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# What Gets Measured Gets Treated? A composite Measure of Child Malnutrition and its Determinants

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# What Gets Measured Gets Treated? A composite Measure of Child Malnutrition and its Determinants

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## Abstract

*Micronutrient deficiencies in children are a major health problem at a global level. There are various avenues for solving this multidimensional problem, but all require an accurate assessment of the level of the deficiency. In this study, we assessed the prevalence of four essential micronutrients deficiencies using defined cutoff values and determine an aggregate burden of malnutrition named as the Composite Index of Micronutrient Deficiencies (CIMND). We used the National Nutrient Survey 2011 from Pakistan (n = 7,173) to develop this new index. We also built a multinomial logistic regression model to express the probability of an infant falling into a particular category of CIMND as a function of various covariates. Concomitant deficiencies of three micronutrients have the highest percentage (38.6%) among all other levels of malnutrition. Children of rural households are less malnourished.Food security did not prove to be a strong predictor of child malnutrition while demographic and economic dependency showed negative associations with undernourishment.*

***Keywords:*** micronutrient deficiency; operationalization; stunting; wasting; underweight.



## 1. Introduction

Good nutrition is essential for human flourishing and to maintain a healthy lifestyle in all stages of life. Poor nutrition, especially in the early infancy stage, can result in irremediable physical and intellectual impairments that might constitute a crucial and long lasting effect on a child's mental and physical capabilities, his/her resistance power against diseases and earning capabilities as a adult (Bailey et al., 2015; Tolson et al., 2010). Adequate nutrition therefore is essential at the individual and societal level, as it avoids social costs associated with morbidity, disability and disease while also contributing to economic goals through a higher capacity to develop, innovate and accumulate (Koc et al., 2008). Despite its importance, however, it has been observed in various global studies that children suffer from a condition of micronutrient (vitamin and mineral) malnutrition; also known as 'hidden hunger' (Ghosh-Jerath et al., 2016). It seems that despite recent advances in science and policy of food systems during the last decades (Sahn, 2015), chronic malnutrition remains an important global problem. It is also a fact that there are inherent structural inequalities in food systems in some regions such as sub-Saharan Africa and Southeast Asia (Po et al., 2020; Otsuka, 2013) producing food insecurity (Rocha, 2007) and making them more vulnerable to malnutrition.

Although the current literature cites many reasons for nutritional deprivation including poverty, limited access to the healthcare system, economic inequalities, state policies and social practices etc. (Horak et al., 2015). However, operationalization of this complex and multidimensional construct in terms of measurement accuracy and construct validity is needed. By operationalization, we mean the translation of rather complex conceptual ideas of malnutrition into more concrete indicators that allow empirical observation and recording of results by assigning numerical values to these observations (Waltz, 2010). In this exercise one move from the abstract to the concrete by first grasping the whole concept intuitively and then identifying the various dimensions of its attributes or meaning in order to fully capture its essence (Lehane & Savage, 2013). If done correctly, operationalization can provide an accurate or truthful assessment of the various levels or degrees of the concept. This is necessary in the field of nutrition and health as the clinical, social and economic interventions required to tackle the problem vary with the degree of malnutrition (Wachs, 1995).

Despite the importance of this, existing measures do not capture the degrees of infant malnutrition. This study aims to overcome this shortcoming by measuring five separate categories of malnutrition using the developed Composite Index of Micronutrient Deficiency

(CIMND) which can provide a more nuanced understanding of malnutrition for researchers and practitioners. These categories range from no deficiency to profound deficiency in order to separate out the degree of nutritional deficiency in infants. Additionally, we have expanded the existing list of nutrients (vitamin A, iron) to include vitamin D and plasma zinc. This is in line with recommendations by health researchers to measure multiple micronutrient malnutrition (Ramakrishnan, 2002). We hope that interventions based on our categories of the Composite Index of Micronutrient Deficiency (CIMND) will be more suitable and optimal with the biggest bang for the buck.

The remainder of this paper is organized as follows. We will first present a review of existing measures of infant malnutrition to highlight the need of better operationalization. This will be followed by an explanation of our research context and the methodology we have used to create categories of malnutrition from a national survey. We will then turn to an explanation of our statistical analysis and will conclude the paper by drawing out some policy level implications.

## 2. Existing Measures of Children Malnutrition:

Chronic malnutrition (or stunting) in children remains an important global problem. This is evident from the estimate that there are around 170 million children who fail to grow due to lack of nutrition (Olofin et al., 2013). A consensus is also emerging among health researchers that the first 1,000 days of an infant's life are the most critical and malnutrition during this period can cause long-term damage (Black et al., 2013; Ruel et al., 2008). This is an important reason why we chose to study malnutrition in infants.

There are many studies which empirically illustrate that an infant can have multiple types of MNDs. For example, Herrador et al. (2014), studying Ethiopian children quantified that around 50% of them are suffering from one MND and around 20% have two or more coexisting nutrient deficiencies. However they did not explain correlations and the strength of relationships among the constructs of their study clearly. Globally, iron deficiency anemia and vitamin D deficiency is a common problem especially in infants. Jin et al. (2013) observed frequent adverse outcomes in children aged less than or equal to two years with iron deficiency and estimated that 67% of anemic infants are also deprived of vitamin D. Therefore it makes sense to measure the symptoms of vitamin D deficiency in infants while assessing MNDs. Nevertheless, many existing measures do not provide a satisfactory level of importance to this nutrient.

Similarly, zinc deficiency in children has been associated with dwarfism, hypogonadism and loss of appetite (Lee & Nieman, 2013). The literature suggests that zinc deficiency is prevalent estimate of 31% by Caulfield and Black, (2006) and presents a global health problem. Similarly, Hettiarachchi and Liyanage (2012) found lack of multiple micronutrients among Sri Lankan preschoolers such as vitamin D, iron, zinc and serum retinol while quantifying infant health risks. The burden of disease attributed to this particular deficiency is borne mostly by South-East Asian and African countries and existing evidence based on randomized controlled trials show that zinc deficiency is a significant contributor to the mortality and morbidity of infants (Caulfield & Black, 2006). Therefore, plasma zinc concentrations should also be an important part of a multiple MND measure.

After establishing the importance of zinc and vitamin D, let us turn our attention to how the existing studies of malnutrition are operationalized. The table below shows important aggregated measures of assessing malnutrition among preschoolers that are presently used in research. These measures strictly concerned with nutritional problems and don't take into account the other social and institutional linkages with hunger and malnutrition.

The above discussion also depicts that researchers have proposed multifaceted measuring approaches to deal with the complexity of nutrition problems. For example, the Hidden Hunger Index (HHI) is perhaps the best composite index to examine micronutrient deficiencies among the preschool aged children and provides an equal weight to iron, anemia, vitamin A and zinc deficiency (Ruel-Bergeron et al. 2008). However, it is not free from flaws as it only provides averages not the individual nutritional levels. Stunting prevalence is utilized as a proxy for zinc deficiency instead of actually measuring the lack of zinc in a child. This has negative implications for the index as stunting is attributable to multiple factors other than zinc which can be responsible for impaired linear growth. Moreover the HHI did not take into account the other vulnerable group; pregnant women (Muthayya et al., 2013).

**Table 1. A comparative analysis of the existing composite measures of malnutrition**

| A comparative analysis of the existing composite measures of malnutrition among infants | | | | | |
|---|---|---|---|---|---|
| **Authors and publication year** | **Publication outlet** | **Sample size, country & time period** | **Indicators for the Nutrition** | **Name of Measure** | **Citation count** |
| Ruel-Bergeron et al. (2008) | PLoS One | 138 countries 1995–2011 | iron amenable anemia, vitamin A & plasma zinc | Hidden Hunger Index (HHI) | 34 |
| Webb et al. (2015) | Food Security | 89 low and middle income countries 1993-2011 | Stunting, Anemia, Under Weight, Overweight, Exclusive Breastfeeding and Wasting | Net State of Nutrition Index (NeSNI) | 13 |
| Rosenbloom et al. (2008) | Food and Nutrition Bulletin | 192 countries, 2005 | disability-adjusted life years, Obesity and Food security, | A Global Nutritional Index (GNI) | 18 |
| Wiesmann (2006) | IFPRI | 118 countries, 1981-2003 | Stunting, wasting, child mortality, dietary calorie intake, | Global Hunger Index (GHI) | 75 |
| Nandy et al. (2005) | Bulletin of the World Health Organization | 24396 children age (0-3)years, India | Stunting, Wasting, Underweight | Composite Index of Anthropometric Failure (CIAF) | 411 |
| Wiesmann, et al. (2000) | ZEF–Discussion Papers on Development Policy, (26). | 106 countries (1997- 1998) | dietary energy intake, Underweight, and mortality rate, | International Nutrition Index | 24 |

Net State of Nutrition Index (NeSNI) is based on the multidimensional nature of malnutrition and it allows for measuring time based changes in multiple deficiencies simultaneously (Webb et al., 2015). However, the underweight category it uses cannot demarcate between the categories of malnutrition such as acute and chronic. It also cannot identify those infants who are wasted and/or stunted which leads to a problem of underestimation.

The Global Nutritional Index (GNI) is a contemporary approach modeled on the Human Development Index and provides a single number for the overall nutrition level of each country (Rosenbloom, 2008). It provides information about undernourishment, obesity and micronutrient deficiency which makes it unique since it measures, at a global level, not only deficiency but also excess. GNI is a step in the right direction since it is a composite index but there are problems in the measurement of its elements. GNI does not actually estimate deficiencies from food consumption but it models estimates of disability losses from macroeconomic data which do not provide adequate information about the micronutrients included in the estimate.

Similarly, Global Hunger Index (GHI) is extensively used as a multidimensional measure to comprehensively track hunger at a global level. This index, developed by International Food Policy Research Institute, is an equal combination of three separate indicators of hunger including: (a) undernourishment (insufficient caloric intake); (b) child underweight; and (c) child mortality. The first indicator is of direct relevance to our study since it represents deficiencies in protein, energy, essential vitamins and minerals. Secondly, food security measurement based upon the FAO methodology for evaluating the prevalence of food deprivation and undernourishment, is widely criticized (de Haen et al., 2011) on the grounds of database uncertainties and gaps. Finally, the use of arithmetic averages is not recommended in such an index without providing suitable weights since there are large variations in the indicators (Aiga, 2015; Nigam, 2019).

Lastly, the Composite Index of Anthropometric Failure (CIAF) is also an aggregated measure of anthropometric (measurement of physical properties) data Nandy and Svedberg (2012) which shows an overall extent of malnutrition in children. It consists of six subgroups that are combinations of stunting, underweight, wasting or normal Nandy et al. (2005) and its output is a single number which shows the total of children having micronutrient deficiencies. However, this classification has been problematized since it does not improve the existing Waterlow classification Bhattacharyya (2006), clinical correlation is not possible and also because it is unable to estimate the severity of undernourishment as it doesn't include micronutrient malnutrition (Boregowda et. al., 2015). Relying only on anthropometric data hides the complete story of starvation and economic vulnerabilities.

Seemingly all the above indicators have some advantages. They are easy to estimate on the readily available secondary data and guide policy makers about the issues of malnutrition and hunger. Nevertheless, as we have shown in the discussion above, all the existing operationalizations are not without their own problems. This clearly establishes that there is a need to develop a better measure and the composite index of micronutrient deficiencies developed in this study employs a novel approach that provides a more comprehensive picture of malnutrition with mutually exclusive categories. It includes those vitamins and minerals that have crucial role in neurologic functioning Villagomez and Ramtekkar (2014) adequate bone growth, digestion, sex hormone development, and a strong immune system (Viteri & Gonzalez, 2002). Additionally if children are deficient in these essential items, stunting, wasting and even child mortality might result (Caulfield et al., 2006).

This research study aims to improve the operationalization of MND measures by attempting to account for most of the problems that we have mentioned in this section. However, before we go into the technical details of our operationalization, it is important to know the context in which we conducted our research.

## 3. Research Context and Methodology

According to UNICEF, the under-five mortality rate in Pakistan is 69 per 1,000 births. This is an alarming situation caused mainly by malnutrition, spread of diseases such as diarrhea and pneumonia and lack of access to drinking water, healthcare facilities and sanitation (Spielman et al., 2016). This is also echoed by the World Food Program which estimates that 98% Pakistani infants have at least one nutrient inadequacy (Ghani, 2018). Deficiencies of vitamin A, D, iron, and plasma zinc are common among all, in preschoolers that pose the utmost public health concern because of their high pervasiveness (Harding et al, 2018; Hussain et al. 2013). This data indicates that Pakistan represents a case of extremely high child malnutrition and can be used to develop a range of categories of MND.

Pakistan is one of the signatory of the Sustainable Development Goals which seek to improve health of a population and also reduce poverty and hunger of not only infants but also their mothers (Hawkes & Popkin, 2015). Their target is to end all forms of malnutrition by 2030 (zero hunger), attaining the internationally agreed targets on stunting (low height for a given age) and wasting (low weight for a given height) in preschoolers, by 2030. The interventions in Pakistan by international organizations to achieve these goals might work in its favor but the current improvement in indicators is minimal. Annually, Pakistan is at loss of 3% of its total GDP as an economic consequence of malnutrition, which amounts to around $7.6 billion, as recognized by National Nutrition Survey of Pakistan (NNS) 2011. The link between MNDs and socioeconomics of Pakistan has been studied by scholars with various methodologies and datasets (Ali, 2020; Ali & Shah, 2020; Arif et al., 2012; Khuwaja et al., 2005) but overall these studies converge on the high incidence of MNDs in Pakistani infants.

NNS is a detailed survey and it can help us find out the repercussions of micronutrient deficiencies in children and the problems associated with variety of diets. Therefore, we used NNS 2011 as our secondary data source for analysis.

NNS 2011 is the most recent nutritional survey conducted by the Planning Commission (Nutrition wing) of Pakistan. Although many current data sets are available for malnutrition in Pakistan, like the Demographic and Health Survey (DHS), the levels of key minerals and vitamins for children estimated by clinical examination of blood report is only included in NNS 2011. For example, DHS 2018 for Pakistan only includes information about anthropometric indicators such as stunting, wasting and underweight. Despite the fact that UNICEF published a report on health key indicators including micronutrient deficiencies on the basis of the data collected in 2018 termed as NNS 2018, their final report has still to be approved by the Planning Commission. A brief initial report by UNICEF on the basis of NNS

2018 only includes percentages about nutrient inadequacies and is not sufficient for a detailed statistical analysis.

The sample size of NNS 2011 is composed of 7,173 infants of 30,000 households covering four provinces and two autonomous territories along with both urban and rural settings. This study is based upon the clinical examination of blood tests for four essential nutrients; vitamin A, D, iron and zinc. Overall the data tells us that, at an aggregate level, around 50% of adult women have anemic problems, 48% have zinc deficiency, 43% have vitamin A deficiency, and 69% have vitamin D deficiency. These MNDs of mothers is also reflected in infants as 54% have vitamin A deficiency, 39% have zinc deficiency and 62% are deficient in iron. The survey also depicts the alarming level of stunting in Pakistan (44%) while 15% are wasted and 32% are under-weight.

Our methodological approach consists of zooming in on this data through several interrelated steps, given below.

1- The construction of a composite index of micronutrient deficiency which represents our main contribution to a better operationalization of MNDs.

2- We coded the explanatory variables from this survey

3- We applied multinomial logit model to test the relationship of different categories of our index with these explanatory variables.

**Operationalization of the Composite Index of Micronutrient Deficiencies:**

CIMND that we developed in this study is based on the potentially simultaneous existence of four micronutrients (vitamin D, vitamin A, iron, plasma zinc) which are essential for the early growth of infants. We then cross examined the data to determine which of these micronutrients are deficient in each infant. This was determined to know the possibility that a child might need multiple micronutrients simultaneously. Such a situation is only analyzable through the use of a composite index with mutually exclusive categories.

There are five categories of CIMND. These are as follows:

**Table.2 Categories of Composite Index of Micronutrient Deficiencies**

| **Coding scheme of dependent variable** | | |
|---|---|---|
| **Category Level** | **Category Meaning** | **Category Explanation** |
| 0 | No deficiency | All four micronutrients are sufficiently present in the child |
| 1 | Mild deficiency | The child is deficient in any one of the four micronutrients |
| 2 | Moderate deficiency | The child is deficient in any two of the four micronutrients |
| 3 | Severe deficiency | The child is deficient in any three of the four micronutrients |
| 4 | Profound deficiency | The child is deficient in all four micronutrients |

We applied the above categories to NNS 2011 data with the following result.

It is alarming to note the results as 26% of the infant population of NNS 2011 are suffering from profound deficiencies. Moderate deficiency level has the highest percentage (38.6%) among all categories. In an ideal situation, the highest percentage should fall in the no deficiency level.

Thus CIMND provides a platform to policy makers and health administrators, seeking to consolidate international standards in health and nutrition, to work on every modifiable agent for effective nutrition interventions and control of malnutrition among children under five years of age. The study has assured that policies based on CIMND will reduce the burden of malnutrition.

**Table.3 Child Malnutrition as estimated by CIMND and its categories**

| **Concomitant prevalence of malnutrition among infants** | | |
|---|---|---|
| **Deficiency levels** | **Frequency** | **Percentage** |
| **No Deficiency** | 499 | 7.0 |
| **Mild Deficiency** | **Frequency** | **Percentage** |
| Deficient(Vitamin D) | 384 | 5.4 |
| Deficient (Vitamin A) | 782 | 10.9 |
| Deficient(Iron) | 390 | 5.4 |
| Deficient (Plasma Zinc) | 456 | 6.4 |
| Sub-total | 2,012 | 28.0 |
| **Moderate Deficiency** | **Frequency** | **Percentage** |
| Vitamin A +Vitamin D | 510 | 7.1 |
| Vitamin A + Iron | 534 | 7.4 |
| Vitamin A + Plasma Zinc | 746 | 10.4 |
| Vitamin D + Iron | 318 | 4.4 |
| Plasma Zinc + Iron | 323 | 4.5 |
| Vitamin D + Plasma Zinc | 338 | 4.7 |
| Sub-total | 2,769 | 38.6 |
| **Severe deficiency levels** | **Frequency** | **Percentage** |
| Vitamin A + Vitamin D + Iron | 366 | 5.1 |
| Vitamin A + Vitamin D + Zinc | 418 | 5.8 |
| Vitamin A + Iron + Zinc | 529 | 7.4 |
| Vitamin D + Zinc + Iron | 249 | 3.5 |
| Sub-total | 1,562 | 21.8 |
| **Profound deficiency** | 331 | 4.6 |
| Total | 1,893 | 26.4 |
| **Total Sample** | **7,173** | **100** |

In the next section of the paper, we will describe the independent/explanatory variables and their coding plan in order for us to build a statistical model to explain the variation of CIMND.

**Table. 4 A portrayal of the Explanatory Variables used in the analysis**

| **Coding scheme of explanatory variables** | | |
|---|---|---|
| **Variables** | **Description** | **Categories** |
| Region | 1 for Urban and 2 for Rural | Same for Analysis |
| Family size | 1=2-4 members<br>2=5-6 members<br>3=7-8 members<br>4=above 8 | 1= smaller Families<br>2 = medium sized Families<br>3 = larger Families<br>4 =overcrowded Families |
| Gender of the infants | 1 for Boy & 2 for Girl | Same for Analysis |
| Number of siblings (< 5 years) | 1=1<br>2=2<br>3=above 2 | 1= no sibling(alone)<br>2 = only one sibling<br>3 = 2 or more |
| Gender of the household head | 1 for female & 2 for male | Same for Analysis |
| Demographic dependency ratio | $\frac{\sum_{i=1}^{n} Dep(X_i)}{\sum_{i=1}^{n} Sup(X_i)}$<br>Dependents=below 15 +Over 64<br>Sup(Independents=15-65 | 1= Up to 50 % dependency<br>2= Above 50 & up to 100 %<br>3= above 100 % and less than 200<br>4= 200 and above 200 |

| | | |
|---|---|---|
| Economic dependency ratio | $\dfrac{\sum_{i=1}^{n} Dep(X_i)}{\sum_{i=1}^{n} Sup(X_i)}$ | 1 =0-0.9(Employed>Unemployed)<br>2 =1 (E=U)<br>3 =more than 1(E<U) |
| Wealth Status of the households | Asset based index computed by employing PCA | 1 for richest,<br>2 for richer,<br>3 for Mediocre,<br>4 for poorer<br>5 for poorest |
| Food security position of the households with children | Calculated by 18-item "core module" set of indicators as recommended by (USDA, 2000) | 0 = food secure<br>1 =food insecure without hunger<br>2 =food insecure with hunger<br>3 =for food insecure with severe hunger |
| Age in months | 1=6-12<br>2=13-24<br>3=25-36<br>4=37-48<br>5=49-60 | Same for Analysis |

## Statistical Analysis

NNS 2011 for Pakistan was launched by the collaboration of UNICEF, Health Ministry of Pakistan and Division of women and child health of Agha khan University. 12,139 children under the age of five were selected for blood examination, belonging to 30,000 households. Further 9,641 children's clinical examination report was available incorporating non response and error rate. However, some values are missing in the survey owing to insufficient blood quantity and contaminated and hemolyzed blood. After adjusting for the missing data and equalizing the sample values to construct the composite index, we are left with 7,216 study subjects. Moreover as Federally Administered Tribal Area (FATA) sample showed zero correlations with respect to one of the category of CIMND, it was excluded from the targeted sample. This left us with a sample size of 7,173 children less than five years of age.

First, we present the demographic and socioeconomic characteristics of the families and the infants in the table below.

**Table. 5 Univaraite Analysis of the factors associated with the micronutrient sufficiency of the infants**

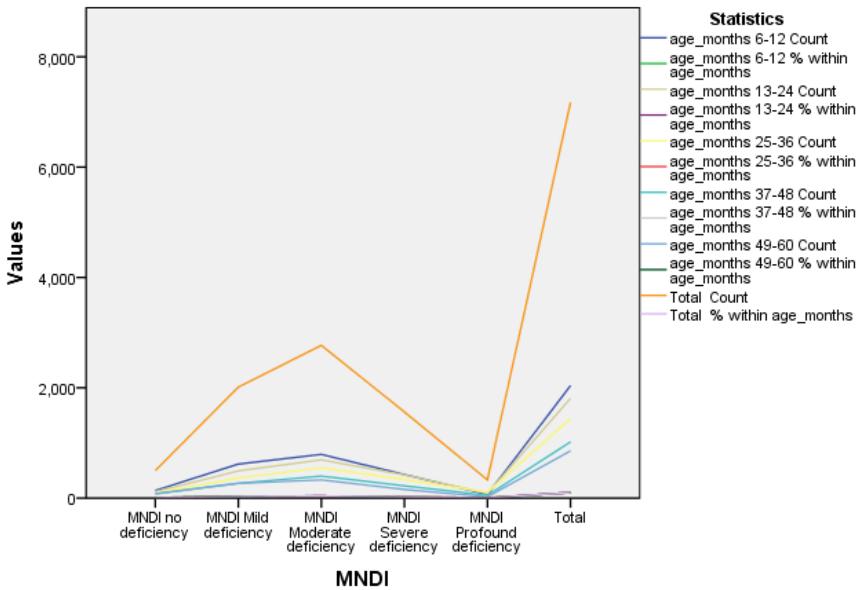
| **Univaraite analysis of the explanatory variables** | | |
|---|---|---|
| **Socioeconomic & demographic characteristics of the Households** | **N** | **Percent of the total** |
| Region | | |
| Urban | 2,765 | 38.5 |
| Rural | 4,408 | 61.5 |
| Family size | | |
| 2-4 members(smaller) | 1,263 | 17.6 |
| 5-6 members(medium size) | 2,225 | 31.0 |
| 7-8 members(large) | 1,850 | 25.8 |
| Above8 members(overcrowded) | 1,835 | 25.6 |
| Gender of the Infants | | |
| Boy | 3679 | 51.3 |
| Girl | 3,494 | 48.7 |
| Age in Months | | |
| 6-12 | 2,040 | 28.4 |
| 13-24 | 1,809 | 25.2 |
| 25-36 | 1,446 | 20.2 |

| | | |
|---|---|---|
| 37-48 | 1,020 | 14.2 |
| 49-59 | 858 | 12.0 |
| Number of Siblings(<5 years) | | |
| No Sibling | 3,612 | 50.4 |
| 1 | 2,698 | 37.6 |
| 2 & above | 863 | 12 |
| Gender of the Household Head | | |
| Female | 182 | 2.5 |
| Male | 6,991 | 97.5 |
| Demographic dependency Ratio | | |
| Up to 50% Dependency | 1,376 | 19.2 |
| Up to 100% | 2,135 | 29.8 |
| Above 100 - below 200% | 1,666 | 23.2 |
| Above 200 % | 1,996 | 27.8 |
| Economic Dependency Ratio | | |
| Up to 90 % | 1,100 | 15.3 |
| Above 90 to 100% | 4,073 | 56.8 |
| Above 100% | 2,000 | 27.9 |
| Wealth index | | |
| Poorest | 1,320 | 18.4 |
| Poor | 1,696 | 23.6 |
| Mediocre | 891 | 12.4 |
| Richer | 3,111 | 43.4 |
| Richest | 155 | 2.2 |
| Food Security Index | | |
| Food Secure | 2,898 | 40.4 |
| Food Insecure without Hunger | 1,838 | 25.6 |
| Food Insecure with Hunger | 1,569 | 21.9 |
| Food Insecure with severe Hunger | 868 | 12.1 |

The descriptive analysis informs us that there are more rural households as compared to their urban counterparts. The number of medium sized families is greater than all other categories because the study is analyzing the characteristics of the households with infants that's why it is normal and expected. There are more boys under five years of age as compared to girls. Most of infants lie in the limits of below one and equal to one year. Almost half of the offspring are a single infant in their family to feed. Most of them are up to three years old and most are boys. A great number of the families are headed by a male. The highest category of the dependency ratio is up to 100%. It means that an equal number of dependents and independents carry a greater percentage in the household. We also computed the economic dependency ratio due to the fact that only having more people in the working age group doesn't constitute the actual working force in the population. The one to one ratio of unemployed and employed persons has the highest frequency. Only 15% families have more employed members as compared to unemployed. This is an indication of lack of economic opportunities. Nearly 57% of the households are above the poverty line. Most of the mothers are living with their families. The most inauspicious report is that 60% of the households with children are food insecure, not having enough amount of the food for their wellbeing.

The graph below represents a simple cross-tabulation between the 5 categories of MNDs and the age of children.

**Figure 1. Crosstabulation between Micronutrient Deficiency status of infants with their age in months**




The sudden rise of deficiencies that we observe in the above graph is due to the behavioral change in feeding patterns that occur within the first five years of the child's life. The decline in breastfeeding is accompanied by a rise of malnutrition as the child could not receive appropriate semi-solid, solid or soft foods in the diet.

## Multinomial Logistic Regression Analysis

Since the micronutrient deficiency index is a nominal variable with five levels, we employed multinomial logistic regression model (Anderson & Rutkowski, 2008). Because having an outcome variable in categorical form violates the assumption of linearity in simple regression model. Logistic regression allows us to model a nonlinear association in a linear way by applying a logarithmic transformation on the dependent variable (Zeigler-Hill, 2017). The linear regression equation in logarithmic form, termed as logit can be expressed as

$$\text{Logit(p)}=\log\left(\frac{p(y=1)}{1-(p=1)}\right) = \beta0 + \beta1Xi2 + \beta2Xi2 + \ldots\ldots\ldots\ldots + \beta pXin$$

Where $i$= 1,2,3…..n

The probability of micronutrient deficiency can be calculated as

$$P_r(Micronutrient\ Deficiency = j) = \frac{e^{z_i}}{1+e^{-z_i}}$$

Where j =1,2,3

We included some possible covariates such as wealth status of the household, food status, family size, region, economic dependency ratio and many other variables. The model with possible covairaites can be written as

$$Z_i = \beta_0 + \beta_1 POR + \beta_2 FSH + \beta_3 DRH + \beta_4 EDRH + \beta_5 GHH + \beta_6 WSH + \beta_7 FSSH + \beta_8 CG + \beta_9 NOS + \beta_{10} CAM$$

Where
POR= Place of Residence
FSH= Family size of the household
DRH= Dependency ratio in the household
EDRH= Economic dependency ratio of the household
GHH= Gender of the Household Head
WSH= Wealth Status of the Household
FSSH= Food Security Status of the Household
CG=Child gender
NOS=number of siblings (under five years of age)

CAM=child age in months

The goal is to model the odds of an infant falling into a particular category of CIMND as a function of the covariates and to express the results in terms of an odds ratio. We used SPSS version 20 for building this model. The results are shown in table 6

## 4. Discussion and Interpretation of Results

The main assumption of multiple logistic regression model, i.e. interaction among the explanatory variables and the problem of multicollinearity need to be checked before analysis. As we had a large sample size while the total number of variables used in the model is relatively small, we relied on the Hosmer-Lemeshow statistic (Rossi, 2010) to check the overall goodness of fit of the model. Since the p-value was greater than α (95%), the model was a good fit to the data and we could proceed with the analysis. We used the odds ratio to estimate the strength of relationship between dependent and independent variables and their significance. Non deprivation among infants is the reference category.

**Wealth Status of the family:**

According to a report from UNICEF (2010), the wealth and economic status of a family is an indicator of access to sufficient food supplies, health services and other facilities essential for the overall wellbeing of the family. Therefore, belonging to lower income strata of society is an underlying cause of infant malnutrition. Various studies consistently demonstrate that wealth status of the family is negatively related to nutritional and health levels of children (Busse et al., 2016; Pongou et al., 2006; Hong & Mishra, 2006).

**Table 6. Results of Multivariable Logit model sho wing the association of Infants malnutrition with their potential cofounders**

| Results of the multivariate analysis | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Independent Variables** | **Very Low MND** | | **Moderate MND** | | **Severe MND** | | **Profound MND** | |
| | **Coeff.** | **Odd ratio** | **Coeff.** | **Odd ratio** | **Coeff.** | **Odd ratio** | **Coeff** | **Odds ratio** |
| **Intercept** | 1.730 | | 1.950 | | .885 | | 2.736 | |
| **Wealth Status of the Households** | | | | | | | | |
| Richest | .265 | 1.303 | .158 | 1.171 | .138 | 1.148 | -.148 | .862 |
| Richer | -.027 | .974 | .040 | 1.041 | -.003 | .997 | .275 | 1.316 |
| Mediocre | -.003 | .997 | .070 | 1.073 | .102 | 1.108 | .377 | 1.458 |
| Poorer | .252 | 1.287 | .218 | 1.244 | .045 | 1.046 | .013 | 1.013 |
| Poorest | $0^b$ | . | $0^b$ | . | $0^b$ | . | $0^b$ | . |
| **Food status of the Households with Children** | | | | | | | | |
| Food secure | .164 | 1.178 | .255 | 1.290 | .133 | 1.142 | .385 | 1.470 |
| Food insecure without Hunger | .038 | 1.039 | .020 | 1.020 | -.131 | .877 | .138 | 1.148 |
| Food insecure with Hunger | .120 | 1.128 | .179 | 1.196 | .176 | 1.192 | .342 | 1.408 |
| Food insecure with severe Hunger | $0^b$ | . | $0^b$ | . | $0^b$ | . | $0^b$ | . |
| **Family Size** | | | | | | | | |
| Small Families | .170 | 1.186 | .143 | 1.154 | .155 | 1.168 | -.130 | .879 |
| Medium sized | .006 | 1.006 | -.093 | .911 | .071 | 1.073 | -.096 | .909 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Larger Families | -.204 | .815 | -.174 | .840 | -.160 | .852 | -.165 | .848 |
| Over-croweded | 0[b] | . | 0[b] | . | 0[b] | . | 0[b] | . |
| **Region** | | | | | | | | |
| Urban | .215 | 1.240 | .040 | 1.041 | .212 | 1.237 | .162 | 1.176 |
| Rural | 0[b] | . | 0[b] | . | 0[b] | . | 0[b] | . |
| **Gender of the Household Head** | | | | | | | | |
| Female | -.705 | .494 | -.614 | .541 | -1.08 | .338 | -.801 | .449 |
| Male | 0[b] | . | 0[b] | . | 0[b] | . | 0[b] | . |
| **Number of the Siblings(<5)** | | | | | | | | |
| No sibling | -.025 | .975 | -.019 | .981 | -.080 | .923 | .284 | 1.328 |
| One sibling | .053 | 1.055 | .077 | 1.080 | .031 | 1.032 | .235 | 1.264 |
| 2 & above | 0[b] | . | 0[b] | . | 0[b] | . | 0[b] | . |
| **Gender of the Infants** | | | | | | | | |
| Boy | .094 | 1.099 | .011 | 1.012 | .217 | 1.243 | -.149 | .861 |
| Girl | 0[b] | . | 0[b] | . | 0[b] | . | 0[b] | . |
| **Age in Months** | | | | | | | | |
| 6-12 | .064 | 1.066 | .080 | 1.083 | .159 | 1.173 | .288 | 1.334 |
| 13-24 | .263 | 1.301 | .366 | 1.442 | .588 | 1.801 | 1.029 | 2.799 |
| 25-36 | .124 | 1.132 | .301 | 1.352 | .513 | 1.671 | 1.288 | 3.627 |
| 37-48 | -.060 | .941 | .069 | 1.072 | .220 | 1.246 | .694 | 2.002 |
| 49-59 | 0[b] | . | 0[b] | . | 0[b] | . | 0[b] | . |
| **Dependency Ratio** | | | | | | | | |
| Up to 50% | -.421 | .656 | -.254 | .776 | -.254 | .776 | .063 | 1.065 |
| 51 to 100% | -.250 | .779 | -.200 | .819 | -.219 | .803 | .025 | 1.025 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 101–less than 200 % | -.067 | .935 | -.057 | .945 | .048 | 1.049 | .015 | 1.015 |
| 200 & above | 0[b] | . | 0[b] | . | 0[b] | . | 0[b] | . |
| **Economic Dependency Ratio** | | | | | | | | |
| E>U | .226 | 1.253 | .239 | 1.270 | .124 | 1.132 | -.195 | .823 |
| E=U | -.180 | .835 | -.053 | .949 | -.213 | .808 | .056 | 1.058 |
| E<U | 0[b] | . | 0[b] | . | 0[b] | . | 0[b] | . |

However, our study has mixed results. The findings reveal that as compared to children from poorest households, children from medium and richer households are 0.99 and 0.97 times more likely to escape from having low level of nutrient deficiency. Likewise the infants from poor families are 1.28 times more likely to have one nutrient deficiency. On the other hand, the richest households' category is not associated with under nutrition of infants. The results of double burden of deficiency are also not consistent with the existing literature. Probably this is the reason why some researchers did not find any consistent association between the household wealth and child nutrition and argued that this relationship is not conclusive (Larrea & Kawachi, 2005).

In case of medium level of deficiency, infants from richer households are 0.9 times more likely to not having three micronutrient deficiencies. Contrary to this, other categories did not show a negative relationship with child malnutrition. Furthermore with respect to highly deficient infants, richest family's children are 0.86 times less likely to have acute level of malnutrition.

**Food security status of the households:**

The effects of food security on child malnutrition are pervasive. Although food security is a prerequisite for nutrient adequacy, it is not sufficient to assure optimum nutritional balance. Malnutrition in children might be the result of inadequate diet, lack of health care services and an unhealthy environment that leads to improper utilization and poor absorption of consumed nutrients (Thomas et al., 2014). Food insecurity position of the family is significantly and positively related with all categories of malnutrition of infants. The children belonging to food insecure families are 1.12 times more likely to be deficient of one nutrient. However children of food secure households did not show significant association with nutrient deficiency. If two nutrient deficiencies were present, children of food insecure with hunger and food insecure families are 1.19 and 1.02 times respectively, more chances to be deficient. Moreover, children of food insecure with hunger families, have 1.19 more chances to have any three nutrient deficiencies. Now in case of such type of deficiency, kids belonging to food insecure families are inversely related with under-nutrition.

Similarly, infants who of food insecure families with hunger and food insecure families have 1.40 and 1.14 times more probability to have severe deficiency of essential nutrients. These outcomes are consistent with preceding studies and confirm that food insecurity is significantly correlated with child malnutrition (Saaka & Osman, 2013; Betebo et al., 2017) but not with the generalized level of nutrition (Weigel et al., 2016).

**Family size of the households:**

The findings of current study show that as compared to the reference category, infants residing in large families are 81% more inclined to have at least one nutrient deficiency. All other categories are not negatively related to malnutrition. Same is the case of severe category of malnutrition. However infants living in medium sized and large families are more likely to have double burden of nutrient deficiencies. Conversely the children residing in small, medium and large families all have 0.87, 0.90 and 0.84 more chances, respectively to face a severe level of nutrient deficiency. Souganidis et al. (2012) verified that higher odds of nutrient inadequacy are associated with the children living in families, having more than four members eating from the same kitchen.

**Region:**

It is found almost within all the categories of malnutrition that rural children are more deficient as compared to their urban counterparts. Rural children live with impoverished conditions and in an area with inadequate health infrastructure (Petry et. al., 2019; Herrador et. al., 2014). In a similar vein, Laxmaiah et al. (2013) conducted a community-based survey in India and found out that micronutrient deficiency is a chronic problem in the rural areas and its incidence is higher in marginalized communities, illiterate parents as well as those areas where sanitary latrines are not available.

**Gender of the household head:**

The analysis of this variable shows that, as compared to the reference category (level 0), children of females who were head of their household are 50% less likely to have nutrient deficiency. This is true for all the categories of malnutrition from mild to profound. The children of female headed families have 54% more chances to be saved from the dual burden of nutrient inadequacy. This is the highest percentage among all the categories. Globally, it is generally accepted that being a female head of the family invariably enhances likelihood of living in poverty (Darnton-Hill et al., 2005). However other researchers are of the view that it does not necessarily mean that they have inadequate supplies of food and hence suffering from micronutrient malnutrition (Lemke et al., 2003; Rogers, 1996). Our study shows that even with low income mothers as head, child nutritional status is better as affluent members of society makes up for the shortfall in food owing to voluntary almsgiving and philanthropy. Another reason might be that mothers understand the nutritional needs of their children much better than fathers and it is beneficial for a child if they are the decision makers of their dietary habits.

**Number of siblings under five years of age:**

The evaluation of odds ratios divulged that as compared to children from the households having two or more kids, those with only two kids are 1.05 times more likely to have low malnutrition level. It is anticipated that parents are not as attentive, if they have more children at home (Jeyaseelan, 1997). Hence, family characteristics matter. However, having a single infant in the household have negative and strong relationship with first degree malnutrition. The estimations about second degree and third category of nutrient deficiency also have similar outcomes. While, in case of highly deficient infants, if the child have no sibling or have one sibling at home, it will amplify his risk of being severely deficient (Souganidis et al., 2012).

**Gender of the Infants:**

The analyses presented that as compared to the reference category (female), male infants are more likely to have low, moderate and mild level of nutrient deficiencies. These findings are consistent with the previous literature. For example, scholars have found out that iron deficiency is higher in boys as compared to girls (Petry et al., 2019; Wirth et al., 2018; Gebreegziabiher et al., 2014). Similarly, a study on Ethiopian children confirms that there are higher chances of vitamin D deficiency in baby boys (Herrador et al., 2014). The manifestation of vitamin A deficiency is also in higher proportion among boys (Laxmaiah et al., 2013). Merely, in case of acute level of undernutrition, the findings are in favor of being a baby boy. A male child is 86% less likely to have burden of multiple nutrient deficiencies.

## Age in months:

Findings from the current study advocate that the children whose age is between 37 to 48 months are negatively related to the first category of nutrient deficiency. All the other categories showed direct relationship between child age and nutrient deficiency. Probably they are more inclined to have nutrient insufficiency. Similarly all the categories of age with respect to all categories of the dependent variable, have confirmed that as compared to the reference category, the decrease in age leads to decrease in micronutrient malnutrition.

Children greater than six months old are more at the risk of nutrient deficiencies because now there is a need to start adding some healthy snack with breast feed to fulfill the growing child requirement of essential nutrients (Ntila et al., 2017). There is a need to shift diet from exclusive beast feeding to semi-solid or solid food normally covers the period from 6 - 23 months of age. Some studies observed this dramatic change in kids above 23 months (Gebreegziabiher et al., 2014; Onyemaobi & Onimawo, 2011). Some scholars are of the view that the infants younger than two years have more iron deficiency as compared to other age groups (Kounnavong et al., 2011; Tengco et al., 2008). This might be attributable to high iron requirement due to growth velocity and low availability of iron rich foods. Similarly, Cuadrado-Soto et al. (2019) estimated zinc manifestation as higher in younger as compared to older preschoolers.

## Dependency Ratio:

The infancy developmental milestones are within standard limits, though they are delayed in. If the children belong to a family where dependency ratio is above 100%, up to 100% and up to 50% as compared to the reference category representing severe level of dependency in the family, then the child have 1.01, 1.02, 1.06 times more capability of avoiding severe and fourth category of nutrient deficiency. Akbar (2020) also confirmed the same results that the children of a household are more likely to be undernourished in case of having more dependents in the family. Whereas with respect to medium level of deficiency, the children only belonging to the families having less dependency, as compared to reference category, can avoid third degree malnutrition level (Titus & Adetokunbo, 2007). All the other categories do not have any robust relationship.

There can be different effects of family size and structure. Now what generally matters is the dependency ratio. Though large families comprised of more working age group then having more economies of scale in purchases can increase the wellbeing of their younger members. Child health and nutritional position will be better in this group. Conversely small families having more dependents will vie for food and other resources and hence tagged as vulnerable.

**Economic dependency Ratio:**

Less is known regarding the association between economic dependency and the micronutrient status of children in the existing literature. Our results imply that as compared to more unemployed members in the family, if the employed and unemployed members are equal in the household then their children are at a lower risk of carrying first, second and third category levels of malnutrition. However the results are not satisfactory with more employed individuals in the household. Conversely, the infants of families with more employed members are 82% less likely to be in the zone of severe deficiency of vitamins and minerals (fourth category). Therefore the results justify the thesis that economic burden is a crucial factor in determining severe, mild and moderate malnutrition (Tegegne et al., 2017; Soofi et al., 2017).

## 5. Conclusion

This study evaluated nutritional status of preschoolers in Pakistan by taking the data form National nutrition survey of 2011. Nutritional status has been examined on the basis of biochemical assessment of certain essential micronutrients. A composite index of micronutrient deficiencies has been constructed for children, to verify the amalgam of malnutrition. Moreover the associations between CIMND and underlying demographic and socioeconomic confounders have also been checked by applying multinomial logit model.

It is evident from the measurement of child malnutrition by CIMND that Pakistani children are suffering from concomitant prevalence of multiple micronutrients. Among those deficiencies, two micronutrient inadequacies are the highest; 38.6%. In case of individual estimated percentages, vitamin A, as a single nutrient deficiency and combined deficiency of vitamin A and zinc, is the highest among all. The results of the multinomial logit model indicates that wealth status of the households, number of family members in a household, and female headed households having infants are inversely related with low as well as profound level of nutrient deficiencies. Infants having no sibling are more nutrition secure but not in case of extreme existence of malnutrition. Households with lower age dependency ratios have less malnourished children. However it's not true in case of profound level of malnutrition. Likewise families with more employed members are inversely related with child malnutrition. Children of all ages are correlated with micronutrient deficiencies. However food security of households with children has no influence on nutrient inadequacy.

Child malnutrition is endemic and demands serious attention from the government of Pakistan. A multidimensional and multi-sectoral approach is needed to address the complexity of nutrition problems, and their link with socioeconomic and familial risk factors to design and plan nutritional interventions. Developmental and poverty reduction programs should be integrated to target the disadvantageous rural segments and urban slum areas. These programs target pregnant women and infants in their first 1,000 days and try to make up for the deficiency of all four micronutrients. Exclusive breast feeding should be ensured at initial infancy stage and the later stages should be characterized with partial breast feeding with proper complementary diet. Food-based interventions such as food fortification programs, food provisions and gross expansion in the caloric intake per capita is also recommended as a long term strategy to combat child micronutrients malnutrition since there is still a window of opportunity for the improvement of infant nutritional status and correcting unhealthy nutritional practices in Pakistan.

Overall, although measurement is an important part of the equation, the real challenge extends beyond measurement as we need a strong political will and normative prioritization in government policy while dealing with this issue.

| | |
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