USE OF NATIONAL AND INTERNATIONAL STANDARDS IN ASSESSING THE GROWTH AND NUTRITIONAL STATUS OF RURAL INDIAN CHILDREN

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ABSTRACT

This study compares anthropometry of rural Indian schoolchildren using national and international reference values, and explores association between demographic and socioeconomic variables and growth measures among rural children. A cross-sectional survey of height, weight, and BMI was conducted among schoolchildren (5-16 years) in Gujarat, where there were pre-established contacts who could facilitate access to schools and data collection for this study. Gender- and age-specific *Z*-scores were obtained for 519 children (234 girls, 285 boys) based on Indian reference values (Khadilkar et al., 2009) using an Excel® macro. Percentages of children stunted (height-for-age ≤ -2SD), underweight (weight-for-age ≤ -2SD), and wasted (BMI-for-age ≤ -2SD) were obtained (Khadilkar & Khadilkar, 2011). Children falling between adult Indian BMI levels 23 and 28 kg/m^2 were considered *overweight*, and those above 28 kg/m^2 were considered *obese*. Those stunted (height-for-age < -2SD), wasted (BMI < -3SD), overweight (BMI > +1SD), and obese (BMI > +2SD) were generated similarly using the WHO International Growth Standards (WHO, 2015). Regression analyses were conducted to model the relationship between growth measures, determined using national references, and predictor variables: age, gender, school, and caste. 21.4%, 23.1%, 8.9%, 2.7% and 0.2% of children were respectively stunted, underweight, wasted, overweight and obese based on Indian References and recommendations, and 27 %, 8.7%, 6.4% and 2.7 % respectively stunted, wasted, overweight and obese based on WHO Standards and recommendations. School was found to have significant interaction with all growth measures (P<.0001) and age had a significant interaction with height-for-age (P = 0.05).

The current level of undernutrition, and emerging problems of overnutrition, in this study highlight a need to concentrate efforts to improve nutrition of Indian schoolchildren in rural areas.

I dedicate my thesis to my parents Lucane and Bernadette Jeannot, whose sacrifices and prayers have motivated me to make it thus far. My brother Luckben, who constantly reassured me in moments of doubt. My grandfather Belizaire, who unfortunately passed away before the completion of this project; I promise to take the time to properly mourn your loss.

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CHAPTER 1

INTRODUCTION

In India, malnutrition is a significant scourge and one of the worst challenges for the country in terms of human development. Despite substantial economic growth in the last two decades, childhood malnutrition remains a significant problem and one of the biggest challenges for India in terms of human development. Malnutrition occurs when there is an insufficient intake of food or when a person is not getting the right sort of food (Maitra et al., 2013). Although poverty is often cited as the cause for the alarming level of malnutrition in Indian children, other factors such as social caste discrimination, gender inequality, insufficient education and inadequate access to health care also need to be considered (Kanjilal et al., 2010; Meshram et al., 2014). Some studies have reported group-specific factors related to discrimination that low caste groups experience in accessing income earning assets, education, and government-provided food and health services (Sabharwal, 2011). Additionally, the National Family Health Survey (NFHS) has reported that mothers and children from low caste groups had poor access to public health services compare to other castes (IIPS, 2007). Compared to men, women in India tend to have lower literacy rates, poorer education status and greater unemployment, which together result in a poor and inadequate diet. As a result, pregnant women who suffer from malnutrition tend to have malnourished children and lack the knowledge to feed their children properly (Gulati, 2010; IIPS, 2007). As reported by NFHS, access to health services is a challenge among the 27% of Indians who live in poverty and cannot afford

healthcare from the private medical sector. As a result, they have to travel long distances to government health centers where the quality of services is often poor. (IIPS, 2007).

To assess the nutritional status and growth of a child, population anthropometric parameters are most commonly used as reference values. For example, a child would be considered stunted if they have a low height-for-age, underweight if they have low weight-for-age, and wasted if they have low weight-for-height (BMI-for-age) (Deaton & Drèze, 2009; UNICEF, n.d.). BMI-for-age is also used determine childhood overweight and obesity (WHO, 2006). The cut-off values and levels for height-for-age, weight-for-age, and BMI for age are predetermined by growth charts based on growth standards or references. Recent Indian studies of children over 5 years have used the 2007 WHO International Child growth standards or the 2007 Affluent Indian Children. In the next chapter we discuss the development of these growth tools in more details.

Periodic surveys of Indian children by the Government of India and several academic studies have been conducted over the past three decades to study nutrition trends among Indian children, and report that while malnutrition declined over the years, children still face a persistent issue of undernutriton, and the extent of childhood undernutrition in rural areas is higher than in urban area areas (Agarwal et al., 1992; Deaton & Drèze, 2009; IPSS, 2007; Khadilkar & Chiplonkar, 2010; Khadilkar & Khadilkar, 2001; Khadilkar et al., 2007; Khadilkar et al., 2009; Khadilkar et al., 2012).

Objectives

In the present study we compare anthropometry of rural Indian schoolchildren aged 5–16 years in Gujarat using the most recently generated national and international reference values, and explore the association between demographic variables and growth measures among rural children in Gujarat, India.

Specific Aims

i. To assess growth status of rural Indian schoolchildren aged 5-16 years in the State of Gujarat—specifically, weight-for-age, height-for-age, and BMI-for-age—using growth charts developed for affluent urban Indian schoolchildren (Khadilkar et al., 2007) and the World Health Organization's International Growth Standards (WHO, 2006; WHO, 2015).
ii. To explore the associations of gender-specific height-for-age, weight-for-age, and BMI (weight-for-height) measurements with demographic factors (age, gender, caste, and school) among rural children in the State of Gujarat, India.

CHAPTER 2

REVIEW OF LITERATURE

Country and State Profile

India

India is one of the oldest civilizations and one of the most diverse countries in the world in terms of culture, heritage, society and religion. The Republic of India (called Bharatiya Ganarajya in Hindi) is located in Southern Asia, bordering the Arabian Sea and the Bay of Bengal, between Burma and Pakistan. India has a total area of 3,287,263 square kilometers and is the seventh largest country in the world. As of July 2014, the total estimated population of India is 1,236,344,631 inhabitants; it is the second most populous country after China. The Indian constitution recognizes 23 official languages in India, but the two official languages are English and Hindi (CIA, 2014). India has one of the 10 fastest growing economies worldwide, with the Gross National Product rising from Rs 20.7 trillion in 2001–02 to Rs 32.5 trillion in 2006, an increase of almost 60 percent in five years (IIPS, 2007).

The 2005–2006 National Family Health Survey-3 (NHFS-3), the third in a series of national surveys, reported that the population of India tripled in size between 1951 and 2001, going from 361 million to 1,028 million. The first National Family Health Survey (NFHS-1) had estimated infant mortality at 79 per 1,000 live births; NFHS-2 reported 68 deaths per 1,000 live births; and NHFS-3 noted 57 deaths per 1,000 live births. These rates were greater in rural areas: between 2001 and 2005 the number of infant deaths per

1,000 births was 62 in rural areas compared to 42 in urban areas. About 69 % of the Indian population lives in rural areas, and children from scheduled castes and tribes had the highest mortality rates (IIPS, 2007). As of 2014, the estimated birth rate was 19.89 births per 1,000 population and the death rate was 7.35 deaths per 1,000 population (CIA, 2014).

Gujarat

The state of Gujarat is located on the west coast of India, it is currently divided into 26 districts and is the seventh largest state in India in terms of area. The capital of Gujarat is Gandhinagar, with Ahmedabad as its largest city. Gujarati and Hindi are the state's official languages (Pathak & Lodrick, 2014). According to the *Gujarat Population Census Data 2011* (Indian Census 2011, n.d.), the state had a population of 60,383,628 people in 2011—approximately five percent of the total Indian population—with 42.6 % living in urban areas and 57.4 % in rural areas. The state had a literacy rate of 79.31 % in 2011 (male literacy 87.23%; female literacy 70.73%). In Surendranagar district, where the municipality of Dhrangadhra is located and where the participants of this study were recruited, the Registrar General (2003) reported an approximate of 1,112,700 people living in rural areas and only 402,448 in urban areas. Scheduled Castes accounted for about 11 % of the total population and Scheduled Tribes were about one percent of the district's population. The sex ratio was 924 females to 1,000 males and the largest age group was 15-59 year olds (870,590), followed by 5-14 year olds (359,042), 0-4 years olds (173,263), and lastly 60 years and older (112,253). Following national literacy patterns, males had a higher literary rate of 74.19 % compared to 48.10 % in females. The

total number of literates in Surendranagar was 781,155, representing about 51 % of the district population (Registrar General, 2003).

Primary schooling is available in most villages with 500 or more inhabitants for all children aged 7–11 years, and special schools serve children in the rural tribal regions. Secondary schools are spread throughout the state in larger villages, towns, and urban areas. There are medical services available in Gujarat that focus on infectious and communicable diseases (malaria, tuberculosis, HIV/AIDS etc.), reproductive and family health, and health education. Primary Health Centers provide most of the medical services throughout Gujarat, but specialized services are mainly provided by hospital and medical colleges that are located primarily in urban areas. The states also have special health programs to assist Scheduled Castes and Scheduled Tribes (Pathak & Lodrick, 2014).

Conceptual Framework of Child Undernutriton

Malnutrition is a condition that is characterized by a lack of nutritional elements sufficient to meet the body's needs for health and well-being (Maitra et al., 2013). The nutritional components primarily involved in malnutrition are calories, protein, carbohydrates, vitamins and essential minerals. Inadequate calories, protein, or micronutrients contributes to undernutrition. Excessive calories is the basic cause of overnutrition leading to obesity (ACF, 2010; Save the Children, 2012). In developing countries such as India, the greatest nutritional problem is undernutrition, due to insufficient caloric intake as a result of poverty or environmental factors (such as

drought, poor sanitation, and overcrowding). Figure 1 illustrates a conceptual framework developed by the United Nations Children's Fund (UNICEF) to explain the different causes of undernutriton and their importance (2013). The framework has three major layers of causality.

i. The first layer represents the immediate causes of undernutrition, such as poor dietary intake and disease. These causes are interconnected: low food intake increases the vulnerability to diseases (such as common childhood infections) and the occurrence of such diseases can reduce food intake and alter metabolism.
ii. The second layer depicts the underlying causes, including inadequate access to food, inadequate care for children and women, insufficient health services, and unhealthy environment.
iii. The third layer represents the basic societal determinants—the scarce resources available to families and communities and how these are distributed at the societal level—that contribute to the underlying causes of undernutrition.

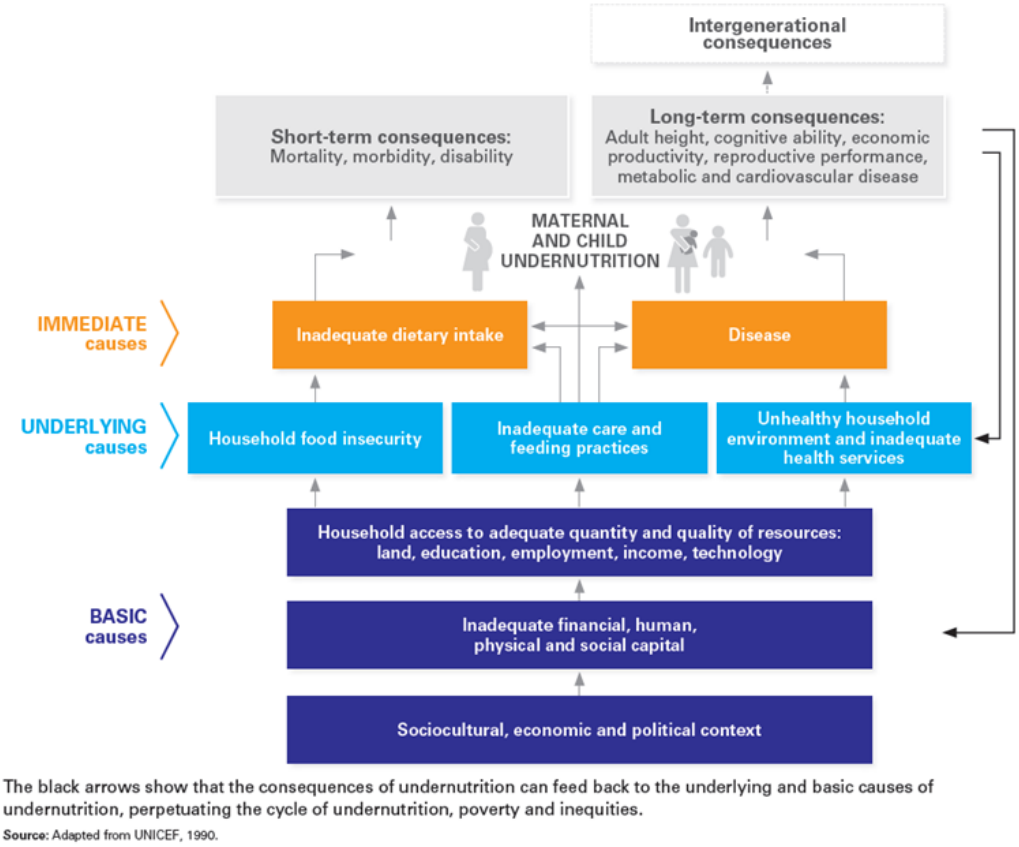

Figure 1. Conceptual Framework of the Determinants of Child Undernutrition. Adapted from "Improving Child Nutrition: The achievable imperative" United Nations Children's Fund, 2013, p. 4. Reprinted with permission.

Malnutrition in India

India has had several decades of impressive economic growth and Gujarat now has one of the largest state economies in India (Hirway & Mahadevia, 2003). This growth has led to an improvement in socioeconomic factors, improved access to potable water, and lowered morbidity. However, poverty and malnutrition continue to be a harsh reality for millions, especially children. NFHS-3 reports that 48 % of children under 5 years were stunted, 43% underweight, and 20% wasted (IIPS, 2007). Hirway and Mahadevia reported that more than 60% of children under 5 years of age were either moderately or

severely malnourished in Gujarat (2003). Aside from poverty, other factors have been cited in contributing to malnutrition in Indian children.

Caste and Social Class

A characteristic of Indian society is the caste system of social classes. Although attempts have been made to eliminate the caste system, it persists in many areas of India, especially in rural and poor areas. According to the Encyclopedia of Gender and Society:

> Caste is a form of social organization that is unique to India and is based on Hindu religious belief …Although the caste system derives from Hinduism, it also informs the social organization of other religious groups in India, including Jains, Christians, and Muslims … Indians use two terms, *Varna* (color) and J*ati* (kind), to describe the caste system. Varna refers to the ancient textual system of classifying individuals according to four groups: *Brahmin* (priests and scholars), *Kshatriyas* (warriors and soldiers), *Vaisyas* (traders), and *Sudras* (servants of the other three castes) (Brien, 2009).

Dalit, a fifth class, comprises the untouchables or outcasts. There are many different names proposed to define this group of people but the Government of India recognizes and protects them as *Scheduled Castes (SC)* and *Scheduled Tribes (ST)*. These lower caste groups remain discriminated against by a large part of society. About 19 % of Indian households were identified as belonging to Scheduled Castes, 8 % were Scheduled Tribes, and 40 % were assigned to Other Backward Classes (OBC). People belonging to OBC are considered educationally and socially disadvantaged and the NHHS-3 reported that children in from low-caste are more likely to be malnourished compare to children from higher caste (IIPS, 2007). While abolished in 1948, the caste system still holds enormous power in daily social life and remains prominent in rural areas. Segregation of this group is reinforced by the government's allocation of resources. Basic amities such

as water wells, medical and sanitation facilities, and electricity are mostly available to high-caste community while neglected in low-caste community ("Untouchability and Segregation", 2001).

Gender Disparity, Education and Illiteracy

Gender disparity is very prominent in India and is an underlying cause for low literacy, educational status, malnutrition, and employment rates among women, thus impeding social and economic growth. Many parents in India do not allow their female children to go to school and believe male infants to be more valuable than female infants. As a result boys receive more education and girls leave school to work or to be married off at a young age, contributing to the low female literacy level (Gulati, 2010). Although the Indian government mandated that all children younger than 14 years receive free education, more than one in four children aged 6-17 years were not attending school at all. Illiteracy remains high in India and even more so in rural areas (80%) compared to urban area (58.7%). Overall, the illiteracy rate has been estimated at 64.8 % (IIPS, 2007). All of these contribute to malnutrition in women which in turn affects child nutrition. Poor nutrition among pregnant women leads to low birth weight in newborn children and affects post-natal health. Malnutrition in women also affects their ability to breastfeed, properly care for their children, and seek care (Gulati, 2010; IIPS, 2007).

Healthcare Access and Living Conditions

Based on findings from NFHS-3, about 65% of Indians sought health care from the private medical sector and the remaining population used the public medical sector. Common sources for health care were private doctors or clinics, followed by public and

private hospitals, and lastly community health centers. Poor quality of service and traveling distance were the major causes for not using public sector health care facilities (IIPS, 2007). While the NFHS-3 reported improvement in the housing condition and the standard of living compared to previous reports, 27% of Indian households lived below the poverty line. About 88% of households had access to improved sources of drinking water such as piped water. Seventy-one percent of these households were located in urban areas, and 28% in rural areas. In rural areas it is more common to obtain drinking water from a tube well or borehole. Throughout India, only 45% of households had any toilet facilities; in urban areas 53% of households had an improved toilet facility and in rural areas only 18% had a toilet facility. Sixty-eight percent of Indian households had electricity and about 46% of the population lived in a *pucca* house, which is a house made of concrete, stone, clay tiles and/or metal, compared to older houses which were made of mud and organic materials (IIPS, 2007).

Assessment of Nutritional Status and Growth

Worldwide, nutrition is recognized as a significant reference of human development and the nutritional status of children is an indicator of community health (Sachdev, 1995). Anthropometric measures, such as a child's height and weight, are the traditional way of assessing general health status, dietary adequacy, and growth of children over time (De Onis, 2006). Information from anthropometric measures is used to generate several indices: height-for-age, weight-for-age, and BMI-for-age (weight-for-height). A child with low height-for-age would indicate stunting, low weight-for-age

would indicate underweight, and low weight-for-height would indicate wasting (Deaton & Drèze, 2009; UNICEF, n.d.). Anthropometric measurements of individuals can be characterized in relation to their expected values based on population-derived reference values or standards. Deviation from the median expected value can be quantified through the use of *Z*-scores, percentiles, or percentages of the median and can then be used to compare a child or a group of children with a reference population (WHO, 1995). Standard scores, most commonly referred to as *Z*-scores, are calculated based on the distribution of the reference population (Wang & Chen, 2012). A major advantage of using *Z*-scores is that it allows the mean and standard deviation to be calculated for a group of *Z*-scores when it comes to population-based applications (WHO, 1995). In addition, *Z*-scores allow comparison of scores that are from different distributions, and can quantify the growth status of children outside of the percentile ranges. As noted by De Onis and Blössner (1997), in relation to population-based assessments such as surveys and nutritional surveillance, *Z*-score is the best system for analysis and presentation of anthropometric data due to its advantages over other methods such a percentiles, and percentage of median. For these reasons we will use *Z*-scores to present our findings in this study.

References and Standards for Growth

In pediatric practice and research growth charts are commonly used to assess children growth, and nutritional status. As explained by Khadilkar and Khadilkar (2011):

> Growth charts mainly belong to two types: growth standards and growth references. Growth standards are prescriptive and define how a population

> of children should grow given optimal nutrition and optimal health. Growth references on the other hand are descriptive and are prepared from a population which is thought to be growing in the best possible state of nutrition and health in a given community. These describe the growth of children at that time. They represent how children are growing rather than how they should be growing.

In developed countries growth charts are used mainly to delineate obesity or overnutrition, but in developing countries such as India they are used to assess nutritional and growth failure in terms of stunting, wasting, and underweight (Kahdilkar & Kahdilkar, 2011). In 2007, the World Health Organization (WHO) developed children and adolescent growth standards and recommended their use to evaluate the growth of a child or a population of children aged 5 to 19 years. Around the same time, a new set of measurements from affluent urban Indian schoolchildren was published by Khadilkar and colleagues (Khadilkar et al., 2007) and this led to a debate as to the appropriate reference values that should be used in assessing Indian children's growth.

2007 WHO Child Growth Standards

In April 2006, WHO published growth standards of height and weight for children up to the age of 5 years to provide an international standard for healthy children and to replace the previous NCHS/WHO International Growth Standards. The NCHS/WHO International Growth Standards used data from a longitudinal study of a single community with children of European descent in the United States while the 2006 WHO standards used data involving more than eight thousand children from different countries such as Brazil, Ghana, India, Norway, Oman, and the United States of America (WHO, 2006). These new standards resulted from a study initiated in 1997 by WHO and its main partner, the United Nations University, and used height and weight data from the

WHO Multicentre Growth Reference Study (MGRS), with measurements obtained in a standardized manner from breastfed and properly nourished children of different ethnic backgrounds (De Onis, 2006).

Later in 2007, WHO published new standards for children and adolescent from age 5 to 19 years (61-228 months) to supplement the WHO Child Growth Standards for infant children 0-60 months published in April 2006 (WHO, 2015). The 2007 standards were constructed using the original 1977 NCHS data set complemented with data from the 2006 WHO child growth standards sample for under-fives to facilitate a smooth transition at 5 years. The same statistical methods used from the 2006 WHO standard which is the Box-Cox power exponential (BCPE) method with suitable analytic tools to select the best model was used to create the 2007 WHO Child Growth Standards (WHO, 2006; De Onis et al., 2007). As explained in the article, *Development of a WHO Growth Reference for School-Aged Children and Adolescents*:

> The BCPE method, with curve smoothing by cubic splines, was used to construct the curves. This method accommodates various kinds of distributions, from normal to skewed or kurtosis. After the model was fitted using the whole age range (18 months to 24 years), the curves were truncated to cover the required age range (i.e. 5–19years for height-for-age and BMI-forage, and 5–10 years for weight-for-age), thus avoiding the right- and left-edge effects (De Onis et al., 2007).

The final sample to develop the growth curves include a total number of 30,907 observations (15,537 boys and 15,370 girls) for height-for-age curves, 30,100 observations (15,136 boys and 14,964 girls) for weight-for-age curves, and finally 30,018 observations (15,103 boys and 14,915 girls) for BMI-for-age curves. The authors of this study reported that the newly developed curves lined up just about the same to the 2006

WHO Child Growth Standards at 5 years and to the recommended adult cut-offs for overweight and obesity at 19 years, and that they offered suitable reference growth standards for healthy children and adolescent age 5 to 19 years.

2007 Affluent Indian Growth References

Following WHO's recommendation that each country update their local standards every decade, from June 2007 to January 2008 Khadilkar and colleagues conducted a cross sectional survey to document the new growth trends of affluent urban Indian children to replace outdated Indian references for growth. Affluent urban children were specifically chosen because this group of children were less likely to have nutritional and socio-economic constraints that could impair growth, and they were most likely to have access to health care (Khadilkar et al., 2009; Khadilkar & Khadilkar, 2011).

To collect data for this study the Indian Academy of Pediatrics separated India into five regions (North, South, East, West, and Central) and 11 schools catering to children from affluent families were selected from the following cities: Delhi, Chandigarh, Chennai, Bangalore, Kolkata, Mumbai, Pune, and Baroda. As reported by the study investigators, the nutritionally well off areas were identified based on per capita income of cities (from IAP zones) and the schools selected for the study had an average yearly fee of Rs 10000 (Indian per capita income 2007-2008, Rs 2021/month). Data for 18666 children were analyzed (10496 boys and 8170 girls) and with the use of the LMS method, standards growth reference percentiles adjusted for skewness were developed for height, weight, and BMI (Khadilkar et al., 2009; Khadilkar & Khadilkar, 2011). The

LMS method converts measurements to exact SD scores with the use of the following formula:

$$SD - score = [measurement/M(t)] L(t) - 1/ L(t) S(t)]$$

In the formula, measurement represents the child's height or weight and L(t), M(t) and S(t) are values read from the smooth curves for the child's age t and sex (Khadilkar et al., 2009). As explained by Khadilkar and Khadilkar (2011):

> Each growth reference was summarized by 3 smooth curves plotted against age representing the median (M), the coefficient of variation (S) and the skewness (L) of the measurement distribution. The models were checked for goodness of fit using the detrended Q-Q plot, Q Tests and worm plots. Least mean square (LMS) method is the universally accepted method for construction of growth charts as it has certain advantages. The fitting procedure ensures that the values of LMS change smoothly with age so that they can be represented as smooth curves plotted against age, since these curves are smooth the resulting percentiles are also smooth, data is normalized using Box Cox transformation and any number of percentiles can be generated.

Where Is the Trend In Growth Heading?

Trends in childhood growth over time reflect changes in the livings standards of a population. While India has experienced substantial economic growth in the last few decades, the prevalence of undernutrion in Indian children, especially children of rural areas, continues to be a major problem. As reported by Deaton and Drèze (2009) India has two major sources of anthropometric data for children, the National Institute of Nutrition (NNMB) and the NFHS. According to data by NNMB, from 1975 to 2005, the percentage decline of stunting was 34%, percentage decline of underweight was 29%, and percentage decline of wasting 17%, suggesting a decline in the prevalence of

undernutrition (Deaton & Drèze, 2009). Based on NFHS surveys between 1998-1999 and 2005-2006, stunting declined from 51% to 45%, and underweight went from 43% to 40% among children less than 3 years old. The rate of wasting, however, went from 20% to 23% during the same period (Deaton & Drèze, 2009). Based on NFHS data the nutrition and growth patterns suggest overall that Indian children have grown taller and heavier since 1989.When comparing Indian Reference data collected in 1989 by Agarwal and colleagues to the 2007 Indian Reference data by Kahdilkar and colleagues there was an increase in height and BMI compared to 1989 data.

A number of methodological issues are worth considering with respect to the data collected over the last 20-30 years. Of the numerous surveys and studies on childhood nutrition and growth conducted in India, including those by Government agencies (NFHS and the NNMB) and academic researchers (Agarwal et al., 1992; Khadilkar et al., 2009; Khadilkar et al., 2010; Khadilkar et al., 2011; Khadilkar & Khadilkar, 2011) the various study populations have been selected differently and anthropometric measurements have generally not been standardized across these studies, which makes it difficult to interpret the trends in childhood growth patterns. The NNMB surveys have small sample sizes, are restricted to rural and tribal areas, have unclear methodology, and used NCHS standards. On the other hand, the NFHS surveys focused mainly on state-level indicators and were conducted at wide intervals. The NFHS-1 and NHFS-2 used NCHS standards while NFHS-3 used the 2006 WHO standards. The academic study by Agarwal and his colleagues and those by Khadilkar and colleagues used two different local references. Because the socioeconomic development of India has changed over the last 30 years,

some of the earlier studies represent a very different environment for Indian children to develop than is true today. As a result it is difficult to interpret the reported trends in nutrition status and growth of Indian children.

Indian children from rural areas are usually the most at risk for undernutriton and its complications. While there have been many studies of the growth patterns of Indian children, most have focused on affluent urban children and those that focused on rural children are outdated. Additionally, India is a diverse country, where each state has its own specific economic growth, ethnic groups, and food customs, so it is important to understand the pattern of growth among rural children based on these local factors, and to implement nutritional actions that are appropriate to those local conditions. One of the first steps to ensure that nutrition actions are relevant among children living in rural areas is to assess properly their growth and development based on accurate standardized anthropometric measurements, using relevant growth standards and references, and to identify population-specific factors that affect malnutrition. These data are essential to implementing relevant interventions that will enhance the nutritional status and growth of children living in rural areas.

CHAPTER 3

METHODS

A cross-sectional survey of rural Indian schoolchildren was conducted in 2013 by graduate students from Temple University's Department of Public Health under the supervision of two faculty members (Professor I. Greaves, MD and Professor J. Jhala, PhD). The study was conducted in the rural community of Dhrangadhra in the State of Gujarat, with the purpose of determining the causes and risk factors associated with child malnutrition and to develop a program to help address the issue of child malnutrition.

Study Design

Sample

Schoolchildren aged 5-16 years were recruited from rural schools located in the Surendranagar District of the State of Gujarat, India. A goal of the study was to recruit 500-600 students from a range of socioeconomic backgrounds. To achieve this goal, students were selected from private and Government schools in the belief that students attending the private schools would come from more affluent families than those attending Government schools.

Seven elementary schools with more than 500 students were approached in the towns of Dhrangadhra (total population 70,653) and Halvad (total population 26,026). The nature of the research project was explained to the headmaster and teachers at each school. Headmasters at all the schools agreed to allow their students to participate, and

they provided class lists (alphabetical by last name) for the purpose of selecting children to participate.

Consent processes for the parents of the students were explained to the teaching staff and a letter written in Gujarati was sent home with each student to explain the nature of the research study and to request parental consent for their child to participate. In a few cases where students were boarding at the school, the headmaster had a written legal power of attorney to act on behalf of the parents, and he signed the consent forms for those children to participate in the study. Signed consent forms were returned to the study team and were retained as a record of informed consent. More than 96% of parents provided written consent for their children to participate.

After excluding those students for whom parental consent had not been provided, one-fifth of students were selected systematically by starting variously at the first through fifth student for a particular class, and then selecting every fifth student thereafter on that class list. In this way we avoided the possibility of sampling children from the same family, and we also tried to avoid taking siblings from different classes by consulting with the teachers as to who may be related.

Data Collection

The children selected in this manner were brought one class at a time to the testing area where each child was asked if he or she agreed to participate. Only those who assented verbally to continuing were interviewed briefly and had their height and weight measured. Verbal assent was obtained from more than 98% of children who presented for testing. Children were asked their date of birth (if known) and the caste to which they

belonged. For children who did not know their date of birth, their headmaster provided it later from the school's records.

All staff performing the anthropometric measurements had been trained previously in a standard method for measuring height and weight. Using 10 children and the same set of scales and stadiometer for each measurement, six observers had coefficients of variation for intra- and inter-observer errors less than 1% for both weight and height measurements.

Weight was measured with an electronic scale (Salter, India) that was calibrated with a standard 5 kg weight before and after each testing session, and the scale was consistently found to be accurate to within ± 0.1 kg. Standing height was measured with a portable stadiometer. The child stood in bare feet or socks on the flat base of the stadiometer with the back of the head, shoulder blades, buttocks and heels touching the vertical rod, and the head in the Frankfurt plane. Gentle traction was applied to the mandibular process and the headboard lowered. Two readings were taken to the last completed millimeter, avoiding parallax, and these were averaged.

Variables

Generally for children, anthropometric indicators are based on age, height and weight, and gender. The outcome variables for this project are gender-specific measures of height-for-age and weight-for-age. Another outcome variable for this project is Body Mass Index (BMI), which is a measure used to approximate body fat in the absence of specific fat measures. The BMI-for-age for each participant in the sample was calculated using the formula weight in kilograms divided by height in meters squared (weight (kg) /

[height (m)] ^{2}). The 2007 Affluent Indian Growth References provide information on growth from birth to 18 years in affluent urban Indian children, and were recommended for use by the Growth Monitoring Guidelines Consensus Meeting of the Indian Association of Pediatrics (Khadilkar et al., 2007). In another attempt to provide standard reference values for height and BMI, countries were encouraged by the WHO to adopt its 2007 growth standards to monitor the growth of children and adolescents between the ages of 5 and 19 years (De Onis et al., 2007). Consequently in this project we will use both these growth standards and references to determine how rural Gujarati children fare relative to affluent urban Indian children and to international norms.

The independent variables for this project are age, caste, gender, and school (every school was dummy coded). Age in years was expressed either as a continuous variable or grouped into six categories (5-6, 7-8, 9-10, 11-12, 13-14, and 15-16 years.). Gender was categorized as male or female. The children reported about 48 different castes to which they belonged, so to simplify the analysis, castes were grouped into three categories (High castes, Middle castes, and Low castes/Untouchables), which corresponded approximately to their respective socio-economic status. School was categorized as Banjara, Brilliant Primary School, Gals Middle School N4, Jegadava, Pay Center School N4, and Vivekanard School Gujarati, Sandipani School–English Section and Sandipani School–Gujarati Section. The Sandipani School was the only private school that had both English-speaking and Gujarati-speaking students; children who attended the English-speaking section likely came from wealthier households than

students who were educated in Gujarati only. Table 1 present the distribution of the students according to their reclassified caste.

Table 1

Distribution of Social Caste According to School.

School ID	**Total**	**Caste**		
		High (1)	**Middle (2)**	**Low (3)**
		N (%)	N (%)	N (%)
Banjara	18	1 (5.6)	-	17 (94.4)
Brilliant Primary	80	38 (47.5)	28 (35.0)	11 (17.5)
Gals Middle Sch.	40	6 (15)	23 (57.50)	9 (22.5)
Jegadava	22	-	-	22 (100)
Pay Center No 4	80	48 (60.0)	16 (20.0)	16 (20.0)
Sandipani–Eng.	98	74 (75.5)	14 (14.3)	4 (4.1)
Sandipani–Guj.	91	67 (73.6)	5 (5.5)	18 (19.8)
Vivekanard	90	39 (43.3)	32 (35.6)	17 (18.9)
Note. Overall, 14 school-children had missing caste value, 3 at Brilliant Primary school, 2 at Gals Middle School, 6 at Sandipani – English, and 2 at Vivekanard.				

Statistical Analysis

Gender- and age-specific *Z*-scores, using Indian reference values (Khadilkar et al., 2009), were generated for each subject using an Excel® macro (V Khadilkar, personal communication, 2014). The percentages of children stunted (height-for-age ≤–2 SD),

underweight (weight-for-age ≤–2 SD), and wasted (BMI-for-age ≤–2 SD) were obtained (Khadilkar et al., 2009; Khadilkar & Khadilkar, 2011). The *Z*-scores percentage-stunted (height-for-age <–2SD), percentage-wasted (BMI <–2SD), percentage-severely-wasted (BMI <–3SD), percentage-overweight (BMI >+1SD), and percentage-obese (BMI >+2SD) were generated similarly using the WHO International Growth Standards (WHO, 2009).

BMI was analyzed further for overweight and obesity using the method developed by Khadilkar and colleagues (2012): the BMI values were compared with gender- and age-specific BMI percentiles that corresponded to adult BMI values of 23 kg/m^2 (BMI_{23}, the upper limit of normal for an Indian adult) and 28 kg/m^2 (BMI_{28}, above which is considered obese for an Indian adult). Children falling between the percentile curves equivalent to the adult BMI levels of 23 and 28 kg/m^2 ($BMI_{23\text{-}28}$) were considered *overweight*, and those above the 28 kg/m^2 percentile curve were considered *obese*.

Furthermore, logistic regression analyses were conducted, using Statistical Analysis System (SAS), to model the relationship between the dependent variables *Z*-scores for height-for-age, weight-for-age, and BMI (weight-for-height) based on Affluent Indian Reference Values and explanatory variables age, gender, school, and caste.

Results

A total of 519 children [234 girls (45%), 285 boys (55%)], aged 5-16years, underwent measurements of height and weight. Using recent Affluent Indian Reference Values obtained from urban schoolchildren (Khadilkar et al., 2009), we calculated *Z*-scores for height-for-age, weight-for-age, and BMI-for-age. A series of graphs (Figures

2–4) illustrate the overall prevalence of stunting, underweight, and wasting by gender, among students attending the various Government or private schools in this study. The definitions of stunting, underweight, and wasting were taken from the work of Khadilkar and coworkers (2009). The overall prevalence of stunting was 21.4% (8.7% of girls and 12.7% of boys); the overall prevalence of underweight was 23.1% (8.5% of girls and 14.6% of boys), and the prevalence of wasting was 8.9% (3.3% in girls and 5.6% in boys).

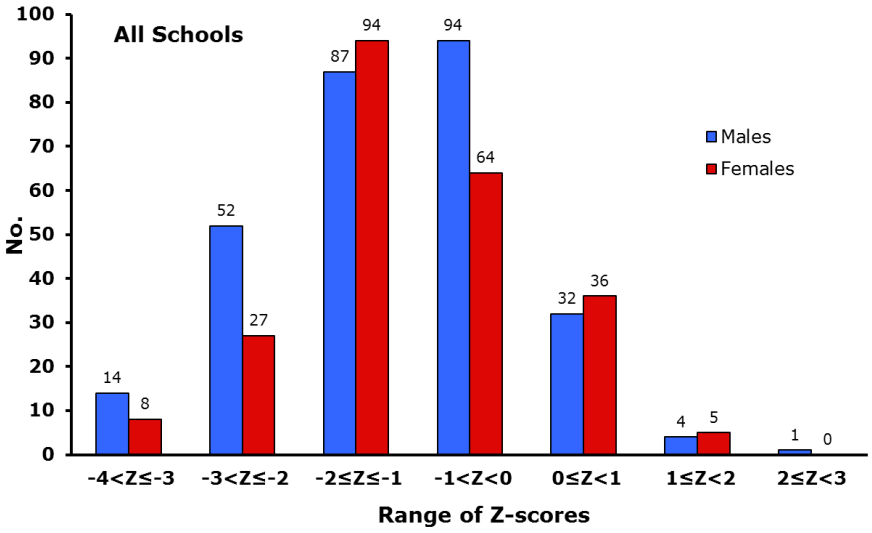

Figure 2. Prevalence of Stunting, Determined Using the 2007 Affluent Indian Growth References.

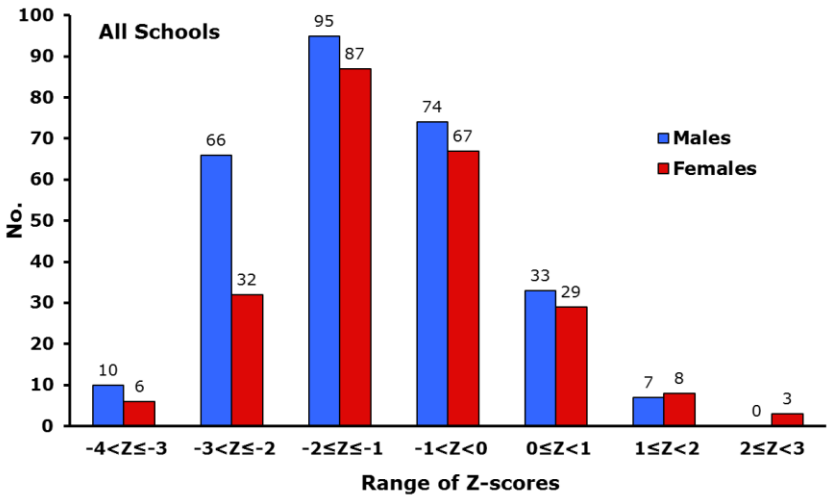

Figure 3. Prevalence of Underweight, Determined Using the 2007 Affluent Indian Growth References.

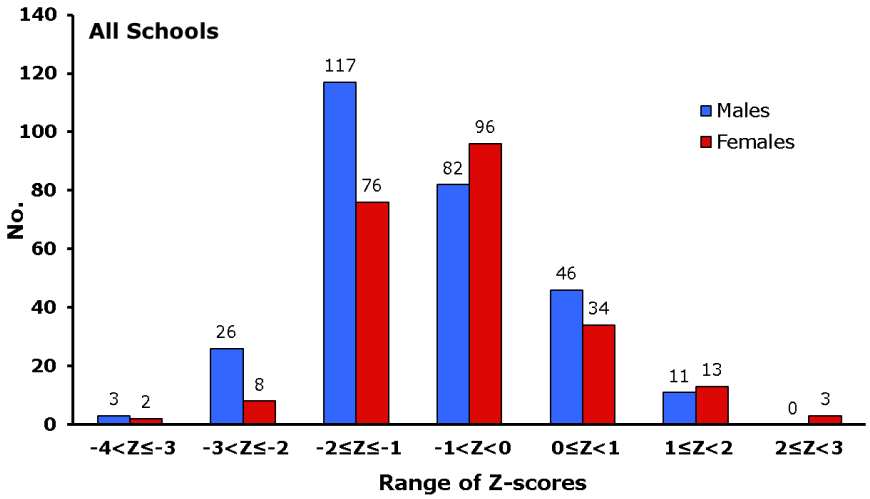

Figure 4. Prevalence of Wasting, Determined Using the 2007 Affluent Indian Growth References.

In Figures 5 and 6, the overall prevalence rates of stunting, wasting, and severe wasting are shown based on *Z*-scores derived from the WHO International Growth Standards and using the WHO definitions for these terms (De Onis et al., 2007; WHO &

UNICEF, 2009). Overall, 27.0% of children were classified as stunted (12.5 % of girls, 14.5% of boys) and 18.9% were wasted (6.9% of girls, 12.0% of boys), while 8.7% of children were classified as severely wasted (2.1% of girls, 6.6% of boys).

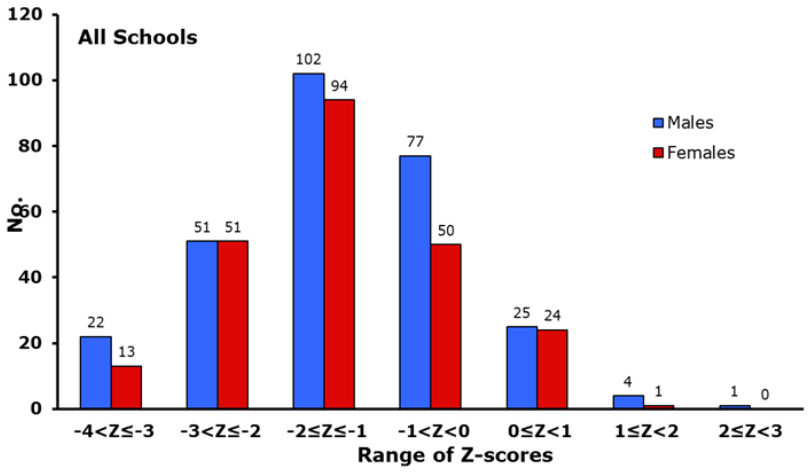

Figure 5. Prevalence of Stunting, Determined Using the 2007 WHO Child Growth Standards.

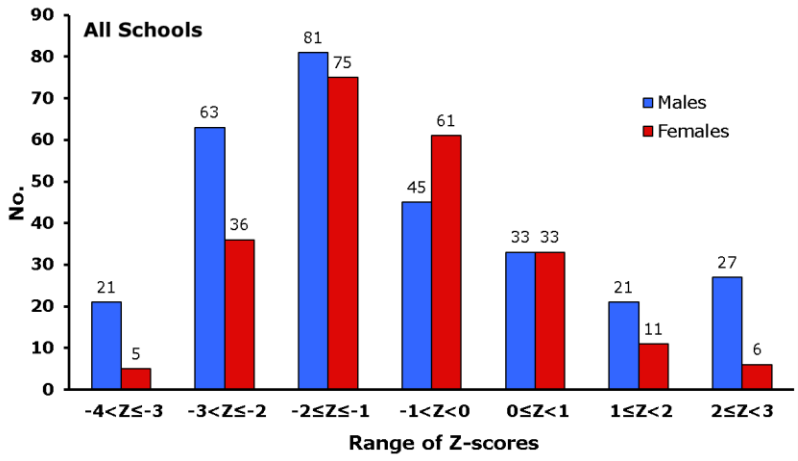

Figure 6. Prevalence of Wasting, Severe-wasting, Overweight, and Obesity Determined using the 2007 WHO Child Growth Standards.

In addition to using *Z*-scores as cut off points for overweight and obesity, it has been recommended by Indian investigators that children with BMI values equivalent to adult Indian BMI levels of 23 to 28 kg/m^2 be considered *overweight,* and those with BMI values equivalent to adult values above 28 kg/m^2 be considered *obese* (Khadilkar et al., 2012). Overweight and obesity were defined differently in the WHO International Growth Standards: children aged 5–19 years with BMI *Z*-scores greater than +1.0 using the international standard values (equivalent to an adult BMI of 25 kg/m^2) were defined as *overweight,* and those with BMI *Z*-scores greater than +2.0 (equivalent to an adult BMI of 30 kg/m^2) were considered *obese* (See "Assessment of differences", 2006; WHO, 2015).

Using the Indian Reference Values and recommendations, we found that 2.7% of rural children were overweight (1.7% girls, 1.0% boys) and 0.2% were obese (all girls). Using the WHO International Standards and recommendations, we found that 6.2% of rural children were overweight (2.1% girls, 4.1% boys) and 2.7% were obese (1.2% girls, 1.5% boys).

Z-scores Analysis

The overall mean *Z*-scores of the three growth parameters, height-, weight- and BMI-for-age are shown in Table 2 for all subjects using the Indian Reference Values or the WHO International Standards. The mean *Z*-scores for all parameters differed significantly from zero ($P<0.0001$) when calculated using either the Indian Reference Data or the WHO International Standards. The *Z*-scores for height- and BMI-for-age

derived from the WHO International Standards were significantly lower ($P<0.0001$ in each case) than those derived from the Indian Reference Values, as has been observed previously in Indian children (Khadilkar & Khadilkar, 2011).

This finding is illustrated in more detail in Figure 7 where the BMI *Z*-scores derived from Indian Reference Values were compared within the same individuals with the corresponding values derived from WHO International Standards. The individual data points are shown for 519 students; the solid line is the least squares regression line and the dotted line is the line of identity if the *Z*-scores derived from the Indian and WHO data were the same. The regression line shows a very close relationship between the two estimates of BMI *Z*-scores. The R^2-value for this regression line is 0.990, which means that only 0.01 or 1.0% of the variance is not explained by the regression. This is a very high degree of correlation. It is also obvious, however, that the line of identity (representing BMISDS–India = BMISDS–WHO) is very different from the observed regression line. The *Z*-scores derived from the Indian Reference Values consistently underestimate the amount of wasting present in underweight children, and underestimate the amount of obesity in overweight children, relative to the *Z*-scores derived from the WHO Standards. This difference is quantified by the regression equation, in which:

$$\text{BMISDS (India)} = 0.6003 \times \text{BMISDS (WHO)} - 0.0806.$$

The present findings show that these rural Indian schoolchildren were shorter and had lower weight-for-height than would be expected among affluent urban Indian schoolchildren or among well-nourished children worldwide.

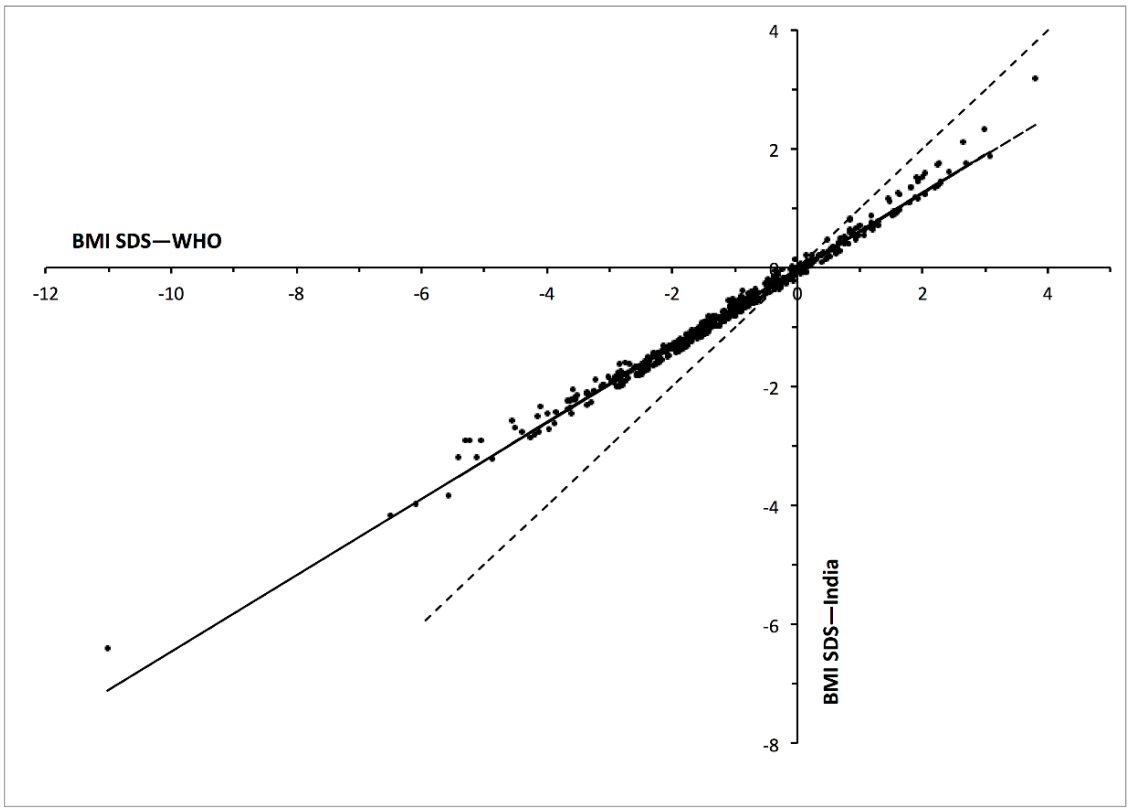

Figure 7. Plot of Z-Scores for BMI-For-Age Derived from Indian Reference Values on Z-Scores for the Same Individuals Derived from WHO International Standards.

Table 2

Comparison of Z-Scores in 519 Rural Indian Schoolchildren Using Population Data Derived from Affluent Indian Reference Values or WHO International Standards†.*

	Affluent Indian Reference Values*				**WHO International Standards†**				**Paired *t*-tests (Indian Reference – WHO Standard)**			
	Mean	**SD**	***t*-value**	***P*-value**	**Mean**	**SD**	***t*-value**	***P*-value**	**Mean**	**SD**	***t*-value**	***P*-value**
Height-for-Age	-1.15	1.11	23.60	< 0.0001	-1.37	1.10	28.37	< 0.0001	0.22	0.85	5.86	< 0.0001
Weight-for-Age	-1.11	1.06	23.86	< 0.0001	—	—	—	—	—	—	—	—
BMI-for-Age	-0.79	1.04	17.31	< 0.0001	-1.17	1.61	16.56	< 0.0001	0.39	0.59	14.94	< 0.0001

Note. The *t*-tests and *P*-values refer to the likelihood of the respective means being zero.

* (Khadilkar et al., 2009)

† (De Onis et al., 2007)

Table 3

Mean Z-Scores Based on Affluent Indian Reference Values for Height-, Weight-, and BMI-For-Age, by Gender, in Each School.

	Males				**Females**			
	Mean	**SD**	***t*-value**	***P*-value**	**Mean**	**SD**	***t*-value**	***P*-value**
Sandipani–Eng	N = 60				N = 39			
Ht-for-age	-0.67	0.99	5.24	< 0.0001	-0.55	1.06	3.24	0.0025
Wt-for-age	-0.38	1.05	2.80	0.0069	-0.13	1.06	0.77	0.4462
BMI-for-age	-0.11	1.06	0.80	0.4269	0.15	1.02	0.92	0.3635
Sandipani–Guj	N = 55				N = 35			
Ht-for-age	-1.31	1.01	9.62	< 0.0001	-1.27	0.85	8.84	< 0.0001
Wt-for-age	-1.48	1.08	10.16	< 0.0001	-1.27	0.80	9.39	< 0.0001
BMI-for-age	-1.14	1.09	7.76	< 0.0001	-0.87	0.75	6.86	< 0.0001
Vivekanard	N = 45				N = 45			
Ht-for-age	-1.41	1.17	8.08	< 0.0001	-1.10	1.05	7.03	< 0.0001
Wt-for-age	-1.41	1.10	8.60	< 0.0001	-1.21	1.42	5.72	< 0.0001
BMI-for-age	-0.86	0.92	6.27	< 0.0001	-0.88	1.45	4.07	0.0002
Pay Center N4	N = 51				N = 45			
Ht-for-age	-1.28	0.83	11.01	< 0.0001	-1.34	0.83	10.83	< 0.0001
Wt-for-age	-1.40	0.72	13.89	< 0.0001	-1.26	0.95	8.90	< 0.0001
BMI-for-age	-0.98	0.69	10.14	< 0.0001	-0.75	0.89	5.65	< 0.0001
Gals Middle Sch	N = 21				N = 19			
Ht-for-age	-0.88	0.90	4.48	0.0003	-0.98	0.90	4.75	0.0002
Wt-for-age	-1.10	0.85	5.93	< 0.0001	-1.35	0.71	8.29	< 0.0001
BMI-for-age	-0.92	0.80	5.27	< 0.0001	-1.19	0.90	5.76	< 0.0001
Jegadava	N = 12				N = 10			
Ht-for-age	-1.42	1.79	2.75	0.0205	-0.68	1.23	1.75	0.1182
Wt-for-age	-1.92	1.03	6.46	< 0.0001	-1.39	1.06	4.15	0.0032
BMI-for-age	-1.03	0.55	6.49	< 0.0001	-1.44	0.84	5.42	0.0006
Banjara	N = 7				N = 11			
Ht-for-age	-1.25	0.96	3.44	0.0184	-1.37	1.14	3.99	0.0032
Wt-for-age	-1.40	0.87	4.26	0.0080	-1.03	0.80	4.27	0.0021
BMI-for-age	-0.99	0.57	4.60	0.0058	-0.57	0.84	2.25	0.0510
Brilliant Primary	N = 43				N = 36			
Ht-for-age	-1.43	1.21	7.75	< 0.0001	-0.97	1.05	5.54	< 0.0001
Wt-for-age	-1.69	0.94	11.79	< 0.0001	-1.02	1.04	5.88	< 0.0001
BMI-for-age	-1.23	0.79	10.21	< 0.0001	-0.69	0.90	4.60	< 0.0001

Note. The *t*-tests and *P*-values refer to the likelihood of the respective means being zero.

Table 3 presents the mean *Z*-scores and standard deviations of height-for-age, weight-for age, and BMI-for age, by school, based on Affluent Indian Reference Values. The distribution of height-for-age and weight-for-age in all Government and private schools were shifted to the left for both genders, with the exception of the height-for-age of male students in the Jegadava group whose average height did not differ significantly from the reference population ($P>0.10$). The distribution of BMI-for-age was to some extent different; while the distribution was significantly shifted to the left for both genders in Government schools, the distribution of BMI-for-age in the English section at Sandipani school was not (mean BMI *Z*-scores were not significantly different from zero for either gender). The children from the Gujarati section at Sandipani School followed the same pattern as the children in Governments schools in terms of BMI-for-age, showing a decreased weight-for-height overall relative to affluent urban Indian schoolchildren.

Regression Analysis

The association between growth parameters [*Z*-scores for height-for-age, weight-for-age, and BMI (weight-for-height)] determined using Affluent Indian Reference and predictor variables were analyzed based on two general linear models. The first model included predictor variables age, gender, and school and the second included age, gender, school, and caste.

Table 4 presents a summary of the association between Z-scores for height-for-age and the independent variables age, gender, and school. School is found to have a

significant interaction with Z-score height-for-age ($F = 5.73$, $P < .0001$). Figure 8 illustrates the distribution of mean Z-scores of height-for-age across the different school. There is a significant difference in the mean height-for age *Z*-score of private school Sandipani – English section ($P < .0001$) and government school Gals Middle School ($P = 0.05$) compared to the reference group Brilliant Primary School, indicating the children from Sandipani–English Section and Gals Middle School were taller compared to children from Brilliant Primary School.

Table 4

Regression of Z-Scores for Height-For-Age (Based on Indian Reference Values) on Age, Gender and School.

	Estimate	**SE**	**F Value**	**P-value**
Age			2.05	0.07
5-6 years	0.45	0.22		
7-8 years	0.57	0.22		
9-10 years	0.52	0.23		
11-12 years	0.43	0.22		
13-14 years	0.80	0.27		
15-16 years	0	-		
Gender			0.02	0.88
Female	-0.01	0.09		
Male	0	-		
School			5.73	<.0001
Sandipani–Eng	0.68	0.158		
Sandipani–Guj	-0.02	0.161		
Vivekanard	0.01	0.160		
Pay Center N4	-0.09	0.163		
Gals Middle	0.39	0.203		
Jegadava	0.22	0.250		
Banjara	-0.20	0.276		
Brilliant Primary	0			

Note. Estimate represents the difference of mean height-for age *Z*-score from the reference group.

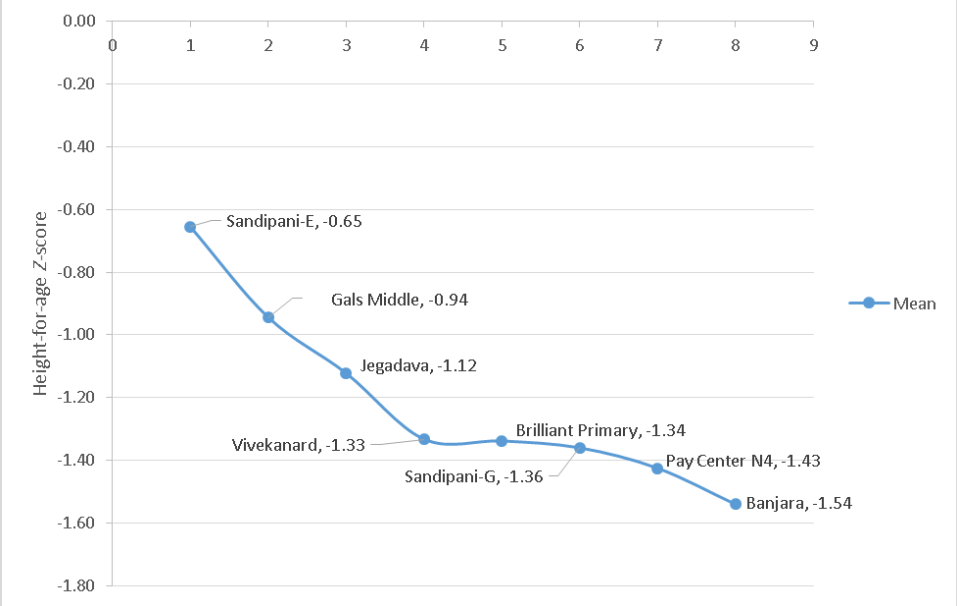

Figure 8. Mean Z-Scores of Height-For-Age by School, Based on First Linear Model including Age, Gender, and School.

Table 5 presents a summary of the second liner regression model which studied the association between *Z*-scores for height-for-age and the independent variables age, gender, school, and caste. Age has significant interaction with *Z*-score height-for-age ($F = 2.29$, $P = 0.04$). Figure 9 illustrates the mean height-for-age *Z*-score by age group, and each age group differs significantly from the reference group (age 15-16 years), indicating that 15-16 year-old students were significant shorter compared to all other age groups.

Similarly to the first linear regression model with age, gender and school, as predictor variables, school also has a significant interaction with *Z*-score height-for-age ($F = 5.75$, $P < .0001$) and Figure 10 illustrates that children from Sandipani – English

Section (*P*<.0001) and Gals Middle School (*P* = 0.05) were also taller than children from Brilliant Primary School.

Table 5

Regression of Z-Scores for Height-For-Age (Based on Indian Reference Values) on Age, Gender, School, and Caste.

	Estimate	**SE**	***F* Value**	***P*-value**
Age			2.29	0.04
5-6 years	0.55	0.23		
7-8 years	0.64	0.23		
9-10 years	0.48	0.23		
11-12 years	0.60	0.23		
13-14 years	0.85	0.28		
15-16 years	0	-		
Gender			0.00	0.99
Female	0.001	0.09		
Male	0	-		
School			5.75	<.0001
Sandipani–Eng	0.73	0.17		
Sandipani–Guj	-0.02	0.17		
Vivekanard	0.04	0.16		
Pay Center N4	-0.07	0.17		
Gals Middle	0.41	0.21		
Jegadava	0.10	0.28		
Banjara	-0.29	0.30		
Brilliant Primary	0	-		
Caste			1.06	0.35
High caste	-0.15	0.14		
Middle caste	-0.23	0.16		
Low caste	0	-		

Note. Estimate represents the difference of mean height-for age *Z*-score from the reference group.

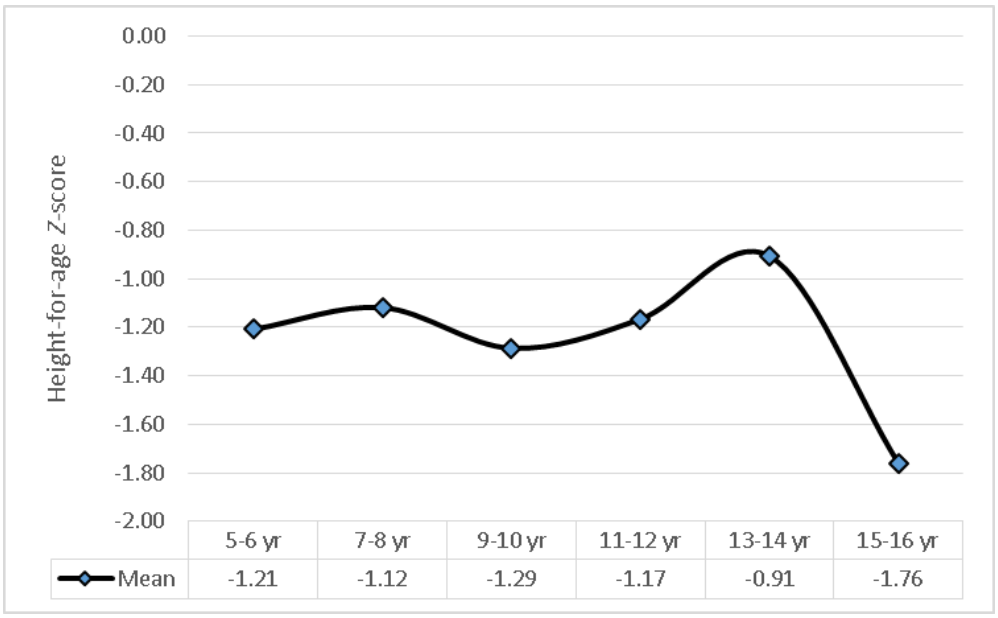

Figure 9. Mean Z-Score of Height-For-Age by Age, Based on Second Linear Model including Age, Gender, School, and Caste.

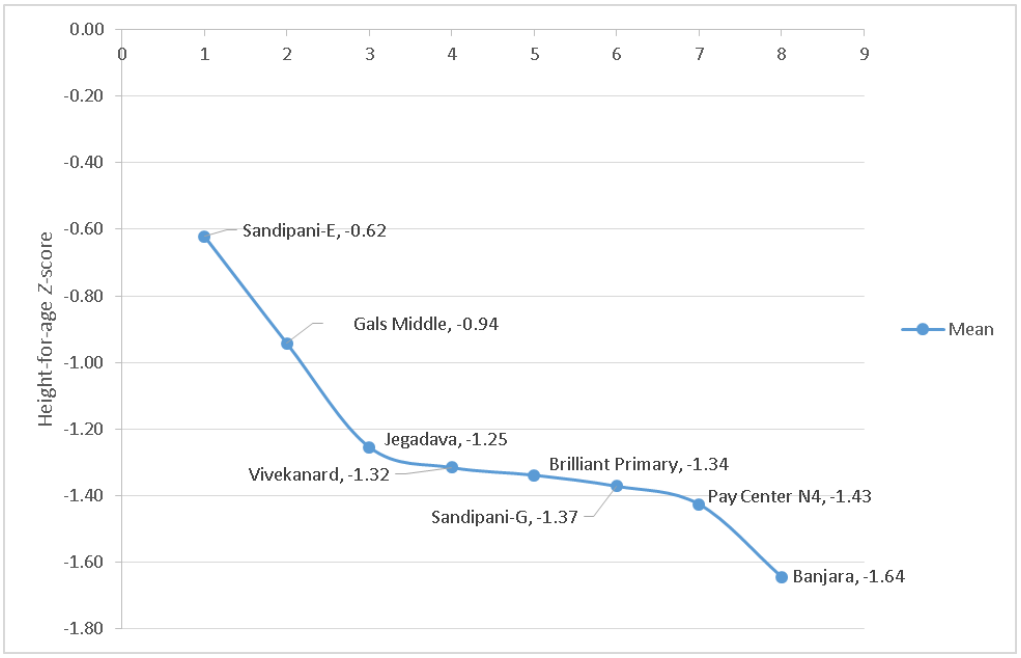

Figure 10. Mean Z-Scores of Height-For-Age by School, Based on Second Linear Model including Age, Gender, School, and Caste.

Table 6 presents a summary of the association between *Z*-scores for weight-for-age and the independent variables age, gender, and school. School has a significant interaction with *Z*-score weight-for-age ($F = 13.42$, $P = <.0001$), although no significant difference in the mean weight-for age *Z*-score in any of the schools is found compared to the reference school Brilliant Primary School.

Table 6

Regression of Z-Scores for Weight-For-Age (Based on Indian Reference Values) on Age, Gender, and School.

	Estimate	**SE**	**F Value**	**P-value**
Age			0.97	0.44
5-6 years	0.20	0.22		
7-8 years	0.31	0.22		
9-10 years	0.18	0.23		
11-12 years	0.33	0.22		
13-14 years	0.48	0.27		
15-16 years	0	-		
Gender			1.50	0.22
Female	-0.11	0.09		
Male	0	-		
School			13.42	<.0001
Sandipani–Eng	1.16	0.16		
Sandipani–Guj	0.05	0.16		
Vivekanard	0.10	0.16		
Pay Center N4	0.05	0.16		
Gals Middle h	0.22	0.20		
Jegadava	-0.23	0.25		
Banjara	0.15	0.28		
Brilliant Primary	0	0.16		

Note. Estimate represents the difference of mean weight-for age *Z*-score from the reference group.

Table 7 presents a summary of the second liner regression model which studied the association between *Z*-scores for weight-for-age and the independent variables age, gender, school, and caste. School has a significant interaction with Z-score weight-for-age ($F = 10.61$, $P = 0.04$) and no significant difference was found in the mean weight-for age *Z*-score for the schools compared to the reference school.

Table 7

Regression of Z-Scores for Weight-For-Age (Based on Indian Reference Values) on Age, Gender, School and Caste.

	Estimate	**SE**	***F* Value**	***P*-value**
Age			1.11	0.35
5-6 years	0.24	0.23		
7-8 years	0.34	0.23		
9-10 years	0.35	0.23		
11-12 years	0.18	0.23		
13-14 years	0.52	0.28		
15-16 years	0	-		
Gender			1.78	0.18
Female	-0.12	0.09		
Male	0	-		
School			10.61	<.0001
Sandipani–Eng	1.11	0.17		
Sandipani–Guj	0.03	0.17		
Vivekanard	0.10	0.16		
Pay Center N4	0.04	0.17		
Gals Middle	0.24	0.21		
Jegadava	-0.22	0.28		
Banjara	0.16	0.30		
Brilliant Primary	0	-		
Caste			0.42	0.65
High caste	0.05	0.14		
Middle caste	-0.07	0.16		
Low caste	0	-		

Note. Estimate represents the difference of mean weight-for age *Z*-score from the reference group.

Table 8 presents a summary of the association between *Z*-scores for BMI-for-age and the independent variables age, gender, and school. School has a significant interaction with *Z*-score BMI-for-age ($F = 12.73$, $P = <.0001$). Figure 11 presents the distribution of mean *Z*-scores of BMI-for-age across each school, the children from Sandipani–English Section are significantly less wasted ($P < 0.0001$) compared to children from Brilliant Primary school, and children from Jegadava School are significantly more wasted ($P = 0.02$) compared to children from the reference group Brilliant Primary school.

Table 8

Regression of BMI-For-Age (Based on Indian Reference Values) on Age, Gender, and School.

	Estimate	**SE**	**F Value**	**P-value**
Age			0.64	0.67
5-6 years	0.07	0.21		
7-8 years	0.09	0.21		
9-10 years	0.11	0.21		
11-12 years	0.18	0.22		
13-14 years	0.37	0.26		
15-16 years	0	-		
Gender			3.26	0.07
Female	-0.16	0.09		
Male	0	-		
School			12.73	<.0001
Sandipani–Eng	1.03	0.15		
Sandipani–Guj	0.02	0.15		
Vivekanard	0.13	0.16		
Pay Center N4	0.10	0.16		
Gals Middle	-0.01	0.19		
Jegadava	-0.53	0.24		
Banjara	0.23	0.27		
Brilliant Primary	0	-		

Note. Estimate represents the difference of mean BMI-for age *Z*-score from the reference group.

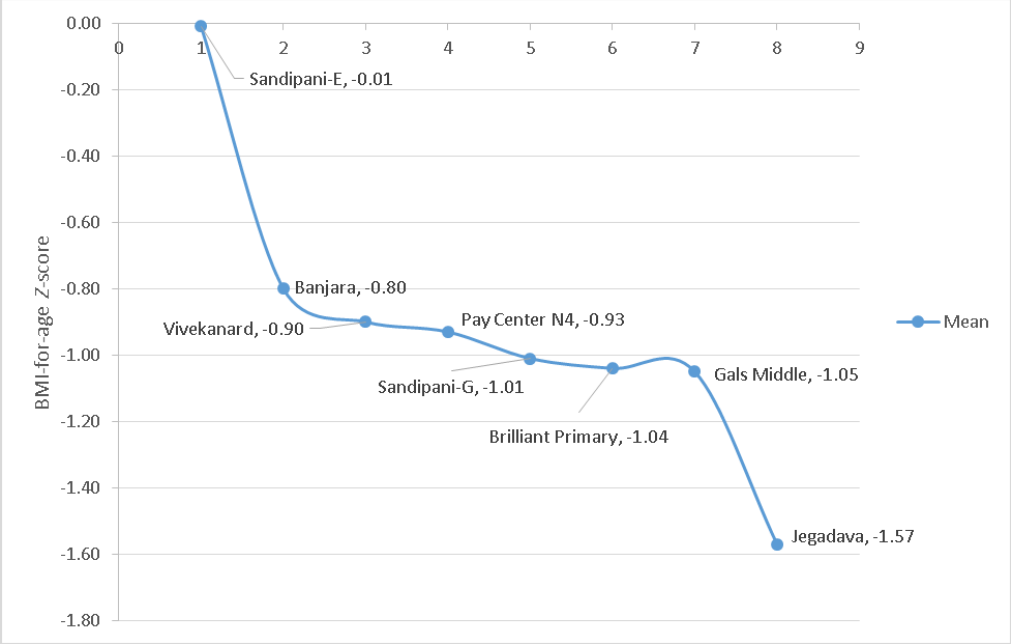

Figure 11. Mean Z-Scores of BMI-For-Age by School, Based on First Linear Model including Age, Gender, and School.

Table 9 presents a summary of the second liner regression model which examined the association between *Z*-scores for BMI-for-age and the independent variables age, gender, school, and caste. School has a significant interaction with *Z*-score BMI-for-age ($F = 8.76$, $P = <.0001$). Figure 12 present a distribution of mean *Z*-scores of BMI-for-age across each school and we observe that children from Sandipani- English Section were significantly less wasted ($P < 0.001$) compared to children from Brilliant Primary school.

Table 9

Regression of Z-Scores for BMI-For-Age (Based on Indian Reference Values) on Age, Gender, School and Caste.

	Estimate	**SE**	***F* Value**	***P*-value**
Age			0.82	0.54
5-6 years	0.05	0.22		
7-8 years	0.08	0.22		
9-10 years	0.17	0.22		
11-12 years	0.06	0.22		
13-14 years	0.40	0.26		
15-16 years	0	.		
Gender			3.17	0.08
Female	-0.16	0.09		
Male	0	.		
School			8.76	<.0001
Sandipani–Eng	0.93	0.16		
Sandipani–Guj	0.00	0.16		
Vivekanard	0.12	0.16		
Pay Center N4	0.08	0.16		
Gals Middle Sch.	0.01	0.20		
Jegadava	-0.39	0.27		
Banjara	0.34	0.28		
Brilliant Primary	0	.		
Caste			1.49	0.23
High caste	0.22	0.13		
Middle caste	0.11	0.15		
Low caste	0	.		

Note. Estimate represents the difference of mean BMI-for age *Z*-score from the reference group.

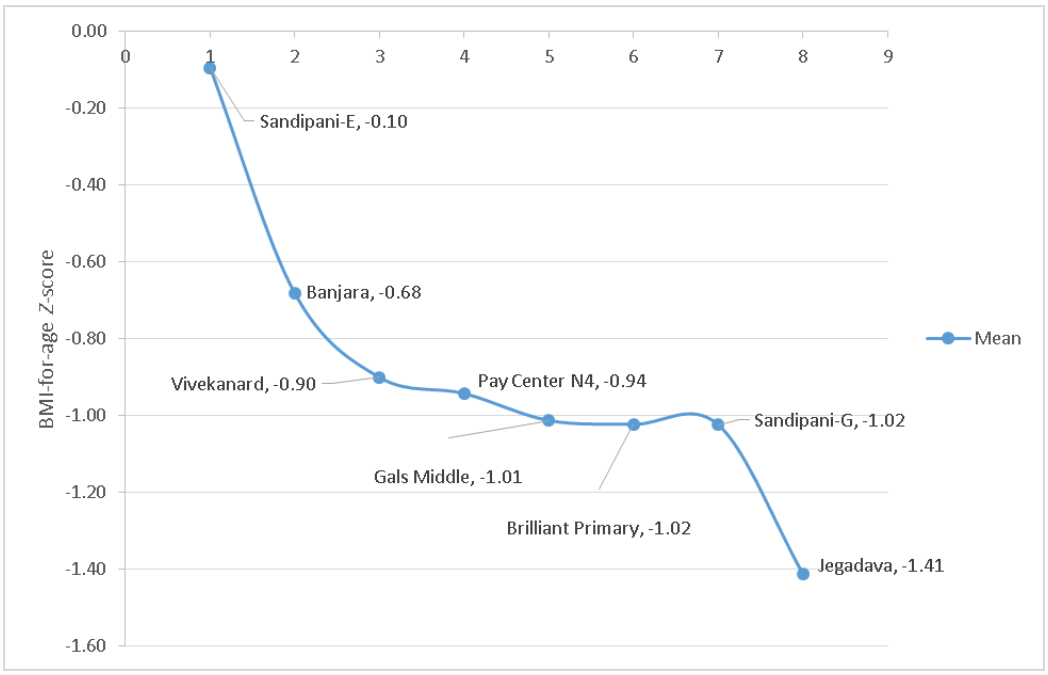

Figure 12. Mean Z-Scores of BMI-For-Age by School, Based on Second Linear Model including Age, Gender, and School.

CHAPTER 4

DISCUSSION & CONCLUSION

Study Summary

Prior studies of childhood growth in India have reported different rates of undernutrition, overweight, and obesity among schoolchildren. While there are many reasons for these differences, one major concern has been the use of different definitions of growth measures and different reference populations in these various studies (Kumaravel et al., 2014). Furthermore, the population reference data in Indian children have focused on affluent urban schoolchildren (Agrarwal et al., 1992; Khadilkar et al., 2007), while data for rural children have been sparse. The main goal of this study was to determine how the growth measures of rural schoolchildren from the state of Gujarat compared with recent national and international standards, and to explore the associations between growth measures, demographic and socioeconomic factors among rural children.

Data used in the present study were obtained from a cross-sectional survey of Indian schoolchildren that was conducted in 2012–2013 by graduate students from Temple University and approved by the Institutional Review Board at Temple University. Consent was obtained from the principals of the schools and community leaders to use the children in their respective schools. Written consent was obtained from a parent or guardian of each child before data were collected, and verbal assent was obtained from children prior to data collection. The present study used de-identified data sets to preserve the anonymity of the study participants.

Findings

A comparison of growth parameters based on Affluent Indian Growth Reference Values and WHO International Growth Standards revealed that children in this study were significantly stunted, underweight, and wasted compared with affluent urban Indian children and even more so relative to healthy, well-nourished children in developed and developing countries around the world. Children were more likely to be classified as overweight and obese when using the WHO International Standards than the Indian Reference Values. This finding is illustrated in Figure 7, where the BMI *Z*-scores derived from Indian Reference Values are regressed on those derived from WHO International Standards. The regression line departs markedly from the line of identity, such that the *Z*-scores based on Indian Reference Values consistently underestimate the degree to which children are underweight/wasted or overweight/obese relative to the *Z*-scores based on the WHO International Standards.

These findings emphasize that the assessment of growth parameters and nutritional status are influenced greatly by the normative values that are used to derive *Z*-scores or percentiles. The 2007 Indian Reference Values represent the existing growth pattern of healthy urban children in India. At the population level, these references can help determine prevalence and monitor trends in growth, and at the individual level they are vital in monitoring and diagnosing growth-related disorders. A shortcoming of the Indian Reference Values is that, in a country such as India where the incidence of childhood obesity is believed to be rising, such local reference values may be more likely to define an overweight child as a normal weight child, and this is why WHO

recommends using standards based on data drawn from many different health populations of children (Van Buuren, 2007; Khadilkar & Khadilkar, 2011).

The WHO International Standards were developed as an assessment tool to evaluate whether children are growing and developing at a normal and healthy rate. Van Buuren (2007) relates that: "Standards embrace the notion of a norm or desirable target, and thus involve a value judgment." As explained in the article *Growth Charts: A diagnostic tool* an advantage of using the WHO International Standards is that they allow an easier comparison between children from different countries, races and ethnicity, resulting in a more objective assessment. In developed countries such as India where there may be a concern about childhood obesity, the WHO standards are essential as they allow for a better detection of overweight and obese children before it becomes too difficult to prevent or control, compared to the local reference that identify the problem only after a child has become obese. At the same time, using international standards from developed countries is likely to over-diagnose underweight and stunting in children whose country's reference values would rate as normal (Khadilkar & Khadilkar, 2011).

Given the high levels of stunting, underweight, and wasting among the schoolchildren in this study, we conducted regression analyses to determine the relationship between growth parameters, based on Indian Reference Values, and demographic and socioeconomic factors. The first regression analysis model included age, gender, and school as predictor variables and the second model included age, gender, school, and social caste. These analyses are shown in Tables 4–9. While all schools had children with significantly impaired height ($P < 0.0001$), Figures 8 and 9 show that

children from Sandipani – English Section ($P < 0.0001$) and Gals middle school ($P = 0.5$) were found to be significantly taller than children from other schools in both linear regression models. In Figure 11 we observed that children at Sandipani – English Section ($P < 0.0001$) were less wasted than other schools and those at Jegadava ($P = 0.02$) were more wasted compared to the other schools. Figure 12 based on the second regression analysis of BMI-for-age *Z*-scores with age, gender, school, and caste, also showed that children from Sandipani – English Section were significantly less wasted compared to other schools ($P < 0.0001$). The identification of Sandipani – English Section children as being less wasted than other children in this study probably reflects a level of affluence among the Sandipani children that is not captured by the use of caste as a socioeconomic indicator in the analysis.

Age had a significant relationship with height-for-age *Z*-scores only in the regression model with age, gender, school, and caste as predictor variables ($P = 0.04$), this analysis is presented in Table 5. In Figure 9 we observed that mean *Z*-scores for height-for-age were decreased at all ages, but the highest age group (15-16 years) had significantly lower mean *Z*-scores for height-for age-than all other ages. The findings suggest that stunting was a significant problem at all ages, but especially among the oldest children we studied.

Stunting has a significant effect on a child's health and is a risk factor for adult obesity. Stunting is a result of protein deficiency over a prolonged time period, and has been associated with decreased resistance to infectious diseases and suboptimal brain development, resulting in poor scholastic performance and low income earning capability

(WHO & UNICEF, 2013). The higher *Z*-scores for height-for-age among children at Sandipani – English Section might again be a result of children from an English speaking private school coming from more affluent households, and thus experiencing less nutritional or socio-economic restraints compare to the students from the other schools. Children from Gals Middle school had the second highest mean height-for-age *Z*-scores among all the schools, also suggesting less nutritional constraint compared to children for the other schools, although the reason for this is unclear.

The lower height-for-age among 15-16 year-olds suggests they had poorer nutrition than those who were born after them. This could have occurred at any time in these children, from the period of fetal development through adolescence, but most likely in early childhood. Government programs aimed at improving the nutrition of mothers and children have been increasingly active in this region of Gujarat over the last 10-15 years, and some would argue that poorer growth parameters in older children reflects an improvement in nutrition and growth among younger children as a result of Government actions. The cross-sectional nature of the present study does not permit an assessment of growth longitudinally in these children, which makes differences in height-for-age among the various age groups difficult to evaluate.

Underweight in children is indicative of acute malnutrition, not consuming enough food, underlying illness, and genetics among other factors (UNICEF, 2013). As reported by WHO and UNICEF (2013), children living in rural areas are more likely to be underweight compared to children in urban areas, and this trend was observed in the significantly low heights and weights across all the schools in this study. An article

published in The Indian Express (2013) regarding underweight in the State of Gujarat reported that the Comptroller and Auditor General of India (CAG) has criticized the Indian Government's poor implementation of Integrated Child Development Services (ICDS) whose purpose is to fight malnutrition among Indian children. In its audit report the CAG found that every third child in the state of Gujarat is underweight. Furthermore the CAG argued that, "Though there were 223.16 lakh [22.3 million] eligible beneficiaries under Supplementary Nutrition (SN) programme under the Integrated Child Development Scheme (ICDS), 63.37 [6.3 million] lakh beneficiaries were left out"

Contrary to stunting, wasting is a sign of acute malnutrition and can have short duration; it is usually caused by food scarcity or disease. The children at Jevagava school were significantly more wasted compared to the other schools, indicating less access to food compared to the other schools at the time these measures were collected. All children in this group were from very low (*dalit*) castes. Again the high number of beneficiaries left out of supplementary nutrition program in Gujarat could also account in part for the level of wasting in this study and particularly among the Jegadava children.

The prevalence of overweight and obesity among Gujarati schoolchildren were also examined in this study. According to the Indian Reference Values and recommendations, 2.7% of the students in this study were overweight (1.7% girls, 1.0% boys) and 0.2% (all girls) were obese. According to WHO International Standards and recommendations 6.2% of children were overweight (2.1% girls, 4.1% boys) and 2.7% were obese (1.2% girls, 1.5% boys). These overall percentages reflect an increasing trend in overweight and obesity among Indian children, as observed by others (Khadilkar &

Khadilkar, 2011; Khadilkar et al., 2011). Overweight and obesity result from energy imbalance and can have serious effects on health (WHO, 2006); this rising trend may be a result of a lack of physical activity, increasing access to junk foods, and changes in family lifestyle habits.

Limitation and Strength

There are some limitations to this study. First, the 2007 WHO International Standards do not provide weight-for-age information for children over the age of 5 years. As a result, we were unable to compare weight-for-age data based on national standards with international standards. Secondly, a number of important pieces of nutritional information were not available in this study: such as parental heights and weights, mother's education, nutritional information and infant health care available to the mother and child during early childhood, participation in Government nutrition programs, birth order.

A strength of this study is that it is the first to perform anthropometric growth measurements in rural Indian schoolchildren and evaluate those using the 2007 Indian Reference Values and the updated WHO International Growth Standards.

Conclusion

In conclusion, given that the students in this study were all from rural communities of India, where children have been found to be consistently more stunted, underweight, and wasted than children in urban areas (IIPS, 2007), the use of the 2007 Indian Reference Values seems the most appropriate comparison group if clinical

decision are to be made. Since the pattern of population growth changes over time, Khadilkar (2011) has advocated updating the Indian reference values at least every decade to properly capture trends in growth and allow for comparisons among different groups of Indian children.

The current level of stunting, underweight, and wasting among the children in this study highlight a need to reduce ongoing undernutrition of children in rural areas. Ways in which this might be achieved include promoting and supporting healthy nutrition among pregnant women, emphasizing breastfeeding for newborns and young children, and enhancing the effectiveness of programs aimed at broadening children's nutrition to encompass sufficient intake of calories, proteins, and micronutrients.

An effective way of achieving many of these goals has been to increase the earning capacity of mothers (Gillespie & Mason, 1991; Thompson & Amoroso, 2014). For example, micro-loans for mothers to start small businesses have been very useful in helping mothers obtain more income, and that income is usually directed to the welfare of their children. Additional methods are needed to promote improved food safety, greater education of mothers, and improved access to public health resources.

Additionally nutrition interventions should be established in schools to target children during the period of adolescence to prevent the risk of overweight and obesity as they reach adulthood. As reported by the Centers for Disease Control and Prevention (CDC), schools are critical in establishing supportive and safe environments with policies and practices to support healthy behaviors in children. They also provide children with the opportunity to learn about healthy eating and physical activity (CDC, 2014)

Solving undernutrition and the emerging problems of overnutrition in Indian children will not be simple. Substantial information is available concerning the level of malnutrition among urban Indian children, and the present study highlights the significant problems among rural children. While potential solutions to these problems have been recognized and advocated for more than 20 years, the implementation of corrective measures has been slow, especially in rural areas. Future programs need to be directed to sustainable, community-led efforts that are embraced widely by mothers. This will involve the broader question of the roles of women in Indian society, and how those roles have been changing. Rural areas have been more conservative regarding the roles of women, and change has come very slowly relative to urban areas. This presents a significant, ongoing challenge for the nutrition of rural Indian children.

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APPENDIX A

IRB PROTOCOL REVIEW

TEMPLE UNIVERSITY
Office of the Vice Provost for Research

Research Integrity & Compliance
Student Faculty Center
3340 N. Broad Street, Suite 304
Philadelphia PA 19140

Institutional Review Board
Phone: (215) 707-3390
Fax: (215) 707-9100
e-mail: irb@temple.edu

Date: 13-Apr-2015

PI:	GREAVES, IAN
Committee:	B BEHAVIORAL AND SOCIAL SCIENCES
Protocol Number:	22897
Project Title:	Malnutrition in Gujarati Schoolchildren and Relation to Indices of Socioeconomic Status

The IRB reviewed your proposal and found that this does not meet the criteria of human subjects research. Therefore, IRB review/approval is not required.

Please contact the IRB at (215) 707-3390 if you have any questions.

APPENDIX B

CITI CERTIFICATE 1

COLLABORATIVE INSTITUTIONAL TRAINING INITIATIVE (CITI PROGRAM)

COURSEWORK REQUIREMENTS REPORT*

* NOTE: Scores on this Requirements Report reflect quiz completions at the time all requirements for the course were met. See list below for details. See separate Transcript Report for more recent quiz scores, including those on optional (supplemental) course elements.

- **Name:** lovemine jeannot (ID: 3187929)
- **Email:** tub50794@temple.edu
- **Institution Affiliation:** Temple University (ID: 926)
- **Phone:** 215-985-2090

- **Curriculum Group:** Human Research
- **Course Learner Group:** Social/Behavioral Research Course
- **Stage:** Stage 2 - Refresher Course
- **Description:** Choose this group to satisfy CITI training requirements for Investigators and staff involved primarily in Social/Behavioral Research with human subjects.

- **Report ID:** 15555853
- **Completion Date:** 03/15/2015
- **Expiration Date:** 03/14/2017
- **Minimum Passing:** 75
- **Reported Score*:** 100

REQUIRED AND ELECTIVE MODULES ONLY	DATE COMPLETED	SCORE
Temple University	03/15/15	No Quiz
SBE Refresher 1 – Defining Research with Human Subjects	03/15/15	2/2 (100%)
SBE Refresher 1 – Privacy and Confidentiality	03/15/15	2/2 (100%)
SBE Refresher 1 – Assessing Risk	03/15/15	2/2 (100%)
SBE Refresher 1 – Research with Children	03/15/15	2/2 (100%)
SBE Refresher 1 – International Research	03/15/15	2/2 (100%)
SBE Refresher 1 – History and Ethical Principles	03/15/15	2/2 (100%)
SBE Refresher 1 – Federal Regulations for Protecting Research Subjects	03/15/15	2/2 (100%)
SBE Refresher 1 – Informed Consent	03/15/15	2/2 (100%)
SBE Refresher 1 – Research with Prisoners	03/15/15	2/2 (100%)
SBE Refresher 1 – Research in Educational Settings	03/15/15	2/2 (100%)
SBE Refresher 1 – Instructions	03/15/15	No Quiz

For this Report to be valid, the learner identified above must have had a valid affiliation with the CITI Program subscribing institution identified above or have been a paid Independent Learner.

CITI Program
Email: citisupport@miami.edu
Phone: 305-243-7970
Web: https://www.citiprogram.org

APPENDIX C

CITI CERTIFICATE 2

COLLABORATIVE INSTITUTIONAL TRAINING INITIATIVE (CITI PROGRAM)

COURSEWORK TRANSCRIPT REPORT**

** NOTE: Scores on this Transcript Report reflect the most current quiz completions, including quizzes on optional (supplemental) elements of the course. See list below for details. See separate Requirements Report for the reported scores at the time all requirements for the course were met.

- **Name:** lovemine jeannot (ID: 3187929)
- **Email:** tub50794@temple.edu
- **Institution Affiliation:** Temple University (ID: 926)
- **Phone:** 215-985-2090

- **Curriculum Group:** Human Research
- **Course Learner Group:** Social/Behavioral Research Course
- **Stage:** Stage 2 - Refresher Course
- **Description:** Choose this group to satisfy CITI training requirements for Investigators and staff involved primarily in Social/Behavioral Research with human subjects.

- **Report ID:** 15555853
- **Report Date:** 03/15/2015
- **Current Score**:** 100

REQUIRED, ELECTIVE, AND SUPPLEMENTAL MODULES	MOST RECENT	SCORE
SBE Refresher 1 – History and Ethical Principles	03/15/15	2/2 (100%)
SBE Refresher 1 – Federal Regulations for Protecting Research Subjects	03/15/15	2/2 (100%)
Temple University	03/15/15	No Quiz
SBE Refresher 1 – Informed Consent	03/15/15	2/2 (100%)
SBE Refresher 1 – Research with Prisoners	03/15/15	2/2 (100%)
SBE Refresher 1 – Research in Educational Settings	03/15/15	2/2 (100%)
SBE Refresher 1 – Instructions	03/15/15	No Quiz
SBE Refresher 1 – International Research	03/15/15	2/2 (100%)
SBE Refresher 1 – Defining Research with Human Subjects	03/15/15	2/2 (100%)
SBE Refresher 1 – Assessing Risk	03/15/15	2/2 (100%)
SBE Refresher 1 – Privacy and Confidentiality	03/15/15	2/2 (100%)
SBE Refresher 1 – Research with Children	03/15/15	2/2 (100%)

For this Report to be valid, the learner identified above must have had a valid affiliation with the CITI Program subscribing institution identified above or have been a paid Independent Learner.

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APPENDIX D

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March 10, 2015

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Attention: Permission, H-6F
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