020. https://doi.org/10.1093/cdn/nzac020

Aung, S. S. (2024). *Association between household food insecurity and psychological distress among women aged 15-49 in Nepal: A secondary analysis of demographic health survey in Nepal 2022* Uppsala University]. https://uu.diva-portal.org/smash/get/diva2:1878745/FULLTEXT01.pdf

Bhattarai, P., Vaidya, A., & Tylleskär, T. (2025). Overweight, obesity and physical inactivity among women of reproductive age in Eastern Nepal: a cross-sectional community-based study. *PLOS Glob Public Health*, *5*(3), e0004360. https://doi.org/10.1371/journal.pgph.0004360

Bishwajit, G. (2017). Household wealth status and overweight and obesity among adult women in Bangladesh and Nepal: Household wealth status and BMI among women in Bangladesh and Nepal. *Obesity Science & Practice*, *3*. https://doi.org/10.1002/osp4.103

Biswas, T., Townsend, N., Magalhaes, R. J. S., Islam, M. S., Hasan, M. M., & Mamun, A. (2019). Current Progress and Future Directions in the Double Burden of Malnutrition among Women in South and Southeast Asian Countries. *Curr Dev Nutr*, *3*(7), nzz026. https://doi.org/10.1093/cdn/nzz026

Black, R. E., Victora, C. G., Walker, S. P., Bhutta, Z. A., Christian, P., de Onis, M., . . . Uauy, R. (2013). Maternal and child undernutrition and overweight in low-income and middle-income countries. *Lancet*, *382*(9890), 427-451. https://doi.org/10.1016/s0140-6736(13)60937-x

Boateng, G. O., Workman, C. L., Miller, J. D., Onono, M., Neilands, T. B., & Young, S. L. (2022). The syndemic effects of food insecurity, water insecurity, and HIV on depressive symptomatology among Kenyan women. *Social Science & Medicine*, *295*, 113043. https://doi.org/https://doi.org/10.1016/j.socscimed.2020.113043

Brewis, A. A., Piperata, B., Thompson, A. L., & Wutich, A. (2020). Localizing resource insecurities: A biocultural perspective on water and wellbeing. *WIREs Water*, *7*(4), e1440. https://doi.org/https://doi.org/10.1002/wat2.1440

Cairncross, S., & Kinnear, J. (1992). Elasticity of demand for water in Khartoum, Sudan. *Social Science & Medicine*, *34*(2), 183-189. https://doi.org/https://doi.org/10.1016/0277-9536(92)90095-8

Caruso, B. A., Conrad, A., Patrick, M., Owens, A., Kviten, K., Zarella, O., . . . Sinharoy, S. S. (2022). Water, sanitation, and women's empowerment: A systematic review and qualitative metasynthesis. *PLOS Water*, *1*(6), e0000026. https://doi.org/10.1371/journal.pwat.0000026

Centers for disease Control and Prevention. (2022a). *Assessing Access to Water & Sanitation*. U.S. Department of Health and Human Services. https://www.cdc.gov/healthywater/global/assessing.html

Centers for Disease Control and Prevention. (2022b, April 27, 2022). *Global Water, Sanitation, & Hygiene (WASH): Sanitation*. U.S. Department of Health and Human Services. Retrieved April 5, 2025 from https://www.cdc.gov/healthywater/global/sanitation/index.html

Centers for Disease Control and Prevention. (2024). *About Body Mass Index (BMI)*. Retrieved April 4, 2025 from https://www.cdc.gov/bmi/about/index.html

Central Statistical Agency (CSA) [Ethiopia], & ICF. (2016). *Ethiopia Demographic and Health Survey 2016*.

Chase, C., & Ngure, F. (2016). *Multisectoral Approaches to Improving Nutrition: Water, Sanitation, and Hygiene*. W. B. G. Water and Sanitation Program. https://documents1.worldbank.org/curated/en/881101468196156182/pdf/102935-WSP-Box394845B-PUBLIC-ADD-SERIES-Water-and-Sanitation-Program-WSP.pdf

Chattopadhyay, A., Sethi, V., Nagargoje, V. P., Saraswat, A., Surani, N., Agarwal, N., . . . Unisa, S. (2019). WASH practices and its association with nutritional status of adolescent girls in poverty pockets of eastern India. *BMC Women's Health*, *19*(1), 89. https://doi.org/10.1186/s12905-019-0787-1

Chemjong, B., & KC, Y. (2020). Food Security in Nepal: A Review. *Rupantaran : A Multidisciplinary Journal*, *IV*, 31-43. https://doi.org/https://doi.org/10.3126/rupantaran.v4i1.34015

Concern Worldwide and Welthungerhilfe. (2024). *2024 Global Hunger Index: Tougher challenges ahead*. https://www.globalhungerindex.org/pdf/en/2024.pdf

Cunningham, K., Headey, D., Singh, A., Karmacharya, C., & Rana, P. P. (2017). Maternal and Child Nutrition in Nepal: Examining drivers of progress from the mid-1990s to 2010s. *Global Food Security*, *13*, 30-37. https://doi.org/https://doi.org/10.1016/j.gfs.2017.02.001

Cunningham, K., Singh, A., Headey, D., Rana, P. P., & Karmacharya, C. (2016). Reaching New Heights: 20 Years of Nutrition Progress in Nepal. In S. Gillespie, J. Harris, & S. Kadiyala (Eds.), *Nourishing millions: Stories of change in nutrition* (pp. 115–122). International Food Policy Research Institute. https://doi.org/https://doi.org/10.2499/9780896295933_13

Dangour, A. D., Watson, L., Cumming, O., Boisson, S., Che, Y., Velleman, Y., . . . Uauy, R. (2013). Interventions to improve water quality and supply, sanitation and hygiene practices, and their effects on the nutritional status of children. *Cochrane Database Syst Rev*, *2013*(8), Cd009382. https://doi.org/10.1002/14651858.CD009382.pub2

Daniel, D., Diener, A., Pande, S., Jansen, S., Marks, S., Meierhofer, R., . . . Rietveld, L. (2019). Understanding the effect of socio-economic characteristics and psychosocial factors on household water treatment practices in rural Nepal using Bayesian Belief Networks. *International Journal of Hygiene and Environmental Health*, *222*(5), 847-855. https://doi.org/https://doi.org/10.1016/j.ijheh.2019.04.005

Dangour, A. D., Watson, L., Cumming, O., Boisson, S., Che, Y., Velleman, Y., Cavill, S., Allen, E., & Uauy, R. (2013). Interventions to improve water quality and supply, sanitation and hygiene practices, and their effects on the nutritional status of children (Issue 8, Article CD009382). *Cochrane Database of Systematic Reviews*. https://doi.org/10.1002/14651858.CD009382.pub2

Dave, J. M., Chen, T. A., Castro, A. N., White, M. A., Onugha, E. A., Zimmerman, S., & Thompson, D. (2024). Urban-Rural Disparities in Food Insecurity and Weight Status among Children in the United States. *Nutrients*, *16*(13). https://doi.org/10.3390/nu16132132

de Onis, M., Borghi, E., Arimond, M., Webb, P., Croft, T., Saha, K., . . . Flores-Ayala, R. (2019). Prevalence thresholds for wasting, overweight and stunting in children under 5 years. *Public Health Nutr*, *22*(1), 175-179. https://doi.org/10.1017/s1368980018002434

Dhital, S. R., Chojenta, C., Evans, T. J., Acharya, T. D., & Loxton, D. (2022). Prevalence and Correlates of Water, Sanitation, and Hygiene (WASH) and Spatial Distribution of Unimproved WASH in Nepal. *Int J Environ Res Public Health*, *19*(6). https://doi.org/10.3390/ijerph19063507

Dodos, J., Mattern, B., Lapegue, J., Altmann, M., & Aissa, M. A. (2017). Relationship between water, sanitation, hygiene, and nutrition: what do Link NCA nutrition causal analyses say? *Waterlines*, *36*(4), 284-304. http://www.jstor.org/stable/26600801

Fagbamigbe, A. F., Kandala, N. B., & Uthman, A. O. (2020). Demystifying the factors associated with rural–urban gaps in severe acute malnutrition among under-five children in low- and middle-income countries: a decomposition analysis. *Scientific Reports*, *10*(1), 11172. https://doi.org/10.1038/s41598-020-67570-w

Ferdausi, F., Al-Zubayer, M. A., Keramat, S. A., & Ahammed, B. (2022). Prevalence and associated factors of underweight and overweight/obesity among reproductive-aged women: A pooled analysis of data from South Asian countries (Bangladesh, Maldives, Nepal and Pakistan). *Diabetes & Metabolic Syndrome: Clinical Research & Reviews*, *16*(3), 102428. https://doi.org/https://doi.org/10.1016/j.dsx.2022.102428

Ferede, A., Lemessa, F., Tafa, M., & Sisay, S. (2017). The prevalence of malnutrition and its associated risk factors among women of reproductive age in Ziway Dugda district, Arsi Zone, Oromia Regional State, Ethiopia. *Public Health*, *152*, 1-8. https://doi.org/10.1016/j.puhe.2017.06.011

Food and Agriculture Organization of the United Nations. (2013). *The state of food insecurity in the world 2013: The multiple dimensions of food security*. https://www.fao.org/4/i3434e/i3434e02.pdf

Food and Agriculture Organization of the United Nations, International Fund for Agricultural Development, United Nations Children's Fund, World Food Programme, & World Health Organization. (2018). *The state of food security and nutrition in the world 2018: Building climate resilience for food security and nutrition*. FAO. https://openknowledge.fao.org/server/api/core/bitstreams/f5019ab4-0f6a-47e8-85b9-15473c012d6a/content

Ford, N. D., Patel, S. A., & Narayan, K. M. (2017). Obesity in Low- and Middle-Income Countries: Burden, Drivers, and Emerging Challenges. *Annu Rev Public Health*, *38*, 145-164. https://doi.org/10.1146/annurev-publhealth-031816-044604

Freeman, M. C., Garn, J. V., Sclar, G. D., Boisson, S., Medlicott, K., Alexander, K. T., . . . Clasen, T. F. (2017). The impact of sanitation on infectious disease and nutritional status: A systematic review and meta-analysis. *Int J Hyg Environ Health*, *220*(6), 928-949. https://doi.org/10.1016/j.ijheh.2017.05.007

Gensch, R., & Tillett, W. (2019). Strengthening sanitation and hygiene in the WASH systems conceptual framework. In: German Toilet Organisation.

Guerrant, R. L., Oriá, R. B., Moore, S. R., Oriá, M. O., & Lima, A. A. (2008). Malnutrition as an enteric infectious disease with long-term effects on child development. *Nutr Rev*, *66*(9), 487-505. https://doi.org/10.1111/j.1753-4887.2008.00082.x

Gurung, A., Adhikari, S., Chauhan, R., Thakuri, S., Nakarmi, S., Ghale, S., . . . Rijal, D. (2019). Water crises in a water-rich country: case studies from rural watersheds of Nepal's mid-hills. *Water Policy*, *21*(4), 826-847. https://doi.org/10.2166/wp.2019.245

Hasan, M. M., Ahmed, S., Soares Magalhaes, R. J., Fatima, Y., Biswas, T., & Mamun, A. A. (2022). Double burden of malnutrition among women of reproductive age in 55 low- and middle-income countries: progress achieved and opportunities for meeting the global target. *Eur J Clin Nutr*, *76*(2), 277-287. https://doi.org/10.1038/s41430-021-00945-y

Headey, D. D., & Hoddinott, J. (2015). Understanding the Rapid Reduction of Undernutrition in Nepal, 2001–2011. *PLoS One*, *10*(12), e0145738. https://doi.org/10.1371/journal.pone.0145738

Henjum, S., Torheim, L. E., Thorne-Lyman, A. L., Chandyo, R., Fawzi, W. W., Shrestha, P. S., & Strand, T. A. (2015). Low dietary diversity and micronutrient adequacy among lactating women in a peri-urban area of Nepal. *Public Health Nutr*, *18*(17), 3201-3210. https://doi.org/10.1017/s1368980015000671

Janmohamed, A., Karakochuk, C. D., McLean, J., & Green, T. J. (2016). Improved Sanitation Facilities are Associated with Higher Body Mass Index and Higher Hemoglobin Concentration Among Rural Cambodian Women in the First Trimester of Pregnancy. *Am J Trop Med Hyg*, *95*(5), 1211-1215. https://doi.org/10.4269/ajtmh.16-0278

Keats, E. C., Das, J. K., Salam, R. A., Lassi, Z. S., Imdad, A., Black, R. E., & Bhutta, Z. A. (2021). Effective interventions to address maternal and child malnutrition: an update of the evidence. *Lancet Child Adolesc Health*, *5*(5), 367-384. https://doi.org/10.1016/s2352-4642(20)30274-1

Khan, R. E. A., & Azid, T. (2011). Malnutrition in primary school-age children. *International Journal of Social Economics*, *38*(9), 748-766. https://doi.org/10.1108/03068291111157221

Li, Z., Kim, R., Vollmer, S., & Subramanian, S. V. (2020). Factors Associated With Child Stunting, Wasting, and Underweight in 35 Low- and Middle-Income Countries. *JAMA Network Open*, *3*(4), e203386-e203386. https://doi.org/10.1001/jamanetworkopen.2020.3386

Lindner, James R. (2002), Handling of Nonresponse Error in the *Journal of International Agricultural and Extension Education. Journal of International Agricultural and Extension Education*, Vol. **9**, No. 3, pp. 55–60.

Lindner, J. R., & Lindner, N. (2024). Interpreting Likert type, summated, unidimensional, and attitudinal scales: I neither agree nor disagree, Likert or not. *Advancements in Agricultural Development*, *5*(2), 152–163. https://doi.org/10.37433/aad.v5i2.351

Madiba, S., Chelule, P. K., & Mokgatle, M. M. (2019). Attending Informal Preschools and Daycare Centers Is a Risk Factor for Underweight, Stunting and Wasting in Children under the Age of Five Years in Underprivileged Communities in South Africa. *Int J Environ Res Public Health*, *16*(14). https://doi.org/10.3390/ijerph16142589

Maharjan, K., & Khatri-Chhetri, A. (2006). Household Food Security in Rural Areas of Nepal: Relationship between Socio-economic Characteristics and Food Security Status. *International Association of Agricultural Economists, 2006 Annual Meeting, August 12-18, 2006, Queensland, Australia*.

Maharjan, K. L., & Joshi, N. P. (2011). Determinants of household food security in Nepal: A binary logistic regression analysis. *Journal of Mountain Science*, *8*(3), 403-413. https://doi.org/10.1007/s11629-011-2001-2

Mehata, S., Parajuli, K. R., Rayamajhee, B., Yadav, U. N., Mehta, R. K., & Singh, D. R. (2022). Micronutrients deficiencies and its correlation with the soil-transmitted helminthic infections among children and non-pregnant women in Nepal: findings from Nepal national micronutrient status survey. *Scientific Reports*, *12*(1), 22313. https://doi.org/10.1038/s41598-022-24634-3

Merkina, M. M., Guyo, T. G., Hayelom, D. H., Assefa, D. T., & Gutema, B. T. (2024). Underweight associated with water, sanitation, and hygiene among women of reproductive age in Arba Minch Health and Demographic Surveillance Site, Southern Ethiopia. *Food Science & Nutrition*, *12*(8), 5836-5843. https://doi.org/https://doi.org/10.1002/fsn3.4184

Marmot, M., Friel, S., Bell, R., Houweling, T. A. J., & Taylor, S. (2008). Closing the gap in a generation: Health equity through action on the social determinants of health. *Lancet, 372*(9650), 1661–1669. https://doi.org/10.1016/S0140-6736(08)61690-6

Miller, J. D., Young, S. L., Bryan, E., & Ringler, C. (2024). Water insecurity is associated with greater food insecurity and lower dietary diversity: panel data from sub-Saharan Africa during the COVID-19 pandemic. *Food Security*, *16*(1), 149-160. https://doi.org/10.1007/s12571-023-01412-1

Ministry of Health, New ERA, & ICF. (2017). *Nepal Demographic and Health Survey 2016*. http://dhsprogram.com/pubs/pdf/FR336/FR336.pdf

Ministry of Health, New ERA, & ICF. (2022). *Nepal Demographic and Health Survey 2022*. https://dhsprogram.com/pubs/pdf/FR379/FR379.pdf

Momberg, D. J., Ngandu, B. C., Voth-Gaeddert, L. E., Cardoso Ribeiro, K., May, J., Norris, S. A., & Said-Mohamed, R. (2021). Water, sanitation and hygiene (WASH) in sub-Saharan Africa and associations with undernutrition, and governance in children under five years of age: a systematic review. *J Dev Orig Health Dis*, *12*(1), 6-33. https://doi.org/10.1017/s2040174419000898

Morakinyo, O. M., Adebowale, A. S., Obembe, T. A., & Oloruntoba, E. O. (2020). Association between household environmental conditions and nutritional status of women of childbearing age in Nigeria. *PLoS One*, *15*(12), e0243356. https://doi.org/10.1371/journal.pone.0243356

Nagpal, A., Hassan, M., Siddiqui, M. A., Tajdar, A., Hashim, M., Singh, A., & Gaur, S. (2021). Missing basics a study on sanitation and women's health in urban slums in Lucknow, India. *GeoJournal*, *86*(2), 649-661. https://www.jstor.org/stable/48754220

Nepali, S., Simkhada, P., & Davies, I. G. (2020). Association between wasting and food insecurity among children under five years: findings from Nepal demographic health survey 2016. *BMC Public Health*, *20*(1), 1027. https://doi.org/10.1186/s12889-020-09146-x

National Planning Commission. (2017). *Multi-Sector Nutrition Plan II (2018–2022)*. Government of Nepal. https://extranet.who.int/ncdccs/Data/NPL_B11_MSNP%20ii.pdf

Nubé, M., & Van Den Boom, G. J. (2003). Gender and adult undernutrition in developing countries. *Ann Hum Biol*, *30*(5), 520-537. https://doi.org/10.1080/0301446031000119601

Opoku, A. A., Abushama, M., & Konje, J. C. (2023). Obesity and menopause. *Best Pract Res Clin Obstet Gynaecol*, *88*, 102348. https://doi.org/10.1016/j.bpobgyn.2023.102348

Organization, W. H. (2019). *Nutrition Landscape Information System (NLiS) country profile indicators: interpretation guide, 2nd edition*. W. H. Organization. https://iris.who.int/bitstream/handle/10665/332223/9789241516952-eng.pdf?sequence=1

Pandey, A. R., Chalise, B., Shrestha, N., Ojha, B., Maskey, J., Sharma, D., . . . Aryal, K. K. (2020). Mortality and risk factors of disease in Nepal: Trend and projections from 1990 to 2040. *PLoS One*, *15*(12), e0243055. https://doi.org/10.1371/journal.pone.0243055

Pandey, S., & Fusaro, V. (2020). Food insecurity among women of reproductive age in Nepal: prevalence and correlates. *BMC Public Health*, *20*(1), 175. https://doi.org/10.1186/s12889-020-8298-4

Patlán-Hernández, A. R., Stobaugh, H. C., Cumming, O., Angioletti, A., Pantchova, D., Lapègue, J., . . . N'Diaye, D. S. (2022). Water, sanitation and hygiene interventions and the prevention and treatment of childhood acute malnutrition: A systematic review. *Matern Child Nutr*, *18*(1), e13257. https://doi.org/10.1111/mcn.13257

Phelps, N. H., Singleton, R. K., Zhou, B., Heap, R. A., Mishra, A., Bennett, J. E., . . . Ezzati, M. (2024). Worldwide trends in underweight and obesity from 1990 to 2022: a pooled analysis of 3663 population-representative studies with 222 million children, adolescents, and adults. *The Lancet*, *403*(10431), 1027-1050. https://doi.org/10.1016/S0140-6736(23)02750-2

Popkin, B. M., Corvalán, C., & Grummer-Strawn, L. M. (2020). Dynamics of the double burden of malnutrition and the changing nutrition reality. *The Lancet, 395*(10217), 65–74. https://doi.org/10.1016/S0140-6736(19)32497-3

Pries, A. M., Huffman, S. L., & Adhikary, I. (2019). Consumption of commercially produced snack foods and sugar-sweetened beverages during the complementary feeding period in Nepal. *Maternal & Child Nutrition, 15*(S4), e12738. https://doi.org/10.1111/mcn.12738

Rai, A., Gurung, S., Thapa, S., & Saville, N. M. (2019). Correlates and inequality of underweight and overweight among women of reproductive age: Evidence from the 2016 Nepal Demographic Health Survey. *PLoS One*, *14*(5), e0216644. https://doi.org/10.1371/journal.pone.0216644

Rana, K., Chimoriya, R., Haque, N. B., Piya, M. K., Chimoriya, R., Ekholuenetale, M., & Arora, A. (2022). Prevalence and Correlates of Underweight among Women of Reproductive Age in Nepal: A Cross-Sectional Study. *Int J Environ Res Public Health*, *19*(18). https://doi.org/10.3390/ijerph191811737

Rana, K., Ghimire, P., Chimoriya, R., & Chimoriya, R. (2021). Trends in the Prevalence of Overweight and Obesity and Associated Socioeconomic and Household Environmental Factors among Women in Nepal: Findings from the Nepal Demographic and Health Surveys. *Obesities*, *1*(2), 113-135. https://www.mdpi.com/2673-4168/1/2/11

Rana, K., Shrestha, V., & Chimoriya, R. (2020). The Effect of Housing on Health and Challenges of Demographic Changes. *Global Journal of Science Frontier Research*, *20*, 75-82. https://doi.org/10.6084/m9.figshare.14128952.v1

Regmi, H., Rijal, K., Joshi, G., Sapkota, R., & Thapa, S. (2019). Factors Influencing Food Insecurity in Nepal. *Journal of Institute of Science and Technology*, *24*, 22-29. https://doi.org/10.3126/jist.v24i2.27253

Sahiledengle, B., Petrucka, P., Kumie, A., Mwanri, L., Beressa, G., Atlaw, D., . . . Agho, K. E. (2022). Association between water, sanitation and hygiene (WASH) and child undernutrition in Ethiopia: a hierarchical approach. *BMC Public Health*, *22*(1), 1943. https://doi.org/10.1186/s12889-022-14309-z

Said-Mohamed, R., Micklesfield, L. K., Pettifor, J. M., & Norris, S. A. (2015). Has the prevalence of stunting in South African children changed in 40 years? A systematic review. *BMC Public Health*, *15*(1). https://doi.org/10.1186/s12889-015-1844-9

Sarkar, B., Mitchell, E., Frisbie, S., Grigg, L., Adhikari, S., & Byanju, R. M. (2022). Drinking Water Quality and Public Health in the Kathmandu Valley, Nepal: Coliform Bacteria, Chemical Contaminants, and Health Status of Consumers. *J Environ Public Health*, *2022*, 3895859. https://doi.org/10.1155/2022/3895859

Schuster, R. C., Butler, M. S., Wutich, A., Miller, J. D., Young, S. L., & Network, H. W. I. E.-R. C. (2020). "If there is no water, we cannot feed our children": The far-reaching consequences of water insecurity on infant feeding practices and infant health across 16 low- and middle-income countries. *American Journal of Human Biology*, *32*(1), e23357. https://doi.org/https://doi.org/10.1002/ajhb.23357

Schwinger, C., Chandyo, R. K., Ulak, M., Hysing, M., Shrestha, M., Ranjitkar, S., & Strand, T. A. (2020). Prevalence of Underweight, Overweight, and Obesity in Adults in Bhaktapur, Nepal in 2015-2017. *Front Nutr*, *7*, 567164. https://doi.org/10.3389/fnut.2020.567164

Shariful Islam, M., Ola, O., Alaboson, J., Dadzie, J., Hasan, M., Islam, N., . . . Saif-Ur-Rahman, K. (2022). Trends and socioeconomic factors associated with overweight/obesity among three reproductive age groups of women in Nepal. *Lifestyle Medicine*, *3*(1), e51. https://doi.org/https://doi.org/10.1002/lim2.51

Shrestha, A. (2015). *Diet, Obesity, and Diabetes in Suburban Nepal - A Community-Based Study* University of Washington].

Shrestha, A., Kunwar, B. M., & Meierhofer, R. (2022). Water, sanitation, hygiene practices, health and nutritional status among children before and during the COVID-19 pandemic: longitudinal evidence from remote areas of Dailekh and Achham districts in Nepal. *BMC Public Health*, *22*(1), 2035. https://doi.org/10.1186/s12889-022-14346-8

Shrestha, A., Six, J., Dahal, D., Marks, S., & Meierhofer, R. (2020). Association of nutrition, water, sanitation and hygiene practices with children's nutritional status, intestinal parasitic infections and diarrhoea in rural Nepal: a cross-sectional study. *BMC Public Health*, *20*(1), 1241. https://doi.org/10.1186/s12889-020-09302-3

Shrestha, S. K., Vicendese, D., & Erbas, B. (2020). Water, sanitation and hygiene practices associated with improved height-for-age, weight-for-height and weight-for-age z-scores among under-five children in Nepal. *BMC Pediatrics*, *20*(1), 134. https://doi.org/10.1186/s12887-020-2010-9

Siddiqui, M. Z., Illiyan, A., Akram, V., & Nigar, K. (2024). Revisiting swimming against tide; inequalities in child malnutrition in Nepal. *Discover Global Society*, *2*(1), 26. https://doi.org/10.1007/s44282-024-00047-7

Singh, A., Singh, A., & Ram, F. (2014). Household food insecurity and nutritional status of children and women in Nepal. *Food Nutr Bull*, *35*(1), 3-11. https://doi.org/10.1177/156482651403500101

Singh, D. R., Sunuwar, D. R., Shah, S. K., Sah, L. K., Karki, K., & Sah, R. K. (2021). Food insecurity during COVID-19 pandemic: A genuine concern for people from disadvantaged community and low-income families in Province 2 of Nepal. *PLoS One*, *16*(7), e0254954. https://doi.org/10.1371/journal.pone.0254954

Smith, C. (1998). Prevalence of obesity and contributing factors among Sherpa women in urban and rural Nepal. *Am J Hum Biol*, *10*(4), 519-528. https://doi.org/10.1002/(sici)1520-6300(1998)10:4<519::Aid-ajhb12>3.0.Co;2-b

Srinivasan, C. S., Zanello, G., & Shankar, B. (2013). Rural-urban disparities in child nutrition in Bangladesh and Nepal. *BMC Public Health*, *13*(1), 581. https://doi.org/10.1186/1471-2458-13-581

Strong, R., Wynn, J. T., Irby, T. L., & Lindner, J. R. (2013). The relationship between students' leadership style and self-directed learning level. Journal of Agricultural Education, 54(2), 174-185. doi: 10.5032/jae.2013.02174

Subramanian, S. V., Perkins, J. M., & Khan, K. T. (2009). Do burdens of underweight and overweight coexist among lower socioeconomic groups in India? *The American Journal of Clinical Nutrition, 90*(2), 369–376. https://doi.org/10.3945/ajcn.2009.27487

Sutradhar, I., Akter, T., Hasan, M., Das Gupta, R., Joshi, H., Haider, M. R., & Sarker, M. (2021). Nationally representative surveys show gradual shifting of overweight and obesity towards poor and less-educated women of reproductive age in Nepal. *J Biosoc Sci*, *53*(2), 214-232. https://doi.org/10.1017/s0021932020000152

Tiwari, R., Ausman, L. M., & Agho, K. E. (2014). Determinants of stunting and severe stunting among under-fives: evidence from the 2011 Nepal Demographic and Health Survey. *BMC Pediatr*, *14*, 239. https://doi.org/10.1186/1471-2431-14-239

Tolossa, D., & Tafesse, T. (2008). *Linkages between water supply and sanitation and food security: A case study in four villages of East Hararghe zone, Oromia region*. R.-i. P. a. P. L. i. E. a. t. N. r. (RiPPLE).

https://assets.publishing.service.gov.uk/media/57a08baa40f0b64974000cca/wp6-water-and-food-security.pdf

United Nations Children's Fund South Asia. (2019). *Stop stunting: Power of maternal nutrition Scaling-up the Nutritional Care of Women in South Asia*. https://www.unicef.org/rosa/reports/stop-stunting

United Nations Children’s Fund. (2013). *Improving Child Nutrition: The Achievable Imperative for Global Progress*. https://data.unicef.org/wp-content/uploads/2015/12/NutritionReport_April2013_Final_29.pdf

United Nations Children’s Fund. (2020). *UNICEF conceptual framework on the determinants of maternal and child nutrition* . https://www.unicef.org/media/113291/file/UNICEF%20Conceptual%20Framework.pdf

United Nations Children’s Fund. (2012). *Water, sanitation and hygiene (WASH) in schools: A companion to the Child Friendly Schools Manual*. https://www.unicef.org/reports/wash-schools

United Nations Educational, Scientific and Cultural Organization. (2020). *Global Education Monitoring Report 2020: Inclusion and education – All means all*. UNESCO. https://unesdoc.unesco.org/ark:/48223/pf0000373718

United Nations Water. (2025). *Sustainable Development Goal 6 on water and sanitation (SDG 6): Global Status*. Retrieved April 5, 2025 from https://www.sdg6data.org/en/node/1

United States Agency for International Development. (2013). *Water, sanitation, and hygiene: Essential components for food security*. https://www.washplus.org/sites/default/files/resource_files/washplus-food_security2013.pdf

United States Agency for International Development. (2022). *Demographic and Health Surveys (DHS) Program: Dataset types*. Demographic and Health Surveys (DHS) Program. Retrieved April 4, 2022 from https://dhsprogram.com/data/Dataset-Types.cfm

United States Agency for International Development. (2023). *Agriculture and Food Security*. Retrieved February 21, 2023 from https://www.usaid.gov/agriculture-and-food-security

United States Agency for International Development. (2024). *The Demographic and Health Surveys (DHS) Program: Available Datasets*. Demographic and Health Surveys (DHS) Program. Retrieved May 25, 2024 from https://dhsprogram.com/data/available-datasets.cfm

United States Agency for International Development. (2025). *Guide to DHS Statistics DHS-8: Nutritional Status*. Retrieved 4/2/2025 from https://dhsprogram.com/data/Guide-to-DHS-Statistics/Nutritional_Status.htm

United States Department of Agriculture. (2025). *Food Security in the U.S. - Definitions of Food Security*. Retrieved April 7, 2025 from https://www.ers.usda.gov/topics/food-nutrition-assistance/food-security-in-the-us/definitions-of-food-security

United States Department of Health and Human Services, Office of Disease Prevention and Health Promotion. (2025). *Social determinants of health*. Healthy People 2030. Retrieved July 28, 2025, from https://odphp.health.gov/healthypeople/priority-areas/social-determinants-health#:~:text=That's%20why%20Healthy%20People%202030,Workgroup%2C%20focuses%20solely%20on%20SDOH.

Vaidya, A., & Krettek, A. (2014). Physical activity level and its sociodemographic correlates in a peri-urban Nepalese population: a cross-sectional study from the Jhaukhel-Duwakot health demographic surveillance site. *Int J Behav Nutr Phys Act*, *11*(1), 39. https://doi.org/10.1186/1479-5868-11-39

Vijay, J., & Patel, K. K. (2024). Malnutrition among under-five children in Nepal: A focus on socioeconomic status and maternal BMI. *Clinical Epidemiology and Global Health*, *27*, 101571. https://doi.org/https://doi.org/10.1016/j.cegh.2024.101571

WASH Advocates. (2013). *Global food security: The critical role of water, sanitation, and hygiene (WASH)*. Retrieved April 5, 2022 from https://www.fsnnetwork.org/resource/global-food-security-critical-role-water-sanitation-and-hygiene-wash

Wolf, J., Johnston, R. B., Ambelu, A., Arnold, B. F., Bain, R., Brauer, M., . . . Cumming, O. (2023). Burden of disease attributable to unsafe drinking water, sanitation, and hygiene in domestic settings: a global analysis for selected adverse health outcomes. *The Lancet*, *401*(10393), 2060-2071. https://doi.org/10.1016/S0140-6736(23)00458-0

Workman, C. L., Stoler, J., Harris, A., Ercumen, A., Kearns, J., & Mapunda, K. M. (2022). Food, water, and sanitation insecurities: Complex linkages and implications for achieving WASH security. *Glob Public Health*, *17*(11), 3060-3075. https://doi.org/10.1080/17441692.2021.1971735

World Food Programme. (2022). *Impact of current shocks on household food security in Nepal: Sixth round of the mVAM household livelihoods, food security and vulnerability survey*. Retrieved July 5, 2023 from https://reliefweb.int/attachments/2a4749c0-f912-43d2-a341-f4bcdde357ef/WFP-0000141846.pdf

World Health Organization. (2015). *Stunting in a nutshell*. Retrieved April 7, 2025 from https://www.who.int/news/item/19-11-2015-stunting-in-a-nutshell

World Health Organization. (2021). *Progress on household drinking water, sanitation and hygiene 2000–2020: Five years into the SDGs*. Retrieved April 5, 2025 from https://iris.who.int/bitstream/handle/10665/345081/9789240030848-eng.pdf?sequence=1

World Health Organization. (2023). *Drinking-water*. Retrieved April 5, 2025 from https://www.who.int/news-room/fact-sheets/detail/drinking-water

World Health Organization. (2024a). *Malnutrition*. Retrieved April 4, 2025 from https://www.who.int/news-room/questions-and-answers/item/malnutrition

World Health Organization. (2024b). *Malnutrition: Key Facts*. https://www.who.int/news-room/fact-sheets/detail/malnutrition/

World Health Organization. (2024c). *Sanitation*. Retrieved April 5, 2025 from https://www.who.int/news-room/fact-sheets/detail/sanitation

World Health Organization. (2025). *Water, sanitation and hygiene (WASH)*. Retrieved April 4, 2025 from https://www.who.int/health-topics/water-sanitation-and-hygiene-wash#tab=tab_1

World Health Organization & United Nations Children's Fund. (2023, July 5). *Progress on household drinking-water, sanitation and hygiene 2000-2022: Special focus on gender*. WHO. https://www.who.int/publications/m/item/progress-on-household-drinking-water--sanitation-and-hygiene-2000-2022---special-focus-on-gender

World Health Organization, United Nations Children's Fund (UNICEF), & & World Bank Group. (2023). *Levels and trends in child malnutrition: UNICEF / WHO / World Bank Group joint child malnutrition estimates: key findings of the 2023 edition*. W. H. Organization. https://iris.who.int/handle/10665/368038

Yalew, B. M., Amsalu, F., & Bikes, D. (2014). Prevalence and Factors Associated with Stunting, Underweight and Wasting: A Community Based Cross Sectional Study among Children Age 6-59 Months at Lalibela Town, Northern Ethiopia. *Journal of Nutritional Disorders & Therapy*, *4*, 1-16.

Young, S. L., Bethancourt, H. J., Frongillo, E. A., Viviani, S., & Cafiero, C. (2023). Concurrence of water and food insecurities, 25 low- and middle-income countries. *Bulletin of the World Health Organization*, *101*(2), 90-101. https://doi.org/10.2471/blt.22.288771

Young, S. L., Frongillo, E. A., Jamaluddine, Z., Melgar-Quiñonez, H., Pérez-Escamilla, R., Ringler, C., & Rosinger, A. Y. (2021). Perspective: The Importance of Water Security for Ensuring Food Security, Good Nutrition, and Well-being. *Advances in Nutrition*, *12*(4), 1058-1073. https://doi.org/https://doi.org/10.1093/advances/nmab003

Zavala, E., King, S. E., Sawadogo-Lewis, T., & Roberton, T. (2021). Leveraging water, sanitation and hygiene for nutrition in low- and middle-income countries: A conceptual framework. *Matern Child Nutr*, *17*(3), e13202. https://doi.org/10.1111/mcn.13202

Appendix 1 Selected Characteristics of Food-Insecure Households, Nepal, 2022

Household Characteristics	M	SD	Range	Number
Number of household members	4.21	2.09	1-26	6007
Number of women (aged 15-49)	1.09	0.83	0-6	6007
Number of men household	0.34	0.64	0-5	6007
Number of children 5 and under (de jure)	0.51	0.76	0-6	6007

Appendix 2 Socioeconomic Characteristics of Food-Insecure Households, Nepal, 2022

Household Characteristics	N (%)
Type of place of residence	
Rural	3193 (53.2)
Urban	2814 (46.8)
Has a bank account	
Yes	4072 (67.8)
No	1935 (32.3)
Wealth Index combined	
Poorest	2701 (45)
Poorer	1391 (23.2)
Middle	985 (16.4)
Richer	660 (11)
Richest	270 (4.5)

Appendix 3 Mean Food Insecurity Score by Type of Drinking Water Source, Type of Drinking Water, Type of Toilet Facility, Nepal, 2022

Variables	M	SD	N	F-ratio	p
Source of drinking water					
Piped to yard/plot	2.71	1.78	2403	10.58	<0 .001
Tube well or borehole	2.69	1.74	1791		
Public tap/standpipe	3.05	1.86	937		
Piped to the neighbor	3.30	1.95	184		
Piped into the dwelling	1.97	1.45	178		
Protected spring	3.29	2.05	154		
Bottled water	2.25	1.61	130		
Unprotected spring	3.23	1.87	113		
Unprotected well	2.60	1.76	43		
Protected well	2.50	1.67	38		
River/dam/lake/ponds/stream/canal/irrigation channel	3.16	1.92	32		
Tanker truck	2.50	2.38	4		
Location of Drinking Water Source					
On premises	2.65	1.76	4516	10.69	<0.001
Not on premises	3.13	1.88	1490		
Type of toilet facility					
Flush to pit latrine	2.81	1.80	3127	30.38	< 0.001
Flush to septic tank	2.41	1.63	1584		
No facility/bush/field	3.52	2.01	630		
Pit latrine with slab	3.13	1.81	232		
Flush to piped sewer system	2.24	1.60	156		
Biogas attached toilet	1.90	1.10	122		
Ventilated Improved Pit latrine (VIP)	3.07	1.85	83		
Pit latrine without slab/open pit	3.08	1.65	40		
Others	3.27	2.05	33		
Presence of water at hand washing place					
Water is available	2.61	1.72	4924	12.71	<0.001
Water not available	3.45	1.97	1053		
Soap or detergent present at wash site					
Yes	2.44	1.63	3403	15.58	<0.001

No	3.18	1.91	2574		
Ash, mud, sand present at wash site					
No	2.79	1.82	4524	2.61	<0.001
Yes	2.66	1.71	1453		
Anything done to water to make safe to drink					
No	2.85	1.83	4807	8.42	<0.001
Yes	2.4	1.61	1197		
Share a toilet with other households					
No	2.61	1.7	3992	-4.396	<0.001
Yes	2.86	1.86	1385		
Location of toilet facility					
In own yard/plot	2.72	1.75	4293	34.21	<0.001
In own dwelling	2.11	1.52	555		
Elsewhere	2.89	1.85	529		

Appendix 4 Total Number of Children Aged 0-5 Years Included in Study After Excluding Missing or Flagged Data Nepal, 2022

Total cases	Stunting	Underweight	Wasting
	5,372	**5,372**	**5,372**
System missing	2,780	2,601	2,592
9998 (Flagged cases)	1	1	2
9996 (Height out of plausible limits)			3
After the system missing/ flagged cases	2,591	2,600	2,587
Remove missing data/ Not a de jure resident/don't know			
Final cases for analysis	2,202	2,208	2,198

Source: Nepal Demographic and Health Survey, 2022

Appendix 5 Total Number of Non-Pregnant Women Aged 15-49 Years, Nepal 2022

	Women (BMI)
Total cases	**14845**
System missing	7442
9998 (Flagged cases)	2
9999 (Missing)	49
After the system missing or flagged cases for	**7352**
Missing data/ Not a dejure resident/*don't know* for source of drinking water/ location of drinking water/ types of toilet facility/ share the toilet with others/ BMI	803
Pregnant women	258
Final data for analysis	**6291**