A Preventable Loss of Human Potential: The Association of Drinking Water Quality and Stunted Growth in Indian Children

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ABSTRACT

India has the highest rate of stunted growth in children under five in the world. Stunted growth, low height for age, can lead to physical and cognitive defects. Poor diet can contribute to stunted growth, but recent studies suggest that water, sanitation, and hygiene may be more significant than previously thought. This study examined the association between stunted growth, diet, and drinking water quality in slum and non-slum children under five in Pune, India. I aimed to determine which factor, drinking water quality or diet, was more closely associated with stunting. Each child completed a Health Assessment, which included a demographic questionnaire, anthropometric measurements, and a 24-hour diet recall. In addition, six drinking water samples were collected from the study sites and tested for pH, turbidity, hardness, alkalinity, chloride concentration, nitrite concentration, nitrate concentration, fecal coliform growth, E-coli growth, and residual chlorine concentration. With this information, I determined stunting, wasting, malnutrition prevalence, and percent of daily recommended caloric intake (%DRCI) per child and average drinking water quality index value (WQI) per group of children. I found that stunting, wasting, and malnutrition prevalence was higher in slum children and that these outcomes were weakly positively associated with %DRCI. I found that all of the tested samples contained non-potable water, but was not able to test its association with health outcomes. Based on these results, I conclude that further analysis is needed to fully understand the relationship between drinking water quality and health outcomes.

Ethical certification: This study was approved by the Ethics Board of Cowasji Jehangir Hospital Medical Research Institute on June 22, 2016.

KEYWORDS

stunted growth, children, drinking water quality, diet, slums, India, global environmental health

INTRODUCTION

After decades of record economic growth and development, India has made a name for itself as a rising world power. Nevertheless, the nation continues to face alarming public health crises. As the country with the highest rate of outdoor defecation in the world, poor sanitation has long been a problem in India (Spears et al. 2013). However, the Indian government hasn't taken water quality, sanitation, and hygiene (*WSH*) concerns seriously. As of 2016, drinking water and sanitation initiatives formed less than 1% of the nation's total budget (Ministry of Finance 2016). As it stands, such continued oversight may have much more serious consequences than expected.

Today, India is home to the highest rate of stunted growth in children under five in the world – and almost half the nation's children are affected (Schmidt 2014). Defined as height that falls below two standard deviations of the reference population, stunting in children under five can lead to permanent physical and cognitive defects if left untreated. A well-established causative pathway has long linked poor diet and stunted growth (Dobe 2015). As a result, the Indian government has historically dealt with stunting as an issue of food security (WHA 2014). Indeed, through grain subsidies, school meal programs, and nutrition education, chronic widespread hunger has declined in the nation (Dobe 2015). However, despite this progress, the prevalence of stunting has not significantly decreased. Instead, emerging research shows that stunting in India occurs even "among well-fed children," and that poor WSH may be playing a larger role than previously thought.

New research suggests an alternate causative pathway (Figure 1) that links poor WSH with stunted growth. Contact with contaminated food or water, vomit, or feces can spread enteric infections that can lead to diarrheal disease. As studies are beginning to indicate, such disease can consequently lead to stunted growth. It has been found that the severity of diarrheal disease by age two is correlated with the severity of stunting by age five (Checkley et al. 2008). In addition, a 2016 study found that children infected with an environmental pathogen are two times as likely to be severely stunted by age two (Korpe and Petri 2012). These studies, and others like them, were conducted in slum communities – as such populations are at much higher risk than other, more-developed regions.

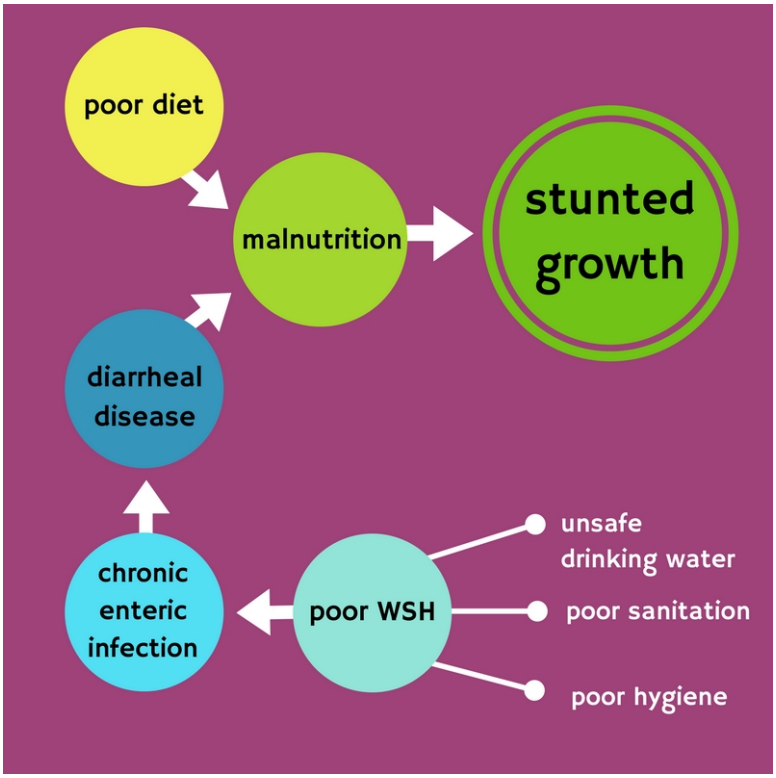


Figure 1. Causative Pathways for Stunted Growth © 2017 Ramanjot Kaur

Today, 65 million people live in informal settlements in India and that number is expected to increase exponentially in the coming years (Ministry of Home Affairs). Research indicates that children who grow up in slums are more vulnerable to stunting than their non-slum counterparts. A comparative study by the International Centre for Diarrhoeal Disease Research, which examined slum and non-slum populations in Dhaka, Bangladesh, found that slum children were more likely to be infected with selected pathogens and thus contract diarrheal diseases that could lead to stunting (Ferdous et al. 2014). Slums are home to "vicious cycles of diarrhea and malnutrition" that occur when individuals afflicted with chronic bouts of diarrhea experience higher rates of malnutrition and thus become more vulnerable to contracting infections that lead to additional and more severe bouts of diarrhea (Moore et al. 2010). Characterized by poor household conditions, (measured by toilet access, drinking water access and family size), slums are correlated with higher and more severe rates of stunting (Som et al. 2007). Nevertheless, it's important to notes that this cycle of environmental risk and disease can be broken - as improved WSH has been found to reduce stunting by 27% in developing countries (Fink et al. 2011).

This study aims to evaluate the relationship between poor WSH and stunted growth to determine: How closely associated is drinking water quality or diet to the prevalence of stunted growth in children under five? Which factor - drinking water quality or diet - is more predictive of stunted growth? Based on previous studies, which found that worse household conditions (measured by toilet access, drinking water access, and family size) were correlated with higher and more severe rates of stunting, it is likely that children from slums and children who drink water of poor quality will exhibit more severe stunting than their peers (Som et al. 2007). According to several recent studies that show that stunting in India occurs even "among well-fed children," it is not likely that there will be a significant association between diet and stunting prevalence (Schmidt 2014). This study will provide insight into stunted growth rates in both slum and non-slum populations in Pune and help researchers better understand the association between drinking water quality, diet, and stunted growth.

METHODS

In association with Cowasji Jehangir Hospital Medical Research Institute (HCJMRI), I conducted a cross-sectional study of children under five in Pune, Maharashtra, India. Study participants included slum children (Group 1) and non-slum children (Group 2). Participants that were recruited from slum welfare centers (Deep Griha Society – Tadiwala and Deep Griha Society – Ramtekadi) were considered as part of Group 1, while children that were recruited from a private nursery school (Paranjape School) were considered a part of Group 2. Each participant's parent/guardian signed a consent form, included in Appendix I, that explained the risks and procedures in Marathi and English. I enrolled 74 consenting households into the study – 42 from Group 1 and 32 from Group 2. With the assistance of a Marathi and Hindi translator, I completed a "Health Assessment" survey with each family. This survey was used to: (1) collect demographic information, (2) determine stunting prevalence per child, and (3) determine average % of recommended daily caloric intake (DRCI) for each child. In addition, 1 L drinking water samples were collected from DGS Tadiwala and Ramtekadi branches and from randomly selected households that visited DGS or attended Paranjape Nursery School. These six water samples were then tested for several parameters to determine average drinking water quality and to compare quality among sites.

Health assessment

The Health Assessment questionnaire, included in Appendix II, was divided into four sections. In Part One, *Demographic Information,* I gathered the following information from each family: participant's age, number of siblings, age of each sibling, and each parent/guardian's marital status, age, education level, income level, and occupation. In Part Two, *Anthropometric Measurements,* I measured the height, weight, and mid-arm circumference of each participant. The results from this survey were input into the World Health Organization's "ANTHRO" program which calculates Z-scores per child in accordance with global health standards. I used these Z-scores to classify the severity of malnourishment, wasting, or stunting for each child as "Healthy," "Mild," "Moderate," or "Severe". These classifications were then used to determine malnutrition, wasting, and stunting prevalence for each group. In Part Three, *Water Storage and Handling Practices,* I asked each family a few questions that to identify common practices among each group. In Part Four, *Diet Recall*, each child's parent/guardian recounted everything their child had eaten in the past 24 hours. These responses were input into a computer program, "C Diet," which had been modified by HCJMRI to compute nutritional values in typical Maharashtrian cuisine. C Diet computed BMI, BMR, calories, protein, fat, carbohydrates, calcium, sodium, potassium, Vitamin C, Riboflavin, Beta Carotene, Folic Acid, Zinc, Iron, Phosphorous, Magnesium, Manganese, Thiamin, Copper, Niacin, Phytates, and Fiber for each child. This information was condensed into % DRCI for each child based upon WHO daily caloric standard for children under 5. This measure was used as a proxy for a child's average diet to determine whether a child was eating the recommended amount of calories on a daily basis.

Drinking water quality

Three drinking water samples were collected from each group. Samples were collected at recruitment centers and from participant households (Table 1).

Table 1. Drinking water sources per group.

	Group 1	Group 2
Source 1	Recruitment Center (Deep Griha Society - Tadiwala Road)	Household 1
Source 2	Recruitment Center (Deep Griha Society – Ramtekadi)	Household 2
Source 3	Deep Griha Society – Tadiwala Road Household	Household 3

I collected 1 L samples from each of the sites above, stored them in a refrigerator from 1-4 days, and sent them to Pune Municipal Water Corporation's Parvati Jal Shuddhi Karan (PJSK) Laboratory. For each sample, the PJSK Lab conducted independent tests for each of the following parameters: pH, turbidity, hardness, alkalinity, chloride concentration, nitrite concentration, nitrate concentration, fecal coliform growth, E-coli growth, and residual chlorine concentration. PJSK Lab independently classified each sample as "potable," or "non-potable" according to their internal criteria. To ensure transparency and accuracy, I reclassified each sample based on the results of the parameter tests. Based on "Water Research Organization's" guidelines, I condensed the results of the parameter tests into a water quality index (WQI) value, ranging from 0 to 100, with 100 being pure water.

Data analysis

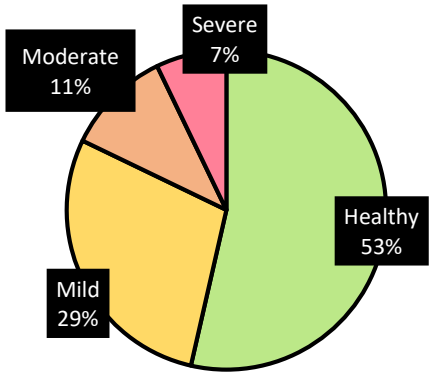
To determine if WQI value was associated with malnutrition, wasting, and stunting prevalence, Group 1 and Group 2 WQI values were graphed against malnutrition, wasting, and stunting z-scores. Each of these graphs included r-values. To determine if % DRCI was associated with malnutrition, wasting, and stunting prevalence, for each group, % DRCI values were graphed against malnutrition, wasting, and stunting z-scores. Each of these graphs included r-values.

RESULTS

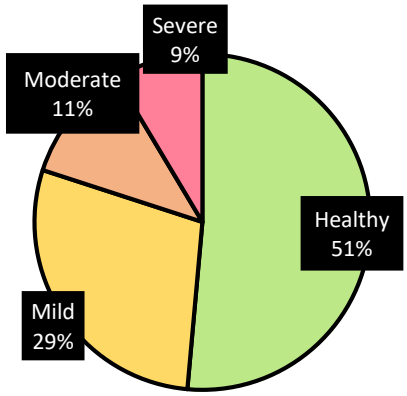
Anthropometric measurements

Malnutrition prevalence

(a) All Children



(b) Group 1



(c) Group 2

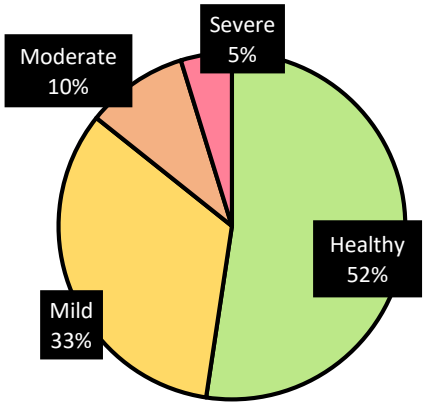
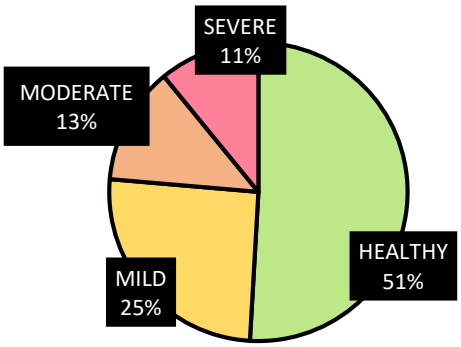


Figure 2. Malnutrition Prevalence. Based on WHO standards, I classified each participant's BMI-for-age Z-scores into the following categories: "Healthy" (no malnutrition), "Mild Malnutrition," "Moderate Malnutrition," and "Severe Malnutrition." The pie charts above indicate the prevalence of each category in the following populations: (a) All groups, (b) Group 1, and (c) Group 2.

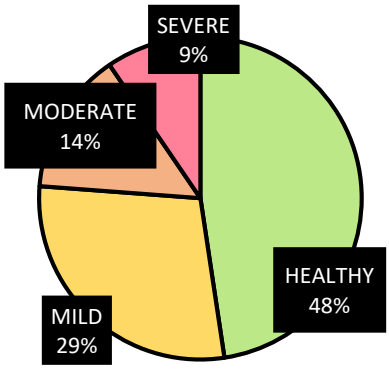
Forty-seven percent of all study participants experienced some form of malnutrition (Figure 2a). While participants from Group 1 exhibited similar levels of malnutrition as their non-slum counterparts in Group 2, they experienced more moderate and severe forms. Forty percent of all malnourished children in Group 1 experienced moderate and severe forms of malnutrition, while only 31% of malnourished children in Group 2 experienced such forms (Figures 2b, 2c).

Wasting prevalence

(a) All children



(b) Group 1



(c) Group 2

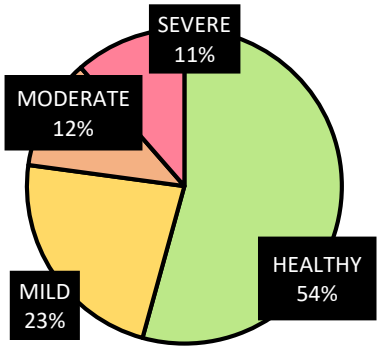
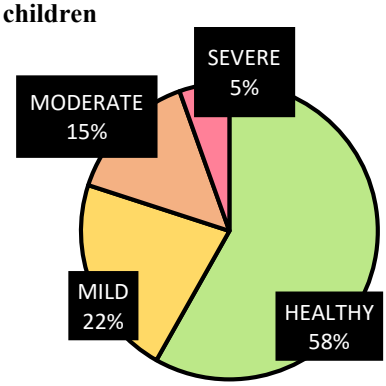


Figure 3. Wasting Prevalence. Based on WHO standards, I classified each participant's weight-for-age Z-scores into the following categories: "Healthy" (no wasting), "Mild Wasting," "Moderate Wasting," and "Severe Wasting." The pie charts above indicate the prevalence of each category in the following populations: (a) All groups, (b) Group 1, and (c) Group 2.

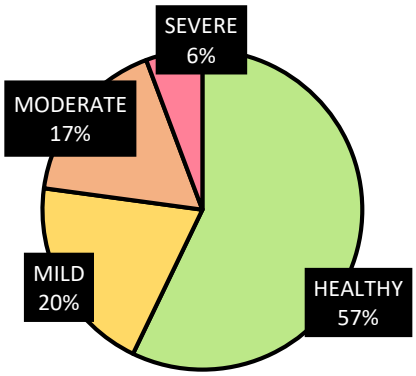
In terms of wasting, while children from both groups experienced wasted group, children in Group 1 displayed a higher rate of wasting than their Group 2 counterparts (Figure 3).

Stunting prevalence

(a) All children



(b) Group 1



(c) Group 2

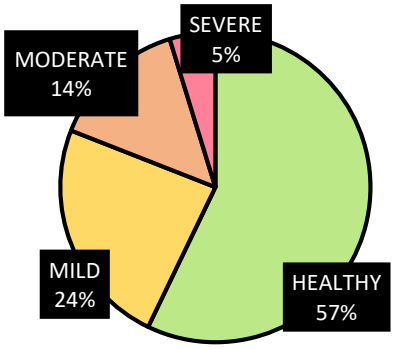


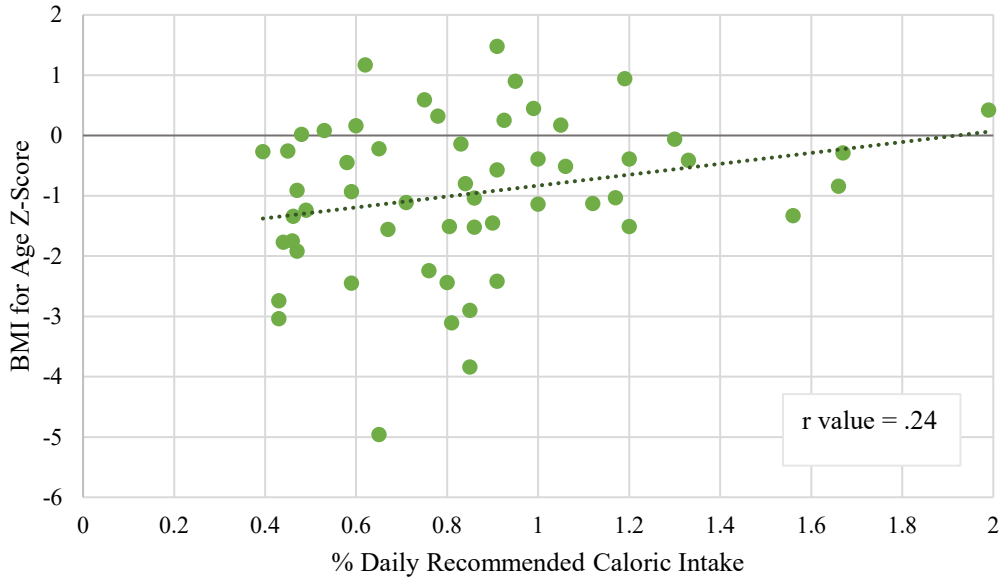
Figure 4. Stunting Prevalence. Based on WHO standards, I classified each participant's Z-scores into the following categories: "Healthy" (no stunting), "Mild Stunting," "Moderate Stunting," and "Severe Stunting." The pie charts above indicate the prevalence of each category in the following populations: (a) All groups, (b) Group 1, (c) Group 2.

A smaller proportion of the tested population, 42%, experienced stunting, compared to malnutrition and wasting. Comparing groups, there is a similar breakdown of stunted vs. non-stunted growth across Group 1 and Group 2 children. However, children in Group 1 faced slightly higher rates of moderate and severe stunting as compared to their non-slum counterparts. For example, 53% of stunted slum children faced moderate to severe stunting, while only 44% of of stunted non-slum children faced those forms of stunting (Figure 4).

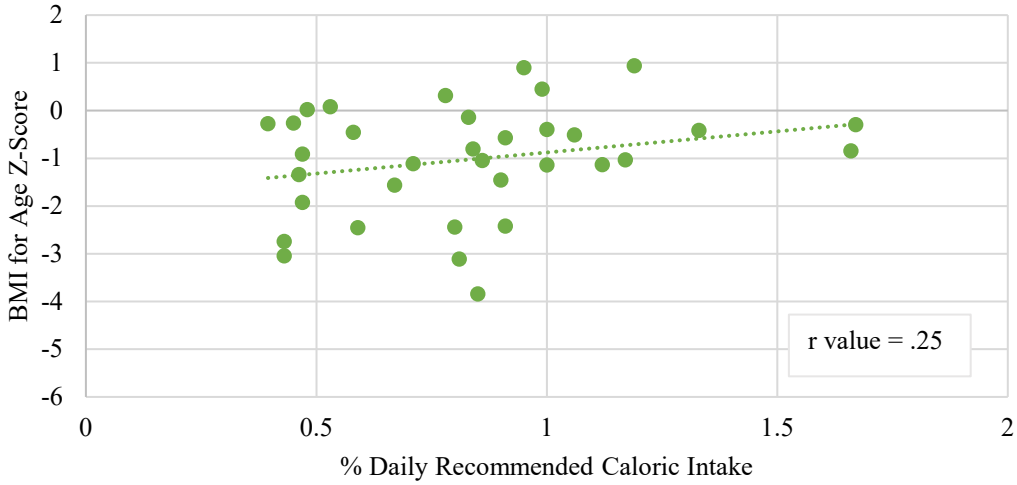
Diet recall

Malnutrition and diet

(a) All children



(b) Group 1



(c) Group 2

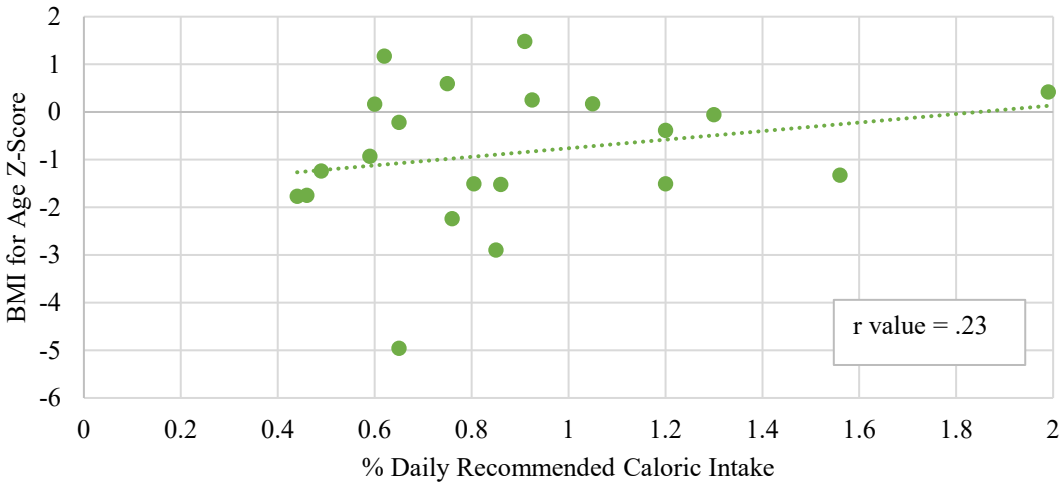
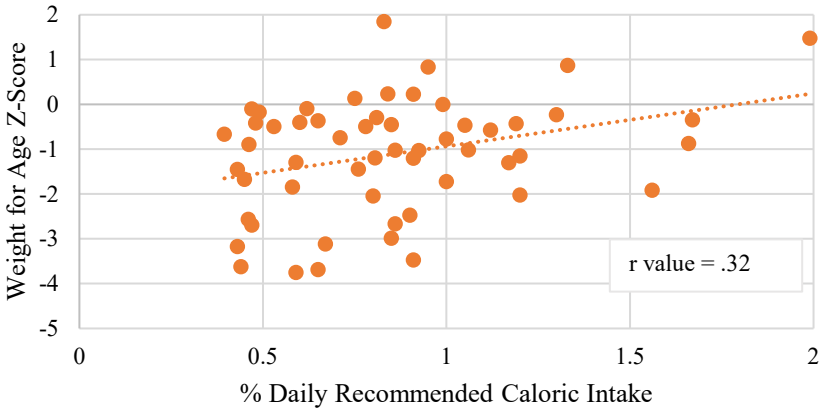


Figure 5. Malnutrition level % daily recommended caloric intake. I compared "BMI for Age" Z-scores with % DRCI and calculated the correlation coefficient. This analysis was done for each of the following groups: (a) All groups, (b) Group 1, and (c) Group 2.

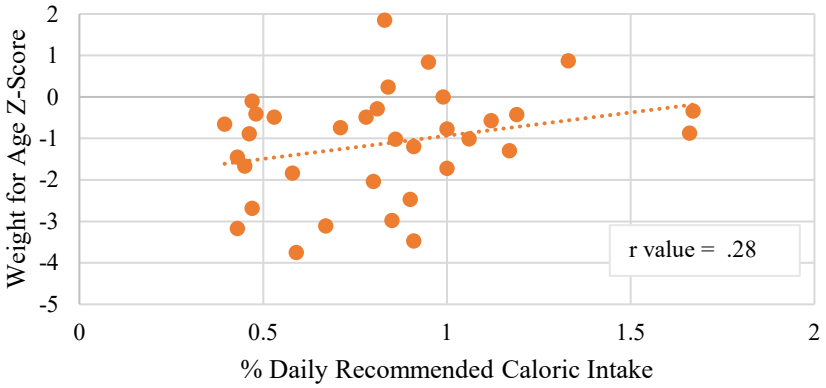
There was a weak positive correlation between malnutrition level and % DRCI. The strength of the correlation was similar and consistent across all groups (Figure 5).

Wasting and diet

(a) All groups



(b) Group 1



(c) Group 2

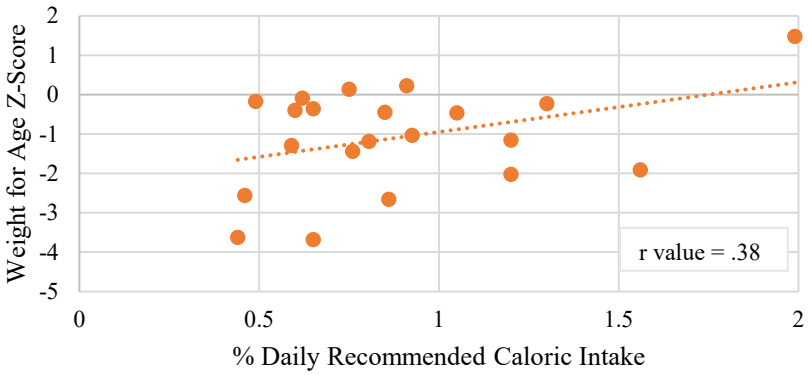
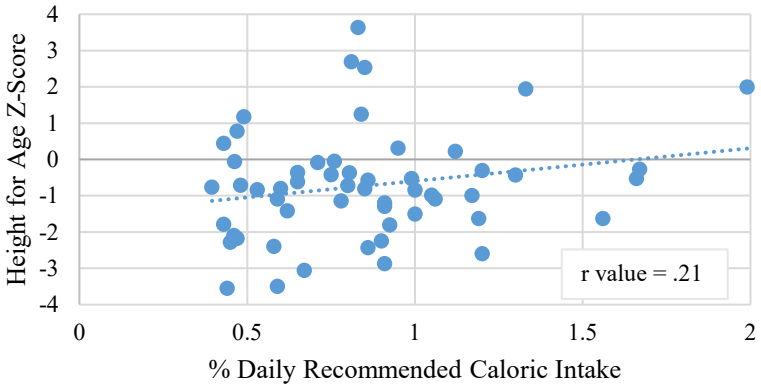


Figure 6. Wasting and % daily recommended caloric intake. I compared "Weight for Age" Z-scores with % DRCI and calculated the correlation coefficient. This analysis was done for each of the following groups: (a) All groups, (b) Group 1, and (c) Group 2.

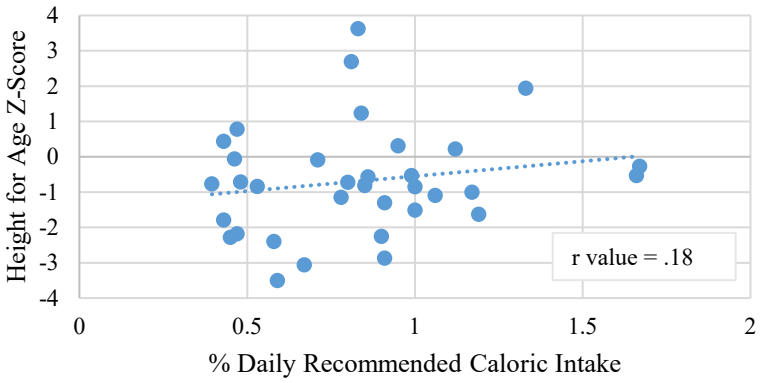
There was a weak positive correlation between level of wasting and % DRCI (Figure 6). However, comparing this relationship across groups indicates a stronger correlation between wasting and % DRCI in Group 2 than Group 1(Figure 6c).

Stunting and diet

(a) All children



(b) Group 1



(c) Group 2

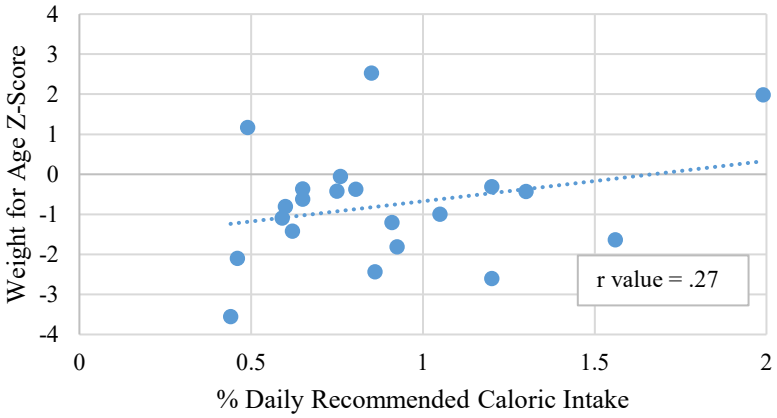


Figure 7. Stunting and % daily recommended caloric intake. I compared "Height for Age" Z-scores with % DRCI and calculated the correlation coefficient. This analysis was done for each of the following groups: (a) All groups, (b) Group 1, and (c) Group 2.

Across groups, there is a weak positive correlation between stunting level and % DRCI (Figure 7). However, the strength of this correlation varies among Group 1 and Group 2 (Figures 7b, 7c). There is a weaker correlation between stunting and % DRCI in Group 1 (Figure 7b).

Drinking water quality

Based on results from the Pune Municipal Water Corporation's Parvati Jal Shuddhi Karan (PVJK) Laboratory, I found that in terms of the almost all of the selected water quality parameter tests, results were fairly similar across the board (Figure 8). The PVJK lab found that all of these parameters (pH, turbidity, hardness, alkalinity, chlorides, nitrates, and nitrites) appeared in "Acceptable" levels (see Appendix for PVJK Lab's "Desired," and "Acceptable" ranges for each parameter). None of the samples, except for one (DGS– Ramtekadi), contained any residual chlorine. The main factor that distinguished samples was fecal coliform growth. Three samples – (Paranjape Household 1, Paranjape Household 2, Tadiwala Road Household) – exhibited high levels of fecal coliform that went above "Acceptable" levels. Two of these samples, (Paranjape Household 1, Paranjape Household 2) exhibited high levels of E. coli that went above "Acceptable" levels. Based on internal standards, the PVJK lab classified all six sample as "Non-Potable." Based on "Water Research Organization" guidelines, all of the samples had a WQI value above 80, but Group 2 samples were of poorer water quality than Group 1 samples (Figure 9).

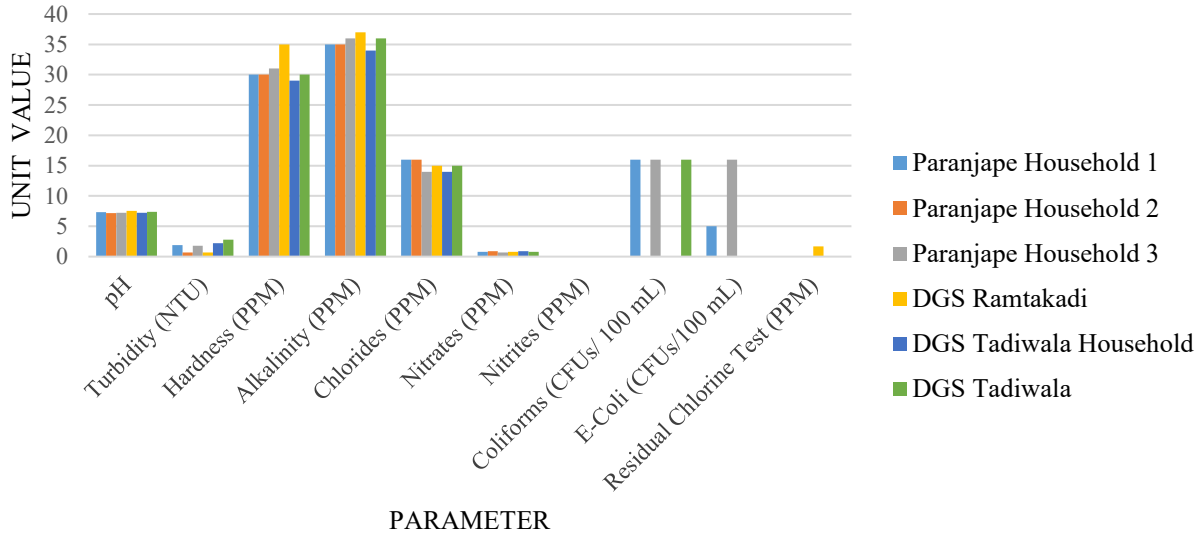


Figure 8. Water quality parameters results per site.

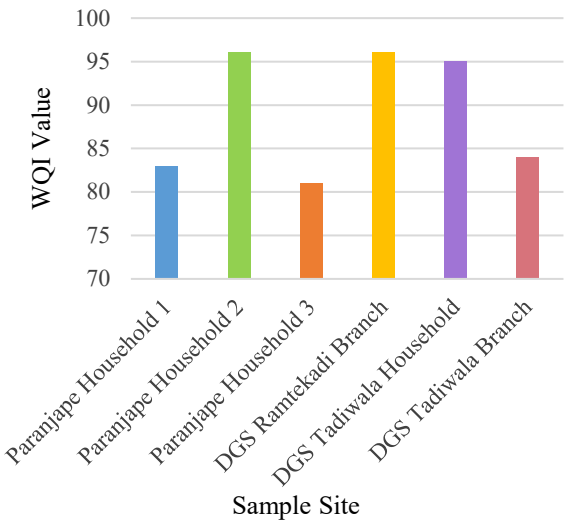


Figure 9. Water quality index values by source.

DISCUSSION

Based on the results of this study, I confirmed the association between stunted growth and diet, but wasn't able to definitively test its relationship with drinking water quality. First, I evaluated how representative my study's health outcome data were, and found that they were very close to district and state averages. Second, I confirmed that slum children face worse health outcomes than their non-slum counterparts. Third, I found a weak positive correlation between health outcomes and % daily recommended caloric intake (%DRCI) overall, but found that the association was weaker in slum communities – possibly indicating that other factors are more important than diet. Lastly, while I was not able to tell if drinking water quality was related to health outcomes, I did find that the WQI results are indicative of the challenges the Pune Municipal Corporation faces in delivering clean water with aging infrastructure, especially during monsoon months when water quality is more difficult to maintain. Overall, this study confirmed the high prevalence of poor health outcomes in Indian children, particularly those living in slums and underscored the need for more research to understand the association of drinking water quality and other factors with stunted growth.

Anthropometric data from this study may be representative of the district of Pune and perhaps the state of Maharashtra, but not necessarily all of India. Consequently, the results of this study may be useful to inform local and state policy in these areas, but perhaps may not be extended

to national policy reform. Wasting and stunting rates are similar to the national, state, and district averages found in the 2015 Indian National Family Health Survey (Ministry of Health and Family Welfare 2016). For my sample population, I found that the average wasting prevalence across both groups was 24% (Table 3). While this value is below India's average value of 38.4%, it is very close to Maharashtra state and Pune district values of 23.4% and 25.6%, respectively (Table 3). Results reveal an overall stunting prevalence of 20%, but national, state, and district values were 38.4%, 34.4%, and 22.4%, respectively (Table 3). These results suggest this study is likely representative of the districts of Pune and Maharashtra, but not necessary of India nationally. This is expected, as India is significantly different across states due to varying environments, climates, languages, cultures, and socioeconomic factors (Fearon 2003). Furthermore, while the state of Maharashtra encompasses the study site and shares similar cultures and languages, it is still a large region with different climates, levels of urbanization, and development.

Table 3. Comparison of health outcomes in this study to national data. I compared the wasting and stunting prevalence results from this study to district, state, and national data reported in the 2016 Indian National Family Health Survey (INFS). Malnutrition prevalence was not included because it was not reported by INFS 2016. Wasting and Stunting % refers to all of the children that were wasted of stunted, whether mildly, moderately, or severely.

	Indian National Family Survey (2016)			**Kaur (2017)**		
Group	**Maharashtra**	**Pune**	**India**	**All children**	**Group 1**	**Group 2**
Average Wasting %	25.6	23.4	38.4	24	23	23
Average. Stunting %	34.4	22.4	38.4	20	23	19

Children from slums face more environmental risk factors than their non-slum counterparts, and thus worse health outcomes were expected (Som et al. 2007). Overall prevalence of malnutrition, wasting, and stunting is high – as 47%, 49%, and 42% of all children in this study were affected, respectively (Figures 2a, 3a, 4a). Group 1 (slum) children exhibited worse health outcomes than Group 2 (non-slum) children. For example, in Group 1, 49%, 46%, 43% of the participants were malnourished, wasted, or stunted, respectively (Figures 2b, 3b, 4b). In Group 2 however, these values were usually lower - 48%, 52%, 43%, respectively (Figures 2c, 3c, 4c). Children in Group 2 also faced less severe forms of malnutrition, wasting, and stunting. Of Group 1 children that were considered malnourished, wasted, or stunted, 41%, 50%, or 48% were moderately or severely affected respectively (Figures 2b, 3b, 4b). In Group 2, however, only 31%, 44%, or 44% were moderately affected, respectively (Figures 2c, 3c, 4c).

These results were expected, as it is well-established that slum populations face greater environmental risk factors than non-slum populations (Som et al. 2007). Slum populations face higher risk for waterborne diseases and diarrheal disease due to poor household conditions (Ferdous, 2014; Bharati, 2007). Slums are home to "vicious cycles of diarrhea and malnutrition" that sustain poor health outcomes (Moore et al. 2010).

In slum populations, diet may not be as

Diet was more closely associated with health outcomes in Group 2 than it was in Group 1, and this suggests that in slum populations there may be factors more significant than diet (Figures 5, 6, 7). In other words, slum populations may face other risk factors that play a larger role in determining health outcomes than diet. These results suggest that the original causative pathway (that links poor diet with malnutrition and stunting) may not be the dominant pathway.

Drinking water quality data highlights Pune Municipal Corporation's (PMC) systemic and seasonal challenges in supplying potable drinking water. All six water samples in this study contained fecal coliform, and thus were not potable. Although this study only tested six samples, they were all part of the same water system and are in line with PMC's internal test results from 2010-2016. A 2016 analysis of Pune district found that 21% of water samples tested were contaminated - a 5% increase from 2010 (State Public Health Laboratory). While 2016 samples directly from the city of Pune indicate a negligible amount of contamination, publicly available PMC monthly data from May 2007 to August 2016 reported that the source water for Pune city was below 50% on the Water Quality Index 68% of the time during the study period, and was definitively polluted seven times. According to PMC disclosures, the system faces issues due to leakages in the Khadakwasla Canal that opens the water supply to contamination from garbage, sewage, and chemical contamination from communities living near the Khadakwasla Dam (PMC YEAR?). According to Bhagwan Pawar, the health officer for Pune District, the main way this contamination may enter into the distribution system is through pipe leaks.

In addition to systemic issues, the low quality of the water samples included in this study might be explained by seasonal variations in water quality. It is widely accepted that during the monsoon months of June - September, drinking water quality decreases, possibly due to increased humidity or flooding (Rajankar, 2009). From this study alone, it is difficult to discern if drinking water quality is associated with stunted growth. The data collected was mostly descriptive and provided a glimpse into PMC water quality.

Limitations

Overall, this study demonstrates that stunting is prevalent in both slum and non-slum communities and that diet is weakly associated with health outcomes. Due to study design, limited resources, and time constraints, this study was unable to adequately address drinking water quality as an exposure. First of all, as a cross-sectional study, this study is unable to definitively link exposures with health outcomes as a function of a temporal relationship. As a result, while this study addresses the association between %DRCI or WQI and health outcomes, results cannot be used to identify whether either exposure *caused* the outcomes. Secondly, due to limited resources and funding, I was not able to test a representative or comprehensive group of water samples. In addition, due to limitations in transportation, some samples were sent to the lab the same day they were collected, while others were sent a few days later. This may have resulted in the poorer WQI for the non-slum samples. As a result, these samples may not be representative of the water quality for all the participants in this study.

Further directions and broader implications

Based on study results, it is clear that much more research is needed. Longer term studies, such as cohort studies that follow pregnant women until their children are five years old, and more specific studies that examine a wide range of environmental exposures and sanitation practices, are needed to better understand the development of stunting in children.

As long as environmental exposures are not being investigated, sanitation infrastructure is not being developed, and drinking water quality is being neglected - millions of children will continue to face developmental issues that will plague them for their entire lifetime. Stunting is preventable, but due to a lack of research, commitment and investment, human potential is continuing to be lost. It is up to the next generation of global health leaders to put an end to the largest loss of human potential in history.

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REFERENCES

Checkley, W., G. Buckley, R. H. Gilman, A. M. Assis, R. L. Guerrant, S. S. Morris, K. Mølbak, P. Valentiner-Branth, C. F. Lanata, and R. E. Black. 2008. Multi-country analysis of the effects of diarrhoea on childhood stunting. International Journal of Epidemiology 37:816–830.

Dobe, M. 2015. Viewpoint: The role of sanitation in malnutrition – A science and policy controversy in India. Journal of Public Health Policy 36:7–14.

Fearon, J. D. 2003. Ethnic and Cultural Diversity by Country. Journal of Economic Growth 8:195–222.

Ferdous, F., S. K. Das, S. Ahmed, F. D. Farzana, M. A. Malek, J. Das, J. R. Latham, A. S. G. Faruque, and M. J. Chisti. 2014. Diarrhoea in slum children: observation from a large diarrhoeal disease hospital in Dhaka, Bangladesh. Tropical medicine & international health: TM & IH 19:1170–1176.

Fink, G., I. Günther, and K. Hill. 2011. The effect of water and sanitation on child health: evidence from the demographic and health surveys 1986-2007. International Journal of Epidemiology 40:1196–1204.

Korpe, P. S., and W. A. Petri. 2012. Environmental enteropathy: critical implications of a poorly understood condition. Trends in Molecular Medicine 18:328–336.

Ministry of Health and Family Welfare. 2016. National Family Health Survey.

Ministry of Home Affairs. 2011. Census of India.

Ministry of Finance. 2016. Annual Report.

Moore, S. R., N. L. Lima, A. M. Soares, R. B. Oriá, R. C. Pinkerton, L. J. Barrett, R. L. Guerrant, and A. A. M. Lima. 2010. Prolonged episodes of acute diarrhea reduce growth and increased risk of persistent diarrhea in children. Gastroenterology 139:1156–1164.

Schmidt, C. W. 2014. Beyond Malnutrition: The Role of Sanitation in Stunted Growth. Environmental Health Perspectives 122:A298–A303.

Som, S., M. Pal, and P. Bharati. 2007. Role of individual and household level factors on stunting: a comparative study in three Indian states. Annals of Human Biology 34:632–646.

Spears, D., A. Ghosh, and O. Cumming. 2013. Open defecation and childhood stunting in India: an ecological analysis of new data from 112 districts. PloS One 8:e73784.

WHA. 2014. Environmental Health Perspectives – Beyond Malnutrition: The Role of Sanitation in Stunted Growth.

APPENDIX

I. Consent form (Marathi)

असोसीएशन ऑफ वॉटर क्वालिटी ॲन्ड मालन्युट्रीशन इन चिल्ड्रेन अंडर ५

सहभागी व्यक्तीसाठी माहिती आणि संमतीपत्र

प्रिय पालक,

पाच वर्षाच्या आतील कुपोषित मुलांना शारीरिक आणि मानसिक अपंगत्व होण्याचा धोका जास्त असतो. आत्ता पर्यंतच्या अभ्यासांन वरून हे सिद्ध झाले आहे कि, कुपोषण हे आहारातील कमतरते मुळे होते. कुपोषण, आहारातील कमतरता व त्यामुळे न होणारी वाढ ह्यांनमधील परस्पर संबंधानवर आत्ता पर्यंत बराच अभ्यास झाला आहे. परंतु नवीन अभ्यासांन वरून असे दिसून आले आहे की, पिण्याचे खराब पाणी, अस्वच्छता यांमुळे आणि आतड्यांच्या संसर्ग आणि अतिसाराशी निगडीत समस्यांमुळे होणाऱ्या रोगांन मुळे देखील कुपोषण होऊ शकते.

तुमच्या मुलाचा सहभाग :
आम्ही महाराष्ट्र, पुणे येथे एक प्रातिनिधिक अभ्यासक्रम राबविण्याचे ठरविले आहे. जेणेकरून आपल्याला खराब पाणी, अस्वच्छता यांचा कुपोषणाशी असणारा संबंध कळून येईल. ह्यामध्ये, पाच वर्षान खालील मुलांन चा सहभाग असेल, आम्ही एकंदर १५० मुलांच्या पालकांन कडून संमतीपत्र आणि प्रश्नावळी भरून घेणार आहोत. त्याच बरोबर ह्या सर्व मुलांची उंची व वजन मोजली जाईल. तसेच आम्ही काही मुलांना गेल्या २४ तासातील आहारा बद्दल माहिती विचारु ज्या वरून आम्हाला अंदाज येईल कि मुलांनी त्यांच्या वजन व उंची प्रमाणे किती आहार घेतला पाहिजे.

जर तुमचे पाल्य निरोगी असले तर ते ह्या अभ्यासात सहभागी होऊ शकते. पण त्याला/ तिला कुठल्याही प्रकारचे औषध अथवा पोषण दिले जाणार नाही. परंतु वरील सर्व मोजमापे त्याच्यावर केली जातील. सर्व प्रकल्प आणि तपासण्या मोफत आहेत. सर्व तपासण्यांचे रिपोर्ट तुम्हाला देण्यात येतील. तुमच्यापाल्यची सर्व माहिती गुप्त ठेवली जाईल. तरी, तुमचे पाल्य ह्या अभ्यासात सहभागी होण्यासाठी आम्ही तुमची सहमती मागतो.

ह्या अभ्यासातील तुमच्या पाल्याचा सहभाग हा पूर्णपणे एच्छीक आहे. तुम्हाला हवा असल्यास तुम्ही कुठल्याही क्षणी तुमचा सहभाग अभ्यासातून काढून घेऊ शकता. तुमच्या पाल्याचे सर्व रिपोर्ट आल्या नंतर आम्ही त्यावरून आवश्यकते नुसार वैद्यकीय व आहाराविषयक सल्ला देऊ.

प्रकल्पाबाबत कुठल्या ही प्रकारचे प्रश्न असतील तर पुढील ठिकाणी संपर्क साधावा: डॉ वीणा एकबोटे / डॉ अनुराधा खाडिलकर – ०२०२६१४१३४०. संपर्क करण्याची वेळ सकाळी ९ ते संध्याकाळी ५ पर्यंत किंवा या नंबर ०९८५०९४६३४९ वर ही संपर्क साधू शकता. तुमच्या अधिकारांबद्दल काही माहिती हवी असल्यास तुम्ही डॉ. रवींद्र घुई, जहांगीर क्लिनिकल डेवेलोपमेंत सेंटर ९९२२९१८९६७ यांना संपर्क करू शकता.

सहभागी व्यक्तींच्या पालकांसाठी

पाल्याची सही :_____ एनरोल नंबर:_____

पाल्याचे नाव :_____

जन्म तारीख/ वय :_____

		सही
१	मी वरील माहिती पूर्ण वाचलेली आहे व ती मला व्यवस्थित समजली आहे. मला माझे शंकानिरसन करण्याची संधी मिळाली आहे.	[ ]
२	हया प्रकल्पात भाग घेणे पूर्णपणे ऐच्छिक आहे व मी माझ्या पाल्याचे नाव हयातून कुठलेही कारण न देता, तसेच मला मिळणाऱ्या वैद्यकीय सुविधा व माझे वैद्यकीय हक्क हयांच्यावर कुठलाही परिणाम न होऊ देता कधीही काढून घेऊ शकतो/शकते याची मला कल्पना आहे.	[ ]
३	मला याची कल्पना आहे कि, मी माझ्या पाल्याचा सहभाग काढून घेतल्यानंतरही या अभ्यासाशी संबंधीत डॉक्टर आणि एथिक्स कमिटी मेंबर यांना माझी कागदपत्रे पहाण्यासाठी माझ्या परवानगीची गरज नाही. मी याची परवानगी देत आहे. मला याचीही कल्पना आहे की, प्रकाशित करताना माझ्या पाल्याच्या नावाबाबत पूर्ण गुप्तता पाळण्यात येइल.	[ ]
४	मी माझ्या पाल्याच्या आरोगयाविषयी माहितीचा व निष्कर्षाचा वापर संशोधनासाठी करण्यास संमती देत आहे.	[ ]
५	मी माझ्या पाल्याच्या हया प्रकल्पातील सहभागाला मान्यता देत आहे.	[ ]

पालकाची सही / अंगठा:

तारीख: _____/_____/_____

सही करणाऱ्या पालकाचे नाव: _____

अभ्यासकाची सही : _____ दिनांक :_____/_____/_____

अभ्यासकाचे नाव: _____

साक्षीदाराची सही : _____दिनांक :_____/_____/_____

साक्षीदाराचे नाव : _____

II. Consent form (English)

Patient Information and Consent Form

Dear Parents,

Children under five that experience stunted growth (low weight for age) are at risk for permanent physical and cognitive disabilities. It is well established that stunting results from poor nutritional intake, and that poor nutritional intake can occur from malnutrition. The causative pathway between malnutrition and poor nutritional intake and stunting is well studied. However, new research suggests an alternative pathway that links unsafe water, poor sanitation, and poor hygiene (WSH) with chronic enteric infection and diarrheal disease which may lead to poor nutritional intake, and as a result, stunting.

Your child's involvement

We are planning a cross sectional study in Pune, Maharashtra to further examine the link between poor WSH and stunted growth. This study will involve children under five in informal settlements. We will ask the parents of 150 children to complete a consent form and complete a semi-structured questionnaire that will be completed by the investigator. As a part of this questionnaire, anthropometric measurement of all 150 children will be taken. These measurements include height (recumbent length if child is under 2) weight. In addition, we will collect 24 hour diet recall from 75 children to determine % recommended dietary allowance.

If your healthy child is participating in this study, he/she will receive no supplementation. However, all the above procedures will be conducted for him/her.
All study procedures and tests will be performed completely free of charge and all your child's reports will be handed over to you. If you decide to allow your child to take part in the study, your child's name and identity will be kept strictly confidential.

We thus request your cooperation and consent for this study, participation is completely voluntary. You can withdraw from the study at any time if you so wish. After we have all your child's results, we will also give any medical or dietary advice as needed by your child.

If you have any questions about the study, you can call Dr. Veena EKbote/ Dr Anuradha Khadilkar on 26141340 from 9.00a.m to 5.00pm Monday to Friday or on 9850946349 at other times. If you have any queries regarding your rights you may contact Jehangir Clinical Development Centre Institutional Review Board - Dr. Ravindra Ghooi at 9922918967.

If you wish your child to participate in this study, please sign below.

Subject's Initials: _____ En. Number: _____

Subject's Name: _____

Date of Birth / Age: _____

		Please initial in the box
(i)	I confirm that I have read and understood the information sheet dated _____ for the above study and have had the opportunity to ask questions.	[ ]
(ii)	I understand that my child's participation in the study is voluntary and that I am free to withdraw his/her name at any time, without giving any reason, without my medical care or legal rights being affected.	[ ]
(iii)	I understand that the doctors and others staff working on the study, the Ethics Committee and the regulatory authorities will not need my permission to look at my child's health records both in respect of the current study and any further research that may be conducted in relation to it, even if I withdraw him/her from the trial. I agree to this access. However, I understand that my child's identity will not be revealed in any information released to third parties or published.	[ ]
(iv)	I agree not to restrict the use of any data or results that arise from this study provided such a use is only for scientific purpose(s)	[ ]
(v)	I agree for my child to take part in the above study.	[ ]

Signature (or Thumb impression) of the Parent:

Date: _____/_____/_____

Signatory's Name: _____

Signature of the Investigator: _____Date: _____/_____/_____

Study Investigator's Name: _____

Signature of the Witness: _____Date:_____/_____/_____

Name of the Witness: _____

III. Health assessment

Drinking Water Quality & Stunted Growth in Children Under 5 in Pune, India
HEALTH ASSESSMENT

Investigator Use Only

Enrollment Date:
Consent Form:
Sample Site:
Diet Recall:
Stunted:
COMPLETE:

I. Demographic Information:

Participant:

1. First Name:
2. Last Name:
3. Date of Birth (& Age):
4. Gender:
5. # and Age of Siblings:

Guardian 1:

1. First Name
2. Last Name:
3. Age:
4. Education Level:
   (none) <4th /<10th/ <12th /grad /postgrad
5. Occupation:_____
   None / unskilled/skilled/business/service

6. Monthly Income:_____
|<5000| |5-10K| |10-20K| |20-30K| |30-40K|
|40-50K| |>50K|

Guardian 2:

7. First Name
8. Last Name:
9. Age:
10. Education Level:
    (none) <4th /<10th/ <12th /grad /postgrad
11. Occupation:_____
    None / unskilled/skilled/business/service
12. Monthly Income:_____
|<5000| |5-10K| |10-20K| |20-30K|30

II. Anthropometric Measurements:

1. Weight:

2. Height

3. Mid-Arm Circumference:

III. Water Storage & Handling Practices

1. Source: Tap / Well / Borewell

2. Water Storage: steel/clay/copper/brass/plastic bottle

3. How do you remove the water?

Cup with no handle/with handle/other

4. How often do you wash the pot?

Everyday/once in 2 days/ 3X week/ once a week/once a month/never

4. How often do you store (obtain) water?

Everyday/once in 2 days/ 3X week/ once a week/once a month/never

5. Treatment:

none/ Boil/ UV/Other filter - Describe:
Alum (collect particles at bottom)

DIET RECALL

Time/Meal	**Food Items**	**Quantity**
Early Morning		
Breakfast		
Lunch		
Afternoon		
Evening Snacks		
Dinner		