The Impact of High Temperatures on Child Anthropometric Outcomes Worldwide

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Abstract: High temperatures caused by climate change significantly impact society, including child nutrition. Our research focuses on the impact of high temperatures on the anthropometric outcomes of children aged 1 to 5 in 54 countries worldwide. We analyze the historical climate and anthropometric data to evaluate the effect of high temperature on weight-for-age (WAZ) and weight-for-height (WHZ) in children. Results indicate that high temperatures negatively affect child nutrition, particularly in areas above 20°C, and children in rural areas are more vulnerable. The impact of monthly temperature on child anthropometric outcomes varies across countries, regions, and cultural practices. Economic status alone is insufficient to address the negative effects of high temperatures on child nutrition. Targeted interventions

addressing socio-economic factors and improving healthcare and sanitation are necessary for better child health outcomes.

1. Introduction

Long-term variations of weather patterns in different regions represent causes of droughts, hurricanes, heatwaves, floods, and precipitation, disrupting social and cultural systems, socioeconomic status, and political development. Such are the negative impacts that all nations' political agendas aim to minimize the social cost and promote sustainable economic growth due to climate change (Carleton & Hsiang, 2016). For example, an increase of 2 degrees Celsius in the average temperature significantly affects food security and public health in developing countries that depend more on agriculture and have low adaptability capacity (Mendelsohn, 2009).

Extreme heat can cause crop failures and droughts, leading to difficulty in accessing adequate nutrition. The impact of climate change on food security varies across regions and depends on a country's overall socioeconomic status. Additionally, food systems are subject to various changes, and their impact varies based on regional and societal differences (Schmidhuber & Tubiello, 2007). Coping with climate change in food systems is feasible through interventions in availability, access, and utilization. However, climate change is causing an increase in overall water stress, threatening the agricultural sector and food security in arid and semi-arid areas. Without adaptive measures such as changes in crop patterns, crop breeding, and innovative technologies, global food production in these regions will continue to decline (Misra, 2014).

Many studies showcased that the temperature rise has significantly threatened public health (Watts et al., 2015). However, vulnerability to high temperatures differs in the age of the population due to its physiological and metabolic capacity to cope with high-temperature stress. Infants are less adaptable, and higher mortality levels are associated with heat waves' impact (Geruso & Spears, 2018; Xu et al., 2014). While children between the ages of 1 and 5 have a lower mortality rate, they are still susceptible to undernutrition, displaying wasting, stunting, and being underweight. Consequently, putting at risk their brain development and physical growth (Pollitt et al., 1996). Most researchers have focused on finding the relationship between climatic variability and children's anthropometrics in Asia and Africa. Given that these regions report the highest percentage of undernourished children (Baker & Anttila-Hughes, 2020; Thiede & Strube, 2020).

To address the urgent and continuous threat of climate change and global warming, it is essential to deepen our understanding of the relationship between high temperatures and child undernutrition. This research aims to investigate how high temperatures affect the anthropometric outcomes of children aged 1 to 5 in various regions and continents worldwide. The study draws on data from the Demographic and Health Surveys (DHS) program, which provides information on child anthropometrics and household demographics, as well as monthly temperature data from the University of Delaware's gridded station-based dataset. Additionally, information on geographic location, income classifications, and economic indicators from the World Bank will be used further to analyze the impact of high temperatures on child undernutrition.

The study confirms that high temperatures harm child health outcomes, particularly on weight-for-age and weight-for-height Z scores. Children in rural areas are more susceptible to losing these scores, and economic status alone cannot mitigate the negative effects on child nutrition. Country-specific contexts must be considered in interventions to improve access to healthcare and sanitation to achieve better child health outcomes. Efforts to address climate change and its effects on food security could help mitigate the negative impact of high temperatures on child health outcomes. The impact of monthly temperature on child anthropometric outcomes varies across different regions and continents, highlighting the need for cross-regional research to understand the factors affecting anthropometric outcomes. The results underscore the importance of targeted interventions and improving access to healthcare and sanitation to achieve better child health outcomes.

2. Background

2.1 Food Security

According to the Food and Agriculture Organization (FAO), food security is a situation that exists when all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life. This definition consists of four main dimensions: (a) availability (whether food is present, e.g., food reserves, production, markets), (b) access (whether households have sufficient physical and economic access), (c) utilization (whether households are maximizing the consumption of adequate nutrition), and (d) stability (whether the system is stable) (UNICEF et al., 2021). Several researchers have studied the effects of climate change on these four dimensions of food security. All the studies agree that its impact occurs differently in regions but starkly affects people with low incomes (Schmidhuber & Tubiello, 2007). For instance, the temperature increase reduces access to fresh water, causing a substantial restriction on agricultural production and deteriorating food quality and quantity of nutrients, especially in arid and semi-arid regions (Misra, 2014; Schmidhuber & Tubiello, 2007). On the other hand, additional precipitation in areas of mid and high-latitude benefits production on farms and livestock (Mendelsohn, 2009). Sazib et al. (2020) found that while Southern Africa experiences high temperatures and droughts, eastern Africa is colder and has higher rainfall. In East Africa, high precipitation causes around 4% and 17% increases in maize and corn production, respectively, contrary to South Africa's 12% and 19% decreases in corn yield. The world food production in the agricultural, livestock, and fishing sectors is affected by climate change. Beyond predicting the net impact, we must be aware of adequate and equitable distribution since food security depends on the ability of people to access, pay for, and use food and its demand (Myers et al., 2017). Thus, agricultural policies play an essential role in investments in implementing systems and techniques that help mitigate losses in agricultural production as new irrigation systems and practices and diversification and rotation of crops (Myers et al., 2017).

2.2 Child Nutrition

Smith and Haddad (2000) and Engle, Menon, and Engle et al., (1999) describe various determinants of child nutrition, separated into three causalities: (1) immediate, (2) underlying, and (3) primary determinants. The primary determinants are dietary intake and health, which are correlated. For example, a child who does not receive enough nutritious food is prone to diseases, losing appetite, and inhibiting nutrient absorption. Food security, care, and the health environment and services are the underlying determinants. As mentioned above, food security relies on the ability of the household and community to food availability, access, utilization, and stability. Furthermore, a child's care from caregivers helps in healthy physical, mental, and social development. The primary determinant is the socio-economic conditions of the household, a home that lacks the adequate income to afford food, health, protection, and education. Lack or failure of the determinants impacts nutrition, thus, the child's health. Climate change is a factor that destabilizes those determinants of nutrition by significantly affecting food security, health, sanitation, behaviors, and politics in society. Therefore, the political agendas should tackle the mitigation and adaptation of imminent climate change (Tirado et al., 2013).

2.3 Anthropometric Child Measurements

The measurement indicators established worldwide to determine undernutrition are stunting, wasting, and underweight. WHO defines that children are affected by stunting, wasting, and being underweight when their height-for-age, weight-for-age, and weight-for-height measures are more than two standard deviations below the respective medians. According to the latest report by Joint Child Malnutrition Estimates of 2021, most children under 5 with undernutrition live in Africa and Asia. In Asia and Africa, 53% and 41% of children are affected by stunting, and those affected by wasting are 70% and 27%, respectively (UNICEF et al., 2021).

2.3.1 Underweight

It is a significant health issue affecting millions of children worldwide. The World Health Organization defines underweight as a weight-for-age z-score more than two standard deviations below the median of the reference population. Hagos et al., 2014) found that child underweight in Ethiopia was positively associated with temperature and negatively associated with precipitation. Specifically, a 1°C increase in temperature was associated with a 16% increase in the odds of being underweight. In comparison, a 1 cm decrease in rainfall was associated with a 5% increase in the odds of being underweight.

2.3.2 Stunting

Multiple researchers have measured the effects of climate variability on stunting regarding height-for-age scores and found significant results (Cooper et al., 2019; Le & Nguyen, 2021). For instance, Cooper et al., (2019) analyzed extreme precipitation in 53 countries over the past few decades. They utilized the Standardized Precipitation-Evapotranspiration Index (SPEI) to assess the effects of precipitation anomalies on children stunting. The results showed that during periods of minor to severe drought and much higher than average precipitation, children tend to have lower HAZ scores than those surveyed during normal conditions. Another way to assess the causes of child stunting is to measure climate variability when a child is in the womb (in-utero), which Le and Nguyen (2021) analyzed in their study on exposure to rainfall variability for children in 55 low and middle-income countries. Exposure to excess and a lack of rainfall in the in-utero stage accounted for lower HAZ and WAZ and weight-for-high scores.

2.3.3 Wasting

Like stunting, wasting is a measurement that many authors have studied. For example, Baker and Anttila-Hughes, (2020) and Thiede and Strube (2020) assessed the relationship between climate change and child nutrition in Sub-Sahara Africa. Both coincide that high temperatures are associated with reduced child weight and an increased risk of wasting across regions. Baker and AnttilaHughes, (2020) analyzed 30 countries in Sub-Sahara Africa and found that Areas with an average temperature of 30°C have approximately 1σ fewer wasting scores than children in areas with an average of 10°C lower on average. Furthermore, assessing rural locations yearly for children exposed to temperatures above 25°C, WHZ and WAZ decline sharply. However, when studying monthly with an increased temperature, there is a decrease in child weight measures in urban locations, causing a 0.2σ reduction in weight-for-height. Their projection by 2100 indicates that Western Africa will increase by 37% of wasting and Central and Eastern Africa by 25%. On the other hand, Thiede and Strube (2020) analyzed 18 countries in Sub-Saharan Africa and, unlike Baker and Anttila-Hughes, (2020), investigated the impacts of precipitation anomalies. They found that temperate and precipitation exposures are significant predictors of WHZ, with above-average temperatures and precipitation associated with reduced weight. Moreover, exposure to high temperatures is associated with reductions in WHZ and corresponding increases in the prevalence of wasting, and precipitation deficits are associated with reduced WHZ. However, these changes do not translate into increased waste risk. In a similar study carried out by Blom et al. (2019), evidence of the impact on nutrition in children in West Africa, has identical findings concerning the increase in high temperatures, the risk of suffering from wasting increases, corresponding to temperatures above 30°C growth wasting by 0.06σ. All these three authors mention the limitations of their work due to limited observations in the child dataset (e.g., the difference in the child's present location w.r.t to the exposure period).

3. Methods

3.1 Data

We utilized publicly available demographic data from the Demographic and Health Surveys (DHS) conducted between 1986 and 2018. DHS surveys are widely recognized as the highest quality population health surveys in developing countries and have collected and analyzed data on population, health, nutrition, and HIV through 400 surveys in 90 countries since 1984. For our study, we selected DHS surveys containing child anthropometric data, household socioeconomic information, type of residence, and geo-location (GPS) to investigate the impact of temperature on child undernourishment.

We obtained climate data from the University of Delaware's gridded station-based dataset to determine climate variability's impact on children's anthropometric outcomes. This dataset includes Terrestrial Air Temperature: Monthly Time Series from 1900 to 2008. In addition, the dataset contains the latitude-longitude coordinates assigned to the 0.5*0.5° grid cell, which we mapped to the DHS data having the exact GPS coordinates.

3.2 Regression Model

This research investigates the correlation between temperature and child nutrition by analyzing cross-sectional data and average relationships over a given period. However, we recognize the challenge of eliminating confounding factors such as poverty, food production, and availability. Therefore, we employ a standard fixed-effects ordinary least squares regression model to estimate the impact of temperature on child anthropometric outcomes while controlling for spatial and temporal invariant factors. The ordinary least squares regression model used is as follows:

$$A_{i,r,c,m,y} = \varphi T_{i,m} + \gamma X_i + \alpha M_i + \omega_{c,y} + \mu_m + \sigma_c + \epsilon_{i,r} \quad (1)$$

$$A_{i,r,c,m,y} = \varphi T_{i,m} + \omega_{c,y} + \mu_m + \sigma_c + \epsilon_{i,r} \quad (2)$$

Our model includes child-specific controls γX_i such as age in months, rural residence, gender, and birth order, and maternal controls αM_i such as age, marital status, the total number of children, and education level. The main variable of interest is the temperature in the interview month, denoted by $\varphi T_{i,m}$. Anthropometric measurements of the child i, including weight for age, height for age, or weight for height, are represented by $A_{i,r,c,m,y}$, where i denotes the child, r denotes the region, c denotes the country, m denotes the month, and y denotes the year of the survey.

To account for potential bias, we include fixed effects to control for temporal bias $\omega_{c,y}$ for each country-by-year of the survey, which captures the average country-level anthropometric trends. We also use the month of the interview μ_m to control for arbitrary seasonal effects and include an indicator variable for country σ_c to remove spatial forms bias. Finally, to account for unobservable regional heterogeneity, we cluster the errors $\epsilon_{i,r}$ based on an identifier of the administrative region by country. By doing so, we aim to obtain more precise estimates of the relationship between temperature and child anthropometric measurements while accounting for potential confounding factors that may affect the outcome.

3. Results

3.1 Summarizing our sample

To better understand the impact of high temperatures on children's anthropometrics, it is important to first identify the regions and countries that are most affected. To achieve this, we created Figure 1, which shows the mean temperature over 30 years in the 54 countries of our sample. The darker red areas in the figure indicate regions where higher temperatures are recorded, while the darker blue areas represent lower temperatures. We also marked with triangles the countries where the mean temperature over the 30 years is consistently above 25°C, highlighting regions where high temperatures are most pronounced.

To further investigate the impact of high temperatures on child health, we have conducted an analysis of the Weight for Age Z score (WAZ), Height of Age Z score (HAZ), Weight for Height Z score (WHZ), and the prevalence of underweight stunting, and wasting in our sample. Table 1 presents the descriptive statistics of these outcomes for the 54 countries in our study. The table includes the number of observations for each variable, the mean, standard deviation, minimum, and maximum. This information provides a comprehensive overview of the health outcomes in our sample and allows us to identify patterns and trends that may be related to high temperatures. By examining the descriptive statistics of these variables in conjunction with the data presented in Figure 1, we can develop a more nuanced understanding of the impact of high temperatures on child health across different regions.

Our analysis of the impact of high temperatures on child health includes a set of maps that display the mean z scores of weight by age, height by age, and weight by height for the 54 countries in our sample. These maps are presented on the left side of Figure 2 (Panel A), illustrating the prevalence of underweight, stunting, and wasting among children in our sample, with darker colors indicating a higher prevalence. The maps reveal that in many countries, a significant proportion of children suffer from these conditions.

On the right side of Figure 2 (Panel B), we present a set of histograms showing the frequency of children who suffer underweight, stunting, and wasting in our sample. These histograms complement the information presented in the maps, providing a more detailed picture of the distribution of child health outcomes in our sample. In addition, by examining the histograms in conjunction with the maps, we can identify the countries and regions where child health outcomes are most prevalent and develop targeted interventions and policies that mitigate the effects of high temperatures on child health in these areas. Overall, the combination of maps and histograms provides a comprehensive overview of the impact of high temperatures on child health across different regions.

Our sample shows that 21% of children in countries with the highest number of underweight children are Nigeria, Bangladesh, Mali, Ethiopia, and Burkina Faso. Additionally, we observed that 38.3% of children in Nigeria, Egypt, Bangladesh, Malawi, and Mali experience stunting. Finally, we found that 8.3% of children in Nigeria, Bangladesh, Mali, Egypt, and Burkina Faso suffer from wasting. These findings highlight the urgent need for targeted interventions to improve child health outcomes, particularly in countries with high prevalence rates of underweight, stunting, and wasting.

3.2 Impact of Temperature on Children's Anthropometric Measurements

This study investigated the impact of temperature on children's anthropometric measurements. Initially, we analyzed the effects without any fixed effects, and then we included fixed effects such as interview year, interview month, and administrative region (provinces) to control for potential confounding factors. By doing so, we aimed to identify the specific effects of temperature on the children's growth and development, independent of other factors that may affect the outcome.

In Table 2, our study indicates a negative correlation between higher monthly temperatures and weight-for-age and weight-for-height Z scores in children. However, after considering fixed effects, we observed a weaker association between temperature and these measures, with a reduction of approximately 0.06 standard deviations. Interestingly, including fixed effects led to a change in the direction and significance of the association, suggesting that some unobserved variables may affect the relationship between Monthly Temperature and HAZ and that these variables were only partially accounted for in the model with fixed effects. It is possible that these unobserved variables were correlated with both Monthly Temperature and HAZ, leading to inaccurate results.

We collapsed the WAZ and WHZ variables by country. By doing this, we could analyze the average effect of monthly temperature on children's measurements across different countries rather than looking at individual measurements for each child. This approach allowed us to explore the overall relationship between temperature and children's health outcomes while controlling for potential country-specific factors that could affect the relationship. Using country-level data also allowed us to understand better the potential impact of climate change on child health in different regions of the world.

Figure 3 shows a clear negative relationship between monthly temperatures and anthropometric outcomes for both WAZ and WHZ. As monthly temperatures increase, we observe a decrease in both WAZ and WHZ. Furthermore, the scatterplot for WHZ indicates a stronger relationship for temperatures above 20°C compared to WAZ.

These findings suggest high temperatures significantly impact child growth and development, particularly in countries where temperatures consistently exceed 20°C. Overall, this highlights the need to consider the potential health consequences of climate change, particularly in vulnerable populations such as children.

To examine the potential influence of other factors, we included control variables for child and maternal characteristics in our analysis. These included child controls such as age in months, rural residence, gender, and birth order, and maternal controls such as age, marital status, the total number of children, and education level. In addition, we estimated country-fixed effects models to account for unobserved heterogeneity across countries.

The results presented in Table 3 indicate that monthly temperature directly and independently impacts weight-for-age and height-for-age z scores, even after controlling for child and maternal characteristics. This suggests that temperature plays a critical role in children's anthropometric outcomes. Furthermore, our analysis reveals that all maternal characteristics are positively associated with anthropometric outcomes and higher levels of maternal education are linked to improved outcomes. Additionally, our findings suggest that children living in rural areas are particularly vulnerable to losing weight-for-age and weight-for-height z scores, which will be further analyzed in subsequent sections of this document.

3.2.1 Differential Impact of Temperature on Anthropometric Outcomes by Residence and Economic Development

In addition to examining the direct relationship between monthly temperature and anthropometric outcomes, we also investigate how this relationship differs based on the child's rural or urban residence and the area's economic development level. We analyze the impact of monthly temperature on anthropometric outcomes separately for rural and urban areas to examine any differences in the effects of temperature. Additionally, we examine the relationship between monthly temperature and anthropometric outcomes while controlling for the area's economic development level, as measured by the natural log of Gross Domestic Product per capita (ln_GDP_PC). This analysis aims to provide insight into how temperature affects vulnerable populations differently based on their living conditions and economic status.

Our regression analysis in Table 4 indicates that children in rural areas have lower weight-for-age z scores and weight-for-height compared to those in urban areas, which is consistent with previous research on undernutrition in rural areas that have highlighted the higher prevalence of undernutrition in rural areas due to factors such as limited access to healthcare, poor sanitation, and inadequate food security. However, we also found that the effect of monthly temperatures on WAZ and WHZ is similar in rural and urban areas, as indicated by the non-significant interaction between monthly temperature and rural status.

Furthermore, we found that higher economic status positively correlates with WAZ scores, but the association between economic status and WHZ scores is not statistically significant. This suggests that economic status may not significantly affect the weight-for-height z score. The interaction term between economic status and monthly temperature indicates that the effect of monthly temperature on both WAZ and WHZ does not vary by economic status.

After controlling for relevant variables and accounting for the fixed effects of rural and urban samples, our regression analysis shown in Figure 4 indicates that children in rural areas have lower WAZ scores than their urban counterparts at all temperature levels. However, the relationship between monthly temperature and WAZ is steeper for urban children, indicating a stronger negative association between the two variables for this group. Furthermore, the relationship between WHZ and monthly temperature for rural and urban children was also examined in our analysis. The results revealed a negative relationship between WHZ and monthly temperature for rural and urban children. Moreover, the similarity in slopes between rural and urban children suggests that the effect of monthly temperature on WHZ is comparable in both areas.

The scatter plot in Figure 5 displays the coefficients of each regression (WAZ and WHZ) for Ln GDP-PC in all countries, plotted against the mean Ln GDP-PC. The almost flat line of both plots suggests that the relationship between economic status and child undernutrition may not vary significantly across countries, and the effect of economic status on child undernutrition is relatively constant across countries.

However, it's important to note that the lack of a significant relationship between economic status and child undernutrition in some countries could be due to unequal distribution of wealth, limited access to healthcare and sanitation, and other socio-economic factors that can affect child health and nutrition.

3.3.1 Heterogeneity Across Continents and Countries

3.3.1.1 Across Continents

To account for potential country-specific contextual factors, we conducted separate regression models for weight-for-age and weight-for-height z scores for each continent in our sample. This approach allowed us to capture unique characteristics that may influence the relationship between monthly temperature and child anthropometric outcomes. By controlling for child and maternal characteristics, fixed effects, interview year, interview month, and a country indicator variable, we could isolate the impact of monthly temperature on child health outcomes. Furthermore, we clustered the errors based on an identifier of the administrative region by country to account for potential correlation within regions. The results displayed in Figure 6 provide a more nuanced understanding of the association between monthly temperature and child health outcomes across different continents.

Interestingly, the results suggest that the relationship between monthly temperature and child anthropometric outcomes varies across different continents, indicating that the impact of high temperatures on child health may depend on regional climate patterns and other contextual factors. Specifically, the negative relationship between monthly temperature and WAZ in Africa, Asia, and Europe is concerning as it suggests that higher temperatures are associated with lower child weight-for-age z scores. Conversely, the positive relationship observed in North America and South America is unexpected and may be due to the limited sample size from these regions.

Furthermore, the negative relationship between monthly temperature and WHZ in Africa, Asia, Europe, and North America highlights the negative impact of high temperatures on child weight-for-height z scores. However, the positive relationship observed in South America is once again unexpected and may be due to the limited sample size from this region.

It is important to note that there is also heterogeneity within continents in terms of the relationship between temperature and child anthropometric outcomes. The limited sample size of North America and South America may also affect the accuracy and generalizability of the results. Therefore, further research with larger samples in these continents is needed to confirm these findings. One possible explanation for the unexpected positive relationship observed in North America and South America is that the information we have in our sample from these regions is insufficient to capture the true impact of temperature on child anthropometrics. Differences in access to air conditioning and cultural practices related to feeding and care may also play a role.

3.3.1.2 Across Countries

To better understand the impact of monthly temperature on child anthropometric outcomes in countries with high prevalence rates of underweight and wasting children, we conducted a regression analysis while controlling for relevant child and maternal factors and fixed effects for the year and month of the interview. The results of this analysis are displayed in Figure 7, which allows us to visualize the relationship between monthly temperature and child anthropometrics in these countries. Our findings suggest a small negative relationship between these variables.

To analyze the results of our sample of 54 countries, we applied the same controls and fixed effects used in our previous analysis. Figure 8 presents the histograms of the frequencies of the coefficients of the regressions of the 54 countries. Our findings indicate that in the majority of countries, the monthly temperature has a negative impact on weight-for-height and weight-for-age z scores. However, there is significant heterogeneity in the results across countries, indicating that the impact of monthly temperature on child anthropometric outcomes may vary depending on regional climate patterns, cultural practices, and access to resources. These findings highlight the need for targeted interventions that consider each country's specific contexts to mitigate the negative effects of high temperatures on child nutrition.

4. Discussions

The findings of this study provide robust evidence of the negative impact of high temperatures on child health outcomes, especially on anthropometric measurements such as weight-for-age and weight-for-height Z scores. Temperatures above 20°C significantly impact child growth and development in many countries. The study confirms previous research indicating that this impact is more pronounced in countries with consistently high temperatures and that children living in rural areas are more vulnerable to losing weight-for-age and weight-for-height z scores (Baker & Anttila-Hughes, 2020; Thiede & Strube, 2020). Furthermore, the study highlights the positive correlation between economic status and WAZ scores but no statistically significant association between economic status and WHZ scores. However, the lack of a significant relationship between economic status and child undernutrition in some countries suggests that other socio-economic factors may play a role in determining child health and nutrition outcomes.

This finding highlights the limitations of relying solely on economic status to adapt and mitigate the negative effects of high temperatures on child nutrition. Therefore, targeted interventions that consider each country's specific contexts are needed to address the socio-economic factors affecting child health and nutrition, improve access to healthcare and sanitation, and achieve better child health outcomes. These findings build upon previous literature identifying high temperatures as a significant risk factor for child undernutrition in regions such as Africa and Asia.

In light of the negative impact of high temperatures on child health outcomes, especially in countries with high prevalence rates of underweight and wasting children, it is imperative to implement targeted interventions to improve child health outcomes. Such interventions may include improving access to nutritious food, promoting safe water and sanitation practices, enhancing healthcare infrastructure, and strengthening social safety nets to alleviate the burden of economic hardships. Additionally, efforts to address climate change and its effects on food security, such as sustainable agricultural practices and climate-resilient food systems, could help to mitigate the negative impact of high temperatures on child health outcomes in the long run(Mendelsohn, 2009).

The impact of monthly temperature on child anthropometric outcomes is not uniform across different regions and continents, suggesting that regional climate patterns and other contextual factors may significantly influence this relationship. In addition, there is considerable heterogeneity in the results across countries, indicating that the impact of monthly temperature on child anthropometric outcomes may vary depending on regional climate patterns, cultural practices, and access to resources. While our analysis reveals a consistent negative association between temperature increase and child anthropometric outcomes across most countries in our sample, including fixed effects, weakens the observed association, suggesting the presence of unobserved variables that may affect the average relationship between monthly temperature and anthropometric outcomes. Therefore, future research should investigate cross-regional variables such as local sanitation, healthcare, and other climate factors to understand better the factors affecting anthropometric outcomes.

The contribution of the results obtained and analyzed in this research has been the expansion of other regions for which information is available in the DHS. Moreover, the findings show that the income level in countries may not necessarily protect from the adverse effects of high temperatures on child anthropometric outcomes, highlighting the need for context-specific interventions.

In conclusion, the results of this study underscore the need for targeted interventions that consider each country's specific contexts to mitigate the negative effects of high temperatures on child nutrition. Additionally, addressing the socio-economic factors that affect child health and nutrition and improving access to healthcare and sanitation are crucial for achieving better child health outcomes.

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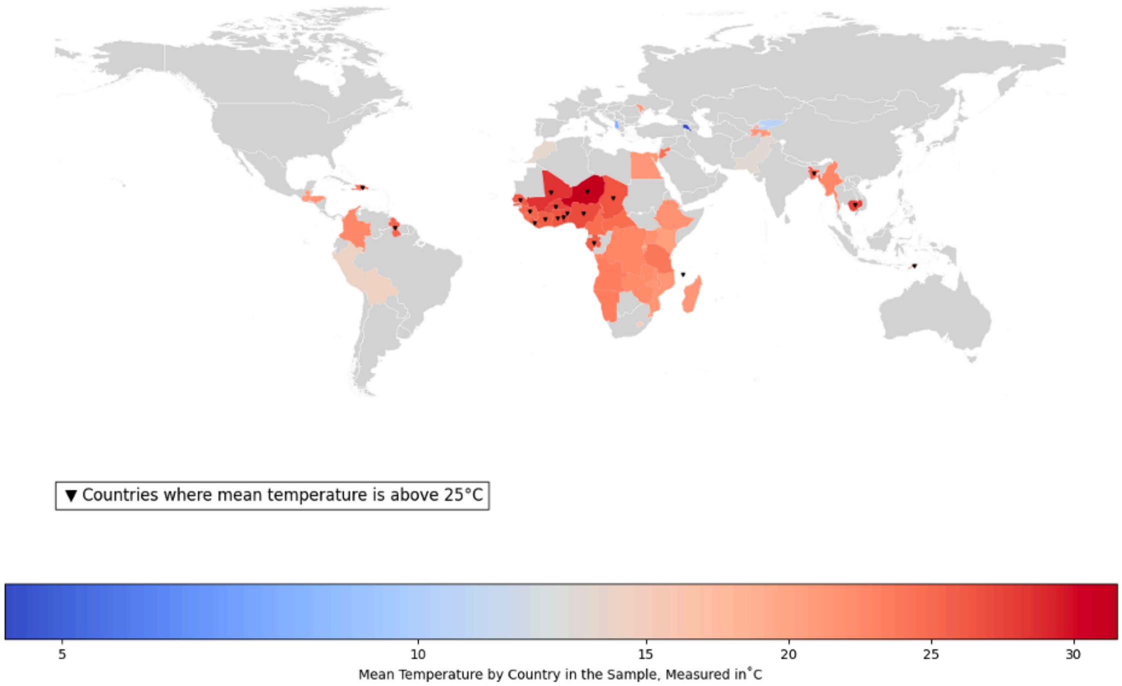


Figure 1: Spatial averages of temperature

Table 1: Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
WAZ	433147	-.9835	1.358	-6	5
HAZ	424210	-1.55	1.664	-6	6
WHZ	421194	-.125	1.414	-5	5

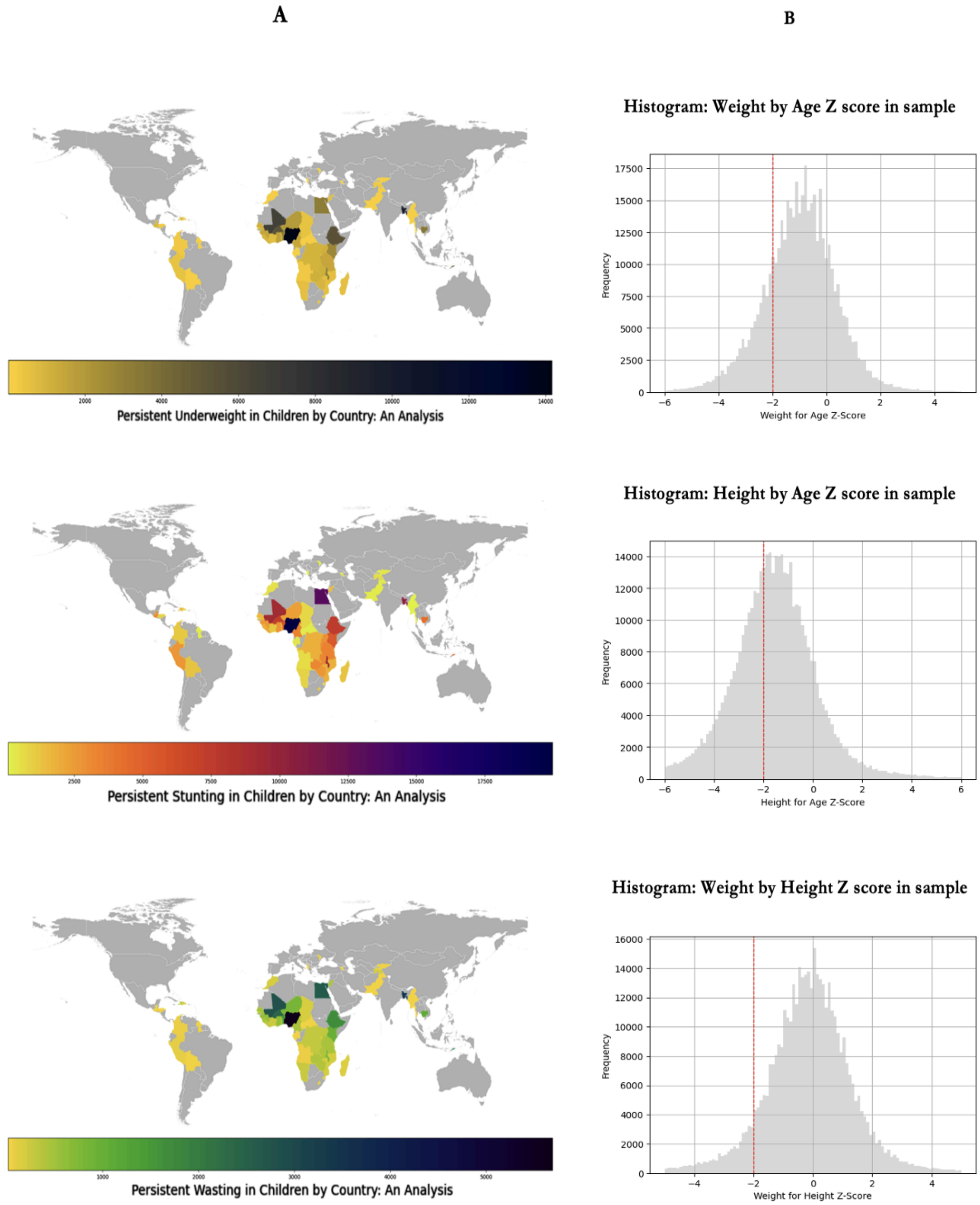


Figure 2: Panel A. Average child anthropometrics. Panel B. Distribution of child anthropometrics.

Table 2. Temperature Effects on anthropometric outcomes on children with and without fixed effects.

	1	2	3	4	5	6
VARIABLES	WAZ	WAZ	HAZ	HAZ	WHZ	WHZ
Monthly Temperature	-0.0500***	-0.0176***	-0.0185***	0.00377	-0.0525***	-0.0260***
	-0.00436	-0.00349	-0.005	-0.00389	-0.00323	-0.00288
Constant	0.197*	-0.551***	-1.102***	-1.617***	1.095***	0.481***
	-0.107	-0.079	-0.126	-0.0894	-0.0823	-0.0658
Observations	433,113	433,113	424,177	424,177	421,161	421,161
R-squared	0.039	0.167	0.004	0.093	0.041	0.109
Year FE	No	Yes	No	Yes	No	Yes
Month FE	No	Yes	No	Yes	No	Yes
Country FE	No	Yes	No	Yes	No	Yes

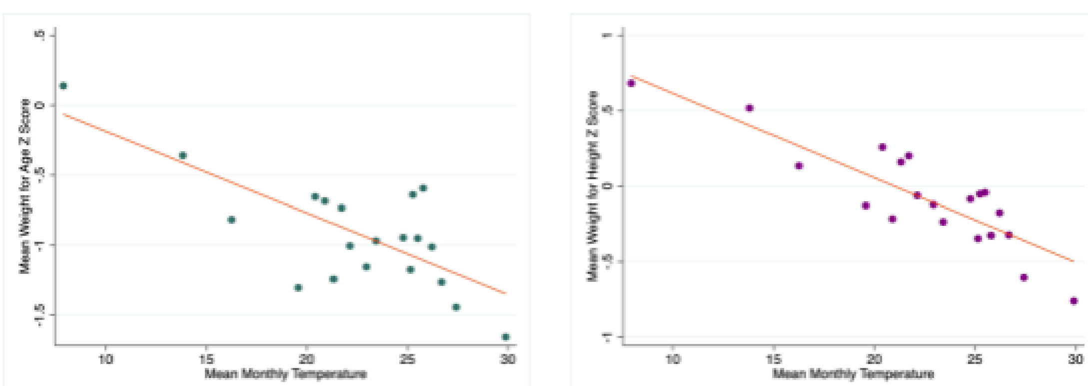


Figure 3 : Average Monthly Temperature Effects on Anthropometric Outcomes Collapsed by Country.

Table 3. Temperature Effects on Anthropometric Outcomes in Children: Comparison of Models with child controls and Fixed Effects.

	MODELS	7	8	9	10	11	12
	VARIABLES	WAZ	WHZ	BMI	WAZ	WHZ	BMI
	Monthly Temperature	-0.0166***	-0.0258***	-0.0263***	-0.0147***	-0.0251***	-0.0259***
		(0.00310)	(0.00281)	(0.00282)	(0.00281)	(0.00269)	(0.00275)
Child controls	Rural	-0.318***	-0.0738***	-0.0148	-0.209***	-0.0339**	0.00772
		(0.0171)	(0.0147)	(0.0151)	(0.0152)	(0.0148)	(0.0154)
	Age in months	-0.00345***	0.00683***	0.00366***	-0.00591***	0.00567***	0.00298***
		(0.000443)	(0.000649)	(0.000661)	(0.000413)	(0.000669)	(0.000695)
	Male	-0.0625***	-0.00852	0.0587***	-0.0635***	-0.00847	0.0589***
		(0.00940)	(0.0107)	(0.0106)	(0.00933)	(0.0106)	(0.0106)
	Birth order	-0.0206***	-0.00576***	-0.00140	-0.112***	-0.0597***	-0.0369***
		(0.00189)	(0.00164)	(0.00166)	(0.0131)	(0.0106)	(0.00992)
Maternal Controls	Mothers age				0.0179***	0.00227	-0.00129
					(0.00149)	(0.00148)	(0.00143)
	Married				0.0438***	0.00755	0.00254
					(0.0164)	(0.0177)	(0.0182)
	Total children				0.0669***	0.0570***	0.0439***
					(0.0137)	(0.00960)	(0.00910)
	Education primary				0.180***	0.0882***	0.0588***
					(0.0200)	(0.0158)	(0.0153)
	Education secondary				0.394***	0.181***	0.116***
					(0.0249)	(0.0185)	(0.0184)
	Education higher				0.616***	0.284***	0.197***
					(0.0369)	(0.0282)	(0.0283)
	Constant	-0.135*	0.317***	0.538***	-0.884***	0.112	0.465***
		(0.0725)	(0.0704)	(0.0710)	(0.0750)	(0.0727)	(0.0754)
	Observations	433,113	421,161	420,104	433,110	421,158	420,101
	R-squared	0.181	0.114	0.092	0.195	0.116	0.093
	Year FE	Yes	Yes	Yes	Yes	Yes	Yes
	Month FE	Yes	Yes	Yes	Yes	Yes	Yes
	Country FE	Yes	Yes	Yes	Yes	Yes	Yes

Robust standard errors in parentheses

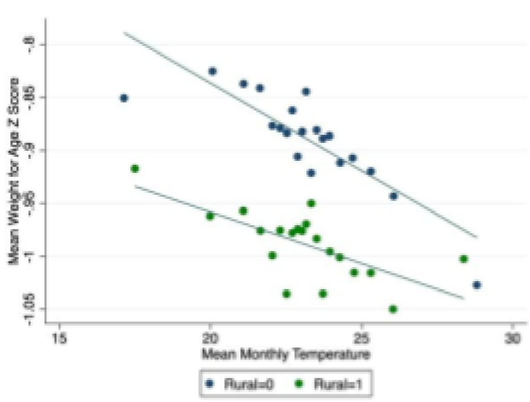
***** p<0.01, ** p<0.05, * p<0.1**

Table 4. Regression Results Regression Results for Anthropometric Outcomes by Rural/Urban Status and Economic Status

	13	14	15	16
VARIABLES	WAZ	WHZ	WAZ	WHZ
Monthly Temperature	-0.0118***	-0.0261***	-0.0174***	-0.0256***
	(0.00349)	(0.00330)	(0.00338)	(0.00285)
Rural	-0.171***	-0.0880		
	(0.0603)	(0.0696)		
Rural*Monthly Temperature	-0.00694***	0.000500		
	(0.00256)	(0.00280)		
Ln_GDP-PC			0.188***	0.116**
			(0.0573)	(0.0481)
Ln_GDP-PC*Monthly Temperature			0.000892	-0.00188
			(0.00292)	(0.00232)
Observations	433,113	421,161	433,113	421,161
R-squared	0.178	0.110	0.167	0.109
Year FE	Yes	Yes	Yes	Yes
Month FE	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes

Robust standard errors in parentheses

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



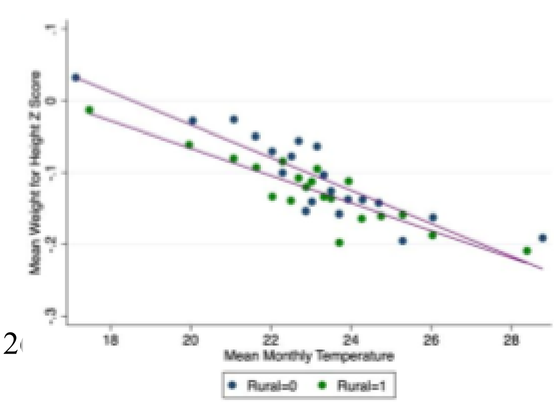


Figure 4 : Relationship between Monthly Temperature and Anthropometric Outcomes for Rural and Urban Children: WAZ and WHZ Analysis

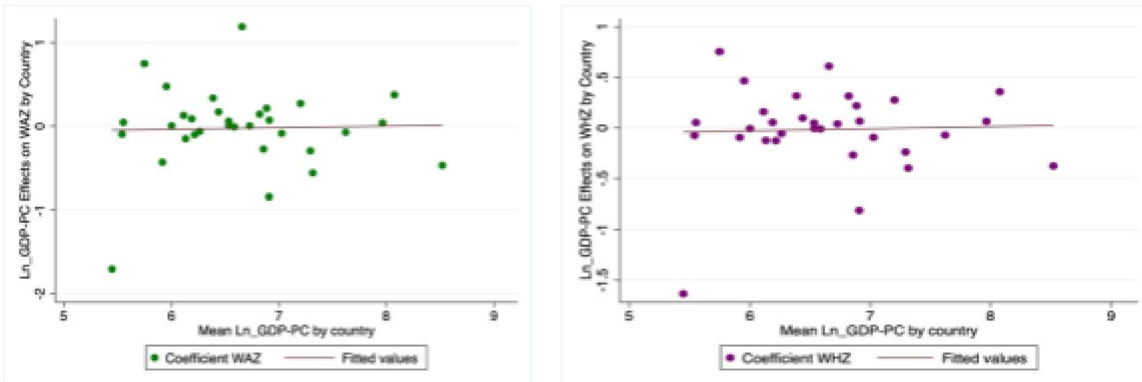


Figure 5: Relationship between economic status and child undernutrition across countries

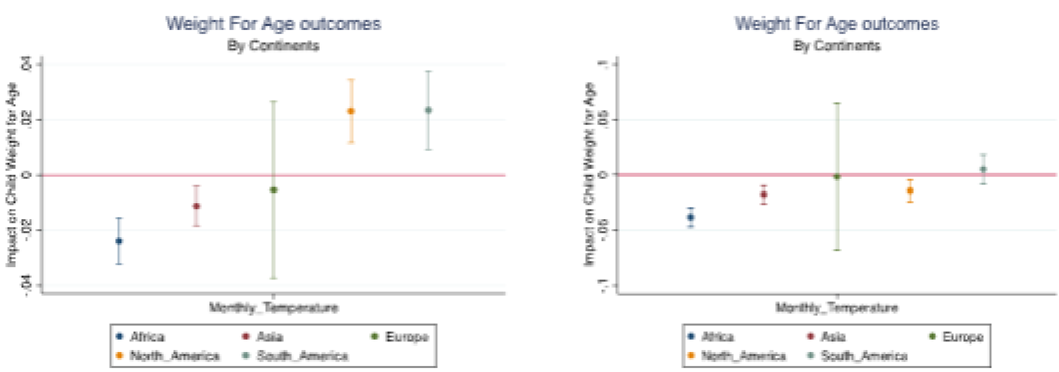


Figure 6 : Comparison of Impact of Monthly Temperature on Child Anthropometric Outcomes Across Continents with child and maternal controls and FE

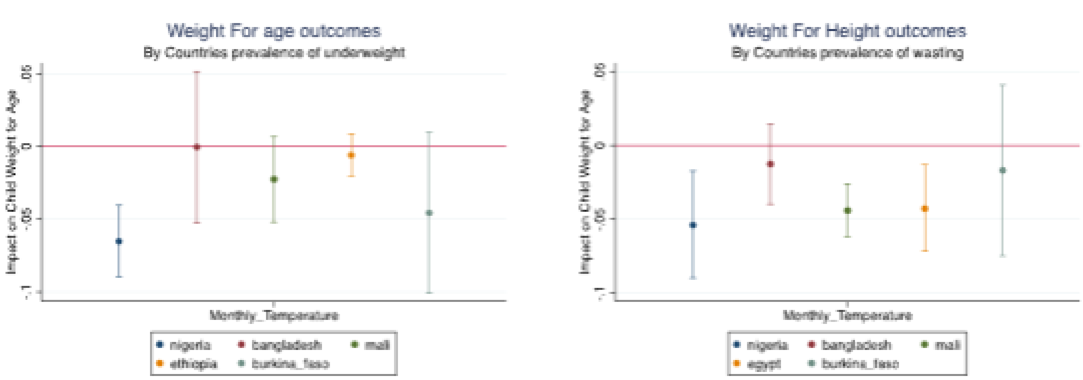


Figure 7 : Impact of Monthly Temperature on Child Anthropometry Across Countries with Underweight and Wasting Prevalence

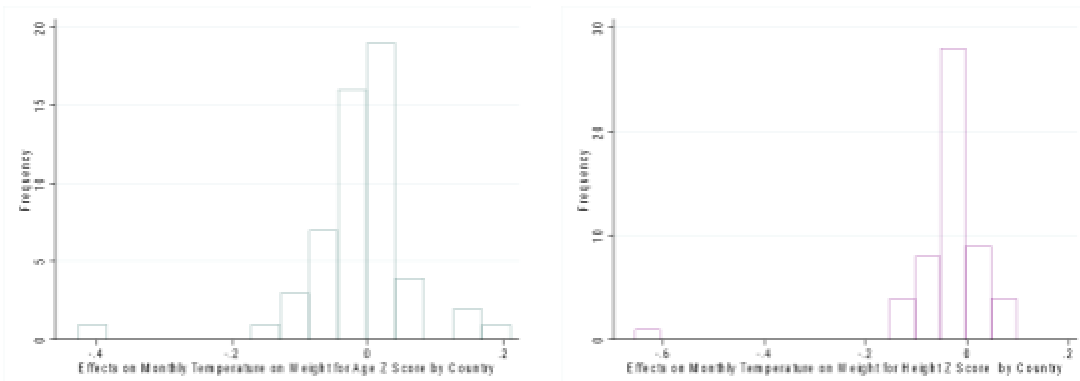


Figure 8 : The Impact of Monthly Temperature on Child Anthropometric Outcomes: A Global View