



**SOCIAL AND ECONOMIC
CHANGE MONOGRAPHS 3**

**PREVALENCE OF IRON
DEFICIENCY ANAEMIA AND
MALNUTRITION IN INDIA**

DR. RAAKRISHNA REDDY

M.D., M.P.S.

**INSTITUTE FOR SOCIAL AND ECONOMIC CHANGE
BANGALORE**

2004

SOCIAL AND ECONOMIC CHANGE MONOGRAPH SERIES

Number 3

January 2004

Series Editor : G. K. KARANTH

© 2004, Copyright Reserved
The Institute for Social and Economic Change
Bangalore

Institute for Social and Economic Change (ISEC) is engaged in interdisciplinary research in analytical and applied areas of social sciences, encompassing diverse aspects of change and development. ISEC works with central, state and local governments as well as international agencies by undertaking systematic studies of resource potential, identifying factors influencing growth and examining measures for reducing poverty. The thrust areas of research include state and local economic policies, issues relating to sociological and demographic transition, environmental issues and fiscal, administrative and political decentralization and governance. It pursues fruitful contacts with other institutions and scholars devoted to social science research through collaborative research programmes, seminars, etc.

The Social and Economic Change Monograph Series provide an opportunity for ISEC faculty, visiting fellows and PhD scholars to disseminate their ideas and research work. Monographs in the series present empirical analyses and generally deal with wider issues of public policy at a sectoral, regional or national level.

Publication of this Monograph has been made possible through the generous support of Sir Ratan Tata Deferred Endowment Fund.

Foreword

Iron deficiency anaemia and malnutrition in India have assumed pandemic proportions affecting almost the entire population. Such a massive prevalence severely affects the human resources – the largest current economic base of the nation, as well as the future generations.

This monograph is an in-depth analysis based on the National Family Health Survey – 1998-99 (NFHS-2) data set carried out by ISEC on the prevalence of iron deficiency anaemia and malnutrition in India. Dr. Ramakrishna Reddy, an obstetrician, gynaecologist and a population scientist with considerable experience in matters related to public health, including primary health care in India, has made the results of this rich survey data and its analysis for wider reading by academicians and policy makers. The data set under analysis relates to a huge sample – more than 79,000 women in their reproductive age (15-49 years) and their children below 3 years of age, numbering more than 24,000.

The study has been presented in two parts. The first part of the monograph presents a comprehensive review of the epidemiological aspects problem. It has a lucid description of the basic medical aspects as related to iron deficiency anaemia and malnutrition, as a background for the analysis. It has been written in a style appropriate for easy understanding by the social scientists, besides explaining the critical health aspects.

The second part deals with the methodology adopted by the NFHS-2, its sample design and implementation. The procedures used in the measurements of iron deficiency anaemia and malnutrition have been described. Logical conclusions and comprehensive set of recommendations have been made to support the policy perspective, strategic planning for programme implementation and future data collection methodologies.

We in ISEC hope that this study as much as many such other studies pertaining to the health status in the country will become useful for policy making pertaining to the health sector.

December 2003

Gopal K. Kadekodi
Director
Institute for Social and Economic Change
Bangalore

Contents

Preface	
Introduction	1
Part I	
Iron Deficiency Anaemia	5
Haemoglobin	14
Haemoglobin Measurement	18
Iron Deficiency Anaemia: The Pandemic	23
Morbidity-Attributable to Iron Deficiency Anaemia	27
Malnutrition	33
Part II	
Iron Deficiency Anaemia and Malnutrition in India	38
National Family Health Survey (NFHS-2):	
An Overview	38
Estimation of Levels of Anaemia and Malnutrition	42
Prevalence of Iron Deficiency Anaemia and	
Malnutrition	54
Prevalence of Malnutrition	67
Comparative Analysis of Prevalence of Iron	
Deficiency Anaemia and Malnutrition	84
The Implications of Prevalence of Iron Deficiency	
Anaemia and Malnutrition Among Women and Children	100
Discussion	105
Conclusions	107
Recommendations	110
References	113

Preface

In a tropical country like India, iron deficiency anaemia is one of the very widely prevalent diseases, which can be diagnosed and treated with equal ease and also expect it to recur with the same vigour. This disease has always fascinated not only the clinicians but also the obstetricians. The result is that this disease is the most investigated, well understood nutritional condition, discussed and debated right from a sub-centre in a remote area to the international level. The prevalence of iron deficiency is so pervading and perpetuating that it has greatly attracted the professionals leading to the institution of several anaemia control programmes in the past with the emphatic failure as the only tangible outcome. Although there is an impression that only a severe degree of anaemia is harmful, it is not borne out by evidence. It should be realised that once the iron deficiency appears, morbidity begins to stalk the individual and tends to increase in severity with the passage of time. The iron deficiency anaemia is so common and insidious that even the apparently healthy individual may have a fairly severe degree of anaemia without the obvious symptoms.

My interest in this easily curable disease at the individual level is due to difficulty in containing the pandemic springs from three decades of diverse clinical experience and a personal experience of severe anaemia following a massive bout of gastrointestinal bleeding. I was lucky to survive and as a clinician I had the most rewarding experience of suffering from a disease which affected millions of people across the globe. I am amazed at the tenacity of the people to go about their routine work with fairly severe anaemia. For that short duration in the winter of 1999, I had experienced all the signs and symptoms of iron deficiency anaemia –understand how invalid I was when I experienced it several times during that period. The morbidity of iron deficiency anaemia is such that one cannot do work to one's full capacity or to the levels performed earlier when healthy. I had also the frightening experience of 'watching' women die in labour who had reached the hospitals late in delivery as a result of very severe anaemia – no time and not even a remote chance to act in their cause. With the passage of time, these experiences aggregated into a desire to understand the malady thoroughly and work towards a solution. In the past two decades, I have been pressurised by the medical and paramedical personnel to perform laparoscopic sterilization in camps on women with severe anaemia - haemoglobin levels as low as 5 g/dl or even less. It is gratifying to mention that I have operated upon several hundreds of them every year in the past

two decades without any untoward outcome. The principal and guiding considerations for such an undertaking were three: the first, the condition of these women was so severe that another pregnancy might be a threat for their lives and had the potential to ruin the entire family; second, there was no reasonably good mechanism in the health care delivery system that ensured treatment of any anaemia; and last, that these women had lived with low levels of oxygen for a very long period and successfully went through the labour recently should reassure a clinician of a reasonably good outcome with short surgical procedure.

My interest in iron deficiency anaemia was rekindled by the enterprise of the NFHS-2 undertaking hemoglobin and anthropometric measurements. My enthusiasm spurred me to discuss with the project administrators about the need for a sound methodology and good fieldwork to obtain robust data, which, by all means, could form the baseline data on iron deficiency anaemia and malnutrition in India. I even ventured to offer the unsolicited advice of suggesting several haematologists in the country with international reputation who could help fine tuning the data collection. It was disheartening when the data on an all pervading pandemic, collected from across the country at huge cost and labour was not widely disseminated, debated at academic and administrative levels to guide policy formulations which could have helped formulate programme interventions. The external research fellowship instituted by the Ministry of Health and Family Welfare, Government of India, came as a good opportunity for me to understand more about this most common disease. The RCH-RHS data on iron deficiency anaemia and malnutrition, which was a district level data, could have been very useful to map the prevalence of iron deficiency anaemia and malnutrition for a meaningful development of programme perspectives. Since there was a delay in the availability of data, for the present, I have to be content with the meta-analysis of NFHS-2 data and hope to work on the RCH-RHS data some time later. Even though I have attempted the mapping of the NFHS-2 data, a statewide data will not be as meaningful as the district level data. In the absence of an alternative I have worked out a compromise for the time being.

This task would not have been very much successful but for the kindness and generosity of a number of individuals who provided me an opportunity to probe into the data. I am extremely grateful to Dr. M. Govinda Rao, the then Director, ISEC, and his illustrious successor Dr. G. K. Kadekodi, for granting me the fellowship initially and extending it for the full year. I am very much thankful to Dr. K.N.M. Raju, Professor and Head, Population

Research Centre, ISEC, for his kindness in supporting my application for the fellowship and all his help and guidance in the research project. I place on record here the generous help extended to me from the time I applied for the fellowship and all through the term of fellowship by Shri H.N. Ranganathan, the Registrar, ISEC. I am grateful to all the members of the faculty and the staff of the Population Research Centre, ISEC, individually and collectively for their encouragement and support during the tenure of the fellowship.

Several scholars have helped me in completing this project. Mention may be made of Dr. P. H. Rayappa, the former Professor and Head of PRC, ISEC, and Dr. C.P. Prakasam, Professor, Department of Public Health and Mortality Studies, International Institute for Population Sciences who was in charge of the Data Centre.

The Chief Librarian, ISEC and his colleagues were of immense help in accessing relevant literature and the other staff in ISEC facilitated my research work in many ways. I am grateful to them all.

It is rare to find a medical man taking up a research project in the field of social science and many eyebrows were raised when I started this research in ISEC. Some of my interactions at ISEC with fellow scholars, though limited, were rewarding experiences. The fellowship was a rare opportunity for me, I am grateful to everyone who helped in this endeavour.

Dr. M. Ramakrishna Reddy

INTRODUCTION

In recent decades, within the broad concept of the wealth of nations, human development has rightly come to occupy the centre stage. The quest for advancement of mankind has been one of the very interesting and intense endeavours all through the history of man, and, this is perpetuating even today. All these endeavours of man had a common goal - the human welfare - the principal objective and the central focus of such endeavours. Civilizations and cultures, both ancient and modern, had their origin and flourished in the lands of the world where men lived in prosperity and perfect physical strength. The concept of development represented the well-being of the people, at all times and continues to be so. In the modern context too, the development of nations connotes, the well-being of the people – a healthy, well-nourished citizenry capable of being economically productive which can create prosperity and not be dependent on or be a burden on the society.

At the micro level of the economy of a nation, each individual citizen constitutes the productive component of the total economy and hence, the national income or wealth is estimated as 'per capita income'. In other words, each individual is expected to contribute to the national economy. Towards the latter half of the last century, the concept of human capital gained currency and it gained recognition all over the world (Behrman 1992; Schultz 1994; World Bank 1994; and Seligmann *et al* 1997). Human capital is the essential function of the economy as related to the citizens. The professed objective of the welfare state is to facilitate or create conditions in which every individual is healthy and productive. India is endowed with world's second largest population – a billion and more, which holds an immense economic potential for the nation, provided they are healthy and physically capable. For several decades, in the future, the human capital would be a promising, renewable, and apparently inexhaustible economic resource.

The economic capacity or potential of an individual is the outcome of the two primordial functions of human beings: one, the intellectual capacity, and the other, a matching physical endowment. Hardly are there any substitutes for these natural faculties of the human body. Even if the final success of an endeavour is achieved with the aid of sophisticated technology and mechanical marvels eventually, the human brain and brawn are the prime movers behind such successes. A well-developed intellectual faculty housed in a healthy body of an individual lends the thrust or steam or energy, as it might be called, for the economic advancement.

Currently, the developing countries have the largest accumulation of human capital. These countries were in the similar situation at the beginning of the 20th century as developing countries are today. However, with the advent of industrialisation and epoch making strides in science, technologies, and medicine, the economic wealth resulting from the industrial economy have heralded greatest developments in the human resources sector, especially the quality of life aspect, therein. Advances in public health in these countries have been the corner stone of such successes.

Manpower is a perpetual natural resource when tended carefully, an inexhaustible resource of greatest value. Human resource, unlike the other naturally occurring material resources is infinite and versatile in its elasticity. Able-bodied human resources can make a nation plentiful, economically.

Human Development – The Ultimate Goal of All Nations

Prosperity of a nation is reflected in the strength of its human resources, and the welfare states all over the world aim to the well-being of their populations in order to remain in the forefront of development at all times. Setback to any population for reasons whatsoever is directly reflected in the economic outcome of the country.

The number of Indians born in poverty and suffering from malnutrition is growing at an alarming pace. With the passage of time since independence, the growth of undernourished population is multiplying for want of effective programmes to contain the problem of malnutrition through food and nutritional security. Consequently, intergenerational impact of iron deficiency anaemia and malnutrition continue to affect a few more generations of Indians. There appears to be no immediate solution as many programmes being implemented are either ill conceived or improperly executed.

India, with its teaming billion plus population, comprising a very large child population and an equally large female population in the reproductive age suffering from anaemia and malnutrition is a definite threat for the national economy in the long run, for, the disease morbidity will cut-short the economic potential of the population. Monsoon dependent Indian primary sector although subject to severe droughts and floods has made great strides in food production through the green revolution. Nevertheless, the size of malnourished and anaemic population as revealed by a number of recent studies, is still huge in India.

The very thought of improving the quality of life is a far-fetched dream for nearly 70 per cent of the population of the country who are living

in rural areas under poor health and sanitary conditions. Rampant poverty and poor purchasing power, ill-organised public distribution system, and large prevalence of tropical diseases compound the misery and aid in promoting morbidity levels in the population.

Conceptual Framework

This study is basically an in-depth analysis of the secondary data on the prevalence of iron deficiency anaemia and malnutrition. The data was generated as a part of a large, nationwide demographic and health survey – the National Family Health Survey 1998-99 (NFHS-2) conducted jointly by the International Institute for Population Sciences, Mumbai, and ORC Macro, Calverton, MD, USA, in 1998-99. The data on iron deficiency anaemia and malnutrition among the ever married women in the reproductive age group of 15-49 years and their children aged below 3 years were collected by directly measuring the haemoglobin levels in the field and by recording anthropometric measurements of the respondent women and their children under 3 years of age. The data are available for all the 26 states of the country. The analysis for this study has been done within the limitations inherent in the data itself.

The proposed analysis of the Reproductive and Child Health – Rapid Household Survey (RCH-RHS) data could not be carried out, as the nationwide RCH-RHS data were not available at the time of analysis as anticipated. Such data being a nationwide, district level data, it would have been very attractive and interesting to delve into one additional data set for the reasons of comparison and district level spread.

The NFHS-2 data have severe limitations apart from technical shortcomings, such as data being available for very narrow population groups of ever married women of reproductive age 15-49 and their children below 3 years and that too at the state level. Thus, the analysis is limited to the two groups only and therefore, it is not possible for interpolation or generalisation of this data for the entire population. However, it is possible to draw interstate/ regional comparisons within the groups for which data are available.

Within the limitation posed by the data, the analysis has been carried out to understand and interpret the data in terms of morbidity attributable to iron deficiency anaemia and malnutrition fully conscious of the very narrow segment of the population being characterised in the analysis.

For a better understanding of the basis of morbidity, a brief review of iron as a micronutrient and the related physiological aspects have been presented with an overview of the structure and functions of haemoglobin - the principal oxygen carrying molecule, oxygen transport, and the role of

oxygen in the energy metabolism. Effects of malnutrition on growth and physical stature and its impact on the physical capacity have been considered. The combined impact of iron deficiency anaemia and malnutrition on the women and their children and the morbidity outcome has also been discussed.

Notes on Data Quality - Suggestions and Recommendations

From the policy perspective and implementation of remedial interventions and in the background of severe limitations posed by the current data, requirements and modifications in the data collection methodology have been suggested for future surveys. A very strong case has been made for developing our own national reference standards not as a mere symbol of national pride but as an inescapable imperative need for the welfare of the world's second largest population. A country which boasts of the largest scientific manpower and talent pool in the world need not dither. Neither the vastness of the country nor the difficult regional variations should hinder the development of such reference standards. Without such reference standards, programme implementation, effective monitoring and evaluation are not going to be possible and the success of controlling iron deficiency and malnutrition will remain a distant dream for want of proper instruments to measure the disease and the efforts to control it.

PART I

IRON DEFICIENCY ANAEMIA

Introduction

Iron deficiency anaemia is the leading cause of morbidity among the vast sections of people, especially in the developing countries. Concurrent prevalence of malnutrition, both a cause for and an effect of iron deficiency anaemia would worsen the morbidity outcome of the people in the world. Ravages of poverty, illiteracy, poor environmental sanitation, tropical weather and large prevalence of intestinal worm infestations have been the major causes for the prevalence of iron deficiency anaemia and malnutrition. It is a vicious cycle where the prevalence potentiates the morbidity and *vice versa*. The impact on the health of the individuals and their well-being is though not very apparent or dramatic, it is quite profound. Particularly, the significance of morbidity is more for the unborn foetuses, the infants and the very young children than their mothers although they too suffer a great deal because their natural opportunity for a reasonably good physical and mental development is severely compromised. Such a situation leads to inter-generational impact. The impact of iron deficiency anaemia and malnutrition is on the physiological, physical, psychological and economic aspects of the individuals concerned. With the prevalence levels of iron deficiency and malnutrition as indicated by the National Family Health Survey –2, it is necessary to take a considered look at these two major public health problems faced by the people of our country.

Physiological Considerations: Iron – The Metal and Its Biochemistry

Iron is a transition element with an atomic number 26 and atomic weight of 55.847. It is a physiologically very important and an active element whose presence in a variety of substances in the body is critical for the normal physiological functions. It is the fourth most abundant element and second most abundant metal in the earth's crust. It is one of the primordial elements considered to have participated in the chemical evolution on the earth since 500 million years, through reduction, to facilitate the synthesis of molecules essential for life (Bothwell *et al* 1979). In the biological systems iron occurs in oxidised states as ferrous (Fe^{+2}), ferric (Fe^{+3}), and ferryl (Fe^{+4}) forms (Beard 2001). Iron is an essential nutrient for all living organisms with the exception of a very few microorganisms.

Iron is one of the most investigated and best-understood nutrients (Beard *et al* 1996). The relative ease of access to the major body pools of

iron, such as, blood samples and bone marrow aspirates, has greatly facilitated the understanding of iron nutrition and metabolism (Dallman 1990). Iron is an important component or cofactor for hundreds of proteins including the haeme of haemoglobin, myoglobin, transferrin, ferritin, and iron containing porphyrins besides being an essential component of enzymes, such as, catalase, peroxidase, and the various cytochromes. When it comes to life, iron is more precious than gold! (INACG 1979, Dallman 1990 and Beard *et al* 1996)

Average Iron Content of the Human Body

The average total body iron is estimated to be ~3.8g in men and ~2.3 g in women of which ~30 - 40 mg/kg is functional iron and ~0 - 20 mg/kg is storage iron (Bothwell *et al* 1979 and Beard 2001). Iron containing compounds in the body are grouped into two principal categories, viz., functional or essential iron compounds and iron storage complexes. About 85-90 per cent of non-storage iron is found in erythroid mass (Bothwell *et al* 1979)

Essential/Functional Iron Compounds

The essential or functional iron compounds are haemoglobin, myoglobin, haeme enzymes, such as cytochromes, and non-haeme enzymes such as iron-sulphur proteins and metalloflavoproteins. Haemoglobin accounts for more than 65 per cent of the body iron, myoglobin for ~10 per cent of the total body iron, and haeme and non-haeme iron enzymes for ~3 per cent of the total body iron (Dallman 1990). These are the active iron compounds involved in oxidative energy metabolic functions in the body. The main function of the essential iron compounds is to bind and transport oxygen (O₂) from the respiratory organs, i.e., lungs, to the tissues in the body, and transport of carbondioxide (CO₂) and proton (H⁺) from the peripheral tissues to the lungs for subsequent excretion. As enzymatic catalysts, the iron containing enzymes participate in a vast variety of biochemical processes in the body (Rodwell 2000).

Iron Storage Compounds

Approximately, one gram of Iron is stored in the body in different compounds, which maintain the iron homeostasis. The storage ranges from 0-15 mg/kg body weight or ~12 per cent in women and 25 per cent in men. The major iron storage compounds are ferritin and hemosiderin which are present primarily in the liver, reticuloendothelial cells and bone marrow, each one of them accounting for approximately one half of the stored iron (Bothwell *et al* 1979 and Dallman 1990). The quantity of iron stored varies according

to age, sex, and nutritional status of the individual. The range of variation in the stored iron is quite wide yet without an apparent impairment in the iron metabolism or an indication for the depleted stores. Distribution of stored iron is not uniform. Liver contains 60 per cent of the ferritin in the body while the remainder is found in the muscle tissue and reticuloendothelial system. In the liver, hepatocytes host 95 per cent of the stored iron.

Table 1.1: Iron Containing Compounds in Man

Category of Iron Compounds		mg in a 75 kg Male (Approximately)	mg/kg (Approximately)
Functional Compounds	Haemoglobin	2,300	31
	Myoglobin	320	4
	Haeme Enzymes	60	1
	Non-haeme Enzymes	100	1
		2,800	37
Storage Complexes	Ferritin	700	9
	Hemosiderin	300	4
		1,000	13
Total		3,800	50

Source: Adopted from Bothwell *et al* 1979

Dynamics of Iron Metabolism in the Body

Physiologically, iron is a dynamic substance involved in a number of vital functions in the body. Consequently, it undergoes very complex physiological sequences, such as, absorption from the sites of availability, incorporation into and production of functional compounds, release from the senescent functional elements, reabsorption and excretion. This process is incessant.

Normal Iron Requirement

Since iron is involved in the active metabolic processes in the body, its requirements will be fairly elastic depending upon age, sex, phase of life, and increased periodic physiological needs for iron. Also, as a matter of physiological functions certain quantity of iron is lost from the body every day. Pregnancy, growth spurts in children and adolescents, slightly exaggerated physiological functions, and bleeding, both internal and external, and worm infestations, lead to increased requirements for iron.

Pregnancy

Pregnancy places a definitive demand for iron on the women – it is inescapable! Total iron requirement during a normal pregnancy amounts to about 1,000 mg (Cunningham *et al* 2001). Foetus and placenta account for about 300 mg of iron, about 200 mg is lost through normal routes of excretion – this is an obligatory loss of iron which occurs even when the mother is severely iron deficient. An additional demand for 500 mg of iron arises on account of increased volume of about 450 ml of erythrocytes during pregnancy, as each ml of normal erythrocytes contains 1.1 mg of iron. The entire requirement of iron for this purpose arises during the latter half of pregnancy. About half of the erythrocytes added during the pregnancy is lost during normal delivery and through subsequent few days. Loss of erythrocytes is from the site of placental implantation, placenta itself, from the episiotomy or lacerations and in the lochia. Thus, during the normal vaginal delivery of a single foetus, about 500 to 600 ml of erythrocytes corresponding to pre-delivery blood is lost. On the other hand, average blood loss during a caesarean delivery or delivery of twins will amount to about 1,000 ml or nearly twice the amount of blood lost during a normal delivery of a single foetus (Cunningham *et al* 2001). Even though there is conservation of iron due to amenorrhoea of pregnancy, the actual loss of iron is thus greater (Bothwell *et al* 1979). Such is the demand for iron during pregnancy.

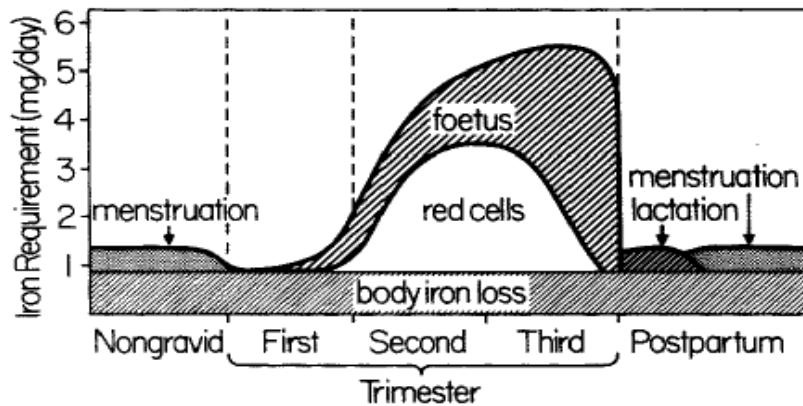


Figure 1.1: Iron Requirement During Pregnancy
Source: Bothwell *et al* 1979

Infancy

At birth, a normal term infant would have, on an average, a total body iron of 75 mg/kg body weight. The iron stores at birth are independent of the maternal iron nutritional status. Therefore, it is reasonable to expect that the infants of iron deficient mothers show no evidence of iron deficiency at birth (Dallman 1989) since such infants are endowed with full complement of haemoglobin. In cases of severe maternal iron deficiency anaemia in premature infants and twins, the neonatal iron stores would be small and subject to further depletion. Even though the total body iron is less in infants with low birth weight than the full term infants the ratio of iron to the body weight will be the same (INACG 1979). Each kilogramme weight gain during infancy and early childhood imposes an iron requirement of ~ 40 mg for the production of essential iron compounds (Dallman 1990).

Childhood

During childhood, from second birthday to twelfth in the boys and the tenth among the girls, the average somatic growth would be of the order of 2.50 - 2.75 kg/year (Bothwell *et al* 1979). The haemoglobin level will also increase by about one g/dl during childhood. Consequently, the daily iron requirements will also increase to the levels of 0.5 – 0.8 mg.

Adolescents

The accelerated body spurt during adolescence leads to an increase in the body mass by about 4.5 kg/year in males and 4 kg/year in females. The age specific increase in haemoglobin concentration among males and females during this period will be 2 g/dl and 1 g/dl, respectively. Considering the increased obligatory losses during adolescence, the total daily iron requirement in the males is about 1.6 mg. Following the growth spurt the progressive increase in iron stores from about 200 to 1,000 mg in the males leads to a daily iron requirement of 1.2 mg.

In females, the menstruation which starts at the end of growth spurt lays additional demand for iron to replace the losses. These losses vary greatly among individuals, the median loss being about 0.5 mg/day. The usual total daily iron requirement will be about 1.4 mg but may be more among the females with increased menstrual losses (Bothwell *et al* 1979).

Women During Child Bearing Years

In an average woman of reproductive age the daily iron requirement should balance the quantity of iron lost during menses, besides the obligatory losses. This imposes an average daily iron requirement of 2 mg. Iron stores are more likely to get depleted during pregnancy and some women may

develop anaemia. A positive iron balance in the preconception period is much desirable and has a positive correlation with better pregnancy outcome subsequently. Mild iron deficiency in the pregnant women has no effect on the haemoglobin concentration of the foetus (Bothwell *et al* 1979 and Dallman 1990).

Adult Men and Postmenopausal Women

In adult males, besides the physiological losses, iron is required to build up normal iron stores of maturity between the ages of 18 and 30 years. Normally, iron stores increase throughout the life of men and postmenopausal women. Inflammatory diseases, neoplasms and more commonly aspirin ingestion and hookworm infestation are the common causes for iron depletion in these groups (Dallman 1990).

Iron Losses

Iron homeostasis in the body is achieved efficiently by regulating the absorption of iron to approximate the losses. The low solubility of iron precludes its excretion and helps in the homeostasis of iron in the body. Almost all the iron lost from the body is by way of obligatory losses. Commonly, such losses occur through the gastrointestinal tract, the skin, the genitourinary tract, menstruation and pregnancy. There is considerable gender variation in the loss of iron from the body (Bothwell *et al* 1979, Dallman 1990, Beard *et al* 1996, and Beard 2001). No known physiological mechanism for excretion of iron exists, consequently, absorption of iron alone regulates the body iron.

The daily iron loss from the gastrointestinal tract amounts to about 0.6 mg, in the faeces, bile and desquamated mucosal cells. Iron losses through the skin account for about 0.2 - 0.3 mg in desquamated skin cells and sweat and less than 0.1 mg in urine. This adds up to a daily total iron loss of 0.9 – 1.0 mg in the adults. This is the basal obligatory loss of iron. In addition to these losses, women in reproductive period of life will have additional median iron losses of about 0.4 mg/day aggregating to a total of 1.4 mg/day. The menstrual bleeding could be more in certain individuals in which case the iron loss will be higher than the median iron losses (Bothwell *et al* 1979 and Dallman 1990).

Iron Turnover and Redistribution

All the iron compounds in the body are continuously broken down and resynthesised. Iron released from the broken down compounds is very efficiently conserved and reutilised without any loss. thus maintaining the balance of iron pool in the body (Dallman 1989).

Regular iron turnover takes place in the body primarily by the destruction of senescent erythrocytes by the reticuloendothelial system. Erythrocytes have a mean functional life of 120 days and contain ~ 80 per cent of the functional iron in the body. In an adult weighing 70 kgs with normal iron status, about 35 mg or 0.66 per cent of the total body iron content is turned over by this route every day. Degraded myoglobin and iron containing enzymes also add to the turnover, but in very small quantities (Beard 2001).

Iron Absorption

Iron metabolism is a tightly balanced homeostasis with very limited average diurnal losses. In the normal course, absorption of iron from the gastrointestinal tract is the only mechanism by which the iron losses are made up. Further, the absorption of iron is influenced by the body's need for it and all the iron presented for absorption even in a suitable form is not absorbed - an enigma not understood well.

Iron in the food exists in many different chemical forms, of which two distinct forms, haeme and non-haeme compounds are important for nutrition. Haeme fraction is derived from the food articles of animal or meat origin such as meat, poultry and fish. The haeme iron already bound to a protein has greater chance of getting absorbed as it is not degraded in the intestinal lumen and the process involved is much different from that of non-haeme iron absorption (Bothwell *et al* 1979, Dallman 1990, and Beard *et al* 1996). Iron in the food of vegetable origin, the most commonly consumed and in large quantities, is found in non-haeme state. Non-haeme iron is bound to a number of chemical complexes in the food articles like grains, pulses and vegetables and needs to be ionised before it is offered for absorption. A combination of haeme iron foods with non-haeme iron foods is known to enhance the absorption of the non-haeme fraction of iron from the diet.

Exogenous iron ligands exert powerful influence on the iron absorption. Ligands like carbonates, bicarbonates, oxalates, phosphates, and tannates decrease iron availability for absorption by forming large polymers. Several other ligands like ascorbic acid, citric acid, tricarboxylic acid, amino acids and sugars form soluble monomeric complexes and promote absorption. Some of these substances act as weak chelators and thus increase the availability of soluble portion of non-haeme iron and promote absorption of iron from non-haeme food.

Extrinsic intraluminal factors such as bran, hemicellulose, cellulose, pectin, phytic acid, and polyphenolic compounds decrease iron absorption.

Metals like calcium, magnesium, zinc, lead, cobalt, manganese, and strontium interfere with iron absorption by competitive inhibition of iron absorption, by blocking the iron uptake at mucosal level, or by occupying the receptor sites on the enterocytes. Lead is notorious in this regard and it is quite hazardous in the case of children. Antacids, possibly including H² receptor blockers, interfere with the absorption of iron from the gut. Lactoferrin present in human milk is a promoter of iron absorption (Bothwell *et al* 1979, Dallman 1989, and Beard 2001). Beverages like coffee and tea largely reduce the iron absorption. India as a tea and coffee drinking nation, transgressing all the socioeconomic barriers, would naturally be at great risk of being a nation of anaemic subjects. Alcohol in the diet influences absorption of ferric chloride by stimulating gastric acid secretion, chronic alcoholism severely interferes with the absorption of iron.

There is a relationship between the dose of iron salts and the quantity absorbed. Although the percentage of iron absorbed drops with the increase in the dosage, there is a progressive increase in the amount of iron absorbed. Valency of iron also plays an important role in the absorption of iron. Absorption of ferric salts from a large dose of iron is less than half that of ferrous salts. This is ascribed to the poor solubility of ferric iron once the pH rises above 3 and very few molecules of ferric ions remain in solution above pH 5.

Although small amounts of iron can be absorbed from the stomach, the ileum, and the colon, a major portion of iron absorption takes place in the upper part of the small intestine, viz., duodenum and upper jejunum. The physical state of iron entering the duodenum greatly influences the absorption of iron. At physiological pH, ferrous iron (Fe²⁺) is rapidly oxidised to the insoluble ferric (Fe³⁺) form. Gastric acid lowers the pH in the proximal duodenum enhancing solubility of ferric iron which facilitates its absorption. Gastric acid has an important role in the absorption of the non-haeme iron from the food. Non-haeme iron absorption is severely affected in achlorhydria and gastrectomised individuals (Bothwell *et al* 1979).

Regulation of Iron Absorption

The absorption of iron in humans is a meticulously regulated process, which helps to serve the physiological functions but prevents iron accumulation in the body. Two distinct steps are involved in the process of absorption of iron — first, ‘uptake’ - the entry of iron into the mucosal cells from the lumen of the gut and, second, its ‘transfer’ – from the mucosal cell into the body. All the iron taken up from the lumen into the mucosal cell is not transferred into the body. Depending upon the needs of the body, variable

proportion of the iron may be sequestered in the mucosal cell and eventually discarded when the mucosal cell is exfoliated. Transfer is a much slower process than uptake and is more restricted to duodenum. It is modulated by the factors such as size of the body iron stores and quantity of iron in the diet (Bothwell *et al* 1979).

The uptake of iron is mediated by a series of receptors and binding proteins. Iron is presented for absorption in two kinds in the lumen of intestine – the haeme and non-haeme iron. The mucosal cells take up haeme iron readily because of its porphyrin content. After binding to its receptors, the haeme iron is internalised after the iron is released by the enzymatic degradation. On the other hand, non-haeme iron is bound to binding proteins and then carry into the cell with the help of specific transporters present on the surface of the mucosal cells. Within the mucosal cell non-haeme iron is bound to an iron binding protein and is transferred to ferritin or to the basolateral side of the mucosal cell. Iron is then either lost when the cell is exfoliated or bound to transferrin and absorbed into the circulation (Beard *et al* 1996).

Factors Involved in the Regulation of Iron Absorption

Two important factors are involved in the regulation of iron absorption. The mucosal factors include availability of functional absorptive surface for absorption of iron, i.e., duodenum and jejunum from where a major portion of iron is absorbed. The functional integrity of this surface is of crucial importance for the absorption of iron. The other somatic factors, include iron status of the person, low plasma levels of iron, increased levels of erythropoietin, and hypoxia. All these factors up regulate the iron absorption by signaling its absorption from the mucosal cells (Bothwell *et al* 1979 and Beard *et al* 1996).

Iron Storage and Mobilisation of Body Iron Stores

Ferritin and hemosiderin are the major storage compounds which are present in liver, reticuloendothelial cells and bone marrow. Iron storage in the body depends upon the iron status of the individual. The storage concentration varies widely from 0 to 15mg/kg body weight and it can happen without any apparent impairment of body functions. Storage iron may be entirely depleted before iron deficiency anaemia develops. On the other hand, in iron over-loading, the storage may increase by 20 fold before the tissue damage becomes apparent (Bothwell *et al* 1979, Dallman 1990, and Beard *et al* 1996).

Stored iron is not distributed uniformly. Liver contains 60 per cent of the ferritin in the body and the remaining 40 per cent is found in the muscle, bone marrow, and spleen. Contribution of storage iron to the total body iron varies widely from about 12 per cent in women to 25 per cent in men.

HAEMOGLOBIN

Haeme Proteins

Porphyrins are the precursors of haemoglobin – the red respiratory protein present in the erythrocytes. Porphyrins are cyclic compounds formed by the linkage of four pyrrole rings through methyl bridges. Characteristically, porphyrins form complexes with metal ions bound to the nitrogen atom of the pyrrole rings (Murray 2000). The two best known porphyrin metal complexes which occur in abundance in the universe and have the greatest physiological functions are the Chlorophyll, the magnesium (Mg^{2+}) porphyrin complex and its near cousin the iron porphyrin complex, the Haeme of haemoglobin. Both are widely distributed and are of greatest physiological importance. Chlorophyll is involved in the synthesis of the energy substrate in the plant kingdom. Virtually all the energy available for life in the earth's biosphere, the zone in which life can exist - is made available through photosynthesis (Microsoft 1998).

Haeme consists of a protoporphyrin ring and a central iron (Fe) atom. The protoporphyrin ring is made up of four pyrrole rings linked by methylene bridges. The iron can either be in the ferrous (Fe^{+2}) the reduced or the ferric (Fe^{+3}) the oxidised state. Haeme proteins perform the vital physiological functions of oxygen binding, oxygen transport, electron transport, enzymatic reactions, and photosynthesis (Rodwell 2000). Physiologically important haeme proteins are myoglobin, haemoglobin and cytochrome enzyme complexes.

Myoglobin

In the muscle, myoglobin is an oxygen-storage protein. Myoglobin is a monomeric, i.e., single chain haeme protein found mainly in muscle tissue where it serves as an intracellular storage site for oxygen. During periods of oxygen deprivation such as severe exercise or physical activity oxymyoglobin releases its bound oxygen which is then used for metabolic purposes. Haemoglobin replenishes the oxygen supply to myoglobin.

Haemoglobin

Haemoglobin is an oxygen carrying protein found in erythrocytes.

Being a transport protein, it transports oxygen (O_2), carbon dioxide (CO_2), and proton (H^+) in the body. Haemoglobin is a tetrameric, globular protein (i.e., folded into a compact, nearly spherical shape) and consists of four sub-units of haeme. Each sub-unit of haeme contains an iron atom that is capable of binding reversibly to one molecule of oxygen (O_2). Therefore, each unit of haemoglobin can bind four molecules of oxygen that diffuse into the bloodstream from the lungs and then transport it to outlying tissues where it is released primarily for aerobic respiration. The oxygen binding varies from fully “unsaturated” haemoglobin (deoxyhaemoglobin) to fully “saturated” haemoglobin (oxyhaemoglobin). During the process of this combination the iron atom remains in ferrous (Fe^{2+}) state, i.e., reduced state. Therefore, the reversible combination of oxygen with the iron is known as oxygenation (chemically the process is an association) (Dewhurst *et al* 1986, and Casiday and Frey 2000).

The binding of oxygen to the first sub-unit of Hb significantly enhances the binding of oxygen to the adjacent sub-units. This interpretation implies that the affinity of oxygen for the first sub-unit is different from that for the fourth sub-unit. It is due to the fact that each oxygen molecule that binds to haemoglobin molecule increases the attraction of haemoglobin for the next oxygen molecule till the available binding sites for haemoglobin are saturated.

Foetal Haemoglobin

The haemoglobin produced during the early foetal life is distinctly different from the haemoglobin found in normal adults. This type of haemoglobin is known as foetal haemoglobin or Haemoglobin F. Although foetal haemoglobin is produced exclusively in the beginning, by about the 6th week of intrauterine life the production of adult type of haemoglobin also appears in the foetus. At times, about three fourths of the total haemoglobin of the foetus is normally haemoglobin F. The proportion of the foetal haemoglobin decreases gradually in the first six to twelve months of life (Cunningham *et al* 2001). Delay in the transition from the foetal to adult type of haemoglobin has been noted in conditions of maternal hypoxia (i.e., reduced oxygen in the maternal blood) in infants of the diabetic mothers, and in infants small-for-gestational age (Stockman III 1990).

Structurally and functionally, the foetal haemoglobin is different from adult haemoglobin. The functional difference is that at any given oxygen level and identical pH, the foetal haemoglobin binds more oxygen than normal haemoglobin. The increased affinity of foetal haemoglobin for oxygen is due to the fact that the foetal haemoglobin binds to 2,3- Diphosphoglycerate

(2,3-DPG) less avidly than the normal haemoglobin. It is interesting to note that concentration of 2,3-DPG increases in maternal erythrocytes during pregnancy. The higher oxygen affinity of the foetal haemoglobin helps in extracting more oxygen to meet the needs of the embryo and the foetus, from the lower oxygen levels that prevail in the intrauterine environment. An important functional aspect of the foetal red cells is their relatively nondeformable character (Stockman III 1990 and Cunningham *et al* 2001).

Estimation of Haemoglobin Levels and Population Screening

Although the prevalence of iron deficiency anaemia is believed to be fairly widespread among the Indian population, it has not been studied extensively. The anecdotal information about the prevalence levels of iron deficiency anaemia does not support the cause of large-scale intervention as preventive measures. Considering these lacunae, for the first time in India, the National Family Health Survey (NFHS-2) undertook haemoglobin measurements among women in the reproductive age 15-49 years and their children age 0-36 months across the country covering all the 26 states. Even though the NFHS-2 provides state level data on the prevalence of anaemia, the extent of the prevalence of iron deficiency anaemia still remains elusive.

Anaemia due to iron deficiency can be diagnosed by clinical findings, haematological and biochemical tests. While the clinical signs and symptoms of iron deficiency are crude, subjective, nonspecific, and least accurate in the initial stages and become remarkable in the severe form of iron deficiency anaemia, they are not reliable for diagnosis or screening purpose (DeMaeyer *et al* 1979 and Filteau 1995). Diagnosis can be established with greater precision with the help of biochemical and hematological tests. The biochemical tests for the diagnosis of iron deficiency anaemia such as serum ferritin, serum transferrin saturation, total iron binding capacity (TIBC), serum transferrin receptor concentration, free erythrocyte protoporphyrin concentration are highly complex and need sophisticated laboratory set up and hence, are unsuitable for population based screening purpose (Dallman 1989, Yip 1989).

On the other hand, the hematological tests have distinct advantage over the biochemical tests even though their precision is slightly lower. The greatest advantage is the easy accessibility of the cell components necessary for the assessment and well-established test procedures (Dallman 1990). Haematocrit (packed cell volume - PCV), haemoglobin measurement, red cell indices such as mean corpuscular volume (MCV) and mean corpuscular haemoglobin (MCH) and mean corpuscular haemoglobin concentration

(MCHC) are established common hematological tests for which cutoff values have been derived. However, in clinical practice, haematocrit and haemoglobin measurements are the most widely used and easily understood tests for detecting the iron deficiency anaemia (Dallman 1979, DeMaeyer *et al* 1989, Yip 1989 and Filteau 1995).

In population screening, anaemia is used as a proxy for iron deficiency because of their strong association. Similarly, haemoglobin measurement is taken as a proxy for the iron levels, as the haemoglobin level is the last of the indicators affected by iron depletion. Theoretically, haemoglobin measurement would be more sensitive than haematocrit as the reduction in the synthesis of haemoglobin precedes the reduction in red cell volume or numbers (Yip 1989). Haemoglobin estimation is one of the best methods for population screening for iron deficiency anaemia (DeMaeyer *et al* 1989, Yip 1989 and WHO/UNICEF/UNU 2001). Although haematocrit is one of the suggested methods for screening, more often, haemoglobin estimation has been the preferred method used for population screening.

A number of quantitative and semi-quantitative methods of measuring haemoglobin levels have been practised. Two very informative manuals - Anaemia Detection Methods in Low-Resource Settings in Health – a Manual for Health Workers (1997), and Anaemia Detection in Health Services: Guidelines for Managers, 2nd Edition (1996), published by Program for Appropriate Technologies in Health (PATH)/OMNI/USAID, outline all the methods used for measuring the haemoglobin levels. Recently, the World Health Organisation has come out with a haemoglobin colour scale for screening purpose especially for use in remote areas in the developing countries. The colour scale comes with an improvised colour scale indicating six levels of haemoglobin and supplied with strips of Whatman 31 ET Chr filter paper. The colour scale is standardised for haemoglobin range 4, 6, 8, 10, 12, and 14 g/dl. The procedure is similar to the earlier filter paper method (Tallqvist). Considering the variations in reading the colour scale in a number of studies reported by the WHO in support of the product, it appears to be quite subjective and does not hold great promise.

Haemoglobin measurement can be made either using capillary blood from skin puncture or venous blood drawn from venepuncture. Skin puncture is easy and safer to perform in field conditions. However, the haemoglobin values obtained from capillary blood is slightly lower than the venous blood and is in the range of 0.5 and 1.0 g/dl. Accuracy of large scale screening programmes will not be significantly affected by the small variation of 0.5 g/

dl (DeMaeyer *et al* 1989). Capillary blood is drawn from the warm fingertip in adults and children and from the heel in infants with the help a sterile lancet which is generally used for the analysis.

Haemoglobin Measurement

Of the several methods of measuring haemoglobin, currently two methods are considered as standard methods. In both of these methods, haemoglobin is converted into stable compounds, the concentration of which is determined by matching its colour in a spectrophotometer or photoelectric calorimeter.

Direct Cyanmethaemoglobin Method: Cyanmethaemoglobin is formed by the haemoglobin when a specified quantity of blood (20 µl) is added to 5 ml of Drabkin's solution and allowed to stand for 2 – 4 hours. The colour density of resulting solution is read in a spectrophotometer at a light wavelength of 540 nm against a haemoglobin standard blank solution. This method, known as the direct cyanmethaemoglobin method, is the best laboratory method, which is very popular and regarded as the Gold Standard for haemoglobin measurement (DeMaeyer *et al* 1989, Yip 1989, Filteau 1995 and Sari *et al* 2001). It requires laboratory set up, experienced technical staff, and spectrophotometer, hence, described as difficult to use in the field studies like population surveys.

Indirect Cyanmethaemoglobin Method: To overcome the technical difficulties, a different version of the cyanmethaemoglobin technique, known as indirect cyanmethaemoglobin method, is being used in some population surveys. In this procedure, 20 µl of the blood is measured precisely and transferred on to a Whatman No. 1 filter paper and allowed to dry at room temperature. After the blood has dried, the filter paper is inserted into a small plastic bag (one sample per bag) which is appropriately labeled with a lead pencil and then placed in an envelope and sent to the laboratory for analysis. The filter paper with the dried blood sample is placed in a test tube containing 5 ml of Drabkin's solution and allowed to stand soaking for 2 hours after vortexing it for five minutes initially. Then the solution is read in a spectrophotometer at a light wavelength of 540 nm. The transit and storage time for the dried sample is between 6 days (ICMR 2001) and 2 weeks (Sari *et al* 2001).

The absolute prerequisite for using cyanmethaemoglobin to determine haemoglobin concentration is to dilute the blood 250 times its volume of Drabkin's solution. Blood samples can be collected in the field, diluted with precisely measured Drabkin's solution and transported to the

laboratory within a few hours for analysis without spillage and evaporation if facilities are available.

HemoCue method: It is a portable haemoglobin measurement system consisting of a specially designed photometer and microcuvettes. It is a direct measurement of haemoglobin from a precise amount of (10 µl) undiluted blood. In this method, the RBCs in the sample of blood are disintegrated and the haemoglobin is released which is oxidised and converted into azidemethaemoglobin. The blood filled microcuvette is placed on the cuvette-holder of the photometer and cuvette-holder is pushed into measuring position and within 30-50 seconds the direct reading will appear on the display panel. Remeasurement is possible and can read in 10-20 seconds.

Functions of Haemoglobin: Oxygen and Carbon Dioxide Transport

Oxygen transport is a highly dynamic process with oxygen continuously being exchanged between the lungs and the capillaries. Each gram of haemoglobin can uptake 1.34 ml of oxygen and therefore, 100 ml of blood containing 15 grams of haemoglobin will uptake 19.5 ml of Oxygen. On the other hand, 100 ml of blood will contain 0.3 ml of oxygen in solution. Therefore, haemoglobin increases the oxygen carrying capacity of blood by 70 –fold (Dewhurst *et al* 1986).

Oxygen forms 21 per cent of the composition of dry atmospheric air at sea level. An adult at rest normally consumes an equivalent of 250 ml of oxygen per minute. The oxygen carrying capacity of normal blood is 200 ml per litre. Assuming that the resting cardiac output (blood pumped by the heart while at rest) of 5 litres per minute with a normal oxygen carrying capacity of 200 ml per litre, one litre of oxygen can be delivered to the tissues in the body per minute. Of this, the tissues extract 25 per cent and the remaining 75 per cent returns to the heart through venous blood. The oxygen consumption of 250 ml per minute at rest is achieved by delivering 1 litre of oxygen to the peripheral tissues. At times of extreme exertion or physical activity oxygen delivery is increased to 3.2 litres per minute, of which 75 per cent is extracted by the tissues and 25 per cent returned to the heart giving an oxygen consumption of 2.4 litres per minute which is almost 10 times that at rest (Dewhurst *et al* 1986).

Oxygen Dissociation Curve

Oxygen binds to the iron atom in the haeme molecule by a very simple chemical reaction known as association in which the oxygen molecule is bound to the iron atom without any interaction or formation of a stable chemical substance. The association of oxygen takes place in the lungs

against a higher gradient of oxygen present in the inspired air in the lungs. As the oxygenated haemoglobin in the blood reaches the tissues where the gradient of oxygen in the tissues is less than that of oxygenated haemoglobin, the oxygen starts off-loading by another chemical process known as dissociation. The cycle is a continuous one as the haemoglobin in the erythrocytes shuttles between the lungs and the tissues through blood circulation. Several factors promote or inhibit the process of oxygen dissociation in the body. The oxygen dissociation curve is a graphic expression of the process of oxygen dissociation in the body. The oxygen dissociation curve explains the physiological conditions which modulate the oxygen offloading from the haemoglobin into the body tissues.

Proton (H^+) promotes the dissociation of oxygen from haemoglobin. As the pH decreases, dissociation of oxygen from haemoglobin is enhanced. This phenomenon is known as the Bohr effect. Carbon dioxide also promotes the dissociation of oxygen from haemoglobin. Carbon dioxide exerts its effect on haemoglobin mainly through the release of Proton (H^+). 2,3 Diphosphoglycerate (2,3-DPG) is produced within the red cells and in higher concentrations promotes dissociation of oxygen from haemoglobin. 2,3-DPG is negatively charged and binds to a positively charged pocket on haemoglobin within the red cell. *Foetal* haemoglobin has a higher affinity for oxygen because it has a lower sensitivity for 2,3-DPG. The concentration of 2,3-Diphosphoglycerate in the stored blood decreases significantly resulting in decreased oxygen dissociation when such blood is transfused. Increase in body temperature increases oxygen dissociation (Churchill-Davidson 1986).

Normal Range of Haemoglobin Levels

Iron levels in the body are estimated by measuring the haemoglobin levels in the blood, and it is commonly done in the laboratory. It is a firmly established and well-accepted practice in clinical medicine to measure the levels of haemoglobin as a proxy for the iron levels in the body. The measurement of haemoglobin levels has advantages, for it can be used not only in the clinic settings but also effectively in population surveys. Haemoglobin levels in the blood are expressed in ranges since its content in the blood varies according to age, gender, and nutritional status of the people (Table 1.2). These levels are expressed for the people living at sea levels. Appropriate adjustments have to be made in the measurement of haemoglobin levels of people living at high altitudes, altitudes greater than 1,000 metres and smokers. Since the former will have higher levels of haemoglobin in response to the reduced levels of oxygen at higher altitudes, the latter will have higher levels of haemoglobin in response to the chronic inhalation of

carbon monoxide. In practice, a correction factor of 4 per cent per 1,000 metres is added in surveys, but a linear correction factor such as this has been disputed based on large scale studies of haemoglobin levels at different heights (Berger *et al* 1997).

Table 1.2 : Normal Haemoglobin Ranges

Population	Haemoglobin (g/dl)	Haematocrit (per cent)
Infants (full term)	10.5 - 19.5	32 – 60
Children (1-9 years)	11.0 – 14.0	33 – 40
Children (10 – 12 years)	11.5 – 15.0	35 – 45
Men (adults)	13.0 – 18.0	40 – 50
Women (adults)	12.0 – 16.0	36 – 44
Pregnant women	11.0–14.0	33 – 42

Source: PATH 1997

Oxygen and Energy Metabolism

Energy is essential to maintain the internal milieu or homeostasis and to support electromechanical activity of the organism. Food supplies the energy necessary for the normal physiological functions and physical activity of the body to sustain life. Food is the source of energy and it is variable to a great extent depending upon its availability and energy content (Delvin and Horton 1990 and Szepesi 1990).

Energy Production in the Body

Energy is necessary to sustain the vital physiological functions, such as the basal metabolic rate (BMR), the thermogenesis, and the extent and energy cost of physical activity (Shetty 1989). The Adenosine triphosphate (ATP) – a high-energy phosphate, is the principal store of energy in the body as it is produced, stored, and utilised in the tissues for their energy needs. Both the production and storage are ultra short in duration. Glucose serves as principal substrate in the energy metabolism and the process is known as oxidative phosphorylation. The efficiency of energy production in the tissues from the glucose is determined by the availability of oxygen at the cellular level (Churchill-Davidson 1986 and The Biology Project 1996)¹. This is a very important aspect of metabolism as the availability or lack of oxygen makes a great deal of difference in the production of energy necessary for the bodily functions of the individuals.

In the presence of oxygen, glucose combines with adenosine diphosphate (ADP) to produce Adenosine triphosphate (ATP) through a

¹ See, The Biology Project of the University of Arizona (1996). (www.biology.arizona.edu/biochemistry).

complex biochemical reaction. ATP is regarded as the universal currency of biological energy. In aerobic metabolism, i.e., in the presence of oxygen one unit of glucose supplies energy equivalent to convert 36 molecules of adenosine diphosphate into 36 molecules of adenosine triphosphate (ATP) with the release of water and carbon dioxide. ATP is hydrolysed in the cells as and when the need for energy arises (The Biology Project 1996, Mayes 2000). This is an aerobic process in which 38.3 per cent of the energy released from the glucose is captured in ATP bonds.

On the other hand, in the absence of oxygen at the tissue level the production of ATP takes an alternative route, viz., anaerobic metabolism. During anaerobic metabolism a mere two ADP molecules are converted into two molecules of ATP with the energy derived from the same amount of glucose utilised in aerobic metabolism. Thus, during the anaerobic metabolism of energy production in the body is highly inefficient – just about five per cent as efficient as the aerobic metabolism.

Metabolic Implications

Availability of oxygen at the tissue level is critical for the efficient production of energy in the body at rest as well as during physical activity of various degrees. Under normal physiological conditions oxygen for such vital activities is supplied to the tissues by the haemoglobin contained in the circulating red cells. Haemoglobin uptakes oxygen from the lungs and downloads it to the tissues. Normal levels of haemoglobin are sufficient to meet the oxygen requirements of the tissues in the body at rest and will have sufficient reserve to meet the increased oxygen demand during physical activity. Normal individuals depending upon their age, sex and body mass will have natural endowment of haemoglobin. There can be physiological variations in the levels of haemoglobin which are considered normal (Table 1.2).

Normally nourished individuals have sufficient quantity substrate available for the production of energy in the body. They also possess equally sufficient compliment of haemoglobin to supply oxygen for the production of energy required for the thermodynamic functions of the body. This is the normative physiological function.

The economic output of an individual is the result of energy produced through the physiological process in the body and its utilisation for the physical activity. The body uses the substrate (glucose obtained from food) and in the presence of oxygen produces energy in the form of ATP and supplies it to the target tissues like vital organs and the muscles. Thus, the functional capacity of the body is expressed as efficient functioning of the vital organs

and the output generated by the physical activity. It can be represented as:

$$\begin{aligned} \text{Economic output of the Individual} &= \text{Energy reserve} + \text{Musculoskeletal and} \\ \text{(Physical capacity / Intellectual output)} & \quad \text{Neurological capacity} \quad \dots\dots(1) \end{aligned}$$

$$\text{Or} \quad \quad \quad = \text{Energy available} + \text{Physical capacity} \quad \dots\dots(2)$$

$$\text{Productivity} \quad \quad = \text{Energy Produced} + \text{Physical capacity to} \\ \quad \quad \quad \quad \quad \quad \quad \quad \text{utilise such energy} \quad \dots\dots(3)$$

IRON DEFICIENCY ANAEMIA: THE PANDEMIC

Its Prevalence

Iron deficiency is the most common form of malnutrition with a worldwide prevalence initially believed to be affecting more than two billion people around the world throughout their life cycles (Draper 1997, Berger *et al* 1997, Stoltzfus and Dreyfuss 1998, WHO/UNICEF/UNU 2001). It is recognised that if anaemia affects more than 40 per cent of a population, virtually the entire population is likely to be iron deficient (Filteau 1995). Therefore, it is a public health problem of a huge magnitude, more specifically in the developing countries and to some extent in the developed countries.

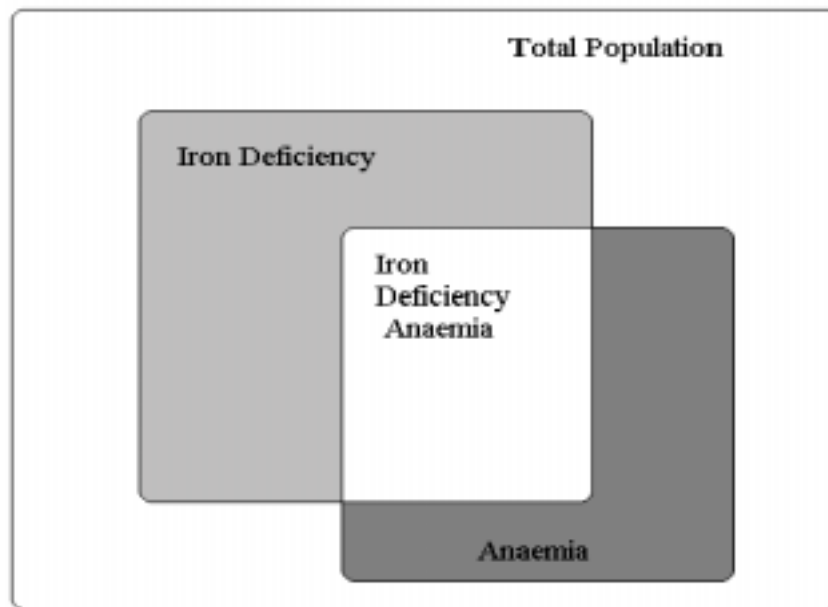


Figure 1.2: Conceptual Diagram of the Relationship between Iron Deficiency and Anaemia in a Hypothetical Population
 Source: Adopted from Yip 1989

Basically, prevalence of anaemia is a statistical concept than a physiological one (Sari *et al* 2001). The current estimates of prevalence of iron deficiency and anaemia is between a low of 2 billion (at a prevalence rate of 30 per cent) and a high of 5 billion (at a prevalence rate of 80 per cent) (Stoltzfus 2001). The former can be regarded as iron deficiency anaemia and the latter as iron deficient - with or without anaemia.

For the purpose of public health, the prevalence of iron deficiency can be classified into four grades depending upon the prevalence of anaemia in a given population (WHO/UNICEF/UNU 2001).

Table 1.3: Public Health Significance of Iron Deficiency Anaemia

Category of Public Health Significance	Prevalence of Anaemia (per cent)
Severe	> or = 40
Moderate	20.0 – 39.9
Mild	5.0 – 19.9
Normal	< or = 4.9

Source: WHO/UNICEF/UNU 2001

Prevalence of Iron Deficiency in India

There are no population-based anaemia surveys in India, which can provide prevalence levels of iron deficiency anaemia across the country for the entire population. The National Family Health Survey –2 (NFHS-2) and the Reproductive and Child Health – Rapid Household Survey (RCH-RHS II Round) are being selective population-based studies. Therefore, they cannot be considered as representative in nature for the entire population.

The National Family Health Survey – 2 (NFHS-2 1998-99) is the first ever nationwide study of iron deficiency anaemia by direct measurement of haemoglobin in ever married women in the reproductive age 15 - 49 and their children under three years of age. Overall, 52 per cent of the women have some degree of anaemia while 74 per cent of their children have similar degree of anaemia (IIPS/ORC Macro 2000). The recent multicentre study by the Indian Council of Medical Research in sixteen districts of eleven states has indicated an overall prevalence of 84.9 per cent among pregnant women and 90.1 per cent among adolescent girls (ICMR 2001).

Epidemiology

The prevalence of iron deficiency varies widely according to host factors like age, gender, physiological, pathological, environmental and socioeconomic status (Sari *et al* 2001).

Age: Normal full term infants will have adequate haemoglobin and iron stores. Iron requirements of the body increase with the growth peaking at the infancy, childhood, and adolescence. In women, iron requirements will increase during the reproductive years and may also in old age due to hypoalimentation.

Gender: Iron deficiency can occur among females during adolescence, as demand for iron will peak at that time of life cycle.

Physiological status: Pregnancy and lactation impose higher demand for iron since the foetus is dependent on the mother for iron irrespective of the iron status of the mother. However, amenorrhoea during lactation may help to balance the iron loss to some extent.

Pathological state: While common chronic and recurrent infections suppress hemopoiesis leading to anaemia, parasitic infestations – like malaria, lead to haemolysis, intestinal infestations cause blood loss from the intestine leading to chronic iron loss.

Environmental factors: The extensive prevalence of hookworm infestation in the tropics is an important cause of anaemia in varying degrees. *Necator americanus* is more notorious and has greater prevalence in India than *Ancylostoma duodenale*. Intestinal worm load is directly proportional to the loss of blood (Stoltzfus and Dreyfuss 1998). Low iron content of food and/or low bioavailability of iron in the food consumed and availability of other nutrients necessary for hemopoiesis are the other factors leading to iron deficiency anaemia.

Socioeconomic status: Iron deficiency is common among the socioeconomically disadvantaged segments of population (WHO/UNICEF/UNU 2001).

Iron Nutritional Status: Iron Deficiency and Iron Deficiency Anaemia

Iron deficiency is a state of diminished total body iron content. Iron deficiency is defined as a condition in which there are no mobilisable iron stores and in which signs of compromised supply of iron to tissues, including the erythron, are noted. Iron deficiency is a worldwide major public health problem with an incidence of greater severity in the developing countries. In any population, iron deficiency occurs in three different stages depending upon the degree of iron depletion in the population or the individual. The first of the three stages is the stage of *iron depletion*. It is a state in which the body iron stores are depleted without any effect on the essential iron compounds in the body or their function. The second stage is the stage of *iron deficiency without anaemia*. This stage is characterised by lack of

iron sufficient for normal production of haemoglobin and other iron compounds but the haemoglobin concentration does not fall below the levels indicative of anaemia. The third stage is a frank iron deficiency anaemia wherein the production of haemoglobin is depressed below the normal reference levels for individuals of same age and sex (Bothwell *et al* 1979, Dallman 1990). Thus, iron status can be considered as a continuum from iron deficiency to iron deficiency anaemia (WHO/UNICEF/UNU 2001).

Cut-off Values of Haemoglobin for Defining Iron Deficiency Anaemia

Distribution levels of haemoglobin vary widely across all ages, gender, and physiological state of normal population as well as people affected by iron deficiency. It is necessary to define levels of haemoglobin and establish 'cut-off' values which separate the anaemic population from non-anaemic population. In the absence of accurately conducted large-scale population surveys for estimating the typical haemoglobin levels among different populations across the world the following haemoglobin values given in the table are generally agreed upon as acceptable 'cut-off' values with the notion that there are large variations across the populations (Table 1.4).

Grading of Iron Deficiency Anaemia

The iron deficiency anaemia is further graded, though arbitrarily, into mild, moderate, and severe grades depending upon the haemoglobin values. Besides recognising the severity of the disease instantaneously, this grading also helps as a management tool for the care of iron deficient people and in the implementation of preventive measures to contain the iron deficiency anaemia. Population surveys have been using this grading to estimate the levels of prevalence in their populations. The National Family Health Survey – 2 (NFHS-2) and Reproductive and Child Health – Rapid Household Survey II Round (RCH-RHS) as also some of the Demographic Health Surveys (DHS) elsewhere in the world have used this grading.

Iron deficiency anaemia is considered as mild when the haemoglobin values are 80 per cent and above, moderate between 80 per cent and 60 per cent and severe when less than 60 per cent of the cut-off levels. In other words, iron deficiency anaemia is diagnosed as mild when the haemoglobin concentration above 10 g/dl but below the cut-off level, is moderate between 7 and 10 g/dl, severe when the concentration of haemoglobin is below 7 g/dl and very severe when concentration of haemoglobin is below 4 g/dl ((DeMaeyer *et al* 1989 and PATH 1997) (Table 1.5).

Table 1.4: Haemoglobin and Haematocrit Levels Below Which The Population is Considered as Anaemic

Age or Gender Group	Haemoglobin g/dl	Haematocrit per cent
Children 6 months to 59 months	11.0	33
Children 5-11 years	11.5	34
Children 12 – 14 years	12	36
Non-pregnant women (Above 15 Years of Age)	12	36
Pregnant women	11	33
Men (above 15 years of age)	13	39

Source: Baker and DeMaeyer 1979, DeMaeyer *et al* 1989, WHO/UNICEF/UNU, 2001.

Table 1.5: Grades of Iron Deficiency Anaemia

Grades of Anaemia	Haemoglobin Values
Mild	<11.0 g/dl but > 10.0 g/dl
Moderate	7.0 g/dl – 10.0 g/dl
Severe	< 7.0 g/dl
Very Severe*	< 4.0 g/dl

* (PATH 1997)

MORBIDITY-ATTRIBUTABLE TO IRON DEFICIENCY ANAEMIA

Manifestations of Iron Deficiency Anaemia

Iron deficiency and iron deficiency anaemia result in a broad spectrum of physiological and pathological consequences in the populations affected. The morbidity affects the entire life cycle of human beings right from the foetus to the elderly. The spectrum of affliction is quite wide and comparable to that of the very wide prevalence of the nutritional deficiency. Perhaps, it portends greater morbidity among the populations of the developing countries who suffer the worst of iron deficiency.

Iron deficiency insidiously affects physiological functions ranging from very minute molecular function such as electron transport within the cell to tissues and organ systems with innocuous to profound morbidity. The range of affliction spans from the highly sensitive brain cells to the rugged

prime movers, the muscles in the body.

The functional consequences of iron deficiency are a continuum, basically due to decrease in oxygen supply to the tissues and the level of morbidity is proportionate to the deficit in oxygen supply to the tissues of the body (Beard 2001). There is overwhelming evidence which indicates the six broad areas of outcome due to iron deficiency and/or iron deficiency anaemia (Stoltzfus 2001). These include, foetal development and child growth, psychomotor and cognitive development, pregnancy outcome, endocrine and neurotransmitters production, work capacity and productivity, and resistance to infection and immunity (WHO/UNICEF/UNU, 2001).

Iron Deficiency Anaemia and Pregnancy Outcome – The Reproductive Morbidity

Iron deficiency with its very wide prevalence virtually affects all females in the developing countries throughout their life-cycle. Poor nutrition affects women in childhood, increased nutritional demand during adolescence, and repeated pregnancies place them in perpetual iron deficiency throughout their adulthood. The cycle perpetuates as underdevelopment and consequent malnutrition, including the micronutrient deficiencies, continues to affect large segments of the people. Currently in India, the iron deficiency anaemia has almost assumed the proportion of intergenerational prevalence. The sinister cycle of “anaemic mother begetting - anaemic offspring - growing to become anaemic mother” is getting firmly established.

Anaemia is a commonly prevalent major medical condition – a non-obstetric maternal risk factor during pregnancy in India as well as among other developing countries. It affects a very large number of women. It is one of the leading causes of obstetric morbidity and mortality. Iron deficiency anaemia increases maternal mortality, prenatal and perinatal *foetal* loss and prematurity (WHO/UNICEF/UNU 2001).

Anaemia affects all segments of population in varying degrees but its prevalence increases with lower levels of education, socioeconomic status, poor housing and sanitation, lower age at marriage, short birth interval, higher birth order, and women with poor antenatal care (Thangaleela and Vijayalakshmi 1994, and Rao 1992).

Mild and moderate anaemia may not have produced very obvious effects but for the fact that with the progress of the pregnancy the iron status of the women deteriorates. Incidence of antepartum hemorrhage, preterm delivery, postpartum hemorrhage, maternal mortality, mild to moderately increased cardiac output (heperdynamic circulation), progressing cardiac failure, thrombophlebitis and thromboembolic phenomenon, puerperal

infections, stillbirths are most frequently seen maternal complications of iron deficiency anaemia (Whitfield 1988, Raman 1989, Bhatt 1992, and Sharma 2003). Practically all the complications of pregnancy are aggravated quantitatively by anaemia (Donald 1986). In a recent analysis, Brabin and his colleagues have estimated the relative risk of mortality associated with moderate anaemia (Hb 4-8 g/dl) as 1.35 (95 per cent confidence interval - CI) and for severe anaemia (Hb < 4.7 g/dl) as 3.51 (95 per cent CI). In the absence of sufficient data in developing countries about the adolescent anaemia related mortality, it can only be presumed that onset of nutritional anaemia at an early age results in chronic anaemia that perpetuates any risk of anaemia related mortality through subsequent pregnancies. Frequent antenatal care may reduce the risk (Brabin *et al* 2001).

The negative association between iron deficiency anaemia and duration of pregnancy and low birth weight has been reported by a number of scholars even though the causal factors remain unproven. The risk factors, which operate for both preterm delivery and intrauterine growth retardation, are similar. The biological mechanism in operation is fairly complex. The hypoxia caused by anaemia and iron deficiency *per se* lead to increased serum concentration of noradrenaline which can cause maternal and foetal stress, which can stimulate the synthesis of corticotrophin releasing hormone (CRH). Elevated levels of maternal corticotrophin releasing hormone are a major risk factor for premature rupture of membranes, preterm labour, pregnancy-induced hypertension and eclampsia. The foetal effect of the increased corticotrophin releasing hormone increases the foetal production of the cortisol elevated levels of which in the foetus will signal a halt to the foetal growth and proceed with foetal maturation processes. Maternal iron deficiency may also increase the risk of maternal infections, which can stimulate the synthesis of CRH. A significant association exists between the maternal haemoglobin levels and the functional capacity of the placenta as expressed by the levels of human chorionic gonadotrophin (hCG) and human placental lactogen (hPL) which have a significant negative correlation with maternal haemoglobin levels (Allen 2001).

In an extensive literature review, Rasmussen (2001) has pointed out the existence of a strong evidence for an association between maternal haemoglobin levels birth size at birth, duration of gestation, and neonatal or perinatal mortality. On a liberal interpretation of the data, the association appears to be U-shaped denoting a rise in the proportion of low birth weight infants (with a drop in the mean birth weight) when the maternal haemoglobin levels are at the lowest or highest ends of the range. A similar U-shaped

relationship is also known with maternal haemoglobin levels and neonatal or perinatal mortality. Severe maternal anaemia (< 8 g/dl) is associated with lower birth weight by about 200-400g than with higher maternal haemoglobin levels (> 10 g/dl).

Iron Deficiency Anaemia and Physiological Functions

Iron deficiency anaemia constrains the supply of oxygen and respiratory capacity of the muscles in the human subjects as seen in exercise physiology work performance. This physiological principle may explain the possible reasons for the lag in the acquisition of new motor skills, motor development, and physical activity as observed in the children with iron deficiency anaemia. This limitation in the acquisition of the motor function as a biomechanical system will then extend to the area of cognitive development since the motor activity contributes to the alignment of visual spatial perception and intersensory organisation. Delays in locomotion and motor activity slow down access to external sources of emotional regulations and constrain the development of self-sufficiency and independence. Children with iron deficiency are at greater risk of delays in the acquisition of appropriate systems of emotional regulation (Pollitt 2001).

In a review of a number of studies, Gratham-Mcgregor and Ani (2001) find association between iron deficiency anaemia and poor cognition, motor development and behavioural problems. Longitudinal studies indicate that children who were anaemic during infancy continue to have poor cognition, school achievement, and behavioural problems during middle childhood. Such children (< 2 years) do not benefit from short-term iron therapy. Several mechanisms linking iron deficiency anaemia and altered cognition have been proposed. One such mechanism is that it affects the development of the structure and function of the central nervous system (CNS).

Recent studies on auditory brain stem responses in children with anaemia provide a measure of the activation of auditory pathways from the distal part of the acoustic nerve to the lateral lemniscus. The central conduction time is considered as an indicator of central nervous system development. The central conduction time is prolonged in anaemic children aged 6 months who are anaemic compared to non anaemic children. Recent investigations have shown that children who were anaemic earlier had latencies in visually evoked potentials. Such prolonged conduction time has been attributed to the changes in the myelination. Studies also link the poor development of anaemic children to functional isolation, as anaemic children explore and move around their environment less than nonanaemic children

and thus, induce less stimulating behaviour in their caretakers which is necessary for acquiring new skills by the children. Anaemic children tend to be more fearful, withdrawn, tense, unreactive to usual stimuli, more solemn, less involved and more unhappy. They stay closer to the care takers, show less pleasure, and are more wary, hesitant and easily tired, less likely to be venturing on to potio or playing interactively with objects. These changes are attributed to several biological mechanisms in which iron deficiency can affect the child development (Grantham-McGregor and Ani 2001).

In an extensive review of studies from across the world, Oppenheimer is of the opinion that in spite of the proven reversible functional immunological defects, a clinically important relationship between states of iron deficiency and susceptibility to infections remain controversial, difficult to prove and may depend on other immune factors in the community. Experimental and in vitro animal studies suggest that pathogens which spend a part of their life-cycle intracellularly such as plasmodium, mycobacteria and invasive salmonellae may thrive with the iron therapy. No deleterious effects have been noted with iron therapy in non-malarious regions. Early studies indicate reduced respiratory infections with milk fortification. One study has indicated reduced infectious morbidity with oral iron supplementation in anaemic school children. A number of studies on the immune response to iron supplementation and therapy are inconclusive about the exact nature of the preexisting immune status and the nature of response following iron intervention. Several cellular and humoral immune mechanisms have been proposed and studied without any significant outcome (Oppenheimer 2001).

Iron is necessary for the pathogens as well as for the host. The pathogens have evolved effective mechanisms of accessing micronutrients. The pathogens obtain iron from the biological fluids through the secretion of siderophores. The host also needs iron for mounting effective immune response. If the host fails to sequester iron from the pathogens, the unrestricted supply of iron in the body fluids will increase the pathogenicity.

Iron is an important element in the synthesis and function of a number of iron containing enzymes such as tyrosine hydroxylase, tryptophan hydroxylase, xanthine oxidase, ribonucleoside reductase, monoamine oxidase, and aldehyde dehydrogenase. These enzymes are involved in the electron transport in the brain and in the catabolism of neurotransmitters. Dopaminergic system is the most important neurotransmitter system in the central nervous system and it is known to be very sensitive to the iron levels. A synthesis of dopamine, serotonin and noradrenaline is affected by iron deficiency anaemia. The enzyme cytochrome-C has been demonstrated

to be particularly important in the oxidative metabolism and endurance (Beard 2001)

Iron has a very important role in the oxidative energy metabolism. A large portion of the iron in the body is used in the transport and supply of oxygen for energy production. This portion of the body iron is known as functional iron and is a constituent of haemoglobin, myoglobin, iron-dependent enzymes and respiratory chain proteins. These iron compounds serve various functions in the energy metabolism as shown in the following table.

Table 1.6: Iron-Containing Compounds Involved in Energy Production

Iron-Containing Protein	Functional Site	Major Biological Functions in Energy Production
Haemoglobin	Red blood cells	Oxygen transport
Myoglobin	Cytoplasm of muscle cells	Facilitates diffusion of oxygen towards the mitochondria
Oxidative enzymes such as dehydrogenase	Mitochondria - inner membranes and matrix	Oxidation of substrate (acetyl-CoA) to produce NADH and FADH
Respiratory chain proteins such as cytochromes	Mitochondria - inner membrane	Electron ² (electrochemical energy) transfer from O ₂ molecule to NADH or FADH ₂

Source: Haas and Brownlie IV (2001)

Energy production in an individual is estimated on the aerobic capacity to assess the maximum oxygen consumption ($VO_2 \text{ max}$) which indicates the physical (aerobic) fitness. The endurance capacity² is the ability of an individual to sustain a given workload over a period of time. It indicates the supply of oxygen to the muscle tissue and utilization of oxygen by the muscle tissue. Energy efficiency is the physiological energy required for performing a given task, such as, sugarcane cutting, tea leaf picking or earth moved in a fixed period of time. Voluntary activity is the ability of the individual to perform strenuous voluntary activities over a period of time or shift to less strenuous sedentary activities. Economic productivity is the ability of the individual to produce goods or objects which can be quantified over a specified period. They include tea picking, rubber tapping, cotton or jute mill work, cigarette rolling and so on, where the production output, especially the earnings can be measured.

The evidence from laboratory studies in animals and humans and field studies before or after iron supplementation is strongest in pointing out that the iron deficiency anaemia causes reduced aerobic capacity. This clearly suggests the impairment of endurance capacity, existence of causal relationship between iron deficiency and voluntary physical activity and economic productivity (Haas and Brownlie IV 2001).

Iron Deficiency from Womb to Tomb

Iron deficiency seems to be all pervading in its prevalence especially in the developing countries affecting people right from the foetal stage through the entire life-cycle of an individual. Characterised as hidden emergency the iron deficiency in the early childhood is quite devastating as it will block the development of the child to attain its own natural potential for growth, both physical and mental. In the adolescence and adulthood besides affecting the growth spurts, it affects the physical capacity, reproductive performance, and economic outcome for an individual. Poverty, illiteracy, poor environmental sanitation and inaccessibility for food escalate the prevalence and the impact of iron deficiency anaemia.

MALNUTRITION

Human body needs energy to meet the physiological and functional needs. Food is the principal source of energy in the Nature. It is the fuel for the maintenance of energy requiring processes that sustain life (Devlin and Horton 1990). Energy is needed for maintaining the physiological milieu to sustain electromechanical activities of the body. The food consumed is converted into body energy stores and the efficiency with which such conversion takes place is subject to individual variations and the quality of food consumed. There are two functions of the food, viz., energy intake and energy expenditure.

Energy intake is an essential function of the living organisms. It is highly variable and depends upon the availability, quality and physiological ability to digest and assimilate the food so consumed.

Energy expenditure is the physiological function in which the food stores are converted into energy to meet the metabolic and functional needs of the body. In the body the energy is required for four very essential functions, viz., to meet the needs of basal metabolism, for the physical activity or exercise, for the digestion of the food consumed and for facultative heat regulation.

Basal metabolic rate (BMR) is the rate at which the energy is used by the body for proper functioning of all the systems in the body and to

maintain the body temperature at normal level. BMR is a very sophisticated scientific expression of energy expenditure wherein the individual is allowed to perform only the most essential bodily functions without giving room for extra energy expenditure. It is measured under strict experimental conditions but is applicable for routine activities of the body. BMR is the major consumer of body energy sources and accounts for 60-75 per cent of the energy expenditure. BMR varies according to age, sex and body size and is influenced by several metabolic factors.

Energy requirements for exercise is the energy required for physical activities ranging from routine tasks to physical work. It is highly variable as it depends upon the activities performed and accounts for 15-30 per cent of the energy expenditure. The spontaneous activity is a major component of energy expenditure and, at its peak performance, the exercise can consume 10-15 times the energy over and above the BMR.

Energy required for digestion (also known as specific dynamic action) is the energy expenditure above the BMR for the digestion, assimilation, and storage of food in the body. The complex processes involved in the digestion and storage of food need varying amount of energy for such activities. The energy required for the synthesis of various components of nutrients varies according to the nature and importance of the nutrients concerned.

Energy for facultative heat regulation is a metabolic function which helps to maintain the body temperature at a given level throughout the life time of the individual. It accounts for \leq 10-15 per cent of the total energy expenditure. It is variable depending upon the weather conditions, body composition, age, and sex of the individual. Any increase in the body temperature above the normal levels will account for higher energy expenditure.

The science of nutrition examines the qualitative and quantitative requirements of diet necessary to maintain good health. All the components of the diet required to maintain life are known. However, there are known variations in the quantities of the components depending upon age, sex, and life-style of the individuals (Mayes 2000).

Principal Energy Sources

There are three major components of food, viz., carbohydrates, fats and proteins. While carbohydrates and fats are the main source of energy, proteins help in the synthesis of substances required for the growth of the individuals.

Carbohydrates

Carbohydrates are the most abundantly and commonly available food for human beings (Szepesi 1990). Most abundant sources of carbohydrates in the diet are starch, simple sugars, and cellulose. Man and other monogastric organisms cannot digest cellulose. Digestion of carbohydrates is regulated by the functional capacity of the gastrointestinal system. The processes involved in the digestion of the carbohydrates are regulation of emptying of the stomach, intestinal motility, secretion of digestive enzymes, and localisation of intestinal enzymes.

Dietary carbohydrates are ingested in three forms: (1) raw or processed vegetables, fruits, and grains (i.e., cooked, boiled, ground etc.); (2) purified carbohydrates added to foods; and (3) carbohydrates dissolved in various drinks.

Carbohydrates serve as the metabolic fuels for all tissues. Absorbed carbohydrates are under a complex control mechanism to maintain constant levels of glucose in the body. Liver is the main organ which regulates the carbohydrate homeostasis in the body. The excess glucose is stored as glycogen or fat. In times of shortage of glucose, liver manufactures glucose: first from its own glycogen and when depleted from amino acids. The carbohydrate intake is determined by cultural and economic factors. Carbohydrates form 50 per cent of the diet in the developed countries and up to 70 per cent of diet in the developing countries.

Lipids or Fats

Dietary lipids are substances which do not dissolve in water but dissolve in organic solvents. The largest proportion of fat in the diet is in the form of triglycerides and other forms consist of fat-soluble vitamins (A, E, D, and K), phospholipids and others (Dupont 1990).

The digestion of the fats starts from the mouth with the addition of saliva to the food. In the duodenum the bile and pancreatic secretions will aid in the digestion and absorption of the fats. Absorbed lipids are rendered water soluble and transported in the blood plasma for incorporation as lipoproteins.

Although lipids do provide a significant proportion of energy required by the body the two essential functions of the lipids are to act as vehicles for fat soluble vitamins and to provide the body with essential polyunsaturated fatty acids which the body is unable to synthesise. The three polyunsaturated fatty acids are linoleic acid, α -linolenic acid and arachidonic acid (Mayes 2000).

The principal function of essential fatty acids is that they serve as precursors of biologically very active substances like leukotrienes, lipoxins, prostaglandins and thromboxanes which act as local hormones.

Proteins

Proteins in the diet supply the body with nitrogenous compounds essential for growth and maintenance of physical size of the body. Proteins contain amino acids, which are the principal source of nitrogenous substances. Nine amino acids have been recognised as essential amino acids in humans, viz., histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine. These essential amino acids are required for the protein synthesis in the body. Proteins are digested in the gastrointestinal tract by a very complex digestive process and absorbed. At times of starvation or increased demand for energy production and when there is a reduced supply of carbohydrates and fats, proteins are the last affected.

Proteins are essential for maintaining metabolic equilibrium. Requirement for the proteins is increased during growth, pregnancy, lactation, tissue repair, and recovery from illness. The quality of the proteins depends upon the amino acid content of the protein. Proteins of higher amino acid content are derived from animal sources. Proteins from plant origin are deficient in several essential amino acids, for example, deficiency of tryptophan and lysine in maize, lysine in wheat, and methionine in some pulses. In a mixed diet the deficiency is made up by the abundance in another protein. Such proteins are known as complimentary proteins, for example, proteins of wheat and pulses provide satisfactory amino acid intake. Amino acids, which are not incorporated into new protein and are unnecessary for immediate requirement cannot be stored and are excreted (Mayes 2000).

Protein Energy Malnutrition (PEM)

Protein energy malnutrition is a major public health problem in developing countries, including India. It is both the quantity and quality of food consumed by the individual or the people at large is responsible for malnutrition.

PEM affects the physical well-being of population and growth of people at the times of growth spurt in children and adolescents. In a recent review of WHO database on malnutrition, Onis and Blössner (2003) have pointed out very high density of malnutrition in South Asia, especially in India. The review has indicated a high prevalence (≥ 40 per cent) of stunting among children in India, which corresponds to the findings of the NFHS-2. Nutritionally induced stunting robs the individuals of their full potential as,

besides the stature, muscle mass is also reduced. Consequently, work capacity is severely compromised because of stunting and poor endurance.

Malnutrition affects mental development of the children who later fail to thrive in motor and cognitive development, school achievements and IQ scores. Most of the effects of malnutrition are reversible if suitable supplementation programmes are instituted.

Children and adults who suffer from malnutrition have higher rates of infectious episodes due to reduced resistance to infections. In them both humoral and cell mediated immunities are affected. As a result, they are prone to have more frequent and more serious infections, specially diarrheal and respiratory infections. Malnutrition contributes to high infant and childhood mortalities in the developing countries. The benefit of better growth during childhood will improve the chances of delivering healthy newborns and decrease the risk of delivery complications and maternal deaths (Martorell 2000).

Reproductive outcome is jeopardised in the women with malnutrition. Poor pregnancy outcome resulting in intrauterine growth retardation, preterm delivery, low birth weight, poor perinatal outcome, maternal morbidity and mortalities are well recognised and they increase with the degree of malnutrition suffered. Maternal stunting besides being a risk factor seems to propagate itself across generations.

Progress of the nations will remain a far fetched dream as long as the scourge of malnutrition is not tackled effectively. Poor human development in the developing countries is an outcome as well as a cause of poverty (Martorell 2000).

PART II

IRON DEFICIENCY ANAEMIA AND MALNUTRITION IN INDIA

A Meta-Analysis of NFHS-2 Data on Iron Deficiency Anaemia and Malnutrition

India is a colourful country with the vividly undulating geography and varying agro-climatic patterns in its vast expanse. Diverse social and economic activities highlight the mosaic of the Indian economy. India can boast of being a great ancient civilization with rich religious and colourful cultures that present a scintillating picture of the people and their life across the land. In its passage through the time warp, India has accepted several religious and cultural influences and has seamlessly assimilated them into its socio-cultural plurality. A glance at the Indian scene anywhere in the country will give a kaleidoscopic representation of the unity in diversity.

Ravaged by the mediaeval invasions and colonial past, the country has earned the distinction of being a very large developing country with very low levels of socioeconomic development at the dawn of independence. Slow economic progress and low literacy levels, coupled with poverty and burgeoning population growth, have affected, in general, the health of the people in the post-independent period. Several population-based surveys in the past have dealt with the issues concerning a number of aspects of public health. The National Family Health Survey (NFHS-2) 1998-99 undertook the estimation of prevalence of iron deficiency anaemia (IDA) and malnutrition by measuring haemoglobin levels and anthropometric measurements of the ever married women age 15-49 and their children below age 36 months.

Earlier studies on the prevalence of iron deficiency anaemia and malnutrition in the country are scattered and very much limited in their extent to produce any representative data for the country as a whole. For a meaningful consideration of a public health problem like iron deficiency anaemia, robust data with a uniform spread across the country is necessary. The NFHS-2 has been able to generate such data for the first time in the country with certain limitations.

National Family Health Survey (NFHS-2): An Overview

National Family Health Survey 1998-99 was one of the largest demographic and health surveys undertaken in the world. It was second in the series, the National Family Health Survey 1992-93 (NFHS-1) being the

first jointly undertaken by the International Institute for Population Sciences, Bombay, ORC Macro, Calverton, MD, USA, and the East- West Centre Honolulu, Hawaii, USA. NFHS-2 was undertaken all over the country simultaneously covering all the twenty-six states. It was a nationally representative sample survey covering more than 90,000 ever married women age 15-49 and their children age below 36 months. The objective of the NFHS-2 was to provide state-level and national-level data on several demographic and health aspects including the nutritional status of women and their children. The survey was also expected to provide regional level data for the states of Bihar, Madhya Pradesh, Rajasthan and Uttar Pradesh, data for the metropolitan cities of Calcutta, Chennai, and Mumbai and slums of Mumbai. The survey was conducted in two phases. Ten states were surveyed in the first phase beginning in November 1998 and the remaining states beginning in March 1999 (Tripura in May-July 2000).

NFHS-2 was funded by the United States Agency for International Development (USAID) with additional funding from UNICEF. The International Institute for Population Sciences (IIPS), Mumbai, coordinated the survey and was technically supported by the ORC Macro, Calverton, Maryland and the East-West Center, Honolulu, USA. Thirteen field organisations - eight private sector organisations and five Population Research Centres (PRCs), established by the Ministry of Health and Family Welfare, Government of India; were involved in collecting the data, editing, processing, tabulation and report writing.

This was the first ever nationwide attempt at the estimation of prevalence of anaemia in the country on a sample survey basis, planned and executed simultaneously in all the twenty-six states of the country, using a single methodology, survey instruments and uniform procedure. This information was intended to help policymakers and programme administrators in planning and implementation of strategies for improving population, health, and nutrition programmes.

Sample Design and Implementation: Sample Size and Reporting Domains

The sample size for each state was specified in terms of number of completed interviews with the eligible women. The sample size was set according to the size of the state, resources available for the survey and the aggregate levels at which separate estimates were required (i.e., urban/rural, regional, metropolitan cities). The population of 1991 was taken as the basis for determining the sample size for the states. With the exception of Uttar Pradesh, Madhya Pradesh, Bihar and Rajasthan, the sample size of

4,000, 3,000, and 1,500 completed interviews with eligible women, was considered adequate for states with 1991 population of more than 25 million, 2-25 million, and less than 2 million, respectively. In order to provide regional estimates, the sample size was increased in the case of Uttar Pradesh to 10,000 completed interviews and 7,000 completed interviews each in Madhya Pradesh, Bihar and Rajasthan.

Similarly, to provide estimates for metropolitan cities of Mumbai, Calcutta, and Chennai, the sample size was set at 5,500 for Maharashtra and 4,750 each for Calcutta and Chennai. The target sample for Mumbai was large enough to support the estimates for slum and non-slum populations.

Urban and rural samples within each state were allocated separately in proportion to the size of the urban and rural population of the states concerned. In states where the urban population was not sufficient to support at least 1,000 completed interviews, the urban areas were appropriately oversampled except, in Goa, Sikkim, and six northeastern states, where the sample size was only 1,500.

Sample Design

NFHS-2 adopted the sample character as Probability Proportionate to Size (PPS) and multistage sampling procedure. In rural areas the sample selection was in two stages and in urban areas it was three stage selection. The villages were considered as Primary Sampling Units (PSUs) and were selected in the first stage. The households within the PSUs were selected randomly in the second stage. In the urban areas, wards were selected on PPS basis followed by random selection of one census enumeration block (CEB) within the selected ward in the second stage (except in Jammu & Kashmir where two CEBs were selected in each selected ward). Household listing was carried out within the CEB. On an average, 30 households per block were selected (except Jammu and Kashmir and Mumbai where the target was 20 households per block).

Sample Selection in Rural Areas

NFHS-2 used the 1991 census list of villages as the sampling frame. Districts were stratified into region and the regions were further stratified on the basis of the following variables: sub-regions, village size, percentage of males working in the non-agricultural sector, percentage of population belonging to scheduled castes and scheduled tribes and female literacy levels, though these variables were not used in all the states. A combination of variables was used to create not more than six strata for small, 12 strata for medium and 15 for large states. Female literacy was used as an implicit

variable in all the states except Kerala and Orissa, where it was used as an explicit stratification variable to order the villages according to the proportion of females who were literate. Villages were selected systematically with the probability proportional to 1991 census population of the said villages. A village with a minimum of 50 households was considered as a PSU and smaller villages with 5-49 households were linked to the adjoining village and villages with fewer than five households were excluded.

In all the states mapping and house listing was followed by selection of households. Villages with more than 500 households were segmented and segments were selected randomly on PPS basis. Households for interviewing were selected with equal probability by systematic sampling. On an average, 30 households were targeted with a minimum of 15 and a maximum of 60 households, for interviewing. All households selected were contacted and no replacement was made if the household was absent during data collection.

Sample Selection in Urban Areas

As stated above, in urban areas a three stage sample selection procedure was followed. In the first stage, wards were selected based on the 1991 census list and arranged according to the level of female literacy, and sample wards were selected on the basis of PPS. In the second stage, one census enumeration block consisting of 150-200 households was selected from each selected ward on the basis of PPS (in Jammu and Kashmir, two CEBs were selected from each selected ward). In the final stage, sample households were selected from the household listing in each CEB, which formed the sampling frame. On an average, 30 households per block were targeted. However, in Jammu and Kashmir and Mumbai 20 households were targeted per block.

Sample Implementation

With a view to achieving better coordination and supervision of the fieldwork, the NFHS-2 operations were carried out in the country in two phases. In the first phase, the survey was conducted in the states of Andhra Pradesh, Bihar, Gujarat, Haryana, Madhya Pradesh, Punjab, Rajasthan, Sikkim, Uttar Pradesh, and West Bengal, from November 1998. Fifteen states, viz., Arunachal Pradesh, Assam, Delhi, Goa, Himachal Pradesh, Jammu and Kashmir, Karnataka, Kerala, Maharashtra, Manipur, Meghalaya, Mizoram, Nagaland, Orissa, and Tamil Nadu were surveyed from March 1999 in the second phase and Tripura in May through July 2000.

A total of 92,466 households were interviewed, of which two thirds were in rural areas. With an overall response rate of 98 per cent it was more than 94 per cent in all states, with 91 per cent and 89 per cent in Delhi and Meghalaya, respectively. In Tamil Nadu, the household response rate was 100 per cent.

A total of 90,489 women were interviewed with a 96 per cent response rate for the country as a whole. The response pattern was similar to household responses across the states.

Recruitment, Training, and Fieldwork

The uniformity of the survey procedure was maintained all over the country with the help of four manuals dealing with different aspects of the survey, viz. The Interviewer's Manual, Manual for Field Editors and Supervisors, Household Listing Manual, and Training Guidelines. Representatives of the field organisations were trained in the training of trainers workshops organised by the IIPS at the beginning of each phase of data collection. These trainers subsequently trained the field staff.

Several interviewing teams conducted the survey. All interviewers were females and each team consisted of one field supervisor, one female field editor, four female interviewers, and one health investigator.

The Health Investigators

The health investigators were non-technical personnel with a variety of educational backgrounds, most often social sciences. All of them were given 'additional specialised training' on measuring height, weight, and testing for haemoglobin at a centralised training programme organised by the IIPS in collaboration with the All India Institute of Medical Sciences (AIIMS), New Delhi. The specialised training consisted of classroom training and extensive practice in the field conditions in schools and anganwadis and communities. Medical health coordinators appointed by the IIPS monitored the nutritional component of the survey.

ESTIMATION OF LEVELS OF ANAEMIA AND MALNUTRITION

The billion people of India would have been an asset if they were healthy and physically capable of being economically productive to the optimum natural endowment. However, a large number of studies have pointed out the prevalence of a number of diseases and poor health conditions which incapacitate the people and divest them of the economic potential leading to deprivation and poverty. Although several epidemiological studies

in the past had pointed out the prevalence of a number of common nutritional deficiencies like iron deficiency anaemia (IDA) and malnutrition, they were flawed either by the methodology, coverage or extent or all of them. The outcome of such studies was insufficient to support a positive policy formulation to contain such deficiencies or to direct programmatic approaches. A large robust data on the prevalence of such conditions which was representative of the entire population was a long felt need. The small, scattered studies would not meet such a need. For the first time in India, the NFHS-2 met such a felt need to some extent.

Considering the vastness of the country with varying degrees of socioeconomic conditions of the people, their access to food, food consumption practices across various regions of the country and among various religious and ethnic groups it is difficult to estimate the prevalence levels of malnutrition. In the absence of the direct methods of estimation of malnutrition, proxy measurements are used to estimate the nutritional status of populations, be it micronutrient deficiency like iron deficiency anaemia or macronutrient deficiency like protein energy malnutrition (PEM) - though inaccurately, but commonly called as malnutrition. In fact, malnutrition is a very broad term and includes all the diseases caused by a number of nutritional deficiencies and there are specific methods to estimate all such deficiencies.

The purpose of this study is to estimate the disease burden attributed to the two very common nutritional deficiency diseases, viz., iron deficiency anaemia and malnutrition. The iron deficiency anaemia (IDA) is a micronutrient deficiency with far reaching physiological consequences. Malnutrition is due to the macronutrient deficiency, i.e., carbohydrate, protein, and fat deficiency, which can affect the growth and the physical capacity of the population. The methods of estimation of the two deficiencies are very different from one another and a very difficult task indeed, more so in the field conditions. These two conditions are known for their synergistic effect potentiating the impact of each other on the affected individuals.

Data Source for the Study - Meta-Analysis

National Family Health Survey (NFHS-2) was the second largest nationwide demographic and health survey, conducted in 1998-99 in all the twenty-six states of the country. The union territories were not included in this survey. It was a household survey with an overall target sample size of 90,000 ever-married women in the age group 15-49 and their children below 36 months of age. This survey was expected to provide state level and national level data on fertility, family planning, infant and child mortality,

reproductive health, child health, nutritional status of women and children, and information on the quality of care in health and family planning services.

The National Family Health Survey (NFHS-1) 1992-93, the first ever large-scale nationwide demographic and health survey conducted in India did attempt a survey of nutritional status of children under age four years. For logistic reasons, only weight was measured in five major states of India, and the data were analysed under certain assumptions, where the validity of the analysis became questionable. Secondly, the age groups chosen for the NFHS-1 was age below four years while that for the NFHS-2 was age below three years, rendering it difficult for straightforward comparison of the data from the two surveys. It was essential to define the age groups for population surveys and to adhere to such age groups consistently in view of replication of the data over a period of time and for the purpose of analysis. Floating age groups would render the data infirm both for internal and international comparisons.

The data for this study on nutrition and prevalence of anaemia has been generated by the National Family Health Survey (NFHS-2) 1998-99. Like its predecessor, NFHS-1, the NFHS-2 is unique for the very large sample size of 90,489 women interviewees (urban 28,113 and rural 62,376) in 92,486 households across the country. The survey population included in the NFHS-2 is ever-married women age 15-49 and their children age 0-35 months at the time of survey, both for iron deficiency anaemia and malnutrition.

The data are available for the entire country covering 99 per cent of the population in 26 states. For the first time in India, the micronutrient status as regards iron deficiency anaemia and nutritional status was surveyed on a large scale and the data have become available at the state level. However, the data are limited to ever married women age 15-49 and their children age below 36 months. That way the data are severely restricted but to two very important age groups among the Indian population - the women in reproductive age and the very young child population. Yet the data provide ample scope for taking a considered view at the current prevalence levels of morbidity among the defined segments and to predict the future trends within these segments.

In the background of the prevalence as shown in this survey, it can be strongly suggested to include the other important segments of the population also in future surveys to obtain a comprehensive picture of the prevalence of the iron deficiency anaemia and nutritional status of the people. That makes the future surveys more meaningful from the point of view of policy decisions, launching of programme interventions, and implementation.

Even the limited data, like the current one, can readily indicate the enormity of the problem, lend itself readily to the policy definitions, immediate programme interventions and implementation to contain the prevalence among the vulnerable segments.

NFHS-2 Sample Size for Iron Deficiency Anaemia and Nutrition Levels

The NFHS-2 estimated the nutritional status of women in the reproductive age and their very young children. The inclusive characteristics of the survey were that the nutritional status had been estimated for 78,118 women age 15-49 years and 24,824 children age 0-35 months with certain exclusions, viz., currently pregnant and women who had given birth two months prior to the survey, children who were not at home or ill at the time of the survey and children who refused to be measured or the mother refused to allow their children to be measured.

With a view of estimating the prevalence of iron deficiency in India, NFHS-2 undertook the direct measurement of the haemoglobin levels of women in the reproductive age 15-49 and their children below 36 months. The haemoglobin measurements were taken among 80,693 women respondents and 20,221 of their children age 6-36 months across the country covering 26 states. Like in the case of the estimation of malnutrition, for the estimation of the prevalence of iron deficiency anaemia, the NFHS-2 restricted population coverage to the women in reproductive age 15-49 and their children age below 36 months.

The data were collected from a very narrow segment of population, viz., ever married women in their reproductive age and their children age below 36 months. Such a restricted segmentation of survey population places very severe limitation on the value of the data for generalisation for the entire population or perhaps, to certain subgroups among them. However, the data on these two subgroups are very valuable as they provide a definite window to the current nutritional status of these two critically important groups in the population.

It is very important to remember that, by its very conceptualisation of population segmentation, these estimates are not representative in nature for the entire Indian population, but relatively for a small but very important segment of Indians – the current cohort of women in reproductive age and their progeny - the future generations of people of this country. To repeat, some very valid deductions can be made from the data but generalisations cannot be made for the entire population based on this data.

Methodology Followed by NFHS-2 for the Estimation of Iron Deficiency Anaemia and Malnutrition

Testing for iron deficiency anaemia

NFHS-2 undertook the estimation of iron deficiency anaemia for the first time in the country by direct measurement of haemoglobin levels of the respondents - women in their reproductive age 15-49 years and their children age 6-36 months. The measurements were made in the field. The HemoCue blood haemoglobin photometer was used to measure the haemoglobin levels all over the country. The methodology adopted for measurement was uniform.

A health investigator, attached to the survey team, had been assigned the task of testing the respondents and their children for haemoglobin levels and also making anthropometric measurements. The non-medical health investigators trained at the International Institute for Population Sciences (IIPS), Mumbai, in collaboration with the All India Institute for Medical Sciences (AIIMS), New Delhi, had been assigned the task of performing the anthropometric measurements and test the respondents and their children for haemoglobin.

The HemoCue blood haemoglobin photometer is a battery-operated photoelectric calorimeter, which records direct measurement of haemoglobin from a drop of undiluted blood filled into a microcuvette and inserted into the HemoCue photometer for reading. Since it is a battery operated portable equipment, it is suitable for use in the field conditions. The chemicals in a dry form coated on the specially designed microcuvette react with the drop of undiluted blood. In the chemical reaction the red blood cells get disintegrated releasing haemoglobin, which will further react with the chemicals to form a very stable haemoglobin compound azidemethaemoglobin. The photometer optically reads the colour absorbance of the product of chemical reaction against a factory calibrated colour blank equivalent of haemoglobincyanide (HiCN) method, which is the international reference standard, and the results would be displayed within 30–50 seconds. The HemoCue photometer reads the sample at double wavelengths of 570 nm and 880 nm to compensate for turbidity; hence, the presence of carboxyhaemoglobin, leucocytosis, and turbidity in the sample will not interfere with the measurement of haemoglobin in the sample.

The chemicals coated on to the microcuvettes are heat sensitive and require to be stored at a temperature of 15⁰ - 30⁰ C. The microcuvettes have an unopened pack shelf life of two years and a shelf life of three months after opening the pack. Microcuvettes are hygroscopic and moisture

sensitive, hence, need to be always kept in a tightly sealable container and used up within a few days after opening the container. The readings from the microcuvettes exposed to atmosphere and used after several days of opening the container are likely to be inaccurate. Higher storage temperature, high levels of humidity, and exposure to atmosphere for longer periods will result in the chemical deterioration of the microcuvettes.

Towards the end of the household interview, the health investigator explained to the respondent in detail about the need for anaemia testing and its methodology and sought her consent for performing haemoglobin test on herself and her children age 6-35 months. She was explained clearly that such testing was voluntary and completely safe and that it was required for research purpose to estimate the prevalence of anaemia among the population in order to institute anaemia prevention and treatment programmes. She was also informed that it was confidential and that if she consented results would be furnished to her doctor for the purpose of treatment, if necessary. In case she chose not to consent, her views were respected and the interview concluded without the haemoglobin test.

The type of data

The NFHS-2 data on haemoglobin estimation among ever married women is grouped into four age intervals – three intervals of five years beginning from age 15 years and one interval of fifteen years (35-49 years). No reason has been assigned for heaping the last three age intervals into one. Because of such heaping the uniformity of the data is lost. Such lack of uniformity in data affects the analysis, comparisons, and policy and programme interventions.

The heaping of ages for women age 35-49 years in the estimation of both nutritional status and anaemia is a severe drawback. Valuable spread of information based on the available data in these age groups is lost forever. No doubt that these women were past the peak of reproductive age, but in a few years they would be approaching menopause and problems related to aging. The data on the last two segments of age, viz., 40-44 and 45-49 would have provided a number of insights into the way that these malnourished and *anaemic* women would cope with the menopause and aging.

In the case of children also there were shortcomings in the collection of data on haemoglobin and malnutrition. Haemoglobin measurements were made for children age 6-35 months and anthropometric measurements for children age 0-35 months. No reasons were assigned for selecting the specific age groups for haemoglobin and anthropometric measurements. As these are significant gaps in the data on the status of iron deficiency of the infants

below age 6 months and beyond 36 months up to 60 months the value of the data is severely compromised. Data from birth to 59 months could have been used to correlate infant and child growth patterns, early childhood mortalities and under five child mortalities.

NFHS-2 has not estimated the prevalence of iron deficiency anaemia and malnutrition among men of corresponding ages. Such estimates would have provided valuable insights into the prevalence of anaemia among men, which is an important requirement from the policy and programme intervention perspectives.

Measurement of Nutritional Status

NFHS-2 has estimated the nutritional status of the ever married women age 15-49 and their children below 3 years of age with the help of the anthropometric measurements. Women respondents and their children below 3 years of age were weighed using a solar powered digital scale with an accuracy of ± 100 grams. Tared weights for very young children, who could not stand on the weighing scales by themselves, were obtained.

Heights of the women and children above two years of age or children more than 85 cms in height, were measured in standing position with an adjustable wooden measuring board designed to provide accurate measurements of women and children nearest to 0.1cm in the field condition. The length of the children below two years of age or less than 85 cms in height was measured lying using the same board placed in horizontal position on a firm surface. NFHS-2 did not measure 13 per cent of the children below age three because either the child was not at home at the time of interview or the mother refused the child to be weighed and/or measured.

Body mass index (BMI, also known as Quetelet's index) – product of weight in kilograms divided by squared height in cms (kg/m^2), was calculated for women using height and weight data to assess the thinness or obesity .

Data on weight and height/length of the children were used to calculate the three important anthropometric indices, viz., weight-for-age, height-for-age and weight-for-height. Standard deviations of these indices were calculated (z-scores) using international reference standards recommended by the World Health Organisation (WHO).

Data on nutritional status for women have been arranged into four age intervals similar to the intervals used in the case of haemoglobin estimates. In the case of children, data on nutritional status have been grouped into four age intervals – two intervals of six months from age 0-11 months and two intervals of one year each from age 12-35 months.

Data on either haemoglobin or anthropometric measurements are not available by parity of the respondent women. It is a serious loss of a highly important information on the effect of parity on maternal anaemia and malnutrition. Data on anaemia for women are available by their height and body mass index. Data on their nutritional status by anaemia are not available. Data on iron deficiency anaemia and malnutrition by birth order of the children are available, and are valuable. Data on the nutrition of the children are available by previous birth intervals but they are not available for iron deficiency anaemia among children.

Reference Standards for Growth and Comparisons

In India, since we do not have our own reference standards for growth among the children of all ages the NFHS-2 estimates have been compared to the reference standards developed by the National Center for Health Statistics (NCHS), Center for Disease Control and Prevention (CDC), Atlanta, Georgia, USA. These standards of growth have been developed for American children and have been recommended to the World Health Organisation (WHO) for adaptation as international reference standards. Several eminent nutritionists and scholars have pointed out that though differences exist between the reference standards of NCHS and the population based data from developing countries, they are very small in the age groups below ten years. It is advanced on the premise that up to the age of 10 years it is the economic and environmental factors which affect the child growth than the inherent genetic potential of the children in any country. The comparisons may not be very valid for the reason that NFHS-2 collected only height/length and weight data for the children as well as their mothers, however insights could be gleaned from the available data.

Critique on Data Collection, Quality and Limitations

The data collection on the prevalence of iron deficiency anaemia and the anthropometric measurements by NFHS-2 was a large-scale extensive exercise. In its extent, the data collection in NFHS-2 covered all the states in the country with a large sample size. It has to be appreciated that for the first time since independence an effort was made to institute large-scale population based survey on the very vital aspects like iron deficiency anaemia and malnutrition, which have a great bearing on the general health of the population in the country and more specifically on the maternal and child health. Earlier attempts by several institutions in estimating the prevalence of iron deficiency anaemia and malnutrition were severely limited and sketchy and the data output was nearly insignificant for either

policy perspective or programme institution. For historical reason, a mention has to be made of the anthropometric measurements carried out during the NFHS-1 in 1992-93. It was an incomplete exercise as data were not collected in some states for want of logistics. It is significant to note that an attempt was made in the past to undertake such a survey. Any lessons learnt or not is not reflected in the data collected in the NFHS-2.

For the reasons stated above, the NFHS-2 was a landmark survey in India in the area of nutrition because of the simultaneity, extent, and coverage. This data are a large state level primary source on the prevalence of iron deficiency anaemia and malnutrition. This data, for all practical purposes, are the *de facto* countrywide baseline data for future programmes in the country or for any analysis and comparisons. Had enough diligence been exercised in the technical aspects of the data collection this data could have been easily considered as a benchmark.

However, collection of such data should have been considered as a very serious task and every earnest attempt should have been made to maintain the quality and accuracy of the data. Choosing a method for testing haemoglobin was an important decision, mostly technical in nature. A wider consultation with and support from the outstanding experts in the field of haematology and nutrition would have lent greater credence to the data as such. Such a consultation would have led to the considerations among other things the precision of the results, which would have rendered the data robust. When there is a method, which is universally considered as a gold standard – the direct cyanmethaemoglobin method, rightly, should have been chosen against a method – HemoCue, which has certain known limitations of its own and is also known to overestimate the haemoglobin levels by around 1 per cent. Although it may appear difficult, it is practical and possible to test the haemoglobin levels by direct cyanmethaemoglobin method in any given field situation in India provided there are trained medical or paramedical personnel and adequate arrangements are made in advance. The advantages of the cyanmethaemoglobin method are that it is a universally accepted method for the estimation of haemoglobin, with a stable reagent solution, stable reaction, easily performed testing procedure and results readable in the field conditions with a photoelectric calorimeter. Alternately, the samples could be transported to a nearby laboratory, say, a first referral unit (FRU) for further analysis. Incidentally, the laboratory at the FRU and the skills of the laboratory technician could have been improved through the training imparted in the course of the survey, which could be used in the future surveys, a good capacity building exercise indeed, which did not happen.

HemoCue method has the advantage of portability and simplicity of operation and can be used in the remote areas without the need for electricity, an advantage for survey application. However, the HemoCue method has certain severe limitations. The recommended microcuvette storage temperature is in the range of 15⁰ - 30⁰ Celsius and cannot be refrigerated. The chemical composition of the basic reagents used in the microcuvettes make them hygroscopic. Once the vial containing the microcuvettes is opened, the shelf life is reduced from normal 2 years to 3 months. The quality of the microcuvettes deteriorates progressively and beyond 12 days the haemoglobin levels tend to get overestimated erratically. HemoCue method cannot detect small differences in the haemoglobin levels such as that of capillary and venous blood samples. It costs considerable amount of money (Sari *et al* 2001 and HemoCue AB n.d.), in the tropical India with regions of either high temperature (> 30⁰ C) or high humidity or both, all through the year. One might find the storage of microcuvettes difficult, consequently it affects the quality of results. The equipment is expensive and so are the microcuvettes.

HemoCue method of haemoglobin testing was used in the NFHS-2 along with UNICEF weighing scales and specially designed measuring board for anthropometric measurements. Haemoglobin testing even by the said-to-be-easy HemoCue method is a technical procedure requiring good knowledge of clinical laboratory procedures. Apparently, insignificant mistakes in the procedure can lead to variations in the final reading of haemoglobin levels by the sensitive photometer. And, that affect the quality of the data. It could have been avoided by recruiting suitable medical or paramedical personnel such as physicians or experienced laboratory technicians and trained them rigorously. Instead, lay persons were recruited, trained to test the haemoglobin levels and to make anthropometric measurements. In the Demographic and Health Survey of Kazakhstan, specially trained physicians were assigned the task of performing the haemoglobin testing (APM and Macro 1999). The HemoCue method is known to overestimate the prevalence of iron deficiency anaemia and even suggestions have been made to add a correction factor of 1.5 g/dl (Sari *et al* 2001 and Kapoor *et al* 2002). Furthermore, even minor technical errors in the process of estimation affect the quality of the data.

In the ongoing RCH-RHS I phase II Round, the haemoglobin estimation and anthropometric measurements have been made (currently the data are being processed). This is a more extensive survey expected to provide district level data and the I phase of the II Round covers 50 per cent

of the districts in the country and the remaining 50 per cent of the districts will be covered during the II Phase of II Round.

In the RCH-RHS, indirect method of estimation of haemoglobin has been chosen for the survey. In this method, a precise quantity of capillary blood, 20 µl, obtained from the finger prick (heel prick in case of small children) is transferred on to Whatman No. 1 filter paper. The blood spot on the filter paper is dried in shade at room temperature and it is appropriately labeled with a lead pencil. The dried filter paper with blood spot is placed in a suitable plastic cover and transferred into an envelope for dispatching to the laboratory for analysis. Samples from all the states were sent to two designated laboratories for analysis (one in North India and the other in South India). The dried blood on the filter paper is allowed to dissolve in 5 ml of Drabkin's solution after vortexing the solution for five minutes and it is allowed to stand for two hours. The resultant solution is read spectrometrically for haemoglobin levels. The accuracy of the test depends upon complete dissolution of the dried blood in the Drabkin's solution. A study has pointed out that the indirect method of haemoglobin testing is also known to overestimate the prevalence of iron deficiency as compared to the direct cyanmethaemoglobin method for the same samples (Sari *et al* 2001). Therefore, overestimations of haemoglobin levels can be anticipated in the RCH-RHS data also.

Moreover, in the RCH-RHS, haemoglobin estimations have been made for children in the age 0-71 months with age intervals of 0-5, 6-11, 12-23, 24-47 and 48-71 months. The heaping of ages in the intervals 24-47 and 48-71 defeats the very purpose of data collection for these age groups as this renders the analysis of the data and comparisons more difficult. Thus, the valuable data for the preschool children become nearly inaccessible.

Data Quality

Methodological shortcomings such as choice of the method, personnel and training, actual performance of the haemoglobin estimations and anthropometric measurements in the field affect the quality of the data so collected. The method chosen in the current survey for haemoglobin estimation is known to overestimate the prevalence of anaemia. This was known at the beginning of the survey yet a decision was made to select the method. The performance of haemoglobin estimation by the lay personnel chosen and trained for the purpose are more likely to be less diligent which adds to the inaccuracy of the estimations. Understanding the importance of handling the microcuvettes, especially their storage after opening the container are technical tasks. The ability to recognise the chance spillage of

a thin film of blood on to the optical eye of the microcuvette or recognition of the air bubbles entering the microcuvettes at the time of filling the microcuvette requires experience. These tasks can be understood and accomplished more diligently by technical personnel than lay persons. Compromise on the personnel leads to compromise in the quality of the data.

Data Limitations

Basically, the NFHS-2 data are limited and restricted to ever-married women in their reproductive age 15-49 and their children below three years only. This is a vital but a very narrow segment of population for whom the haemoglobin estimation and anthropometric measurements were made. The reasons for limiting the estimations in case of children to below three years and not including men in the reproductive age group for estimating the haemoglobin levels and anthropometric measurements has not been explained as these are shortcomings in the survey. The narrow segmentation of the child population to below age three years does not serve any useful analytical or programme interests, that too, when the infant's age below six months is omitted from haemoglobin testing. On the other hand, in the DHS of Kazakhstan, haemoglobin estimations for men and children under age 5 years were carried out (APM and Macro 1999).

Consequently, a large nation-wide survey data like the NFHS-2 data on the haemoglobin levels and anthropometric measurements does not lend itself readily to generalisation for the entire population and comparison outside the specific groups and populations of the country and other populations. Further, restricting the child population to the age group of 0-35 months and not performing haemoglobin estimations for children age below 6 months severely restricts the data from any meaningful analysis. For the same reason, it is also not possible to correlate the iron deficiency anaemia in children with their nutritional status. This is more crucial in a country like India where greater concern is about the neonatal mortality, infant mortality and child mortality, especially, under 5 child mortality. Such data collected at huge cost and effort will not be very useful either for the policy perspective or the programme implementation.

Incidentally, during the NFHS-1, anthropometric data on the nutritional status of children of the respondent ever married women, aged below 4 years were collected. For logistic reasons, the data were not collected in the first phase states viz., Andhra Pradesh, Himachal Pradesh, Madhya Pradesh, Tamil Nadu and West Bengal. The data were collected in other states in five age intervals, two intervals of six months and three intervals of

one year each, respectively (0-5, 6-11,12-23, 24-35 and 36-47).

Obviously, nobody seems to have looked into the usefulness of the data as otherwise several lessons should have been learnt out of such a truncated age intervals when the country is concerned about the welfare of preschool children. No serious thought has been bestowed on the data collected by the other demographic and health surveys (DHS) in the world where data were collected for children up to 5 years or even beyond.

PREVALENCE OF IRON DEFICIENCY ANAEMIA AND MALNUTRITION

Iron deficiency anaemia is a major public health problem in developing countries like India. The tropical climate is highly conducive for the prevalence of intestinal worm infestations, especially the hookworm. Malnutrition, possibly a resultant of iron deficiency anaemia and inadequate nutrition, promotes the prevalence and potentiates of the morbidity outcome of iron deficiency anaemia. The earlier studies on the prevalence of iron deficiency anaemia were very much limited in their extent and size besides the associated methodological problems rendering their data output insufficient for policy formulation or programme interventions. Currently, the NFHS-2 data are available uniformly all over the country with its own limitations and the analysis has been performed within such limitations.

The data on iron deficiency and malnutrition are available with the background characteristics for the respondent women in their reproductive age 15-49 years and by the states to which they belong. And, for their children age 0-35 months (6-35 months in case of iron deficiency anaemia) it is available with children's own background characteristics and that of their mothers and the states to which they belong.

Iron Deficiency Anaemia Among Ever-Married Women

The NFHS-2 data indicate that iron deficiency anaemia was very widely prevalent micronutrient deficiency among the ever married women age 15-49. The data confirm the fact that iron deficiency anaemia was a major public health problem of gigantic proportion. A little over 52 per cent of the women in the reproductive age were anaemic. All age groups were more or less uniformly affected with a slightly higher prevalence in younger ages – ominous in its import because they were the largest fertile population among women in India.

Table 2.1: Iron Deficiency Anaemia among Women in India By Background Characteristics

Background Characteristics	Percentage of Women with any Anaemia	Percentage of Women With			No. of Women
		Mild Anaemia	Moderate Anaemia	Severe Anaemia	
Age					
15-19	56.0	36.2	17.9	1.9	7,117
20-24	53.8	34.8	17.0	2.0	14,560
25-29	51.4	34.8	14.7	1.9	15,965
30-34	50.5	34.8	13.7	1.9	13,595
35-49	50.5	35.1	13.6	1.9	28,426
Marital Status					
Currently married	51.5	43.9	14.8	1.8	74,830
Not Currently married	55.5	36.6	15.7	3.1	4,833
Residence					
Urban	45.7	32.0	12.2	1.5	20,872
Rural	53.9	36.1	15.8	2.0	58,791
Education					
Illiterate	55.8	36.7	16.8	2.3	45,818
Up to Middle School	50.1	34.4	13.8	1.9	15,735
Middle School	48.0	34.0	12.6	1.3	6,718
High School & above	40.3	29.7	9.7	0.9	11,381
Religion					
Hindu	52.4	35.5	15.0	2.0	65,507
Muslim	49.6	34.2	14.2	1.3	9,545
Christian	47.1	30.7	14.4	2.0	2,007
Sikh	39.6	26.6	11.8	1.2	1,315
Jain	42.4	30.8	10.9	0.8	290
Buddist/N.Buddist	48.6	30.1	15.3	3.1	630
Otherd	75.7	47.3	24.6	3.8	265
No-religion	59.5	34.2	24.9	0.4	40
Caste/Tribe					
Scheduled Caste	56.0	37.2	16.5	2.3	14,657
Scheduled Tribe	64.9	41.2	21.4	2.3	6,908
Backward Class	50.7	34.3	14.5	2.0	26,246
Others	47.6	33.3	12.9	1.5	31,112
Work Status					
Own farm/business	53.1	35.7	15.2	2.2	11,450
Employed	54.9	35.8	16.2	3.0	15,671
Self-employed	52.2	35.0	15.3	2.0	3,974
Not worked in 12months	50.4	34.6	14.3	1.5	48,543
Standard of Living					
Low	60.2	38.9	18.6	2.7	25,620
Medium	50.3	34.5	14.1	1.7	37,107
High	41.9	30.1	10.7	1.1	16,034

Contd.

Table 1 (Contd.)

Pregnancy/ Breast Feeding					
Pregnant	49.7	21.8	25.4	2.5	5,654
Breast feeding/Not P.	56.4	38.9	15.8	1.6	19,054
Not Preg./B.feeding	50.4	35.1	13.4	1.9	54,954
Height					
< 145 cms	56.2	36.5	17.2	2.5	10,515
³ 145 cms	51.1	34.8	14.5	1.8	68,954
Body Mass Index					
< 18.5	56.8	37.0	17.1	2.7	27,743
³ 18.5	49.1	34.0	13.7	1.5	51,336
Food Consumption					
Fruits & Vegetables	46.7	32.2	12.9	1.7	23,740
Fruit only	42.9	30.9	10.9	1.2	2,554
Vegetables only	55.1	36.9	16.1	2.0	44,207
Neither	51.5	34.7	14.7	2.0	9,142
Total	51.8	35.0	14.8	1.9	79,663

Source: NFHS, 2000.

In the order of severity of iron deficiency anaemia, 35 per cent of the women were mildly anaemic, about 15 per cent of the women were moderately anaemic, and two per cent of them were severely anaemic. It means that a substantial percentage of women in the reproductive age group had no body iron stores at all. Some of these women were in the early reproductive phase and were more likely to get into at least one more pregnancy. Fifty-six per cent of ever married women in their teens, viz., age 15-19, about 54 per cent of women in the age group 20-24, and 51 per cent of women in the age group 25-29 suffered from some degree of anaemia. These age groups accounted for peak fertility rates in India and more than half of the ever married women who were adolescents had the highest levels of iron deficiency anaemia.

Prevalence of mild anaemia: Women in their teens had a marginally higher prevalence of mild iron deficiency anaemia followed by other age groups, viz. 36 per cent and 35 per cent, respectively.

Prevalence of moderate anaemia: Prevalence of moderate anaemia was higher among the teenage women with an 18 per cent prevalence followed by a 17 per cent among the women age 20-24. The next three age groups recorded a decline of about two per cent in the prevalence.

Prevalence of severe anaemia: The prevalence of severe anaemia seems to be uniform at two per cent among all age groups.

Levels and Differentials in the Prevalence of Iron Deficiency Anaemia among Women

Age: As pointed out above, women belonging to younger age groups (15-19, 20-24, and 25-29 years) who were in the very active reproductive phase of life accounted for the higher prevalence of iron deficiency anaemia, viz., fifty-six, fifty-four and fifty-one per cent, respectively. Women belonging to the age groups of 20-24 and 25-29, who constituted thirty eight per cent of the sample, had a two per cent prevalence of severe iron deficiency anaemia, in addition to the two per cent prevalence of severe iron deficiency anaemia among the women age 15-19. With the gradual lowering of the fertility in the age groups 30-34 and 35-49 years, the prevalence of anaemia reduced marginally with severe anaemia which continued to be at about two per cent throughout their reproductive life. It implies that women enter menopause with varying degrees of anaemia. It is evident that more than half of the women remained anaemic throughout their life-cycles.

Marital status: Currently married women had slightly lower levels of prevalence than the women who were not currently married. The latter had higher prevalence of severe anaemia.

Residence: Women who were residents in urban areas had significantly lower prevalence compared to the women living in rural areas in all the grades of anaemia. This is an important pointer to the effect of poor hygiene and environmental sanitation incident in rural areas and possibly with higher prevalence of intestinal worm infestations.

Education: Prevalence of iron deficiency anaemia negatively correlated with educational attainments of women. Women who were illiterate had higher prevalence of iron deficiency anaemia compared to women with educational attainment up to high school and above. The levels of anaemia declined gradually with the increase in the levels of education.

Standard of living index: Again, the standard of living negatively correlated with prevalence of iron deficiency anaemia. With the increase in the standard of living the levels of anaemia steadily decreased.

Religion: Hindu, Muslim and Buddhist women had a higher prevalence of iron deficiency anaemia among women of all religions. It was slightly lower among the Christian women and substantially lower among the Sikh and Jain women. Women belonging to other religions and women with no religion had the highest prevalence of iron deficiency anaemia.

Caste/tribe: Women belonging to the scheduled tribe had the highest prevalence of anaemia (65 per cent) followed by women from the scheduled castes (56 per cent) and women belonging to other backward classes (51 per cent).

Pregnancy/Lactation: Pregnant women and non-pregnant and non-lactating women had slightly lower prevalence of anaemia. Lactating women had slightly higher prevalence of anaemia.

Nutritional status: Women with shorter height and lower body mass index (BMI) had higher prevalence of anaemia than women with normal height and body mass index.

Nutritional status - height: Women with a height of less than 145 cms had a higher prevalence of iron deficiency anaemia (56 per cent) than women with a height equivalent to greater than 145 cms (51 per cent).

Nutritional status – BMI: women with a BMI of less than 18.5 had a higher prevalence of iron deficiency anaemia (57 per cent) than women with a BMI equivalent to or greater than 18.5 (49 per cent).

Food habits: Women who regularly consumed fruits and vegetables were at a lower risk of iron deficiency anaemia. The differentials in the prevalence of iron deficiency anaemia nearly corresponded to the food consumption practices of the women from different background characteristics. The NFHS-2 data on food consumption practices of women highlights the dietary habits of women across the country and by their background characteristics. Basically, it appears to be a matter of access to different types of food, knowledge about value of food items, and prevailing consumption practices among population which contribute to the nutritional outcome of the women.

The NFHS-2 found that the diet of rural women was poor both in the variety of food consumed and frequency of consumption of certain food items perhaps due to the inaccessibility of the variety of food articles both in terms of availability and affordability compared to their counterparts in urban areas. Increasing levels of education seemed to promote better dietary habits among women especially with the consumption of fruits on a regular basis. The food consumption practices of educated women were slightly better than those of women with high standard of living index.

The NFHS-2 data on religious differentials of food consumption also correlated well with the prevalence of iron deficiency anaemia by religion indicating a combination of traditional food habits, socioeconomic and geographic attributes which contributed to the accessibility of food. Bulk of the people in India does not consume food articles like milk, curds, and fruits

on a regular basis although they do consume them often. Food articles of animal origin like chicken, meat or fish are also not consumed to any significant extent by a large section of the people. This leaves a large section of the people deficient in their diets, which neither provides iron nor promotes its absorption. There are smaller segments of Jain, Sikh and Christian women who consume larger varieties of food articles which promote better nutrition, but they constitute a small segment of the population when we consider the impact of diet on the health of the people of the nation as a whole.

Poverty, socioeconomic status and residential background seem to hold the key to the nutritional levels in India which is reflected in the prevalence of iron deficiency anaemia.

Differentials of Iron Deficiency Anaemia among Women in India

Prevalence of iron deficiency anaemia is almost universal in all the states of India with the only variations in its levels. With an overall prevalence of 52 per cent for the country the iron deficiency anaemia is in reality a very large public health problem in India.

By regions: Eastern region of the country consisting of Bihar, Orissa, and West Bengal had the highest prevalence of iron deficiency anaemia in India - 63 per cent. The northeastern region consisting of Arunachal Pradesh, Assam, Manipur, Mizoram, Nagaland, Sikkim and Tripura – with 53 per cent, then followed it. Central India consisting of Madhya Pradesh and Uttar Pradesh had a prevalence of 52 per cent. Northern India, comprising of the states of Delhi, Haryana, Himachal Pradesh, Jammu and Kashmir, Punjab and Rajasthan, had a prevalence of 46 per cent. Western Indian region consisting of the states of Goa, Gujarat, and Maharashtra had a prevalence of 44 per cent and the Southern region of the country consisting of Andhra Pradesh, Karnataka, Kerala, and Tamil Nadu accounted for the lowest prevalence of iron deficiency in India at 43 per cent. Thus, East and northeast regions were worst affected followed by central India, then the north, west and south in the descending order. Intra-regional disparities in the prevalence did not seem to be very significant except in the northeastern states, which had a mixed prevalence.

By States: Assam had the highest prevalence of iron deficiency anaemia in the country (70 per cent) followed by Bihar (63 per cent), Orissa (63 per cent), West Bengal (63 per cent), Meghalaya (63 per cent) Arunachal Pradesh (62 per cent), Sikkim (61 per cent), Jammu & Kashmir (59 per cent), and Tripura (59 per cent).

Table 2.2: Iron Deficiency Anaemia among Women in India by State

State	Percentage of Women with any Anaemia	Percentage of Women With		
		Mild Anaemia	Moderate Anaemia	Severe Anaemia
India	51.8	35.0	14.8	1.9
North				
Delhi	40.5	29.6	9.6	1.3
Haryana	47.0	30.9	14.5	1.6
Himachal Pradesh	40.5	31.4	8.4	0.7
Jammu & Kashmir	56.7	39.3	17.6	1.9
Punjab	41.4	28.4	12.3	0.7
Rajasthan	48.5	32.3	14.1	2.1
Central				
Madhya Pradesh	54.3	37.6	15.6	1.0
Uttar Pradesh	48.7	33.5	13.7	1.5
East				
Bihar	63.5	42.9	19.0	1.5
Orissa	63.0	45.1	16.4	1.6
West Bengal	62.7	45.3	15.9	1.5
Northeast				
Arunachal Pradesh	62.5	50.6	11.3	0.6
Assam	69.7	43.2	25.6	0.9
Manipur	28.9	21.7	6.3	0.8
Meghalaya	63.3	33.4	27.5	2.4
Mizoram	48.0	35.2	12.1	0.7
Nagaland	38.4	27.8	9.6	1.0
Sikkim	61.1	37.4	21.4	2.4
Tripura	59.0	43.5	14	1.4
West				
Goa	36.4	27.3	8.1	1.0
Gujarat	46.3	29.5	14.4	2.5
Maharashtra	48.5	31.5	14.1	2.9
South				
Andhra Pradesh	49.8	32.5	14.9	2.4
Karnataka	42.4	26.7	13.4	2.3
Kerala	22.7	19.5	2.7	0.5
Tamil Nadu	56.5	36.7	15.9	3.9

Source: NFHS, 2000.

Lowest prevalence levels of iron deficiency anaemia in the country were found in Kerala (23 per cent), Manipur (29 per cent), Goa (36 per cent) and Nagaland (38 per cent).

Women in the newly formed state of Uttaranchal had an almost similar pattern of the prevalence of iron deficiency anaemia, with a slightly lower prevalence when compared to the composite state of Uttar Pradesh (46 per cent and 49 per cent, respectively) at five per cent below the national average of 52 per cent. Women in the state of Jharkhand had a higher prevalence of iron deficiency anaemia when compared to the composite state of Bihar (73 per cent and 64 per cent respectively) which is 21 per cent above the national average. Similarly, women in the state of Chhattisgarh had markedly higher prevalence of iron deficiency anaemia compared to the composite state of Madhya Pradesh (69 per cent and 54 per cent, respectively) 15 per cent more than the national average.

The data on the prevalence of iron deficiency anaemia and malnutrition in the newly formed states provide a unique window to an altogether different perspective about the state level data. These three states with varying degrees of prevalence had sharp regional variations in the state level data. Thereby, the regions of the state with lowest and highest prevalence were being represented on the same scale in the NFHS-2 data. This drawback was due to the spread of the sample across the state. Such data would not be useful for focussed programme efforts and targeted implementation of interventions. The NFHS-2 data culled out of the composite states of Bihar, Madhya Pradesh and Uttar Pradesh is a classic pointer to the need for data generation at much disaggregated levels, say district levels, in order to have focussed approach to any health-related problems. Perhaps, the RCH-RHS data at the district level would be of greater advantage in this regard.

There are certain surprises in the prevalence of iron deficiency anaemia in India. One such surprise is the State of West Bengal, which had a prevalence of iron deficiency anaemia of the order of 63 per cent. It is surprising because the state has been ruled uninterruptedly by a communist government for several decades and boast of larger developmental achievements to its credit, but has ranked itself with the least advanced state like Bihar and chronically famine affected state of Orissa. Secondly, the most industrialised state of Maharashtra had an iron deficiency anaemia prevalence equivalent to that of Uttar Pradesh - 49 per cent. Another surprise is the 56 per cent prevalence of iron deficiency anaemia in Tamil Nadu. This is the highest prevalence of iron deficiency anaemia in the south and in

a state, which has some of the well-entrenched nutritional programmes functioning since the early 1980s.

Iron Deficiency Anaemia among Children

The NFHS-2 collected data on the prevalence of anaemia among the children of the respondents, age 6-35 months. The value of the data has been severely compromised by the limitations in age groups of children for whom the haemoglobin levels were estimated. The omission of the children age 0-5 months and children between 36-59 months is a serious drawback from the point of policy formulations and programme interventions. Within the limitations, the data are valuable for the age groups concerned and a good pointer to the trends in the prevalence of iron deficiency anaemia among the children in the country.

The NFHS-2 data indicates a fairly extensive prevalence of iron deficiency of 74 per cent among the children between age 6-35 months. Of them, 23 per cent of the children had mild iron deficiency anaemia, 46 per cent of the children had moderate anaemia and 5 per cent of them had severe anaemia. Comparatively, a large percentage of children, more than 20 per cent, suffered from iron deficiency anaemia than did their mothers. These levels portend a difficult future for the children.

The 5 per cent prevalence of severe anaemia among the young children is a very serious cause for worry. Such high levels of anaemia are bound to affect the very survival of these very young children and most likely to contribute to the existing high levels of infant and child mortalities. It is here that the very potent synergistic combination of iron deficiency anaemia and malnutrition exerts its greatest influence on the child survival. This data on childhood anaemia call for relentless action to contain the malady and to save the children.

Levels and Differentials in the Prevalence of Iron Deficiency Anaemia among Children

Age: About 72 per cent of the infants age 6-11 months had the prevalence of anaemia, with 27 per cent having mild anaemia, 42 per cent with moderate anaemia, and three per cent with severe anaemia.

The prevalence of anaemia seems to have increased in the second year of life of the children age 12-23 months, with an overall prevalence of 78 per cent with 22 per cent mild, 49 per cent moderate and six per cent severe anaemia.

Table 2.3: Anaemia among Children in India by Background Characteristics

Background Characteristics	Percentage of Children with any Anaemia	Percentage of children with			Number of Children
		Mild Anaemia	Moderate Anaemia	Severe Anaemia	
Age of Child					
6-11 months	71.7	27.0	41.5	3.2	3,923
12-23 months	77.7	22.0	49.4	6.3	8,215
24-35 months	72.0	21.9	44.5	5.6	7,877
Sex of Child					
Male	75.1	22.2	47.0	5.9	10,477
Female	73.3	23.7	44.8	4.8	9,539
Birth Order					
1	70.7	23.6	42.5	4.6	5,759
2-3	74.9	22.7	46.4	5.8	8,896
4-5	76.4	22.7	48.0	5.7	3,459
6+	78.4	22.4	50.3	5.7	1,902
Residence					
Urban	70.8	23.7	42.0	5.1	4,642
Rural	75.3	22.7	47.1	5.5	15,374
Mother's Education					
Illiterate	78.2	21.7	50.0	6.4	11,255
Up to Middle School	74.6	24.4	45.1	5.1	3,866
Middle School	69.7	25.2	40.2	4.3	1,959
High School & Above	61.9	24.0	35.1	2.8	2,935
Religion					
Hindu	74.6	22.4	46.7	5.5	15,982
Muslim	74.2	26.0	43.0	5.2	2,952
Christian	61.0	23.7	43.1	3.3	500
Sikh	76.5	18.0	52.8	5.7	304
Jain	69.4	20.7	48.7	0.0	44
Buddist/Neo-Buddist	73.3	27.9	41.9	3.5	139
Others	88.9	16.9	57.0	15.0	60
No-religion	55.1	11.9	40.7	2.5	16
Caste/Tribe					
Scheduled Caste	78.3	22.0	49.7	6.6	4,048
Scheduled Tribe	79.8	22.8	50.1	6.9	1,921
Backward Class	72.0	22.8	44.4	4.8	6,487
Others	72.7	23.6	44.1	5.0	7,373

Contd

Background Characteristics	Percentage of Children with any Anaemia	Percentage of children with			Number of Children
		Mild Anaemia	Moderate Anaemia	Severe Anaemia	
Mother's Work Status					
Family farm/business	75.8	22.0	49.3	4.7	2,669
Employed	76.9	22.8	48.7	6.6	3,067
Self-employed	74.8	22.8	48.6	5.5	707
Not worked in					
12 MO	73.3	23.6	44.5	5.3	13,566
Standard of Living					
Low	78.7	23.1	50.0	5.7	7,064
Medium	73.6	22.7	45.2	5.7	9,444
High	67.3	23.5	39.6	4.2	3,292
Mother's anaemic status					
Not anaemic	67.8	23.2	40.7	3.9	9,172
Midly anaemic	76.8	23.4	48.4	5.1	7,235
Moderately anaemic	85.6	21.6	55.5	8.5	3,212
Severely	86.8	18.0	45.3	23.6	323
Total	74.3	22.9	45.9	5.4	20,016

Source: NFHS, 2000.

The trend in the prevalence of iron deficiency anaemia continued to be at more or less the same levels in the third year of life of children age 24-35 months, with an overall prevalence of 72 per cent with 22 per cent mild, 45 moderate and six per cent severe anaemia. The levels show a slight decline in the third year of life.

Sex: Since birth the girl child seemed to fare marginally better than the boys both in the overall prevalence and in the levels of anaemia, the difference was very small, though.

Birth order: The birth order seems to have a certain effect on the levels of anaemia among the children. With the increase in the birth order there was a noticeable increase in the prevalence of iron deficiency anaemia.

Residence: Children born in rural areas had slightly higher incidence both in the prevalence and in the levels of iron deficiency anaemia.

Mother's education: There appears to be a high negative correlation with mother's education and the prevalence of iron deficiency anaemia. Children born to illiterate mothers had definitely higher prevalence and higher levels

of anaemia, than those born to mothers who had completed high school education.

Mother's work status: Maternal work status did not seem to have much influence on the prevalence of anaemia among their children.

Mother's anaemic status: There was a significant positive correlation between mother's anaemic status and the prevalence of iron deficiency anaemia. While the children of the non-anaemic mothers had a prevalence of 68 per cent, the children of mothers who had mild, moderate and severe anaemia had a prevalence of 77 per cent, 86 per cent, and 87 per cent iron deficiency anaemia, respectively.

Standard of living index: Prevalence of iron deficiency anaemia decreased significantly with the rising standard of living index.

Religion: The prevalence of iron deficiency anaemia seems to be evenly spread across children from all religions with children belonging to Sikh and 'other religion' having a marginally higher prevalence of anaemia compared to other children. The prevalence among children belonging to Christianity was substantially low (61 per cent).

Caste/Tribe: Children belonging to scheduled tribe and scheduled castes, in that order, had higher prevalence of iron deficiency anaemia than the other backward class.

Differentials of Iron Deficiency Anaemia among Children in India

By region: The pattern of prevalence of anaemia among children was almost similar to that among the women except for the fact that the levels were much higher among children.

The eastern region of the country consisting of Bihar, Orissa, and West Bengal had the highest prevalence of iron deficiency anaemia among children age 6-35 months at 77 per cent, three per cent more than the national average. Closely followed was the northern India comprising the states of Delhi, Haryana, Himachal Pradesh, Jammu and Kashmir, Punjab and Rajasthan with a prevalence of 76 per cent. The northeastern region consisting of Arunachal Pradesh, Assam, Manipur, Mizoram, Nagaland, Sikkim and Tripura with 59 per cent had the lowest prevalence of iron deficiency anaemia among the children in India. The central India consisting of Madhya Pradesh and Uttar Pradesh had a prevalence of 74 per cent. The western Indian region consisting of the states of Goa, Gujarat, and Maharashtra had a prevalence of 68 per cent and the Southern region of the country consisting of Andhra Pradesh, Karnataka, Kerala, and Tamil

Table 2.4: Anaemia Among Children in India by State

State	Percentage of Women with any Anaemia	Percentage of Women With		
		Mild Anaemia	Moderate Anaemia	Severe Anaemia
India	74.3	22.9	45.9	5.4
North				
Delhi	69.0	22.2	42.9	3.9
Haryana	83.9	18.0	58.8	7.1
Himachal Pradesh	69.9	28.7	39.0	2.2
Jammu & Kashmir	71.1	28.1	38.5	3.5
Punjab	80.0	17.4	56.7	5.9
Rajasthan	82.3	20.1	52.7	9.5
Central				
Madhya Pradesh	75.0	22.0	48.1	4.9
Uttar Pradesh	73.9	19.4	47.8	6.7
East				
Bihar	81.3	26.9	50.3	4.1
Orissa	72.3	26.2	43.2	2.9
West Bengal	78.3	26.9	46.3	5.2
Northeast				
Arunachal Pradesh	54.5	29.1	24.7	0.7
Assam	63.2	31.0	32.2	0.0
Manipur	45.2	22.6	21.7	0.9
Meghalaya	67.6	23.4	39.8	4.3
Mizoram	57.2	32.2	22.7	2.3
Nagaland	43.7	22.0	18.7	3.0
Sikkim	76.5	28.4	40.7	7.5
Tripura	61.8	21.3	36.3	4.2
West				
Goa	53.4	23.5	27.9	2.0
Gujarat	74.5	24.2	43.7	6.7
Maharashtra	76.0	24.1	47.4	4.4
South				
Andhra Pradesh	72.3	23.0	44.9	4.4
Karnataka	70.6	19.6	43.3	7.6
Kerala	43.9	24.4	18.9	0.5
Tamil Nadu	69.0	21.9	40.2	6.9

Source: NFHS 2000.

Nadu accounted for the lowest prevalence of iron deficiency in India at 64 per cent. Thus, east, north, and central regions had higher prevalence of

iron deficiency anaemia among children followed by west and south. The northeast had the lowest prevalence.

By States: Haryana and Rajasthan had the highest prevalence of iron deficiency anaemia among children in the country, 84 and 82 per cent, respectively pushing Bihar to the third position (81 per cent). Punjab had a prevalence rate of 80 per cent and West Bengal with 78 per cent. Sikkim and Maharashtra with 77 and 76 per cent respectively were just above the national average in their prevalence of iron deficiency anaemia among children.

Lowest prevalence levels of iron deficiency anaemia among the children in the country were found in Kerala (44 per cent), Nagaland (44 per cent), and Manipur (45 per cent).

Children in the newly formed state of Uttaranchal had an almost similar pattern of the prevalence of iron deficiency anaemia with a marginally higher prevalence when compared to the composite state of Uttar Pradesh (74 per cent and 77 per cent, respectively) at three per cent above the national average of 74 per cent. Children in the state of Jharkhand had a similar level of prevalence of iron deficiency anaemia when compared to the composite state of Bihar (81 per cent and 82 per cent respectively) which was 8 per cent above the national average. Similarly, children in the state of Chhattisgarh had markedly higher prevalence of iron deficiency anaemia compared to the composite state of Madhya Pradesh (88 per cent and 75 per cent, respectively) 14 per cent more than the national average.

The NFHS-2 data on iron deficiency anaemia amply support the arguments advanced by Yip and Filteau, that, if the iron deficiency anaemia affects more than 40 per cent of the population, then the entire population is likely to be iron deficient. By implication the prevalence of iron deficiency is more than the NFHS-2 data indicates.

PREVALENCE OF MALNUTRITION

Malnutrition is another major nutrition affliction of Indian population of all age groups. Malnutrition affects the physical growth of the individuals in varying degrees besides severely affecting their physical work capacity. Most often, malnutrition is associated with iron deficiency anaemia as a co-occurrence and that is, a sinister combination each one potentiating the other. Malnutrition during infancy and early childhood leads to reduced physical growth, which is more likely to be carried into the adolescence and adulthood. A number of studies across the world, more so in the developing

countries, have documented the effects of malnutrition on the work capacity of the individuals besides their general well-being.

NFHS-2 undertook the estimation of the prevalence of malnutrition among the women in their reproductive age 15-49 and their children age below 36 months. For women, height and weight-for-height were measured with the exclusion of women who were pregnant or who delivered two months preceding the survey. In the case of children, weight-for-age, height-for-age and weight-for-height were measured using an adjustable measuring board with an accuracy of 0.1 cm and solar powered digital weighing scale with an accuracy of ± 100 grams. Currently, the NFHS-2 data on the nutritional status are available uniformly for all the 26 states in the country and the analysis has been done using the said data.

The data on the nutritional status are available with the background characteristics for the respondent women in their reproductive age 15-49 years and by the states to which they belong. And, for their children age 0-36 months it is available with children's own demographic characteristics and the background characteristic of their mothers and the states to which they belong. Data on maternal nutrition are not available by parity of the respondent women, which is a serious lapse in the data collection. Very valuable information on the effect of parity on the levels of malnutrition is unavailable.

Nutritional Status of Women

The NFHS-2 measured the height of the women as a critical parameter and a height of 145 cms was considered as the cut-off point, women below this level were regarded as being nutritionally at risk, which was closely related to the pregnancy outcome. The other important parameter, the body mass index (BMI), was measured as a proxy for nutritional status of the ever-married women age 15-49. For Indian women, a BMI of less than 18.5 is considered as chronic energy deficiency. The data indicate that 13 per cent of the women in the country measured a height less than 145 cms and 36 per cent of the women had a BMI of less than 18.5. The data confirm the fact that malnutrition among women was widely prevalent. More than one-third of the women (37 per cent) in the reproductive age were malnourished in India. The respondents in all age intervals were more or less uniformly affected with a slightly higher prevalence in younger ages – ominous in its import because they are the largest current and future fertile population in India positioned at the peak of fertility levels in the country.

The NFHS-2 data indicate that 39 per cent of the women age 15-19 had a BMI of less than 18.5. The BMI less than 18.5 peaked in the next age interval of 20-24 years at 42 per cent and then declined with the increasing age of women to reach a nadir of 31 per cent in the age interval of 35-49. It means that a substantial percentage of women in the reproductive group were malnourished. Some of these women were in the early reproductive phase and were more likely to get into at least one more pregnancy. That does not portend well for them, either. These age groups account for peak fertility rates in India. Further pregnancies in these women would heighten the levels of malnutrition among them besides affecting the intrauterine growth of their foetuses.

Levels and Differentials in the Prevalence of Malnutrition among Women

Age: As pointed out above, women belonging to younger age groups (15-19, 20-24, and 25-29 years) who were in the very active reproductive phase of life accounted for a higher percentage of women with BMI lower than 18.5, viz., 39 per cent, 42 per cent, and 39 per cent respectively. Women belonging to these age groups constituted 45 per cent of the sample and were in the peak reproductive ages. With the gradual lowering of the fertility in the age groups 30-34 and 35-49 years, the prevalence of malnutrition was reduced by about 8-9 per cent. Beginning with the age 25-29, the BMI started slowly increasing above 25.0 or more. From an initial increase of 7 per cent in age interval 25-29, it reached a peak of 17 per cent in the women age 35-49. Also, the percentage of women with a BMI of 30.0 or more increased from 1 per cent in the women age 25-29 to 4 per cent in women age 35-49. It means that while a large number of women in the later years of reproductive age suffer from chronic energy deficiency, a small percentage in these age intervals gradually tend to become obese.

Marital status: Currently married women had a marginally lower prevalence of height below 145 cms (13 per cent) than the women who were not currently married (15 per cent). The prevalence of BMI below 18.5 was equivalent to the national average (36 per cent) among the currently married women, whereas the women who were not currently married had a slightly higher prevalence (39 per cent). Both the groups accounted for similar levels of BMI of 25 or more (11 per cent and 10 per cent, respectively) and BMI of 30 or more (2.2 per cent and 2.1 per cent, respectively).

Table 2.5: Nutritional Status of Women in India by Background Characteristics

Background Characteristics	Height			Weight-for-Height				
	Mean Height (cm)	Percent- age below 145 cm	No. of Women (Height)	Mean BMI	Percentage with BMI below 18.5	Percentage with BMI 25.0 or more	Percentage with BMI 30.0 or more	No. of Women (BMI)
Age								
15-19	150.6	14.7	7,480	19.3	38.8	1.7	0.1	6,707
20-24	151.2	13.0	15,185	19.3	41.8	3.6	0.4	12,928
25-29	151.4	12.4	16,618	19.8	39.1	7.3	1.2	15,030
30-34	151.5	12.3	14,015	20.4	35.0	11.7	2.4	13,399
35-49	151.2	13.7	29,451	21.1	31.1	16.8	3.9	29,056
Marital Status								
Currently married	151.3	13.1	77,737	20.3	35.6	10.6	2.2	72,093
Not Currently married	150.8	14.8	5,049	20.1	39.3	10.3	2.1	5,026
Residence								
Urban	151.6	12.0	21,690	22.1	22.6	23.5	5.8	20,563
Rural	151.1	13.6	61,095	19.6	40.6	5.9	0.9	56,556
Education								
Illiterate	150.6	15.4	47,773	19.5	42.6	5.1	0.9	44,251
Up to Middle School	151.4	12.2	16,253	20.6	32.6	12.9	2.7	15,234
Middle School	152.0	9.8	6,908	21.1	28.0	15.7	3.2	6,447
High School & above	152.9	7.7	11,840	22.5	17.8	26.0	6.4	11,178
Religion								
Hindu	151.1	13.5	67,895	20.1	36.9	9.6	2.0	63,394
Muslim	151.5	12.3	10,108	20.5	34.1	12.4	2.8	9,207
Christian	151.1	10.3	2,100	21.4	24.6	17.6	3.4	1,981
Sikh	155.0	3.9	13,58	23.0	16.4	30.1	8.0	1,280

Background Characteristics	Height			Weight-for-Height				
	Mean Height (cm)	Percent- age below 145 cm	No. of Women (Height)	Mean BMI	Percentage with BMI below 18.5	Percentage with BMI 25.0 or more	Percentage with BMI 30.0 or more	No. of Women (BMI)
Jain	153	7.6	300	23.4	15.8	33.7	9.8	286
Buddhist/N.Buddist	149.9	17.3	638	20.4	33.3	10.5	2.8	607
Other	149.5	24.6	270	19.2	49.4	7.0	0.4	261
No-religion	149.8	24.1	42	20.6	34.5	13.8	3.4	37
Caste/Tribe								
Scheduled Caste	150.3	17.0	15,234	19.5	42.1	5.8	0.9	11,040
Scheduled Tribe	150.8	13.5	7,175	19.1	46.3	3.3	0.5	6,590
Backward Class	151.0	13.5	27,295	20.2	35.8	9.4	1.7	25,474
Other	152.0	10.9	32,334	21.0	30.5	15.4	3.7	30,345
Work Status								
Own farm/business	151.5	11.4	11,877	19.5	41.9	5.2	0.8	11,114
Employed	150.8	14.7	16,301	19.5	44.3	6.4	1.2	15,512
Self-employed	150.8	15.4	4,133	20.5	35.0	12.1	2.5	3,955
Not worked in 12 months	151.3	12.9	50,450	20.7	31.6	13.1	2.9	46,514
Standard of Living								
Low	150.0	17.7	26,687	18.9	48.1	2.6	0.3	24,589
Medium	151.3	12.5	38,451	20.1	35.6	8.6	1.5	35,752
High	153.0	7.5	16,706	22.7	17.3	27.2	6.8	15,938
Total	151.2	13.2	82,785	20.3	35.8	10.6	2.2	77,119

Source: NFHS 2000.

Residence: Women who were residents in the urban areas had slightly lower prevalence of height below 145 cms (12 per cent) compared to the women living in the rural areas (14 per cent). The percentage of women with a BMI below 18.5 was significantly lower (23 per cent) among urban residents, compared to women in rural areas (41 per cent). The women in urban areas also accounted for nearly five times higher incidence of BMI of 25 or more and a BMI of 30 or more (24 per cent and 6 per cent, respectively) than the women in rural areas.

Education: Prevalence of malnutrition negatively correlates with educational attainments of women. Women who were illiterate had a higher prevalence of height less than 145 cms (15 per cent), higher rates for BMI below 18.5 or less (43 per cent) and accounted for the lowest percentage of women with a BMI of 25 or more and a BMI of 30 or more (five per cent and one per cent, respectively) compared to women with educational attainment up to high school and above, who accounted for 50 per cent less for height less than 145 cms (8 per cent) and more than 50 per cent for BMI of 18.5 or less (18 per cent). The women with higher educational attainments also had five times higher levels of BMI of 25 or more and six times more of BMI of 30 or more.

Standard of living index: Again, the standard of living negatively correlated with the prevalence of malnutrition. With the increase in the standard of living the per cent of women with the height less than 145 cms declined almost by three times from 18 per cent among the women with low standard of living index to 8 per cent among the women with high standard of living index. The percentage of women with a BMI of below 18.5 was significantly low among the women with high standards of living (17 per cent) than women with low standards of living (48 per cent). Women with high standards of living had more than ten times the prevalence of BMI of 25 or more (27 per cent and 3 per cent, respectively) and more than twenty times prevalence of BMI of 30 or more (7 per cent and 0.3 per cent, respectively).

Religion: Sikh and Jain women had the lowest incidence of height less than 145 cms (4 per cent and 8 per cent, respectively), had the lowest percentage of women with BMI below 18.5 (16 per cent each) and a highest incidence of BMI of 25.0 or more (30 per cent and 34 per cent, respectively) and BMI of 30.0 or more (8 per cent and 10 per cent, respectively) Women belonging to other religions and women with no religion had the highest prevalence of height less than 145 cms (25 per cent and 24 per cent, respectively) BMI below 18.5 (36 per cent and 31 per cent, respectively)

low incidence of BMI of 25.0 or more (7 per cent and 14 per cent, respectively) and BMI of 30.0 or more (0.4 per cent and 3.4 per cent, respectively).

Caste/tribe: Women belonging to scheduled castes and scheduled tribes had a slightly higher prevalence of malnutrition.

The data on BMI reveals that obesity is making its presence felt in some sections of women in India. About one quarter of women in urban areas, women with higher educational attainment, women from households with higher living standards, and Sikh and Jain women had BMI of 25.0 or more and more than six per cent of women in the above categories had a BMI of 30.0 or more.

Differentials of Malnutrition among Women in India

The NFHS-2 data on malnutrition indicates widespread prevalence among women of all the states of India with variations in its levels. The overall prevalence of height less than 145 cms for the country was 13 per cent, women with a BMI below 18.5 was 37 per cent and higher levels of BMI of 25.0 or more and 30.0 or more were prevalent at 11 per cent and 2 per cent, respectively.

By regions: Eastern region of the country consisting of Bihar, Orissa, and West Bengal had the highest prevalence of malnutrition in India – with an 18 per cent of women with a height less than 145 cms, a BMI less than the national average at 19 per cent, percentage of women with a BMI below 18.5 at 44 per cent, the BMI of 25.0 or more were at almost half the national average (6 per cent) and an insignificant percentage of women with a BMI of 30.0 or more.

The central region consisting of Madhya Pradesh and Uttar Pradesh had 14 per cent of women with less than 145 cms of height, 37 per cent of women having a BMI below 18.5, and seven per cent of women with a BMI of 25.0 or more and a mere one per cent with a BMI of 30.0 or more. Women in Uttar Pradesh had a higher percentage with height less than 145 cms (16 per cent).

Malnutrition was widely prevalent in the northeastern region of the country. Women in Meghalaya (21 per cent), Tripura (20 per cent), and Assam (17 per cent) have a height less than 145 cms. Women in the other states in the region having a height almost less than 145 cms which was around the national average of 13 per cent or less. Women in Tripura lead the other states in the region with 35 per cent of them below a BMI of 18.5, Assam 27 per cent, Meghalaya 26 per cent, and Mizoram 23 per cent.

Table 2.6: Nutritional Status of Women in India by State

State	Mean Height (cm)	Percentage Below 145 cm	Mean BMI	Percentage with BMI Below 18.5	Percentage with BMI 25.0 or more	Percentage with BMI 30.0 or more
India	151.2	13.2	20.3	35.8	10.6	2.2
North						
Delhi	152.5	9.9	23.7	12.0	33.8	9.2
Haryana	154.3	4.6	21.3	25.9	16.6	3.9
Himachal Pradesh	152.7	6.1	20.8	29.7	13.1	2.3
Jammu & Kashmir	153.5	6.7	21.0	26.4	13.8	3.0
Punjab	154.5	4.1	23.0	16.9	30.2	9.1
Rajasthan	153.7	5.6	19.9	36.1	7.1	1.6
Central						
Madhya Pradesh	151.7	10.8	19.8	38.2	6.1	1.2
Uttar Pradesh	150.3	16.4	20.0	35.8	7.5	1.5
East						
Bihar	149.5	19.5	19.4	39.3	3.7	0.5
Orissa	150.5	14.9	19.2	48.0	4.4	0.6
West Bengal	150.0	19.2	19.7	43.7	8.6	1.3
Northeast						
Arunachal Pradesh	150.8	11.9	21.0	10.7	5.1	0.6
Assam	149.9	17.3	20.1	27.1	4.2	0.7
Manipur	151.5	10.3	21.1	18.8	10.8	1.2
Meghalaya	150.6	21.1	20.3	25.8	5.8	1.2
Mizoram	151.6	10.7	20.4	22.6	5.3	0.5
Nagaland	151.6	10.6	20.9	18.4	8.2	0.7
Sikkim	150.2	14.8	22.0	11.2	15.7	2.5
Tripura	149.2	19.8	20.3	35.2	NC	NC
West						
Goa	151.8	12.3	21.6	27.1	21.2	4.3
Gujarat	151.8	10.2	20.7	31.0	15.8	4.4
Maharashtra	151.4	11.9	20.2	39.7	11.7	2.9
South						
Andhra Pradesh	151.2	12.7	20.3	37.4	12.0	2.2
Karnataka	152.0	9.6	20.4	38.8	13.6	2.9
Kerala	152.6	8.8	22.0	18.7	20.6	3.8
Tamil Nadu	151.5	12.0	21.0	29.0	14.7	2.7

Source: NFHS 2000.

NC = Not calculated

Women in the state of Sikkim (16 per cent) and Manipur (11 per cent) had a BMI of 25.0 or more and for the region as a whole eight per cent of women had a BMI of 30.0 or more.

Women in northern India comprising the states of Delhi, Haryana, Himachal Pradesh, Jammu and Kashmir, Punjab, and Rajasthan were taller by about 2 cms compared to the rest of women in India and consequently, had the lowest per centage (6 per cent) of women with less than 145 cms. About 25 per cent of the women had a BMI below 18.5 and accounted for the largest number of women with a BMI of 25.0 or more and BMI of 30.0

or more (19 per cent and five per cent, respectively). Delhi had women with the highest prevalence of BMI of 25.0 or more and BMI of 30.0 or more (34 per cent and 9 per cent, respectively), closely followed by Punjab (30 per cent and nine per cent, respectively). The northern region accounted for the overall higher prevalence of BMI of 25.0 or more, and 30.0 or more, in all states in the region except Rajasthan, recording a BMI greater than the national average, at the said levels. Women in the northern region, especially in Delhi and Punjab were becoming obese – another kind of malnutrition.

Women in the western Indian region consisting of the states of Goa, Gujarat, and Maharashtra had a mean height of 152 cms with 11 per cent of them with a height less than 145 cms. Thirtyfive per cent of them had a BMI below 18.5 and 16 per cent of them with a BMI of 25.0 or more and 4 per cent of them with a BMI of 30.0 or more. Twentyone per cent of Goan women were having a BMI of 25.0 or more and 4 per cent, a BMI of 30.0 or more.

Women in the southern region of the country consisting of Andhra Pradesh, Karnataka, Kerala, and Tamil Nadu, were 152 cms tall and had 11 per cent of them less than the height of 145 cms. Thirtyone per cent of the women in the region had a BMI less than 18.5 with 15 per cent having a BMI of 25.0 or more and 3 per cent having a BMI of 30.0 or more with Kerala leading in the levels of higher BMI.

Women in the newly formed state of Uttaranchal were marginally taller than their sisters in the composite state, with 9 per cent having a height of 145 cms and 32 per cent having a BMI below 18.5. In Jharkhand, women were shorter by 1 cm at a mean height of 150 cm and 19 per cent having a height of 145 cms and 41 per cent having a BMI below 18.5. In Chhattisgarh, 13 per cent of the women had a height of less than 145 cms and 48 per cent have with a BMI below 18.5.

Thus, east, central, and parts of northeastern regions had a high prevalence of malnutrition. Northern region had tall and nutritionally better-off women except Rajasthan, followed by the southern and western regions in that order. High prevalence of obesity was observed in northern region followed by western and southern regions.

By States: Percentage of women with a height of less than 145 cms was highest in Meghalaya (21 per cent), followed by Bihar (20 per cent), West Bengal (19 per cent), Assam (17 per cent), and Uttar Pradesh (16 per cent). The percentage of women with a BMI below 18.5 was highest in Orissa (48 per cent), followed by Chhattisgarh (48 per cent), West Bengal

(44 per cent), Jharkhand (41 per cent), Maharashtra (40 per cent), Bihar (39 per cent), Karnataka (39 per cent), Madhya Pradesh (38 per cent), Andhra Pradesh (37 per cent), Gujarat (37 per cent), and Rajasthan and Uttar Pradesh (36 per cent). The largest percentage of women with BMI of 25.0 or more was in Delhi (34 per cent), Punjab (30 per cent), Meghalaya (26 per cent), Mizoram (23 per cent), and Kerala (21 per cent). Nine per cent of women each in Delhi and Punjab had a BMI of 30.0 or more.

Nutritional Status of Children

Considering the importance of child nutrition, NFHS-2 had undertaken the anthropometric measurements of children of the ever married women age 0-35 months. Anthropometric measurements were made using the same weighing scales and measuring boards used for the anthropometric measurements of the women respondents. These measurements were used to calculate summary indices of the nutritional status of the children. There are three indices, viz. weight-for-age, height-for-age and weight-for-length.

The index, weight-for-age, identifies those with underweight in the child population. This index can measure either the past (chronic) or present (acute) undernutrition but cannot distinguish between the two. This index does not take height into consideration and hence, genetically shorter children who are otherwise healthy will more likely to be picked by it. Secondly, age of the child being measured must be known and in many situations it may be difficult to get the age information accurately.

The index, length-for-age or height-for-age, identifies those who are stunted or short for their age among children, which is an indication of the past undernutrition – linear growth retardation, especially during the periods of greatest growth spurts.

The index, weight-for-length, identifies wasting or current undernutrition among the children and it is useful when the information about age is not available. This index can be used for the evaluation of nutritional interventions and effects of seasonal changes in food supply.

For children, three summary indices were calculated along with the standard deviations of the indices from the median of the international reference standard – the z- score. The surveyed child population which had more than two standard deviations below the international reference standards were considered undernourished. And, those with three standard deviations below international reference standards were considered severely under-nourished.

The NFHS-2 data indicate that malnutrition was largely prevalent among the child population in India. Nearly two thirds of the child population

below age three years in India (65 per cent) was undernourished. A large percentage, 47 per cent, were underweight (-2 SD) and 18 per cent were severely underweight (-3 SD). Similarly, more than two thirds of the children in India (69 per cent) were stunted. A large percentage, 46 per cent, were stunted (-2 SD) and 23 per cent severely stunted (-3 SD).

Comparatively, a large percentage of children, almost twice the number of their mothers, suffered from malnutrition. These levels portend a difficult future for these children.

Levels and Differentials in the Prevalence of Malnutrition among Children

By demographic characteristics of the children

Age: About 14 per cent of the infants age 0-5 months were underweight and 2 per cent severely underweight (-3 SD). About 20 per cent of the infants of the same age were stunted and four per cent severely (-3 SD). Eleven per cent of the infants in this age interval were wasted already – currently undernourished, and, two per cent severely (-3 SD).

By the age of weaning, i.e., 6-11 months there was a dramatic increase in the malnutrition level among the infants. About half of the infants, 49 per cent, were underweight, with 12 per cent severely (-3 SD). Fortytwo per cent of them were stunted, 11 per cent severely (-3 SD) and 16 per cent of them wasted, with 3 per cent severely (-3 SD).

The malnutrition levels in the young children age 12-23 months seemed to be heading for further increase. A little over four-fifths, 81 per cent, children in this age interval were underweight, 23 per cent severely (-3 SD). Nearly 90 per cent (87 per cent) of the young children were stunted, 30 per cent of them severely (-3 SD). Twentysix per cent of the young children age 12-23 months were wasted, 4 per cent of them severely.

Third year of life did not make much difference to these children, as the malnutrition levels tended to remain at higher levels as seen in the case of previous age interval. A little over four fifths, 83 per cent of the young children age 24-35 months, were underweight, a quarter of them, 24 per cent, severely (-3 SD). Nearly 90 per cent (88 %) of the young children were stunted, 32 per cent of them severely (-3 SD). There was a slight decline in the percentage of children suffering from wasting in this age interval. Fifteen per cent of the children age 24-35 months were wasted, and 2 per cent of them severely.

Table 2.7: Nutritional Status of Children in India by Background Characteristics

Background Characteristics	Weight-for-Age			Height-for-Age			Weight-for-Height			Number of Children
	Percentage Below -3 SD	Percentage Below -2 SD	Percentage Below -1 SD	Percentage Below -3 SD	Percentage Below -2 SD	Percentage Below -1 SD	Percentage Below -3 SD	Percentage Below -2 SD	Percentage Below -1 SD	
Residence										
Urban	11.6	38.4	15.4	35.6	2.2	13.1	5,757			
Rural	19.9	49.6	25.4	48.5	3.0	16.2	18,842			
Mother's Education										
Illiterate	24.1	55.0	30.2	54.4	3.4	17.1	13,878			
Up to Middle School	13.1	44.6	18.3	40.7	2.0	15.3	4,634			
Middle School	10.8	36.6	13.4	34.0	2.5	13.3	2,400			
High School & Above	5.8	26.6	8.2	25.4	1.6	11.0	3,685			
Religion										
Hindu	18.4	47.7	23.3	46.0	2.9	16.0	19,572			
Muslim	18.6	48.3	24.8	47.1	2.5	14.1	3,745			
Christian	9.6	30.8	14.0	30.6	2.5	13.4	582			
Sikh	8.4	26.8	16.0	35.4	1.1	7.0	365			
Jain	1.3	20.9	0.8	13.2	0.0	11.9	60			
Buddhist/Neo-Buddhist	7.5	43.7	8.7	32.5	0.9	11.9	168			
Others	19.1	49.6	11.2	44.0	0.4	17.7	68			
No religion	20.1	44.1	26.9	54.4	0.0	5.0	17			
Caste/Tribe										
Scheduled Caste	21.3	53.5	27.5	51.7	3.0	16.0	4,919			
Scheduled Tribe	26.0	55.9	27.6	52.8	4.4	21.8	2,236			
Backward Class	18.3	47.3	23.1	44.8	3.4	16.6	7,941			
Others	13.8	41.1	19.4	40.7	1.8	12.8	9,265			

Background Characteristics	Weight-for-Age		Height-for-Age		Weight-for-Height		Number of Children
	Percentage Below -3 SD	Percentage Below -2 SD	Percentage Below -3 SD	Percentage Below -2 SD	Percentage Below -3 SD	Percentage Below -2 SD	
Mother's Work Status							
Own farm/business	22.9	56.0	29.3	52.8	3.0	17.7	3,134
Employed	24.6	55.5	26.9	51.8	3.8	19.6	3,602
Self-employed	21.4	51.7	24.7	47.7	2.8	19.3	838
Not worked in 12 MO	15.5	43.3	21.0	42.7	2.5	14.0	17,018
Mother's Height							
< 145 cm	28.3	59.8	36.8	60.7	2.9	17.1	3,100
≥ 145 cm	16.5	45.1	21.1	43.3	2.8	15.2	21,458
Mother's B.M.I.							
< 18.5	23.4	57.2	25.9	50.3	3.0	19.6	9,824
≥ 18.5	14.4	40.2	21.2	42.3	2.7	12.7	14,698
Standard of Living							
Low	25.3	56.9	29.8	53.7	3.9	19.7	8,548
Medium	16.5	46.8	22.4	45.3	2.4	14.3	11,636
High	6.7	26.8	10.7	28.5	1.5	10.2	4,137
Total	18.0	47.0	23.0	45.5	2.8	15.5	24,600

Source: NFHS, 2000.

Table 2.8: Nutritional Status of Children in India by Demographic Characteristics

Demographic Characteristics	Weight-for-Age			Height-for-Age			Weight-for-Height			Number of Children
	Percentage	Percentage	Percentage	Percentage	Percentage	Percentage	Percentage	Percentage		
	Below -3 SD	Below -2 SD	Below -1 SD	Below -3 SD	Below -2 SD	Below -1 SD	Below -3 SD	Below -2 SD		
Age of Children										
< 6 months	2.0	11.9	4.2	15.4	1.9	9.3	4,203			
6-11 months	11.8	37.5	11.3	30.9	2.8	13.2	4,116			
12-23 months	23.1	58.5	29.8	57.5	4.1	21.9	8,295			
24-35 months	24.1	58.4	32.0	56.5	1.9	13.2	7,986			
Sex of Children										
Male	16.9	45.3	21.8	44.1	2.9	15.7	12,822			
Female	19.1	48.9	24.4	47.0	2.7	15.2	11,778			
Birth Order										
1	13.6	40.9	17.8	39.6	2.8	14.5	7,111			
2-3	16.3	46.2	21.8	44.4	2.5	15.0	10,893			
4-5	23.8	52.9	28.5	52.3	3.2	16.8	4,287			
6+	28.5	58.6	35.2	56.2	3.3	18.2	2,309			
Previous Birth Interval										
First	13.6	41.0	17.9	39.7	2.8	14.5	7,144			
< 24 months	21.3	52.2	27.9	50.8	3.1	15.8	3,908			
24-47 months	19.6	50.0	25.6	48.9	2.5	15.6	9,753			
48+ months	18.0	45.1	21.2	42.5	3.2	16.5	3,794			
Total	18.0	47.0	23.0	45.5	2.8	15.5	24,600			

Source: NFHS, 2000.

To summarise the nutritional status of 24,600 children in the NFHS-2 survey on anthropometric measurements, 57 per cent of the children were underweight or undernourished, 59 per cent were stunted and 17 per cent were wasted. The increase in the percentage of children with malnutrition was dramatic from the time of weaning and it increased as the child grew. The percentage of malnourished children virtually doubled in the second year of life and continued to grow but at a much slower pace.

Sex: Both boys and girls were equally malnourished with girls showing slightly higher levels in underweight, stunting, and wasting.

Birth order: The birth order seems to have a certain effect on the levels of malnutrition among children. With the increase in the birth order there was a noticeable increase in the prevalence of malnutrition, the increase being almost linear.

Previous birth interval: First born children had a lower prevalence of malnutrition and with the increase in the birth interval, the percentage of underweight and stunted children declined. Children born at shorter intervals had higher prevalence of malnutrition.

By background characteristics:

Residence: Children born in rural areas had significantly higher levels of malnutrition than children born in urban areas. Fifty per cent of the children in urban areas had a prevalence of 50 per cent underweight, 51 per cent stunting and 15 per cent wasting compared to 70 per cent underweight, 74 per cent stunting and 19 per cent wasting, respectively among the children in rural areas.

Mother's education: There appears to be a high negative correlation between mother's education and the prevalence of malnutrition. Children born to illiterate mothers had almost twice higher prevalence and higher levels of malnutrition than children born to mothers who had completed high school education.

Mother's work status: Children of the mothers who had not worked in the past one year seemed to have significantly lower prevalence of malnutrition.

Mother's nutritional status: There was a significant positive correlation between mother's nutritional status and the prevalence of malnutrition among children. Children of mothers with a height ≥ 145 cms and a BMI ≥ 18.5 had significantly lower prevalence of malnutrition compared to the children whose mothers had a height ≤ 145 cms and a BMI ≤ 18.5 .

Standard of living index: Prevalence of malnutrition was twice as high

among children from households with lower levels of standard of living index than among children from households with higher standard of living index. These levels correlated very well with mother's education. Thus, higher maternal education and standard of living index greatly promoted nutrition among children.

Religion: Children belonging to Hindu, Muslim, others and 'no religion' had a higher prevalence of malnutrition, while Christian, Sikh, Jain, and Buddhist children were considerably well-nourished.

Caste/Tribe: Children belonging to scheduled tribes, scheduled castes, and other backward classes, in that order, had higher prevalence of malnutrition.

Differentials of Malnutrition among Children in India

The NFHS-2 data on malnutrition among children age 0-35 months indicate a widespread prevalence across all the regions of the country. Sixtyfive per cent of the children in the country were underweight, 18 per cent of them severely, 67 per cent of the children were stunted and 23 per cent of them severely, and 18 per cent of them were wasted with 3 per cent of them severely. It means that about one third of the next generation of Indians will be malnourished and stunted.

By region: The prevalence of malnutrition was widespread in the eastern and central regions of the country with higher levels of wasting among the western and southern states.

The eastern region of the country consisting of Bihar, Orissa, and West Bengal had the highest prevalence of malnutrition among children age 0-35 months. 80 per cent (26 per cent severely), 74 per cent (21 per cent severely), and 65 per cent (16 per cent severely), were underweight, respectively. Eightyseven per cent (34 per cent severely), 62 per cent (18 per cent severely), and 61 per cent (19 per cent severely), were stunted respectively by state. Twentyseven per cent (6 per cent severely), 28 per cent (4 per cent severely), and 15 per cent (2 per cent severely) wasted respectively by state.

Madhya Pradesh had a prevalence of malnutrition among children age 0-35 months similar to Bihar closely followed by Uttar Pradesh. In Madhya Pradesh, 79 per cent (24 per cent severely) of the children were underweight, 79 per cent (28 per cent severely) were stunted, and 24 per cent (4 per cent severely) were wasted. In Uttar Pradesh, of the children age 0-35 months, 74 per cent (22 per cent severely) were underweight, 87 per cent (31 per cent severely) stunted, and 13 per cent (2 per cent severely) wasted.

Table 2.9: Nutritional Status of Children in India by State

State	Weight-for-Age		Height-for-Age		Weight-for-Height	
	Percentage	Percentage	Percentage	Percentage	Percentage	Percentage
	Below -3 SD	Below -2 SD	Below -3 SD	Below -2 SD	Below -3 SD	Below -2 SD
India	18.0	47.0	23.0	45.5	2.8	15.5
North						
Delhi	10.1	34.7	18.0	36.8	4.1	12.5
Haryana	10.1	34.6	24.3	50.0	0.8	5.3
Himachal Pradesh	12.1	43.6	18.1	41.3	3.3	16.9
Jammu & Kashmir	8.3	34.5	17.3	38.8	1.2	11.8
Punjab	8.8	28.7	17.2	39.2	0.8	7.1
Rajasthan	20.8	50.6	29.0	52.0	1.9	11.7
Central						
Madhya Pradesh	24.3	55.1	28.3	51.0	4.3	19.8
Uttar Pradesh	21.9	51.7	31.0	55.5	2.1	11.1
East						
Bihar	25.5	54.4	33.6	53.7	5.5	21.0
Orissa	20.7	54.4	17.6	44.0	3.9	24.3
West Bengal	16.3	48.7	19.2	41.5	1.6	13.6
Northeast						
Arunachal Pradesh	7.8	24.3	11.9	26.5	2.0	7.9
Assam	13.3	36.0	33.7	50.2	3.3	13.3
Manipur	5.3	27.5	11.2	31.2	1.8	8.3
Meghalaya	11.3	37.9	24.5	44.9	1.0	13.3
Mizoram	5.0	27.7	13.9	34.6	2.8	10.2
Nagaland	7.4	24.1	11.7	33.0	2.4	10.4
Sikkim	4.2	20.6	9.7	31.7	0.8	4.8
Tripura	14.4	42.6	22.0	40.4	1.9	13.1
West						
Goa	4.7	28.6	4.8	18.1	0.7	13.1
Gujarat	16.2	45.1	23.3	43.6	2.4	16.2
Maharashtra	17.6	49.6	14.1	39.9	2.5	21.1
South						
Andhra Pradesh	10.3	37.7	14.2	38.6	1.6	9.1
Karnataka	16.5	43.9	15.9	36.6	3.9	20.0
Kerala	4.7	26.9	7.3	21.9	0.7	11.1
Tamil Nadu	10.6	36.7	12.0	29.4	3.8	19.9

Source: NFHS 2000.

Rajasthan in the northern region had malnutrition prevalence among children age 0-35 months similar to the eastern and central regions, of whom 71 per cent (21 per cent severely) were underweight, 81 per cent (29 per cent severely) stunted, and 14 per cent (2 per cent severely) wasted. Rest of the states in the region had a lower prevalence of malnutrition with Delhi and Himachal Pradesh accounting for higher levels of wasting, 17 per cent (4 per cent severely) and 20 per cent (3 per cent severely), respectively .

Prevalence of malnutrition among the children age 0-35 months was lowest in the northeastern region of the country with Assam, Tripura, and Meghalaya having a slightly higher prevalence.

In the western Indian region, Gujarat and Maharashtra had higher prevalence of malnutrition among children age 0-35 months.

The southern region of the country, consisting of Andhra Pradesh, Karnataka, Kerala, and Tamil Nadu, had a lower prevalence of malnutrition among children age 0-35 months with Karnataka having a relatively higher prevalence of malnutrition among the children.

Children in Sikkim, Kerala, Goa, and Arunachal Pradesh had the lowest levels of malnutrition. But the states of Maharashtra, Karnataka and Tamil Nadu had a higher prevalence of wasting among children.

The children in the newly formed state of Uttaranchal had significantly lower levels of malnutrition compared to children in the state of Uttar Pradesh. The prevalence of wasting was particularly low. Children in Jharkhand had the prevalence of malnutrition almost similar to those in Bihar and the state had the highest prevalence of wasting in the country - 30 per cent (5 per cent severely). Children in Chhattisgarh had a prevalence of malnutrition similar to that among children of Madhya Pradesh with slightly higher prevalence of underweight and stunting.

Thus, eastern and central regions and Rajasthan in the northern region had high levels of malnutrition among children age 0-35 months. Prevalence of malnutrition was relatively low in the northeastern, northern and southern regions of the country followed by the western region.

COMPARATIVE ANALYSIS OF PREVALENCE OF IRON DEFICIENCY ANAEMIA AND MALNUTRITION

NFHS-2 collected large data on two widely prevalent nutritional deficiencies - iron deficiency anaemia and malnutrition. Since the data on iron deficiency anaemia and malnutrition were collected from women in the reproductive age 14-49, it was possible to compare the prevalence of the two conditions even though they were two different entities occurring concurrently. Also, the data were collected in a single survey using the same criteria. Hence, there were no mismatches while comparing the data except for the inclusive and exclusive characteristics, which did not interfere with the comparisons. Iron deficiency anaemia and malnutrition were closely interrelated as they co-occured and produced cascading effect on each other, and even then comparisons were possible.

For the purpose of comparison, the percentage of women with any

anaemia, which was a cumulative total of the prevalent mild, moderate and severe anaemia was considered as the relevant unit for comparison. Such a consideration was based on the well-known fact that iron deficiency anaemia appeared (in any of the forms cited above) after all the iron stores in the body had been exhausted completely. Similarly, levels of BMI were considered as the units for comparison in women since it represented the current nutritional status of women; unlike height below 145 cms, which represented the nutritional status of the past, possibly several years or even decades.

Prevalence of Iron Deficiency Anaemia and Malnutrition in Women

It is evident from the NFHS-2 data that iron deficiency anaemia and malnutrition had a significantly large prevalence across the entire country with only regional variations in the prevalence. Otherwise, it could be stated on the strength of the data available that these two conditions affected a very large section of women in the country in their most critical period of life – the reproductive cycle.

Nevertheless, one important aspect is that it is a comparison of two different yet more or less identical conditions. The comparison is not between the two conditions but their prevalence. These two are biological conditions where the measurements to estimate their prevalence are different from one another. While the measurement of haemoglobin can be more or less precise even in field conditions, the estimation of malnutrition based on anthropometric measurements may not be as precise but will not be imprecise. From the point of practical utility, to derive policy perspectives and programme management these measurements are scientifically acceptable. Also, straightforward comparisons can be made despite the biological complexities of the two conditions and their measurements. Moreover, these two conditions affect the same individuals in the cohort as co-occurrence.

Comparison of Levels and Differentials among Women

Age: Iron deficiency anaemia and malnutrition seem to have greater preponderance for younger age groups. The prevalence levels tapered down marginally with each age interval yet to remain above 50 per cent in case of iron deficiency anaemia and 30 per cent in the case of malnutrition. Women in the most prolific reproductive period seemed to bear the brunt of prevalence, specifically women age 15-19, 20-24, and 25-29.

Marital status: Women who were not currently married had a higher prevalence of iron deficiency anaemia and malnutrition. Even though the proportion of women currently not married was very small, it gave an

indication that lack of familial support could be a factor that furthered the prevalence and had significance for programme interventions.

Residence: Women in rural areas seemed to be clearly at greater disadvantage of having higher prevalence than the urban women.

Education: Education seemed to be a great preventive factor in the prevalence of iron deficiency anaemia and malnutrition among women. Illiterate women suffered the largest prevalence.

Standard of living was another important modulator of iron deficiency anaemia and malnutrition. Higher standards of living insulated populations against iron deficiency anaemia and malnutrition.

Religion: Hindu, Muslim, and Buddhist women had higher prevalence of iron deficiency anaemia and malnutrition. Jain and Sikh women were better off with lower prevalence, perhaps due to their food habits.

Caste/tribe: Women from the scheduled tribes had greater prevalence than those from scheduled castes and other backward classes. This might be due to the inaccessible terrains they lived in.

Regional differentials: Regional differentials in the prevalence of iron deficiency anaemia and malnutrition were quite striking and typically characteristic of the development of the regions. The greatest concentration of the iron deficiency anaemia and malnutrition was observed in the east and central India. Women in Bihar experienced the peak levels of iron deficiency anaemia – a staggering 63 per cent, and women in the adjacent Orissa accounted for the peak levels in malnutrition – 48 per cent, although, there were very minor interstate differences in the prevalence of iron deficiency anaemia and malnutrition in the eastern region. The newly formed state of Jharkhand accounted for the highest level of anaemia (72 per cent) and malnutrition levels more than the composite state of Bihar (41 per cent). Bihar and West Bengal had the largest percentage of women with the critical height below 145 cms, viz., 20 per cent, (Jharkhand 19 per cent), and 19 per cent, respectively.

Very high level of iron deficiency anaemia prevailed in the state of West Bengal – 63 per cent – levels on par with those in Bihar, and malnutrition (44 per cent) - a clear five per cent higher than that in Bihar and women with a critical height below 145 cms (19 per cent). The state was under communist rule for more than three decades and recorded silver jubilee tenure by a single leader as chief minister.

Northeastern region had mixed levels of prevalence of iron deficiency anaemia: Assam (70 per cent), Arunachal Pradesh (63 per cent), Meghalaya

(63 per cent), and Sikkim (61 per cent) and with moderate levels of malnutrition having large interstate variations. Manipur had the lowest prevalence of iron deficiency anaemia (29 per cent) in the region while Arunachal Pradesh (11 per cent) and Sikkim (11 per cent) had the lowest prevalence of malnutrition among women.

The central region, consisting of Madhya Pradesh and Uttar Pradesh, was the region with second highest prevalence of iron deficiency anaemia and malnutrition in the country. It was also the most populous region. Madhya Pradesh was clearly ahead of Uttar Pradesh in the matters of prevalence of iron deficiency anaemia and malnutrition with 54 per cent and 38 per cent, respectively, as against the levels in Uttar Pradesh at 49 per cent and 37 per cent, respectively.

In the northern region, Rajasthan led in the levels of prevalence of iron deficiency anaemia and malnutrition, levels very close to Central region, 49 per cent and 36 per cent respectively. Jammu and Kashmir had high levels of iron deficiency anaemia (57 per cent), followed by Haryana (47 per cent), Delhi, Himachal Pradesh, and Punjab seemed to have a uniform level of prevalence of iron deficiency of 41 per cent. Himachal Pradesh had a high prevalence of malnutrition (30 per cent) followed by Jammu and Kashmir and Haryana (26 per cent, each). Delhi had the lowest prevalence of malnutrition at 12 per cent.

In the western region, Maharashtra had the largest prevalence of iron deficiency anaemia and malnutrition, 46 per cent and 38 per cent respectively closely followed by Gujarat at 46 per cent and 31 per cent respectively. Goa had the lowest prevalence of iron deficiency anaemia and malnutrition in the region, 36 per cent and 27 per cent, respectively.

The western region accounted for the second surprise in the prevalence of iron deficiency anaemia and malnutrition in the country. The most industrialised and agriculturally progressive state of Maharashtra with its state capital considered as the commercial capital of the nation, had the prevalence of iron deficiency anaemia and malnutrition on par with Uttar Pradesh and Madhya Pradesh. Levels of malnutrition were similar to those of Bihar.

The southern region had by far the lowest prevalence of iron deficiency anaemia and malnutrition with a cumulative percentage of 43 per cent. Tamil Nadu had the highest prevalence of iron deficiency anaemia (57 per cent) followed by Andhra Pradesh (50 per cent), and Karnataka (42 per cent). Kerala had the lowest prevalence of iron deficiency anaemia in the country (23 per cent). Karnataka led in malnutrition (39 per cent)

followed by Andhra Pradesh (37 per cent), and Tamil Nadu (29 per cent). Again, Kerala had the lowest prevalence of malnutrition in the region.

The Southern region also had a surprise – Tamil Nadu with the high prevalence of iron deficiency anaemia (57 per cent) levels was closely behind the eastern region of the country and malnutrition of 29 per cent. This was in spite of several well-entrenched nutritional programmes being implemented in the state for decades and where piloting of most of the nutritional interventions had taken place including the food fortification with iron salts.

To summarise, the younger women from rural background with lower educational and lower standard of living index had the highest prevalence of anaemia and malnutrition. The eastern region of the country had the highest prevalence of iron deficiency anaemia and malnutrition followed by the northeastern, central, northern, and western regions. Southern region had the lowest prevalence. Kerala, Manipur and Goa have the lowest prevalence of iron deficiency anaemia; Arunachal Pradesh, Sikkim, Delhi and Kerala had the lowest prevalence of malnutrition.

Comparison of Levels and Differentials among Children

As in the case of women, for the purpose of comparison, the percentage of children with any anaemia, which was a cumulative total of the prevalent mild, moderate and severe anaemia was considered as the relevant unit for comparison. Such a consideration was based on the fact that iron deficiency anaemia appeared (in any of the forms cited above) after all the iron stores in the body had been exhausted. It is known that children born to women with iron deficiency anaemia will not have iron stores. Similarly, for the purpose of comparison of malnutrition the sum of – 2 SD and –3SD for weight-for-age (underweight) and height-for-age (stunted) were used with the assumption that both the measures that individually reflected the levels of malnutrition could be combined to obtain population prevalence levels of malnutrition. These two were the appropriate measures of nutrition to characterise the long-term nutritional status at population level (Bender 1998)

Age: Infants in the first six months of life had noticeable levels of malnutrition, 14 per cent had lagged in their weight gain and 19 per cent had lagged in gaining height/length. This was for the period of exclusive breast-feeding. With the initiation of weaning period in the following six months there was a steep increase in the percentage of infants becoming underweight (50 per cent), and a 42 per cent of the infants not growing appropriately. Seventy

two per cent of these infants (6-12 months) had iron deficiency anaemia.

The malnutrition status of the young children got further worsened in the second year of life. The percentage of children who were underweight rose very sharply to 82 and the proportion of children who were stunted registered a staggering 87 per cent. The iron deficiency anaemia levels in these children had also shown an increase but relatively marginal (78 per cent). By implication, about 80 per cent of the children in their second year of life in India were anaemic, underweight and stunted.

The malnutrition levels continued to be high with a marginal increase in the third year of life of the children; underweight at 83 per cent, stunting at 89 per cent and with a slight decrease in iron deficiency anaemia, 72 per cent.

Nutritionally, female children seemed to be at a slight disadvantage - 68 per cent underweight and 72 per cent stunted - compared to male children - 62 per cent of underweight and 66 per cent stunted. However, female children age 6-35 months had a slightly lower prevalence of iron deficiency anaemia (73 per cent compared to 75 per cent of male children).

There was a gradual but marginal increase in malnutrition among the children with the parity progression. From a 55 per cent underweight and 63 per cent stunted during the birth order 1 to 63 per cent and 66 per cent respectively, in the birth orders 2-3, to 76 per cent and 81 per cent respectively in the birth order 4-5 and to peak at 87 per cent underweight and 91 per cent stunted in the birth order 6+. However, iron deficiency anaemia maintained a steady increase from 71 per cent in the birth order 1, 75 per cent in the birth order 2-3, 76 per cent in the birth order 4-5, and 78 per cent in birth order 6+.

Residence: Children in rural areas seemed to be clearly at greater disadvantage of having higher prevalence of malnutrition - 70 per cent underweight and 74 per cent stunted - compared to the children in urban areas - who were 50 per cent underweight and 51 per cent stunted. The prevalence of iron deficiency anaemia was slightly higher among the rural children (75 per cent) compared to children in urban areas (71 per cent).

Education: Mother's education seemed to be a great preventive factor of iron deficiency anaemia and malnutrition among children. Children of illiterate mothers had higher prevalence of malnutrition, 79 per cent underweight and 85 per cent stunted) and an iron deficiency anaemia of 78 per cent compared to less than half the levels of malnutrition (32 per cent underweight and 34 per cent stunted) and significantly low levels of iron deficiency anaemia (62 per cent) in children whose mothers had completed high school education.

Standard of living is another important modulator of iron deficiency anaemia and malnutrition among children. Higher standards of living protect the children from malnutrition and iron deficiency. Children with low standard of living had a prevalence of malnutrition (82 per cent underweight and 83 per cent stunted) and 79 per cent had iron deficiency anaemia compared to less than half the levels of malnutrition (34 per cent underweight and 39 per cent stunted) and 67 per cent have iron deficiency anaemia.

Religion: Like their mothers, Hindu, Muslim, and Buddhist children had higher prevalence of iron deficiency anaemia and malnutrition. Jain and Sikh children were better-off with lower prevalence, perhaps due to their food habits.

Caste/tribe: Children belonging to the scheduled tribes had greater prevalence than those belonging to scheduled castes and other backward classes. This is possibly because of the inaccessible terrains they lived in.

Regional differentials: The regional differentials in the prevalence of iron deficiency anaemia and malnutrition among the children were almost similar to those of their mothers and also followed the same pattern which was quite striking and typically characteristic of the development of the regions concerned. Similar to their mothers, the greatest concentration of the iron deficiency anaemia and malnutrition was observed in the eastern and central India. Children in Bihar experienced the peak levels of iron deficiency anaemia and malnutrition in the country – a staggering 81 per cent iron deficiency anaemia and 80 per cent underweight and 87 per cent stunting. Bihar was closely followed by West Bengal with 78 per cent iron deficiency anaemia, 65 per cent underweight and 61 per cent stunting. In the adjacent Orissa, 72 per cent of the children had iron deficiency anaemia with 75 per cent underweight and 62 per cent stunting. The newly formed state of Jharkhand inherited the highest levels of anaemia - 82 per cent iron deficiency anaemia, 81 per cent underweight and 78 per cent stunting – levels slightly higher than the composite state.

Again very high levels of iron deficiency anaemia and malnutrition among the children in the state of West Bengal were a great surprise in the region.

Northeastern region had mixed prevalence levels of iron deficiency anaemia and malnutrition, which was by far the lowest in the country. The states of Sikkim (76 per cent), Mizoram (68 per cent), Meghalaya (68 per cent), and Tripura (68 per cent) lead the region in iron deficiency anaemia. The state of Tripura (57 per cent underweight and 62 per cent stunting), Assam (49 per cent underweight and 84 per cent stunting), and Meghalaya

(49 per cent underweight and 69 per cent stunting) lead the region in malnutrition among the children.

The central region consisting of Madhya Pradesh and Uttar Pradesh, ranked third highest in the prevalence of iron deficiency anaemia (74 per cent). In childhood malnutrition, Madhya Pradesh led with 79 per cent underweight with an equal percentage of stunted children. Uttar Pradesh had 73 per cent underweight and 87 per cent stunted children. As already pointed out, it was also the most populous region in the country.

The northern region was the region with the second highest prevalence of iron deficiency anaemia among the children. Rajasthan led the region with higher levels of prevalence of iron deficiency anaemia among children (82 per cent), 71 per cent underweight and 81 per cent stunting. Prevalence of iron deficiency anaemia among children in the other states of the region was as follows: Delhi (69 per cent), Haryana (84 per cent), Punjab (80 per cent), and Himachal Pradesh (70 per cent). Delhi, Haryana, and Himachal Pradesh have 45 per cent, 45 per cent and 56 per cent underweight and 55 per cent, 74 per cent and 59 per cent stunted children, respectively.

In the western region, Maharashtra had the highest prevalence of iron deficiency anaemia among children (76 per cent) with 67 per cent underweight and 54 per cent stunted children, closely followed by Gujarat. Goa had the lowest prevalence of iron deficiency anaemia (53 per cent) among the children in the region with 33 per cent underweight and 23 per cent stunted children.

The western region accounted for the second surprise in the prevalence of iron deficiency anaemia and malnutrition among children in the country. The levels were on par with those of West Bengal.

The southern region was by far the second lowest in the prevalence of iron deficiency anaemia among children (64 per cent). Andhra Pradesh had the highest prevalence of iron deficiency anaemia (72 per cent) followed by Karnataka (71 per cent) and Tamil Nadu (69 per cent); and, Kerala had the lowest prevalence of iron deficiency anaemia in the country among children (44 per cent). Karnataka led in malnutrition (60 per cent underweight and 52 per cent stunted), followed by Andhra Pradesh (48 per cent underweight and 53 per cent stunted) and Tamil Nadu (47 per cent underweight and 41 per cent stunted). Again, Kerala had the lowest prevalence of malnutrition in the country (32 per cent underweight and 29 per cent stunted).

The southern region also had a surprise – Tamil Nadu had the high prevalence of iron deficiency anaemia (69 per cent) among children. This was so in spite of a number of nutritional programmes being implemented for decades in the state.

A Résumé of the NFHS-2 Data on Iron Deficiency Anaemia and Malnutrition among Women and Their Children

For the first time, the NFHS-2 data brought out the prevalence of iron deficiency anaemia and malnutrition in the entire country. The national average of prevalence of iron deficiency anaemia and malnutrition (BMI) among ever-married women age 15-49 was quite high at 52 per cent and 36 per cent, respectively. That was a disquieting finding. More disturbing was the prevalence of iron deficiency anaemia and malnutrition among their children. The national averages of prevalence were 74 per cent for iron deficiency anaemia, and underweight at 65 per cent, and stunting at 66 per cent for malnutrition. The figures were alarming. The large states with equally large share of women and child populations had higher prevalence levels, meaning that the bulk of the population was at disadvantage.

Women in the younger age groups had higher prevalence of iron deficiency anaemia and malnutrition, and their children had much greater prevalence – both of them were ominous. The younger women with rural background, lower educational and lower standard of living index had the highest prevalence of anaemia and malnutrition.

The NFHS-2 data highlighted the great regional dominance in the prevalence of iron deficiency anaemia and malnutrition. In the case of women, the eastern region with huge share of prevalence in iron deficiency anaemia and malnutrition topped the distribution charts, closely followed by the central, northern, and western regions in that order. Southern region had the lowest prevalence of iron deficiency and malnutrition except for marginal higher prevalence of malnutrition in Karnataka (39 per cent) and Andhra Pradesh (37 per cent). Among the children, the eastern region tenaciously maintained its dominance by topping the prevalence charts with the exception of slightly higher prevalence of malnutrition in the central region. These then followed the northern, western and southern regions. The northeast had slightly lower levels of iron deficiency anaemia and malnutrition among the children. Kerala, Manipur and Goa had the lowest prevalence of iron deficiency anaemia; Arunachal Pradesh, Sikkim, Delhi and Kerala had the lowest prevalence of malnutrition.

Prevalence of Iron Deficiency Anaemia and Malnutrition in the Population

At the population level, a wider prevalence of any condition that thrives in the background of poverty, illiteracy, and poor economic and environmental conditions can be expected among vast sections of Indian population. The NFHS-2 data though limited to women in their reproductive age 15-49 and their children below 36 months, strongly supports such a view.

Although it is not possible for a straightforward extrapolation of the data for the entire population of India, it is possible to extrapolate it to the respective population segments in the country. Such extrapolations readily lend themselves to drawing inferences on the prevalence of iron deficiency anaemia and malnutrition, which is the summation of the burden of disease among the people caused by iron deficiency anaemia and malnutrition. Since NFHS-2 is based on the 1991 census, extrapolation can be attempted for the 1991 census population. Moreover, since the NFHS-2 data are limited to the women in reproductive period and their young children, the segments for extrapolation are narrow, but very important.

The NFHS-2 is based on the 1991 census population and the disease burden has been estimated on the basis of the said population. Projections of the morbidity can be made for the 2001 census population but it has not been attempted for the reason that the morbidity estimation is expected to be an indication of the magnitude of the problem of morbidity. Ratios and proportions can be worked out, wherever necessary, without resorting to the projections for 2001 census population.

The total 1991 census female population in the age 15-49 was 198,675,627, which was 49.25 per cent of the 1991 census total female population of 403,359,778 in all ages in the country. According to the NFHS-2 data at the national level, 52 per cent of the 103,311,326 women in the reproductive age 15-49 suffered from iron deficiency anaemia of varying degrees and 36 per cent of these women also suffer from malnutrition. In addition, 13 per cent of them also a height less than 145 cms.

The total 1991 census child population age 0-35 months was 55,751,810, which was 54.45 per cent of under five child population of 102,378,032 in India. Twentythree per cent of the child population age 0-35 months had a prevalence of 23 per cent mild anaemia, 46 per cent moderate anaemia and 5 per cent severe anaemia. Sixty six per cent of these children were under-weight and 69 per cent were stunted.

Table 2.10: Prevalence of Iron Deficiency Anaemia among the 1991 Census Population of Women in Reproductive age 15-49 and their children age 0-36 months

State	Women Age 15-49 Total		Iron Deficiency Anaemia Among Women		Children Age 0-35		Iron Deficiency Anaemia Among Children		
	Number	Percent	Number	Percent	Male	Female	Total	Percent	Number
India	198,675,627	51.8	102,913,975	28,606,305	27,145,505	55,751,810	74.3	41,423,595	
Delhi	2,274,334	40.5	921,105	325,885	298,764	624,649	69.0	431,008	
Haryana	3,660,705	47.0	1,720,531	644,850	562,370	1,207,220	83.9	1,012,858	
Himachal Pradesh	1,288,233	40.5	521,734	176,031	614,363	790,394	69.9	552,485	
Punjab	4,860,527	41.4	2,017,119	714,310	614,980	1,329,290	80.0	1,063,432	
Rajasthan	9,802,912	48.5	4,754,412	1,729,980	1,601,022	3,331,002	82.3	2,741,415	
Madhya Pradesh	15,084,124	54.3	8,341,521	2,584,645	2,494,950	5,079,595	75.0	3,809,696	
Uttar Pradesh	30,190,164	48.7	14,702,609	5,330,621	5,035,238	10,365,859	73.9	7,660,370	
Bihar	19,217,913	63.4	12,184,156	3,111,919	3,007,809	6,119,728	81.3	4,975,339	
Orissa	7,763,501	63.0	4,891,006	999,170	967,370	1,966,540	72.3	1,421,808	
West Bengal	16,253,713	62.7	10,191,078	2,180,060	2,107,740	4,287,800	78.3	3,357,347	
Arunachal Pradesh	191,784	62.5	119,865	35,381	35,656	71,037	54.5	38,715	
Assam	5,237,210	69.7	3,650,335	842,393	814,365	1,656,758	63.2	104,707	
Manipur	467,249	28.9	135,035	53,450	51,990	105,440	45.2	47,659	
Meghalaya	412,756	63.3	261,275	80,064	78,863	158,927	67.6	107,435	
Mizoram	162,246	48.0	77,878	26,207	25,476	51,683	57.2	29,563	
Nagaland	286,303	38.4	109,940	38,384	38,425	76,809	43.7	33,566	
Sikkim	92,775	61.1	56,685	14,795	14,364	29,159	76.5	22,307	
Tripura	654,467	59.0	386,136	92,444	89,805	182,249	61.8	112,630	
Goa	322,985	36.4	117,567	27,362	26,371	53,733	53.4	28,693	
Gujarat	10,211,027	46.3	4,727,705	1,354,960	1,261,740	2,616,700	74.5	1,949,441	
Maharashtra	19,067,252	48.5	9,247,617	2,715,440	2,538,339	5,253,779	76.0	3,992,872	
Andhra Pradesh	16,544,169	49.8	8,238,996	1,856,800	1,812,350	3,669,150	72.3	2,641,788	
Karnataka	11,018,771	42.4	4,671,959	1,395,570	1,337,223	2,732,793	70.6	1,929,352	
Kerala	8,087,174	22.7	1,835,789	753,710	719,350	1,473,060	43.9	646,673	
Tamil Nadu	15,007,057	56.4	8,478,987	1,459,260	1,387,034	2,846,294	69.0	1,963,943	

Source: RGI 1997; NFHS - 2000.

Table 2.11: Prevalence of Malnutrition among the 1991 Census Population of Women in Reproductive Age 15-49 and Their Children Age 0-36 Months

State	Women Age 15-49 Total		Women with BMI < 18.5		Children Age 0-35 Total		Children Age 0-35 Under Weight		Children Age 0-35 Stunted	
	Numbers	Percent	Numbers	Percent	Numbers	Percent	Numbers	Percent	Numbers	Percent
India	198,675,627	35.8	71,125,874	35.8	55,751,810	65.0	36,238,677	68.5	38,189,990	68.5
Delhi	2,274,334	12.0	272,920	12.0	624,649	44.8	279,843	54.8	342,308	54.8
Haryana	3,660,705	25.9	948,123	25.9	1,207,220	44.7	539,627	74.3	896,964	74.3
Himachal Pradesh	1,288,233	29.7	382,605	29.7	790,394	55.7	440,249	59.4	326,474	59.4
Punjab	4,860,527	16.9	821,429	16.9	1,329,290	37.5	498,484	56.4	749,720	56.4
Rajasthan	9,802,912	36.1	3,538,851	36.1	3,331,002	71.4	2,378,335	81.0	2,698,112	81.0
Madhya Pradesh	15,084,124	38.2	5,762,135	38.2	5,079,595	79.4	4,033,198	79.3	4,028,119	79.3
Uttar Pradesh	30,190,164	35.8	10,808,079	35.8	10,365,869	73.6	7,629,280	86.5	8,966,477	86.5
Bihar	19,217,913	39.3	7,552,640	39.3	6,119,728	79.9	4,889,663	87.3	5,342,523	87.3
Orissa	7,763,501	48.0	3,726,480	48.0	1,966,540	76.1	1,496,537	61.6	1,211,389	61.6
West Bengal	16,253,713	44.0	7,151,633	44.0	4,287,800	65.0	2,787,070	60.7	2,602,695	60.7
Arumachal Pradesh	191,784	10.7	20,521	10.7	71,037	32.1	22,803	38.4	27,278	38.4
Assam	5,237,210	27.1	1,419,284	27.1	1,656,758	49.3	816,782	83.9	1,390,020	83.9
Manipur	467,249	18.8	87,843	18.8	105,440	32.8	34,584	42.5	44,812	42.5
Meghalaya	412,756	25.8	106,491	25.8	158,927	49.2	78,192	69.4	110,295	69.4
Mizoram	162,246	22.6	36,668	22.6	51,683	32.7	16,900	48.5	25,066	48.5
Nagaland	286,303	18.4	52,680	18.4	76,809	31.5	24,195	44.7	34,334	44.7
Sikkim	92,775	11.2	10,391	11.2	29,159	24.8	7,231	41.4	12,072	41.4
Tripura	654,467	35.2	230,372	35.2	182,249	57.0	103,882	62.4	113,723	62.4
Goa	322,985	27.1	87,529	27.1	53,733	33.3	17,893	22.9	12,305	22.9
Gujarat	10,211,027	37.0	3,778,080	37.0	2,616,700	60.1	1,572,637	66.9	1,750,572	66.9
Maharashtra	19,067,252	39.7	7,569,699	39.7	5,253,779	67.2	3,530,539	54.0	2,837,041	54.0
Andhra Pradesh	16,544,169	37.4	6,187,519	37.4	3,669,150	48.0	1,761,192	52.8	1,937,311	52.8
Karnataka	11,018,771	38.8	4,275,283	38.8	2,732,793	60.4	1,650,607	52.5	1,434,716	52.5
Kerala	8,087,174	18.7	1,512,302	18.7	1,473,060	31.6	465,487	29.2	430,134	29.2
Tamil Nadu	15,007,057	29.0	4,352,047	29.0	2,846,294	47.3	1,346,297	41.4	1,178,366	41.4

Source: RGI 1997; NFHS 2000.

Then, by extrapolating these percentages to the 1991 census the total female population in the age 15-49, and their children age 6-35 months the population prevalence of the iron deficiency anaemia added up to 103,311,327 women and 41,423,595 children. Similarly, the population prevalence of malnutrition added up to 71,523,226 women and 36,238,677 children undernourished and 38,468,749 children who were stunted.

On distributing the total number of women so affected into various categories of anaemia as revealed by the NFHS-2, viz., mild anaemia 35 per cent, moderate anaemia 15 per cent and severe anaemia 2 per cent and 69,536,470 women in their reproductive age were mildly anaemic, 29,801,344 were moderately anaemic and 3,973,513 were severely anaemic. On redistribution of the children age 0-35 months into various categories of anaemia as measured by the NFHS-2, such as mild anaemia 23 per cent, moderate anaemia 46 per cent, and severe 5 per cent anaemia, 12,822,916 children age 0-35 months were mildly anaemic, 25,647,837 were moderately anaemic and 2,787,591 children were severely anaemic.

On the distribution of total number of women affected by malnutrition, 36 per cent of the women in their reproductive age 15-49 added up to 71,125,874 who were malnourished. Of the 55,751,810 children in the age 0-35 months in India, 36,238,677 (65 per cent) were underweight and 38,189,990 (69 per cent) were stunted.

Burden of Disease Attributable to Iron Deficiency Anaemia and Malnutrition

Since the iron deficiency anaemia and malnutrition affect the individuals simultaneously – a co-occurrence, they potentiate the impact of each other. The iron deficiency leads to the reduced supply of oxygen to the tissues of the individual. There will be a shift in the metabolism in the affected individual from aerobic energy production which takes place in the presence of sufficient levels of oxygen in the tissues to a very inefficient anaerobic energy production. During the anaerobic energy production greater amount of substrate is consumed for the production of energy in the body and with the accumulation of metabolites which will not be conducive for the health of the individual.

The co-occurring malnutrition - protein energy deficiency (PED) is a condition caused by a severe shortage of food supply leading to reduced availability of essential nutrients to the body. Because of the reduced availability of the nutrients such individuals are malnourished – acute (present) or chronic (past) malnutrition expressed as underweight. Their growth is severely affected leading to stunting, unable to achieve the natural potential

of proper height for the age because of insufficient food availability. These individuals may be affected seasonally leading to periodical wasting. All the three conditions of malnutrition can occur simultaneously in an individual and in varying degrees. Malnutrition affects the physical capacity or work capacity of the individuals concerned. The physical capacity of an individual is the combination of physical build and the efficiency with which the individual can accomplish physical work or tasks. The combination is one of mechanical and physiological functions of the body. The height of an individual reflects the mechanical advantage as endowed by the physical build and weight represents the energy stores available to meet the physiological demands for substrate at times of physical activity. A normally built individual is expected to have sufficient capacity to produce energy at rest as well as during physical activity. If the growth of the individual is affected leading to stunting and underweight, the mechanical advantage of the physical build is compromised to the extent of loss of height and underweight suffered. In addition, if the individual is wasted, the nutritional reserves of the body are severely exhausted. However, it is a temporary phenomenon due to acute lack of food supply.

Malnutrition in an individual places severe limitation on the availability of the energy yielding substrate because of the lack of body stores. Even the available substrate is thoroughly underutilised by resorting to anaerobic pathway of energy production due to insufficient supply of oxygen as a result of iron deficiency anaemia. This combination leads to low productivity and poor endurance at work.

NFHS-2 estimated the levels of iron deficiency anaemia which led to the reduced oxygen supply to the tissues of the body, and malnutrition, which had affected the populations in the past as well as in the present. The estimations were made on behalf of two important subsets of Indian population – women in reproductive age 15-49 and their children age 0-35 months.

The greater implications of the estimations for these two subsets of population point to more of biological effects of anaemia and malnutrition involved such as reproductive performance and physical growth than to physical activity or work performance. Thirtyseven per cent of the women in the survey were engaged in various economic activities with a majority of them (77 per cent in urban and 63 per cent in rural areas) throughout the year. NFHS-2 points out that a large number of women in urban areas (89 per cent) and rural areas (62 per cent) had been wage earners and contributed to the family income. The iron deficiency anaemia and malnutrition affected their work capacities.

Combined Morbidity Burden Attributable to Iron Deficiency Anaemia and Malnutrition in India

More than half (52 per cent) of the 198 million women (198,675,627) in their reproductive age 15-49, i.e., a huge number of 103 million (103,311,326) women in India suffered from iron deficiency anaemia of varying degrees. Thirtyfive per cent of them mildly, 15 per cent moderately, and 2 per cent severely.

As a co-occurrence, 36 per cent of the women in their reproductive age in India amounting to 71 million (71,523,226) suffered from malnutrition (BMI below 18.5) besides 25 million among them (25,827,832) had an average height less than 145 cms.

Thus, more than half of the women (52 per cent) had iron deficiency anaemia with 39 per cent of them being malnourished as well.

Nearly 75 per cent of the 55 million very young children (55,751,810) age 0-35 months amounting to a huge number of 41 million children (41,423,595) suffered from iron deficiency anaemia of varying degrees. Twentythree per cent of them had mild anaemia, 46 per cent had moderate anaemia and 5 per cent had severe anaemia.

Besides, as a co-occurrence, 69 per cent of the children age 0-35 months accounting for 38 million (38,468,749) stunted with 36 million (36,238,677) children being underweight.

The Public Health Significance of Iron Deficiency Anaemia in India

According to the WHO/UNICEF/UNU classification of the population prevalence of iron deficiency anaemia among the women in the reproductive age 15-49 and their children age 0-35 months India ranks far beyond the severe grade (≥ 40 per cent). Iron deficiency anaemia as well as malnutrition is of pandemic proportion in India.

On the other hand, several eminent scholars have advanced evidence that the prevalence of iron deficiency in a population would be much higher than the prevalence as borne out by the survey data. It is hypothesised that if the iron deficiency anaemia affects more than 40 per cent of the population, then the entire population is likely to be iron deficient (Yip 1994 and Filteau 1995). It seems quite valid and there does not seem to be much to dispute such an opinion on the basis of the available data from various surveys.

The Total Morbidity / Disease Burden

In India, as the NFHS-2 indicates, 103 million women in their reproductive age 15-49 were affected by the iron deficiency anaemia. A large number of them, nearly three fourths or 71 million also suffered from

malnutrition and 25 million women among them had a short stature of less than 145 cms.

Among the very young children age 0-35 months 41 million were affected by iron deficiency anaemia, 38 million of whom were stunted and 36 million underweight.

The ICMR Task Force Study District Project Report

The Indian Council for Medical Research (ICMR) Task Force Study-District Project Report is on the prevalence of iron deficiency anaemia among pregnant women and unmarried adolescent girls age 11-18, in sixteen districts in four regions of the country. The report has indicated an overall prevalence of iron deficiency among women at 85 per cent (mild 11.8 per cent, moderate 60 per cent, and severe iron deficiency anaemia 13 per cent). Among the adolescent girls the prevalence of iron deficiency anaemia was much higher at 90 per cent (mild 32 per cent, moderate 50.9 per cent, and 7 per cent). In fact, the prevalence levels according to the ICMR report were higher than the NFHS-2 figures.

WHO Global Database on Child Growth and Malnutrition

The recent analysis of the WHO Global Database on Child Growth and Malnutrition by Onis and Blössner has pointed out a very high level (≥ 40 per cent) of stunting among Indian children, on par with sub-Saharan Africa. The implication is extremely serious and it strikes at the very root of the nationhood as the future generation of citizens cannot have the benefit of their natural endowment of growth and physical potential.

Food Security Mapping in Rural and Urban India

The pattern of malnutrition very closely resembles the pattern of mapping of the food security in India by the World Food Programme (WFP) and M. S. Swaminathan Research Foundation (MSSRF) in 2001. The regions of the country, which have higher prevalence of iron deficiency anaemia and malnutrition, are the regions with higher degrees of food insecurity. The food security mapping provides a graphic picture of inaccessibility of food in most of the regions of the country and appears like a mirror image of prevalence of iron deficiency anaemia and malnutrition all over the country (Swaminathan 2003).

THE IMPLICATIONS OF PREVALENCE OF IRON DEFICIENCY ANAEMIA AND MALNUTRITION AMONG WOMEN AND CHILDREN

Among Women

As already pointed out, the effect of iron deficiency anaemia and malnutrition is multi dimensional and work in very good synergy. The combination affects the physical growth and physiological functions of reproduction among the adolescents, and adults. The impact of iron deficiency and malnutrition on the health of the women in their reproductive age is very significant. The reasons are that these women pass through a series of very important phases of development in their life-cycles. The adolescence in women is a time of natural growth spurt aimed at achieving true adult proportion of all the organs in the body. The iron deficiency anaemia and malnutrition severely affect the growth, especially the physical stature. There can be greater chances of severely lagging in achieving the expected height proportionate to age. The failure to achieve proper height in the phase of growth spurt when all the physiological processes in the body are favourable be an opportunity lost and may lead to shorter heights. The shortness of height is also a reflection on the quality of the skeletal growth in females, especially of the pelvis whose proper growth is very critical for the obstetric outcome. Secondly, the iron deficiency and malnutrition would lead to reduced storage of fat as a backup of energy required during pregnancy and lactation. Thus, the adolescents have double disadvantage of failure to achieve proper height and reduced energy stores in the body.

Pregnancy places a certain demand for nutrients to support the growing foetus and to maintain the heightened metabolic processes consequent to pregnancy. It is well accepted that the foetus draws its requirement of iron from the mother irrespective of her iron status – obligatory loss. However, the nutrient needs of the foetus for its growth including the placenta which is almost one sixth of the weight of the foetus have not been considered as similar to that of iron deficiency. The possible explanation is that the nutrients transfer to the foetus, though depends on the maternal nutritional status, the entire foetal requirement is not met unlike the foetal requirements for iron – hence, the foetal growth retardation. However, it is possible to observe the reduction in maternal fat and in its absence the reduction in the muscle mass to compensate for the needs of the growth of the foetus and perhaps lactation later on. In clinical practice it is very common to observe the gradual reduction in the size of the abdominal muscles and their final disappearance. The rectus abdominis muscles are notorious in

that regard, as their disappearance is a very common observation. In extreme cases of malnutrition what appears like divarication of the abdominal wall secondary to the stretching of the rectus abdominis muscles during pregnancy is in fact the complete disappearance of both the rectus abdominis muscles. In such cases the entire anterior abdominal wall is converted into a very thin layer consisting of skin and attenuated fascia. Thousands of such cases have been observed in south India during antenatal care and interval female sterilization operations.

Reproductive Performance

Iron deficiency anaemia and malnutrition have serious implications for the reproductive performance of women. The co-occurrence of these two conditions in a very large number of women adds to the magnitude of the problem in India. The well-being of the women in younger age groups, especially the teenage and the immediate two prime reproductive ages, is the major cause for concern. Their nutritional status is bound to deteriorate with every succeeding pregnancy. The progression of anaemia and malnutrition in the absence of definite nutritional supplementation of the pregnant women is an expected phenomenon given the nutritional status and the socioeconomic background of the majority of the women in India. Such a situation is very much conducive in which the mild will be most likely to progress into moderate and moderate to severe anaemia and further depletion of the energy reserves in the body which is likely to affect the reproductive performance of the women and their general well-being.

Mild anaemia may not have any effect on the pregnancy and labour except in the absence of effective supplementation, the women will become more anaemic. Moderate anaemia increases fatigue during pregnancy and labour besides has effect on the growth of the foetus. Postpartum nutritional status and lactation are affected depending on the extent of anaemia. Women with anaemia are at an increased risk of thromboembolic incidents.

Severe anaemia is known to be the cause of preterm labour, pre-eclampsia, and infections of severe nature. Severe anaemia during pregnancy is a medical emergency. The severely decreased hemoglobin levels lead to increase in heart rate, increased stress on the heart, breathlessness and heart failure, which may be fatal. Of large proportion of maternal deaths in the developing countries is attributed to the prevalence of severe iron deficiency anaemia. It is also difficult to manage severe anaemia in pregnancy as most of the women seek medical help almost near about the time of childbirth or when in a very severely compromised condition.

It is well-known that iron deficiency is known to affect production of several enzymes and neurotransmitter in the body. Human breast milk production is controlled by delicate physiological mechanism, which is dependent on a set of neurotransmitter substances and hormones. Iron deficiency is known to interfere with production and function of such biologically active substances. Secondly, the quality of the breast milk also depends upon the nutritional status of the women and the presence of expandable energy resources in the body which can provide necessary substrates for the production of breast milk. If the bulk of the women as found by the NFHS-2 are malnourished both in the past and currently, it is doubtful if they can produce good quality breast milk to feed their babies. Babies, fed on breast milk of poor quality may find it difficult to thrive in achieving proper growth and development. The situation is much difficult with the exclusive breast feeding of the neonates and infants in the first six months of their life.

Outcome for the foetus / child

Intrauterine growth retardation as a consequence of maternal anaemia and malnutrition in spite of the brain sparing effect of foetal circulation lead to low birth weight babies which fail to thrive. As such, babies are easily predisposed to infections. Preterm labour, premature births and increased poor perinatal outcomes are very well-known in such instances.

Lack of proper oxygen supply during the very critical period of foetal life would seriously affect the growth and development of the embryo and the foetus before birth and during the early childhood. Maternal nutrition is known to modulate the outcome. The greater damage is to the development of brain, nervous system and its functions.

Major morbidity of the iron deficiency anaemia and malnutrition during the foetal development, infancy and early childhood have been very well documented. The pronounced effect of iron deficiency anaemia and malnutrition on the development of brain during the foetal life and in infancy and childhood lead to poor neurological, psychomotor and cognitive development, intellectual, and scholastic achievements in later life. Children born to mothers with moderate and severe anaemia are known to suffer from asphyxia at birth as evidenced by the poor Apgar scores at one minute after birth in contrast to normal Apgar scores for the neonates born to mothers without iron deficiency anaemia. Apgar scores are very sensitive indices of the functional status of the brain and nervous system at the time of birth.

Among Children

More than 41 million children, nearly half of whom were female children, in the age 0-35 months were malnourished and anaemic to varying degrees as found by the NFHS-2 who would face the consequences. It seems like the vicious cycle of iron deficiency anaemia and malnutrition is progressing to become an intergenerational affliction of the people of India. Greater levels of childhood morbidity and mortality have been observed in such groups of children. The oft-stated axiom 'small-mother-small-baby-who-would-grow-to-be-a-small-mother' appears to be coming true in the case of disadvantaged Indian children – a potentially poor population outcome indeed.

Loss of growth potential

These children, most of whom were born to mothers with iron deficiency anaemia and malnutrition had greater chances of failing to thrive in their physical growth as most of them were already underweight and stunted within the short span of their life. What rendered their future more poignant was the likelihood of further lack of nutrition and escalation of iron deficiency to keep pace with the anticipated growth at the given age. These children were likely to suffer in their physical growth as well as in the growth and development of their brain and nervous system. The brain and the nervous system grew very rapidly in the first three years of life and needed the full compliment of nutrition and be free from iron deficiency anaemia. Delayed or reduced development of the brain and nervous system would have its impact for the life time of these children. They were likely to have poorly built bodies with imperfect functional control on their musculoskeletal body frames, which were essential for physical activity.

Reduced intellectual achievements

A number of studies from around the world indicate that children with iron deficiency anaemia will have serious consequences in attaining intellectual capabilities to the levels of natural endowment of each one of them. Poor cognition, motor development and behavioural problems have been well documented throughout the world. This would lead to poor scholastic attainments and more behavioural problems in later childhood. This is because the growth of the brain and the nervous system are affected both in terms of size and quality. In addition, it has been documented that there is a delay in the growth of nerve cells and their ability to establish proper connectivity which is very vital for the transmission of nerve impulses between the central and peripheral nervous system. Iron deficiency anaemia

is also known to interfere with the synthesis and metabolism of a number of neurohormones and neurotransmitter substances of vital importance for the development of intellectual and behavioral faculties in an individual.

Population Outcome

With such a huge prevalence of iron deficiency anaemia and malnutrition among women and young children, the population outcome will be very poor. Since more than half of the women in their prime reproductive age are anaemic and malnourished, the reproductive morbidity will increase several folds. Maternal health and pregnancy outcome, especially the perinatal outcome, will be poor for a very large number of women in the country. Without any definitive nutritional supplementation programmes, poverty, food insecurity, illiteracy, poor water supply and sanitation and inaccessibility of primary health care will further add to the misery of these women.

Born with no iron stores, nourished on the poor quality of breast milk and raised on inadequate and inappropriate weaning and child feeding practices the child growth and development are at great peril. In the absence of community level nutrition programmes, large scale food supplementation and fortification for these very young children living in poverty and poor environmental sanitary conditions, their natural potential for growth and development will be severely affected. The future of human resources in the country appears quite bleak because the iron deficiency and malnutrition have taken their toll in full measure leaving more than 75 per cent of the very young children in a state of grossly compromised physical and mental growth and development.

NFHS-2 has driven home an equally strident message for the nation. The message is, unless remedied urgently, the quality of the stock of the country in future would be a big question mark. For, more than three-quarters of a billion plus citizens would be stunted, underweight, and anaemic, with poor mental development. The prevailing levels of poverty and inequities in the distribution of wealth, services, and food insecurity have the potential to aggravate the situation further.

Economic Outcome

The morbidity attributable to iron deficiency anaemia and malnutrition is an outcome of functional deficiencies suffered by the individuals as a consequence of reduced oxygen supply to produce the required energy. Such functional deficiency results from the vicious cycle brought about by the poor availability of food, poor affordability to obtain food, poor quality and nutritive value of the available food and poor utilisation of the assimilated

food. Any or all of the elements in this cycle can contribute to the morbidity.

As a consequence, the growth of an individual from the foetal to the adult stage of development is affected. The growth is affected at the crucial stages of life. The greatest damage is to the development of the brain and the musculoskeletal system leading to loss of mental development and physical status. The greatest periods of growth spurts in the life of an individual are affected leading to permanent loss of physical stature resulting in stunting. The effect of stunting is because of the reduced height and size of an individual. This is a mechanical loss suffered by the individual. In women, the height is critical for reproductive outcome, and in males it is critical for economic activity. Even a loss of several inches of height would place the individual in a greater disadvantage in comparison to the normally built individuals in terms of economic output. The loss of economic advantage consequently leads to reduced affordability for food and thus suffer from malnutrition. The poor growth outcome of malnutrition leads to reduced stature of individuals affected. Such individuals suffer the dual impact of loss of height and oxygen deprivation.

The continuum of iron deficiency probably may last for the entire lifetime as it happens almost without exception in India. The consequence is that the individual might suffer varying degrees of oxygen deprivation leading to over-utilisation of available substrate (glucose) for the production of energy in the body. Such over-utilisation deprives the resources for the physical growth.

DISCUSSION

The NFHS-2 has done a pioneering exercise by expanding the demographic and health survey beyond the conventional demographic variables to estimate the nutritional status of the population in India. The survey in its effort has been able to generate a good deal of data on iron deficiency anaemia among the respondent women in their reproductive age 15-49 and their children age below 35 months. Since this is a large-scale survey conducted simultaneously across the country with a very huge sample size, the data generated will be useful to a great extent in developing policy perspectives for future programme interventions.

The quality of the data has been compromised to a certain extent, which could have been avoided. In view of compelling evidence that the HemoCue system is known to overestimate the hemoglobin levels, serious consideration should have been given for the alternative methods for measuring hemoglobin levels. Most likely, the alternative method of

hemoglobin estimation would have given an opportunity for the capacity building in terms of acquiring photoelectric calorimeters, training the local medical or laboratory medical personnel. It would have certainly aided in expanding the infrastructure in the rural areas and as a fallout would have strengthened the health care delivery system to some extent. The financial outlay on the expensive HemoCue photoelectric calorimeters would have supplemented the health care system with the much needed equipment.

Training lay persons to perform hemoglobin measurements with over reliance on the machine rather than on the diligence of a technique as practised by a deft technician or professional, was an oversimplified approach to a fairly complex problem. Even small countries have used medical personnel in view of getting the best possible results.

Population coverage should have been wider in view of the large data on iron deficiency anaemia and malnutrition among all segments of population. Besides advantages for correlation of the data within the population groups it could have been useful for policy and programme perspectives. Non-inclusion of infant's age 0-6 months for hemoglobin measurement is a serious drawback as this is a very delicate and highly vulnerable segment whose prevalence can be used very effectively to plan early preventive measures. Restricting the children to below 35 months is another decision, which has severely curtailed the utility of the data. Non-inclusion of men in the sample is another opportunity lost in studying the entire population.

Variations in the quality of the data can be expected when a large number of organisations are involved in the collection of data across the country. The centralised training for field staff and the same survey instruments used across the country for data collection do not ensure the uniformity of data collection. Thirteen organisations with myriad personnel from a variety of backgrounds make it nearly impossible to ensure uniformity in conducting survey and data collection.

In contrast, scholars from around the world have always held the quality of data collected through the Census Organisation or the Sample Registration System (SRS) in high esteem. There is a compelling need to build a sound database on the very important aspects of health and nutrition in the country. The population Research Centers (PRCs) are eminently suited for the task as they are spread over the hinterland of the country and are in close interaction with their respective areas. The establishment of the PRCs in the seventies by the Ministry of Health and Family Welfare (MOHFW) was a capacity building effort in this direction. The foresight

needs to be appreciated as there is a need for a system similar to Census or SRS to collect health related data from all over the country. Nevertheless, the involvement of a number of other organisations in conducting the NFHS-1 and NFHS-2 belies this laudable objective. The data quality would always be affected by *ad hoc* approaches as adopted by the NFHS-2 by engaging a number of organisations for just one single survey. It is uncharitable to criticise the data collection under such circumstances although the very purpose is likely to be defeated. A country of the size of a billion plus population needs a sound organisational base for health and nutritional surveillance and a good database.

Nevertheless, with its very large sample size and a vast spread of data collection from across the country, the NFHS-2 data on iron deficiency anaemia and malnutrition can be considered as reasonably good data for a beginning. Moreover, this is for the first time such countrywide data have become available on an important aspect of human nutrition in the country though limited to two narrow segments of population. It is possible to draw inferences with the data available on iron deficiency anaemia and malnutrition among the women in the reproductive age 14-49 and their children age below 35 months.

There is an urgent need for a large-scale dissemination of this data among all the professional groups, policy makers, and administrators all over the country with a view to utilising this data for developing policy frameworks and interventional programmes to contain the existing nutritional deficiencies. This data can also be used to develop appropriate population based nutritional programmes such as food fortification and nutritional supplementation. Effective nutrition communication programmes can be developed on the basis of the data available, as there seems to be a great need for such programmes at the moment.

CONCLUSIONS

NFHS-2 is a pioneering effort in the measurement of the nutritional status of women in reproductive age and very young children in India, the extent and coverage of which have been compromised, though. The very large sample size and vast area of coverage help to repose greater confidence in the data. It should be acknowledged that, as pointed out earlier, that this is a landmark survey in the history of health care in India because of its simultaneity, extent and population coverage. Because of the shortcomings it has lost the characterisation as a benchmark. It would have been extremely useful from the point of view of understanding the implication of iron

deficiency and malnutrition among the children and for correlation with the prevailing morbidity and mortality variables if the coverage of the children had been extended to 0-59 month of age. The data at the population level would have been comprehensive if men had been included in the survey as has been done in several countries. Heaping of ages is another element, which reduces the usefulness of the data, especially among the women in the perimenopausal age.

There is no rationale for choosing the HemoCue method of haemoglobin measurement as it is known to overestimate the prevalence of iron deficiency. The HemoCue photoelectric calorimeter and the microcuvettes are expensive. The microcuvettes are very sensitive to temperature and humidity; as such they are unsuitable for Indian weather conditions. The HemoCue photoelectric calorimeter does not serve any useful purpose beyond the NFHS-2 as the consumables viz., microcuvettes are expensive and difficult to store. Thought should have been bestowed on the utility of the expensive equipment beyond the survey even if it were to be a free gift from a generous source. Beyond the survey the utility of equipment would have been a capacity addition to the primary health care system which is facing chronic financial crunch.

Training non-technical personnel for making haemoglobin and anthropometric measurements was another important aspect that should have been thought of thoroughly. The training imparted to such personnel was inappropriate for they lacked the experience or diligence required to achieve the precision in the measurements. Imprecise measurements affect the quality and validity of the data. Again, beyond the survey, the experience gained by such personnel would be a total waste. Efforts should have been made to spruce up the capability of the laboratory technicians and/or physicians in the primary health care system.

Involvement of a large number of organisations most of which are heterogeneous in nature is a great drawback as it is bound to affect the quality, and more so, the uniformity of data collection. It can serve the short term goal of carrying out a survey, but it adversely affects the capacity building initiative of the seventies, which is sound both in principle and functionality. Health and nutritional data of a billion plus people cannot be handled on *ad hoc* pattern for a long time. There is a need to take a serious view on establishing a health and nutrition related database in the country. Monolithic establishments like census organisation or sample registration system can be expected to be deft and adapted for the specific task. At the moment there is no establishment of such nature in the health care system

in the country even though there is an imperative need for one.

The NFHS-2 data have demonstrated a very large prevalence of iron deficiency anaemia and malnutrition across the entire country among all sections of the survey population with only regional variations in the prevalence. Eastern India had the most prevalence among its population of women and children – the worst affected region. The northeastern and central regions closely followed it. Northern region had a relatively lower prevalence of iron deficiency and malnutrition. Western region of the country was closely behind the northern region. Southern region of the country had the lowest prevalence of iron deficiency anaemia and malnutrition – the least affected region.

The pattern of prevalence is very familiar – follows the trends in the socioeconomic development in the country with exceptions to the rule as in the case of West Bengal, Maharashtra, and Tamil Nadu. The prevalence of iron deficiency anaemia and malnutrition in the country is simply overwhelming – to put it in very simple terms. With such massive prevalence and no definite programmes (except for short-lived, sketchy, isolated and scattered and populist programmes) it is mind-boggling to think of the quality of human resources of the nation which is home for the second largest population in the world. It is affecting the very stock of the nation and by all the available indications would deteriorate further.

The pattern of prevalence also has a very close resemblance to the pattern of food insecurity, data on which have been published by the World Food Programme and M. S. Swaminathan Research Foundation (MSSRF). The nexus between the food insecurity and malnutrition is very well known to overemphasise.

The NFHS-2 data on the prevalence of iron deficiency anaemia and malnutrition in the country clearly indicate that the two conditions were severe grade public health problems as the prevalence of both conditions in the population was greater than 40 per cent. The data support the opinion of the scholars that under such circumstances the prevalence of iron deficiency and malnutrition affected almost the entire population in the country. By implication, the billion plus anaemic and stunted population of India did not augur well for either the quality of life of its people or the economy of the nation that hosted them.

The NFHS-2 data have brought out very clearly that a large section of women in their reproductive phase in India face the greatest disadvantage of the risks involved in reproduction as they enter such an important phase of life in a state of iron deficiency and malnutrition, which will further the

danger of untoward outcome. Poverty, illiteracy, inadequate access to food, poor environmental sanitation and inaccessible primary health care are the great adversities that further aggravate their plight.

The very young child population – the future generation of Indian citizens -is at great peril of perpetuating malnutrition if immediate measures are not initiated to supplement their nutritional needs very effectively – which is most unlikely. The NFHS-2 data are very clear about it. Their development, especially the mental development and intellect will be severely compromised besides their physical stature.

Given the socioeconomic background of the people of India and with such high rates of prevalence it is beyond doubt that almost all the women and very young child population of India suffer from iron deficiency anaemia and a vast majority of them do suffer from malnutrition, the only difference being in the degree of iron deficiency and malnutrition.

RECOMMENDATIONS

There is a need for repeating the haemoglobin and anthropometric measurement at specified intervals so that the trends and differentials can be closely followed up with programme interventions and can be monitored. It is imperative in view of such huge prevalence and in the welfare of such a large population.

Increase the coverage in the childhood from 0-35 months to 0-59 months so that the vagaries in the growth of the preschooler can be monitored very closely and programme initiatives and outcomes also monitored closely.

Five year age interval is reasonable and heaping age interval reduces the utility of the data, which is vital at certain ages. With increasing longevity collection of data among the older women can be considered.

Unmarried adolescents be treated as a prime segment of the female population and data may be collected for them with the view of instituting specific programmes to improve malnutrition and iron deficiency among the numbers of this very vulnerable group who are going to become mothers in a short time (NFHS-2 collected data from ever married women only). At the moment this is a neglected segment whose fragile health conditions can deteriorate and contribute to the prevalence of iron deficiency and malnutrition if their condition is not attended to with sincerity.

Inclusion of men in the reproductive age for haemoglobin and anthropometric measurements enhances the programme perspective and helps in monitoring the nutrition status of the population and in understanding deviations in the prevalence.

Direct cyanmethemoglobin method, which is recognised as Gold Standard for measurements of haemoglobin should be opted and the facilities at the nearest First Referral Units (FRU) must be made use of for the advantage of the survey and also with the view of capacity building in the primary health care system in the country. This will increase the quality and quantity of laboratory services in the primary health care system all over the country and be of assistance to other national programmes.

Training laboratory technicians attached to the FRUs or the physicians increases the quality of the measurements and data. Such training will further the competence of the personnel at the FRUs.

National standards or nomograms have to be developed for the Indian population not with the intent of pride but as we have the capacity to do so to meet the imperative needs of the people. It is a necessity and certainly not a luxury. With the scientific capacity the country, has it is possible to develop our own standards; it pays in the long run.

Data collected at such huge cost and effort should be disseminated widely among the policy makers, administrators, nutritional experts and academics so as to invite greater intellectual participation in developing programmes aimed at containing iron deficiency and malnutrition with greater emphasis on the women and children.

Properly planned programmes with the specific objective of improving the lives of people through the nutritional interventions should be instituted and implemented with equal zeal. Resources pooling from the public and private sources should be considered in the planning and execution of such projects.

Targeted nutritional supplementation programmes must be introduced from infancy and early childhood, for preschool children, pregnant and lactating mothers. Populist approach in the past has not been of any use for the target population in spite of huge financial drain on the exchequer. Duplicity and multiple programmes must be abandoned in the interest of the effectiveness of implementation.

All the nutritional interventions should be monitored during the implementation, and periodically evaluated, and trends and outcomes must be correlated and widely disseminated.

A sustained nutrition information, education and communication (IEC) campaign is an absolute necessity. All available media approaches need be used for an effective communication programme to further the implementation.

With the wide prevalence of iron deficiency all over the country, and more so in the eastern region, there is a need to study the prevalence of

helminthic infestations in human beings and their infectivity load in the soil all over the country. Such a data will emphasise the need for environmental sanitation and quality of potable water.

Food security is another aspect that needs to be considered in the background of such a huge prevalence of malnutrition in the country. Beyond production of food grains meaningful distribution is the essence of successful food security, which needs to be given top priority.

References

- Academy of Preventive Medicine of Kazakhstan and Macro International Inc. (APM and Macro) (1999). *Kazakhstan Demographic and Health Survey 1999*. Calverton, Maryland: Academy of Preventive Medicine of Kazakhstan and Macro International Inc.
- Allen, L.H. (2001). Biological Mechanisms That Might Underlie Iron's Effect on Foetal Growth and Preterm Birth. *Journal of Nutrition*. 131:581S-589S.
- Baker, S.J. and E.M. DeMaeyer (1979). Nutritional Anaemia: Its Understanding and Control with Special Reference to the Work of the World Health Organisation. *American Journal of Clinical Nutrition*, 32(2): 368-417.
- Beard, J. L. (2001). Iron Biology in Immune Function, Muscle Metabolism and Neuronal Functioning. *Journal of Nutrition*. 131:568S-580S.
- Beard, J.L., Harry Dawson and Domingo J. Piñero (1996). Iron Metabolism: A Comprehensive Review. *Nutrition Reviews*. 54(10): 295-317.
- Behrman, Jere R. (1992). *The Economic Rationale for Investing in Nutrition in Developing Countries*, Washington D. C.: US Agency for International Development.
- Bender, B. (1998). *Anthropometric Tutorials*. (<http://www.odc.com/anthro/tutorial/tunit18.html>)
- Berger, Jacques, Victor M. Aguayo, José Luis Miguel, Carmen Lujan, Wilma Telez and Pierre Traissac (1997). Definition and Prevalence of Anaemia in Bolivian Women of Childbearing Age Living at High Altitudes: The Effect of Iron-Folate Supplementation. *Nutrition Review*, 55(6): 247-56.
- Bhatt, R. (1992). Obstetric Management of Anaemia in Pregnancy. *Proceedings of the Symposium on Anaemias, XXXV All India Obstetric and Gynaecological Congress*. Chennai: Post Congress Volume, Obstetric and Gynaecological Society of Southern India.
- Bothwell, T. H., R. W. Charlton, J.D. Cook and C.A. Finch (eds.) (1979). *Iron Metabolism in Man*. Oxford: Blackwell.
- Brabin, B.J., Mohannad Hakimi and David Pelletier (2001). An Analysis of Anaemia and Pregnancy-Related Maternal Mortality. A Paper presented at the Belmont Meeting on Iron-Deficiency Anaemia: Reexamining the Nature and Magnitude of the Public Health Problem, *Journal of Nutrition*, 131: 604S.
- Casiday, Rachel and Regina Frey (2000). *Hemoglobin and the Heme Group: Metal Complexes in the Blood for Oxygen Transport*. Department of Chemistry, Washington University, St. Louis ([http://wunmr.wustl.edu/EduDev/LabTutorials/Hemoglobin/MetalComplexinBlood.html](http://wunmr.wustl.edu/EduDev/LabTutorials/Hemoglobin/Metal-ComplexinBlood.html)). (<http://wunmr.wustl.edu/EduDev/LabTutorials/Hemoglobin/MetalComplexinBlood.html>)
- Churchill-Davidson, H. C. (1986) Pulmonary Gas Exchange and Acid-Base Status. In Wylie and Church-Davidson (eds.) *A Practice of Anaesthesia*. Singapore: PG Publishing Pte Ltd.

- Cunningham, F.G., Norman F. Gant, Kenneth J. Leveno, Larry C. Gillstrap III, John C. Hauth, and Katharine D. Wenstrom, (eds.) (2001). *Williams Obstetrics*, 21st Edition, New York: McGraw-Hill.
- Dallman, P.R. (1989). Review of Iron Metabolism. In L.J. Filer Jr. (ed.) *Dietary Iron: Birth to Two Years*. New York: Raven Press.
- Dallman, P.R. (1990). Iron. In Myrtle L. Brown (ed.), *Present Knowledge in Nutrition*. Washington D. C.: International Life Sciences Institute Press.
- Delvin, J. T. and Edward S. Horton (1990). Energy Requirement. In Myrtle L. Brown (ed.). *Present Knowledge in Nutrition*. Washington D.C.: International Life Sciences Institute Press.
- DeMaeyer, E.M., P. Dallman, J.M. Gurney, L. Hallberg, S.K. Sood and S. G. Srikantia (1989). *Prevention and Controlling Iron Deficiency Anaemia through Primary Health Care: A Guide for Health Administrators and Programme Managers*. Geneva: WHO.
- Dewhurst, Sir John, Michael de Swiet, and Geoffrey V. P. Chamberlain (eds.). (1986). *Basic Science in Obstetrics and Gynaecology*. London: Churchill Livingstone.
- Donald, I. (1986). *Practical Obstetric Problems*, 5th Edition, Singapore: PG Publishing Pte. Ltd.
- Draper, A. (1997). Child Development and Iron Deficiency Anaemia. *The Oxford Brief*, ILSI/OMNI/JSI Inc.
- Dupont, J. (1990). Lipids. In Myrtle L. Brown (ed.). *Present Knowledge in Nutrition*. Washington D. C.: International Life Sciences Institute Press
- Filteau, S. (1995). Iron Nutrition in Children under Five years Old: Requirement and Assessment. In Penelope Nestel (ed.), *Proceedings: Iron Interventions for Child Survival*. London: OMNI/ICH/USAID.
- Grantham-McGregor, S. and Comelius Ani (2001). A Review of Studies on the Effect of Iron Deficiency on Cognitive Development in Children. *Journal of Nutrition*. 131:649S-668S, 2001.
- Haas, J.D. and Thomas Brownlie IV (2001). Iron Deficiency and Reduced Work Capacity: A Critical Review of the Research to Determine a Causal Relationship. *Journal of Nutrition*. 131:676S-690S, 2001.
- HemoCue, AB. (No date) *HemoCue Blood Hemoglobin Photometer Operating Manual and Package Insert*. Sweden: Ängelholm.
- INACG (1979). *Iron Deficiency in Infancy and Childhood*. Washington D. C.: International Nutritional Anaemia Consultative Group.
- Indian Council of Medical Research (ICMR) (2001). Micronutrient Deficiency Disorders in 16 Districts of India. *Part I Report of an ICMR Task Force Study – District Nutrition Project*. New Delhi: ICMR.
- International Institute for Population Sciences (IIPS) (1995). *National Family Health Survey (MCH and Family Planning)*, India 1992-93. Mumbai: IIPS.
- International Institute for Population Sciences (IIPS) and ORC Macro (2000). *National Family Health Survey (NFHS-2), 1998-99*. Mumbai: IIPS.

- Kapoor, S. K., Umesh Kapil, Sada Nanda Dwivedi, K. Anand, Priyali Pathak and Preeti Singh (2002). Comparison of HemoCue Method with Cyanmethemoglobin Method of Estimation of Hemoglobin. *Indian Paediatrics*. 39:743-6.
- Martorell, R. (2000). *Child Nutrition and the Wealth of Nations*. Distinguished Faculty Lecture. Atlanta, Georgia: Emory University.
- Mayes, P.A. (2000). Bioenergetics: The Role of ATP. In R. K. Murray, Daryl K, Granner, Peter A. Mayes and Victor W. Rodwell (eds.), *Harper's Biochemistry*, 25th Edition, New York: McGraw-Hill.
- Microsoft (1998). Photosynthesis. In Microsoft *Encarta 98 Encyclopedia (CD)*. Microsoft Corporation.
- Murray, R. K. (2000). Porphyrins and Bile Pigments. In R. K. Murray, Daryl K, Granner, Peter A. Mayes and Victor W. Rodwell (eds.). *Harper's Biochemistry*, 25th Edition, New York: McGraw-Hill.
- NFHS (2000). *National Family Health Survey (NFHS-2) – 1998-99, India*. Mumbai: IIPS; Claverton, Maryland: ORC-MACRO.
- Onis, Mercedes de and Monika B. Blössner (2003). The World Health Organisation Global Database on Child Growth and Malnutrition: Methodology and Applications. *International Journal of Epidemiology*. 32(4):518-26.
- Oppenheimer, S. J. (2001). Iron and Its Relation to Immunity and Infectious Disease. *Journal of Nutrition*, 131:616S-635S.
- PATH (1997). *Anaemia Detection Methods in Low-Resource Settings: A Manual for Health Workers*. Seattle: Program for Appropriate Technology in Health.
- Pollitt, E. (2001) The Developmental and Probabilistic Nature of the Functional Consequences of Iron-Deficiency Anaemia in Children. *Journal of Nutrition*, 131:669S-675S.
- Raman, L. (1989). Anaemia in Pregnancy. In M..K. Krishna Menon, P.K. Devi and K. Bhasker Rao (eds.) *Postgraduate Obstetrics and Gynaecology*, 4th Edition. Hyderabad: Orient Longman.
- Rao, K. Bhasker (1992). Safe Motherhood. In S. S. Ratnam, K. Bhasker Rao and S. Arulkumaran (eds.) *Obstetrics and Gynaecology for Postgraduates*. Vol I, Hyderabad: Orient Longman.
- Rasmussen, K. (2001). Is There a Causal Relationship between Iron Deficiency or Iron Deficiency Anaemia and Weight at Birth, Length of Gestation and Perinatal Mortality? *Journal of Nutrition*, 131:590S-603S.
- Rodwell, V.W. (2000). Proteins: Myoglobin and Hemoglobin, In R. K. Murray, Daryl K, Granner, Peter A. Mayes and Victor W. Rodwell (eds.), *Harper's Biochemistry*, 25th Edition. New York: McGraw-Hill.
- Sari, Mayang, Saskia de Pee, Elviyanti Martani, Susilowati Herman, Sugiatmi, Martin W. Bloem and Ray Yip (2001) Estimating the Prevalence of Anaemia: A Comparison of Three Methods. *Bulletin of the World Health Organisation*, 79:506-11.
- Schultz, T. Paul (1994). Human Capital Investment in Women and Men: Micro and

- Macro Evidence of Economic Returns. *Occasional Paper No. 44*. San Francisco, California: International Center for Economic Growth.
- Sears, D. W. (2002). *Overview of Hemoglobin's Structure/Function Relationships* (<http://tutor.lscf.ucsb.edu/instdev/sears/biochemistry/>).
- Seligmann, B., Daniel Kress, William Winfrey, Imelda Feranil and Kokila Agarwal (1997). Reproductive Health and Human Capital: A Framework for Expanding Policy Dialogue. *Occasional Paper 1 POLICY Project*. Washington D. C.: The Futures Group International.
- Sharma, J. B. (2003). Nutritional Anaemia during Pregnancy in Non-Industrialised Countries. In John Studd (ed.). *Progress in Obstetrics and Gynaecology*. Vol 15. London: Churchill Livingstone.
- Shetty, P.S. (1989). Metabolic Response to Chronic Energy Deficiency. *Nutrition Foundation of India, Bulletin*, 19(1).
- Stockman III, J. A. (1990). Foetal Hematology. In Robert D. Eden and Frank H. Boehm (eds.), *Assessment and Care of the Foetus*. Connecticut: Appleton and Lange.
- Stoltzfus, R. J. and Michele L. Dreyfuss (1998). *Guidelines for the Use of Iron Supplements to Prevent and Treat Iron Deficiency Anaemia*. INACG/WHO/UNICEF.
- Stoltzfus, R. J. (2001). Defining Iron-Deficiency Anaemia in Public Health Terms: A Time for Reflection. *Journal of Nutrition*. 131:565S-567S.
- Swaminathan, M. S. (2003). Towards a Hunger-Free India: Count Down from 2007. *The Hindu*. Bangalore, April 27.
- Szepesi, Béla (1990). Carbohydrate. In Myrtle L. Brown (ed.). *Present Knowledge in Nutrition*, Washington D. C.: International Life Sciences Institute Press.
- Thangaleela, T. and P. Vijayalakshmi (1994). Prevalance of Anaemia in Pregnancy. *The Indian Journal of Nutrition and Dietetics*, 31(2): 26-9.
- UNICEF (1988). *The Child in South Asia: Issues in Development as If Children Mattered*. New Delhi: United Nations Children's Fund.
- Whitfield, C. R. (1988). Blood Disorders in Pregnancy. In C. R. Whitfield (ed.). *Dewhurst's Textbook of Obsterics and Gynaecology for Postgraduates*. 4th Edition. Singapore: P G Publishing Pte Ltd.
- WHO/UNICEF/UNU (2001). *Iron Deficiency Anaemia: Assessment, Prevention and Control: A Guide for Programme Managers*. Geneva: World Health Organisation.
- World Bank (1994). *Development in Practice: A New Agenda for Women's Health and Nutrition*. Washington D. C.: The International Bank for Reconstruction and Development.
- Yip, Ray (1989). *Iron Nutritional Status Defined*. In L.J. Filer Jr. (ed.), *Dietary Iron: Birth to Two Years*. Raven Press.
- Yip, Ray (1994). Iron Deficiency: Contemporary Scientific Issues and International Programmatic Approaches. *Journal of Nutrition*. 124:1479S-90S.

ABOUT THE AUTHOR

Dr. M. Ramakrishna Reddy is a National Research Fellow at the Population Research Centre (PRC), Institute for Social and Economic Change (ISEC), Bangalore. He is an obstetrician, gynaecologist and a population scientist with a vast experience of more than twenty-five years in the field of women's health and family planning. He has been providing primary health care in all the four south Indian states and has worked as a programme administrator in several sponsored family planning programmes in north India. He has been a visiting professor at the Department of Population Studies, Sri Venkateswara University, Tirupati.