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Double burden of malnutrition among adolescents in India: A Review

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ABSTRACT: *Adolescence is a period of rapid physical growth and transition between childhood to adulthood and consists of important biological and psychological processes. Adolescents constitute a large share of the global population. Therefore, the overall health and nutrition status remain a major issue in overall growth of a population. Prevalence of undernutrition, anaemia and vitamin deficiencies are persistent problems among adolescents in India. Large population size, improper resource distribution, heterogeneity (in socio-economic positions, demographic and cultural differences) and inaccessibility to adequate healthcare facilities are to the major contributing factors of malnutrition (e.g., undernutrition/overweight-obesity). Current nutritional scenario has shown that while undernutrition remains as an everlasting public health problem, overweight-obesity is emerging as a new challenge in the country. Moreover, last two decades have observed major shifts in socio-economic, demographic and epidemiological levels that increase the overall burden of overweight-obesity in Indian population. This trend of simultaneous existence of undernutrition and overweight-obesity is referred as double burden of malnutrition (DBM). The present paper discusses the nutritional scenario of DBM, cause and consequences, intervention and recommendations regarding DBM among adolescents in India. Moreover, DBM has significant effects on the overall growth and well-being among populations where undernourished adolescents become prone to several communicable and infectious diseases whereas overweight-obesity bears significant risks of different non-communicable diseases (e.g., diabetes, hypertension and cardiovascular disease).*

Keywords: Adolescents, Stunting, Thinness, Overweight-obesity, Public Health

INTRODUCTION

During the last two decades, developing countries have faced significant changes in child and adolescent nutrition due to the nutritional, demographic and epidemiological transitions. These led to overall changes in lifestyle patterns, food habits and economic changes (Popkin 2002; Subramanian et al. 2007; Debnath et al. 2018a; Mondal et al. 2018). The possible reasons for the nutritional changes in India are rapid socio-economic, demographic and epidemiologic transitions, changes in dietary habits and a more sedentary lifestyle in Indian populations (Popkin 2002; Subramanian et al.2007; Kapil and Sachdev 2012; Debnath et al. 2018a). India has the highest occurrence of child undernutrition in the world and more than half of the Indian children remain undernourished and underprivileged (Bamji 2003; Ramachandran 2014; Debnath et al. 2018b). The co-existence of undernutrition and overweight-obesity in a household/population is known as "double burden of malnutrition" (DBM) (Doak et al. 2005; Subramanian et al. 2007; Shrimpton and Rokx 2012; Debnath et al. 2018a; Mondal et al. 2018). A decline in prevalence of undernutrition with an increase in overweight-obesity is giving rise to DBM in Indian populations (Popkin 2002; Subramanian et al. 2007; Kapil and Sachdev 2012; Debnath et al. 2018b).

The DBM may be defined as undernutrition (underweight, stunting, thinness, wasting), including micronutrient deficiencies, coexisting with overnutrition (overweight and obesity) (Doak et al. 2005; Shrimpton and Rokx 2012). The prevalence of DBM especially in the household level is considered to be a significant public health concern in several developing countries. This is because it shares similar socio-economic and demographic profiles with overweight-obesity households and increases the major health concern among undernourished individuals (Doak et al. 2005). India is suffering from the dual burden of malnutrition ie., undernutrition in one hand and overweight-obesity on the other (Wang et al. 2009; Kapil and Sachdev 2012; Varadharajanet al. 2013; Misra and Bhardwaj 2014; Kulkarni et al. 2017; Debnath et al. 2018b).

The poor physical growth patterns among adolescents will be apparent as multi-dimensional adverse physical and social conditions leading to delay in the onset of puberty and poor work capacity and reproductive outcomes in adulthood (WHO 1995; Strickland 2002). Harnessing of the full physical and mental potential of the adolescents is considered to be necessary for overall health improvement of the populations and economy of a country. Insufficient intake of food, poor absorption and biological use of nutrients are the principal causes of undernutrition which can result in impaired growth, underweight and impaired body functions among children and adolescents (Venkaiah et al. 2002; Deshmukh et al. 2006; Rao et al. 2006; Malhotra and Passi 2007; Mondal and Sen 2010a,b; Jacob and Nair 2012; Kawade 2012; Sharma and Mondal 2014; Akseer et al. 2017; Maestre et al. 2017; Rengma et al. 2016; Juju et al. 2018). Even during late adolescence, the physique continues to mature with an increase in height. Adequate supply of nutrition in the form of a balanced diet rich in nutrients (e.g., iron) is the key to improve such critical situations (Bogin 1999; Parasuraman et al. 2009; Akseer et al. 2017; Maestre et al. 2017).

The existing literature reveals a significant proportion of Indian adolescents suffering from iron deficiency and anaemia (Basu et al. 2005; Rao et al. 2006; Parasuraman et al. 2009; Premalatha et al. 2012; Ramachandran 2014; Thomas et al. 2015). Unbalanced distribution/inaccessibility to food resources, drastic differences in the socio-economic status and demographic parameters are the major contributors of DBM in Indian populations (Subramanian et al. 2007; Debnath et al. 2018a; Mondal et al. 2018). Several researchers have reported that a significant proportion of the populations are currently affected with overweight-obesity especially in the urban regions of the country (Kapil et al. 2001; Subramanian et al. 2007; Jain et al. 2010; Goyal et al. 2010, 2011; Kapil and Sachdev 2012; Debnath et al. 2018a). The prevalence of overweight-obesity can lead to several preventable non-communicable diseases such as hypertension, diabetes, cardiovascular diseases and cancer (Lobstein et al. 2004; Johannsson et al. 2006; Raj et al. 2007; Franks et al. 2010; Ranjani et al. 2014; Kelishadi et al. 2015; Pozza and Isidori 2018). The existence of both overweight and obesity and undernutrition are causing several health related problems and mortality and morbidity among adolescents (Lobstein et al. 2004; The et al. 2010). The global epidemic of overweight and obesity is in acceleration and has affected virtually all ages, sexes and ethnic groups/populations in both developed and developing countries (Lobstein et al. 2004; WHO 2006; Subramanian et al. 2007; Popkin 2012; Mondal et al. 2018). Overweight/obesity has a multi-factorial aetiology and no substantial change in mankind's genetic makeup has been observed which can explain the obesity epidemic of the last two or three decades (Sorensen and Echwald 2001; Dubois et al. 2012). The principal observed cause of this epidemic is the global shift in consumption of calorie-dense food and reduced physical activity which are the accompanying factors of globalization and are also related with various individual, societal and socio-economic factors (Lobstein et al. 2004; Subramanian et al. 2007; Popkin 2012; Jacob and Nair. 2012; Masoud et al. 2018). It is a proven fact that not all of the individuals who are living in an obesogenic environment are prone to gain weight and in that case genetic propensity for obesity probably is the basic criterion for being obese (Lobstein et al. 2004; Pigeyre et al. 2017).

Undernutrition gives rise to ill-health conditions which are prone to infectious diseases, poor capacity of physical work and weakness. Deposition of excess body adiposity gives rise to overweight and obesity, thereby increasing risks of several non-communicable lifestyle disorders such as metabolic syndrome, insulin resistance, type-2 diabetes mellitus (T2DM), hypertension, dyslipidemia, polycystic ovarian syndrome (PCOS) and coronary heart disease (CHD) and atherosclerosis among both children and adolescents (Kelishadi 2007; Subramanian et al. 2007; Bhardwaj et al. 2008; Wang et al. 2009; Popkin et al. 2012; Mondal and Sen 2014; Singh et al. 2014; Kelishadi et al. 2015; Mondal et al. 2015). Increases in childhood and adolescent obesity are observed to be associated with numerous immediate and long-term health risks that lead to premature morbidity and mortality and non-communicable disorders in later life (Lobstein et al. 2004; Johannsson et al. 2006; Raj et al. 2007; Franks et al. 2010; Ranjani et al. 2014; Kelishadi et al. 2015; Pozza andIsidori 2018). Excess body adiposity is also linked with impaired immune function as a result of increased cortisol secretion which is a steroid hormone released in response to environmental and psychological stress (Shrimpton and Rokx 2012). It may be mentioned here that a number of studies have

been initiated on the issue of DBM among children and adolescents from different countries (Pan and Lee 2007; Wang et al. 2009; Oddo et al. 2012; Cai 2014; Gupta et al. 2014; Severi and Moratorio, 2014; Sharma andMondal2014; Mondal et al. 2015; Piernas et al. 2015; Debnath et al. 2018; Mondal et al. 2018).

ADOLESCENT NUTRITION IN INDIA

The period of adolescence (10-19 years) is an important stage of human growth and is characterised by exceptionally rapid rate of growth from childhood to adulthood (WHO 1995; Bogin 1999; Parasuraman et al. 2009). Adolescents require special care in terms of proper nutrition and growth. During adolescence there is an increase in nutrient demand that is necessary for rapid physical growth and development, where individuals can gain 15% of their ultimate adult height and half of their adult weight (Johannsson et al. 2006; Campisi et al. 2018). Adolescents are considered to be nutritionally vulnerable groups and adequate diet and nutrients are very necessary for their rapid physical growth and development through which they can attain optimum cognitive and learning skills, academic performance and energies, as well as be healthy for future parenthood (Sorensen and Echwald 2001; Campisi et al. 2018). Unfortunately, lack of adequate nutrition impedes growth of adolescents with their full genetic developmental potential (Mahgoub et al. 2017). Proper nourishment and good physique can give rise to a healthy adult population. A large proportion of the growing children and adolescents in the underdeveloped and developing countries are deprived of adequate nutrition due to their poor socio-economic status, lack of proper healthcare facilities and knowledge of nutritious food that leads to prolonged nutritional deprivation and growth retardation (Antony and Laxmaiah 2008; Sharma and Mondal 2014; Rengma et al. 2016; Debnath et al. 2018a,b).

The National Family Health Survey (NFHS-III) data has confirmed that prevalence of anaemia among adolescents (15-24 years) is very critical in the north-eastern states of Assam (68.0%), Sikkim (64.0%), Tripura (61.0%), Arunachal Pradesh (52.0%) and Meghalaya (48.0%) (Parasuraman et al. 2009). Several studies have reported the existence of gender discrimination in terms of access of food, nutrition and health-care facilities among adolescents in the country. Due to the presence of gender-related discrimination, adolescent girls were observed to be nutritionally more deprived than boys. Moreover, a large proportion (28.0%) of adolescent girls get married at an early age of 15-19 years. This again leads to inadequate physical growth attainment and development (Venkaiah et al. 2002; Parasuraman et al. 2009; Mondal and Sen 2010b; Santhya 2011; Mondal 2014; Bundy et al. 2018).

The National Family and Health Survey (NFHS)-III data showed that a total of 44.5% of women aged 20-24 years were married before attaining the age of 18 years, 22.6% were married before attaining the age of 16 years and 2.6% were married before completing 13 years of age (Raj et al. 2009; Mondal 2014). Marriage at an early age leads to early conception and presence of undernourishment leads to poor reproductive outcomes and intra-uterine growth retardation or low birth weight (LBW) (Santhya 2011). Therefore, assessments of nutritional status of adolescent girls bear special significance as they

contribute to the nutritional status of the future population. Many of the physical and psychological changes that occur are closely related to nutritional well-being of adolescents. However, this group has received less importance towards nutritional assessments and promotion to health situations. Research has suggested that the majority of adolescents were suffering from different grades of undernutrition in the country (Singh and Mishra 2001; Venkaiah et al.2002; Deshmukh et al.2006; Medhi et al.2006, 2007; Rao et al. 2006; Das et al. 2007; Mondal and Sen 2010b; Banerjee et al. 2011; Basu et al. 2013; Singh and Mondal 2013; Mondal 2014; Rengma et al. 2016; Debnath et al. 2018a). On one hand, the prevalence of undernutrition remains a very common scenario in rural India, while on the other, the urban society is grappling with the issues of overweight and obesity as a result of changing lifestyles, food habits and higher per capita income than the rural populations (Raj et al. 2007; Subramanian et al. 2007; Wang et al. 2009; Popkin et al. 2012; Gupta et al. 2012; Rengma et al. 2015; Mondal et al. 2015, 2017; Pozza and Isidori 2018). It is important to emphasize here that high intake of protein rich food, low energy expenditure, excessive use of computer gaming and less outdoor activity leads to excess weight gain (Subramanian et al. 2007; Wang et al. 2009; Popkin et al. 2012; Mondal et al. 2015, 2017; Debnath et al. 2018b).

Prevalence of undernutrition among Indian adolescents are the results of poor socio-economic condition and socio-economic disparities in different segments of the population and causes delay in physical development and growth (Venkaiah et al. 2002; Rao et al. 2006; Medhiet al. 2007; Mondal 2014; Rengma et al. 2016). Due to poor nutrition optimal growth potentials of the adolescents are also not reached, causing long term health problems in adulthood. Studies have highlighted the extent of undernutrition to be greater among lower socio-economic groups as compared to higher socioeconomic groups (Deshmukh et al. 2006; Medhi et al. 2007; Debnath et al. 2018a). Minimal catch up growth has been observed among the undernourished individuals and this give rise to stunting in early childhood which perpetuates to adolescence and adulthood (WHO 1995; Bogin 1999). However, improvement in environmental conditions or in living conditions by introducing food supplementation can improve the nutritional situation of these undernourished children and adolescents (WHO 1995; Bogin 1999). Growth before adolescence is very sensitive to environmental factors, whereas growth during adolescence is a result of the complex interaction between biological and environmental factors (Bogin 1999; Khongsdier et al. 2005; Medhi et al. 2007). Moreover, adolescence is a periodwhen the lifestyle and food habits are influenced by socio-cultural factors resulting in inadequacy and imbalance in nutrient intake. These results in delayed physical development and maturation and can arrest or slow linear growth (Mondal 2015; Rengma et al. 2016). Therefore, the consumption of inadequate quality of diets and nutrients play vital role in the manifestation of undernutrition (e.g., stunting and thinness) among early childhood and adolescence (Venkaiah et al. 2002; Deshmukh et al. 2006; Rao et al. 2006; Malhotra and Passi 2007; Kawade 2012; Jacob and Nair 2012; Juju et al. 2018). It is evident that the female adolescents in rural areas are more vulnerable than the urban counterparts, due to inadequate food intake, poor healthcare promotional facilities and socio-economic inconveniences (Rao et al. 2006; Medhi et al. 2007; Mondal and Sen 2010; Maiti et. al. 2011; Mondal 2014; Tigga et al. 2015; Debnath et al. 2018a). In almost all Indian populations, boys were observed to have better access to food and basic amenities than girls

and a pronounced preference for the male child in population is also observed (Ramachandran 2014; Mondal and Terangpi 2014; Debnath et al. 2018b). Several studies have reported discrimination in diet, basic amenities, education and health care against the girl child in India (e.g., Borooah 2004; Khongsdier et al. 2005). These socio-cultural difference leads to nutritional deprivation across the populations in early age groups and adolescents.

ANTHROPOMETRIC ASSESSMENT OF ADOLESCENT NUTRITIONAL STATUS

Anthropometry is widely used due to its non-invasive and easy handling nature. It is also an inexpensive technique than the biochemical methods for assessing the human body composition and nutritional status in different clinical and epidemiological studies. The assessment of nutritional status among children and adolescents are generally done by using conventional anthropometric indices of stunting (low height-for-age), underweight (low weight-for-age), wasting (low weight-for-height), thinness {low Body mass index (BMI)-for-age} and skin fold-for-age (e.g., triceps and sub-scapular), overweight and obesity (high BMI-for-age) (WHO 1995, 2007; Nandy et al. 2005; Cole et al. 2007; Debnath et al. 2018a). The BMI as measured by weight in kilogram (kg) divided by height in meter square (m^2) is a derived surrogate anthropometric measure that has been extensively used to determine the prevalence of overweight-obesity and thinness among children and adolescents (WHO 1995, 2007). The prevalence of stunting is generally assessed below the third percentile or <−2SD of the National Centre for Health Statistics (NCHS/WHO 1983; WHO 1995, 2007). The BMI-for-age can also be used to assess thinness or Chronic Energy Deficiency (CED) among adolescents (WHO 1995). Moreover, BMI can also be adjusted for age to account for changes due to growth and expressed as z-scores (WHO 1995, 2007). The World Health Organisation (WHO) has recommended cut-offs of $<5^{th}$ and the $>85^{th}$ percentiles of the Nutritional Health and Nutrition Examination Survey (NHANES) references to assess the thinness and overweight respectively (WHO 1995). The age-sex specific percentiles of BMI values of $>85^{th}$ and $>95^{th}$ have been used as international standard cut-offs to define overweight and obesity, respectively (Must et al.1991a; de Onis et al.2001; WHO 1995, 2007). An alternative international cut-off of overweight and obesity for children and adolescents (aged 2-18 years) corresponding to an adult BMI >25.00 kg/m^2 and >30.00 kg/m^2 has also been proposed (Cole et al. 2000). Very recently, international age and sex specific cut-off have also been proposed in order to facilitate the measure of fatness and nutritional status in terms of thinness among children and adolescents for the world population aged 2-18 years (Cole et al. 2007). A detail of the anthropometric measures and cut-off used to determine adolescent nutrition status is described in Table 1.

Table 1: Anthropometric indices and references used to assess adolescent nutrition

Category	Indices	Cut-offs	Reference
Undernutrition	Stunting (low height-for-age)	<3rd percentile or <−2SD	NCHS 1983; WHO 2007
		<5th percentile	CDC 2000
	Thinness (low BMI-for-age)	<5th percentile or <−2SD	WHO 1995, 2007
		<BMI 18.50kg/m^2	Cole et al. 2007; IASO 2000
Overweight	BMI-for-age	>85th percentile or >BMI 25 kg/m^2	Must et al. 1991a; Khadilkar et al. 2007; WHO 1995
		>85th percentile	Cole et al. 2000
		= 85th and < 95th percentiles	CDC 2000
		>BMI 25.00 kg/m^2	IASO 2010
		>+1 SD to +2SD	WHO 2007
Obesity	BMI-for-age	>95th percentile or >BMI 30 kg/m^2	Must et al. 1991a; Khadilkar et al. 2007; WHO 1995
		>90th percentile	Cole et al. 2000
		=95th percentile	CDC 2000
		>BMI 30.00 kg/m^2	IASO 2010
		>+2SD	Obesity
	Triceps-for-age	>90th percentile	Must et al. 1991b; WHO 1995
	Sub-scapular-for-age	-	>90th percentile

PREVALENCE OF STUNTING AMONG INDIAN ADOLESCENTS

Stunting (low height-for-age) is considered to be a significant indicator of nutritional assessment of children and adolescents and is also an indicator of chronic undernutrition. This index reflects unattained height of the children/adolescent at a particular age group. Stunting is a prevalent cause of concern in rural and sub-urban populations of India (Deshmukh et al. 2006; Medhi et al. 2006, 2007; Das et al. 2007; Mondal and Sen 2010a, b; Banerjee et al. 2011; Sil et al. 2011; Rengma et al. 2016). Studies have consistently observed that poor living conditions, low socio-economic status and inaccessibility to proper health and hygiene services hamper physical growth, which is then manifested as linear growth retardation. Growth retardation in height, manifested as stunting, among adolescents are probably due to long term chronic nutritional deprivation during the early ages (WHO 1995; Medhi et al. 2007; Mondal and Sen 2010b). Medhi et al. (2007) observed that 50.1% of boys and 43.1% of girls were suffering from stunting in Dibrugarh, Assam. Studies have reported high prevalence of stunting among adolescents of North India (38.50%) (Anand et al. 1999) rural areas (39.00%) (Venkaiah et al. 2002), rural Wardha (50.7%) (Deshmukh et al. 2006), rural West Bengal (52.50%) (Das et al. 2007), rural areas (29.70%) (Malhotra and Passi 2007) and adolescents of North Bengal (boys; 43.10%; girls; 50.10%) (Mondal and Sen 2010b). A study among early adolescents aged 9-14 years and working in tea garden in

Dibrugarh, Assam by Medhi et al. (2006) observed a very high proportion (53.60%) of them suffering from stunting (boys: 51.80%; girls: 56.00%).

It has been observed that mean height and weight of Indian adolescence were mostly <50th percentile as compared to the reference population (Medhi et al. 2007; Mondal and Sen 2010b; Basu et al. 2013). In North-East India, prevalence of stunting was observed to be greater among girls than boys (Medhi et al. 2006, 2007; Sil et al. 2011). Sil et al. (2011) reported the prevalence moderate level of stunting (23.70%) among rural tribal children and adolescents in Tripura. Mondal and Terangpi (2014) reported that overall prevalence of overall stunting was similar among adolescent girls (50.2%) and boys (50.1%) of North-Eastern India. Rengma et al. (2016) observed the high prevalence of stunting among the adolescents of Assam (boys: 48.4% and girls: 37.8%).

Table 2: Comparative evaluation of Indian studies assessing prevalence of stunting among adolescents

Population	Criteria/Reference	Prevalence (%)	Reference
Adolescents of North India	NCHS 1983	38.50	Anand et al. 1999
Rural adolescents of India	NCHS 1983	39.00	Venkaiah et al. 2002
Adolescents of rural Wardha	CDC 2000	50.70	Deshmukh et al. 2006
Tea garden early adolescents of Dibrugarh, Assam	WHO 1995	53.60	Medhi et al. 2006
Rural adolescents of West Bengal	WHO 1995	52.50	Das et al. 2007
Rural adolescents	WHO 2007	29.70	Malhotra and Passi 2007
Adolescents of Dibrugarh, Assam	WHO 1995	49.75	Medhi et al. 2007
School going adolescents of Wardha	WHO 2007	34.5	Dambhare et al. 2010
Rural adolescents, Darjeeling, West Bengal	NCHS 1983	46.60	Mondal and Sen 2010b
Rural tribal children and adolescents of Tripura	WHO 1995	23.7	Sil et al. 2011
Adolescents of Karbi Anglong, Assam	WHO 1995	51.20	Mondal and Terangpi 2014
Adolescents of North-East India	WHO 2007	42.63	Rengma et al. 2016
Adolescent girls of Dibrugarh, Assam	WHO 2007	42.20	Boruah et al. 2017
Adolescent girls of tea gardens in Dibrugarh	WHO 1995	50.27	Nath and Sarma 2017
Adolescents of Uttar Pradesh	WHO 2007	10.3	Aslam and Durrani 2018

According to Aslam and Durrani (2018), overall prevalence of stunting among adolescents of Uttar Pradesh was observed to be 10.3% (11% in boys and 9.5% in girls). High prevalence of stunting (42.2%) has been observed among adolescent girls of Dibrugarh by Boruah et al. (2017). Nath and Sarma (2017) also observed a similar prevalence of stunting (50.27%) among adolescent girls of tea gardens in Dibrugarh. A comparison of the prevalence of stunting reported among adolescents from India is shown in Table 2.

PREVALENCE OF THINNESS AMONG INDIAN ADOLESCENTS

Thinness (low BMI-for-age) is an indicator of chronic undernutrition. It is a generally accepted that there is a high prevalence of thinness among Indian communities with more than 50.00% of adolescents being affected (Deshmukh et al. 2006; Medhi et al. 2007; Parasuraman et al. 2009; Shivaramakrishna et al. 2011). It has been observed that adolescent boys were more affected by thinness than adolescent girls in many studies (e.g. Medhi et al. 2007; Mondal and Sen 2010b; Aslam and Durrani 2018; Debnath et al. 2018a). The greater prevalence of thinness among boys than girl's indicative of 'biological fragility' of males as compared to their female counterparts (Kraemer 2000; Khongsdier et al. 2005). Anand et al. (1999) reported prevalence of stunting in 12-18 years' age group to be 37.20% (in girls) and 41.00% (in boys) with an overall prevalence of 38.50%. Venkaiah et al. (2002) also reported prevalence of thinness to be higher in boys (53.10%) than in girls (39.50%). Khongsdier et al. (2005) reported moderate prevalence of thinness among Khynriam Khasi (8.56%) and War Khasi (27.08%) adolescents in Meghalaya and Hmar (12.77%) in Mizoram. Medhi et al. (2006) observed a very high proportion (53.90%) (boys: 51.80% and girls: 56.70%) of early adolescents (9-14 years) working in tea garden in Dibrugarh, Assam were suffering from thinness. Utilising NNMB data, Rao et al. (2006) observed overall prevalence of thinness among tribal adolescent boys (63.00%) and girls (42.00%) from nine Indian States. However, a lower prevalence of thinness among adolescent girls (30.60%) has been observed from North India (Malhotra and Passi 2007). The NFHS-III (2005-06) suggested that more than half (58.00%) of adolescent boys and 47.00% of adolescent girls were suffering from thinness as compared with 36.00% of men and 41.00% of women (aged 20-24 years) (Parasuraman et al. 2009). Mondal and Sen (2010b) reported prevalence of thinness was greater among boys (52.10%) than girls (32.00%) among rural adolescents of North Bengal. Sil et al. (2011) reported a moderate (23.70%) prevalence of thinness among tribal children and adolescents of Tripura. A recent study by Singh and Mondal (2013) reported high (25.90%) prevalence of thinness among tribal Sonowal Kachari boys (28.10%) and girls (23.90%) using the newly developed thinness reference of Cole et al. (2007). Mondal and Terangpi (2014) reported that overall prevalence of thinness was slightly higher among adolescent girls (14.9%) than boys (12.05%) of North-Eastern India. Sharma and Mondal (2014) have observed overall prevalence thinness to be 19.14% among adolescent girls of Assam. Sinha and Singh (2016) observed that prevalence of thinness among urban adolescent girls of Lucknow was 5.58%. High prevalence of thinness (28.89%) has been observed among adolescent girls of Dibrugarh (Boruah et al. 2017). Nath and Sarma (2017) also observed a similar prevalence of thinness (29.19%) among the adolescent girls of tea gardens in Dibrugarh. According to the study of Aslam and Durrani (2018), overall prevalence of

thinness among adolescents of Uttar Pradesh was observed to be 9.00% (12% in boys and 6% in girls).

A comparison of the prevalence of thinness reported among adolescents from India is shown in Table 3.

Table 3: Comparative evaluation of Indian studies assessing prevalence of thinness among adolescents

Population	Criteria/ Reference	Prevalence (%)	Reference
Adolescents in rural Wardha	CDC 2000	53.80	Deshmukh et al. 2006
Tea garden early adolescents of Dibrugarh	WHO 1995	53.90	Medhi et al. 2006
Tribal adolescent from nine Indian States	WHO 2007	52	Rao et al. 2006
Rural adolescents of West Bengal	WHO 1995	24.48	Das et al. 2007
Adolescent girls of North India	WHO 2007	30.60	Malhotra and Passi 2007
Early adolescent school girls of West Bengal	WHO 2007	20.2	Maiti et al. 2011
Tribal children and adolescents of Tripura	WHO 1995	23.70	Sil et al. 2011
Tribal Sonowal Kachari adolescents	Cole et al. 2007	25.90	Singh and Mondal 2013
Adolescents of West Bengal	Cole et al. 2007	49.1	Mondal 2014
Adolescent girls of North-East India	WHO 1995	13.43	Mondal and Terangpi 2014
Adolescent girls of Assam	Cole et al. 2007	19.14	Sharma and Mondal 2014
Urban adolescent girls of Lucknow	WHO 1995	5.58	Sinha and Singh 2016
Adolescent girls of Dibrugarh	WHO 2007	28.89	Boruah et al. 2017
Adolescent girls of tea gardens in Dibrugarh	WHO 1995	29.19	Nath and Sarma 2017
Adolescents of Uttar Pradesh	WHO 2007	9.00	Aslam and Durrani 2018

PREVALENCE OF OVERWEIGHT-OBESITY AMONG INDIAN ADOLESCENTS

The prevalence of overweight and obesity in the developing countries of South-East Asia have tripled in two decades due to rapid socio-economic development, adoption of western lifestyle and reduction in physical activity. There are substantial evidences suggesting that socio-economic, demographic, diet changes and increasing sedentary lifestyle and subsequent decrease in physical activity have triggered such prevalence in populations (Wang et al. 2009; Popkin et al. 2012; Popkin and Slining 2013; Varadharajan et al. 2013; Misra and Bhadwaj 2014; Kshatriya and Acharya 2016; Deepa et al. 2017; Kulkarni et al. 2017). The major dietary changes appear to be shifting universally toward a diet dominated by higher intakes of animal and partially hydrogenated fats and lower intakes of fibre. Similarly, the physical activity patterns at work, at leisure, during travel, and in the home are equally shifting rapidly toward reduced energy expenditure occurred over time, although the stages and speed of nutritional transitions may vary among both developed and developing countries (Subramanian et al. 2007; Popkin et al. 2012; Deepa et al. 2017; Kulkarni et al. 2017). Children and adolescents in lower and middle income countries who are growing up in an urban environment and following western lifestyle are also facing the problem of obesity (Kelishadi 2007; Pozza and Isidori 2018). Studies have reported prevalence of overweight and obesity among adolescents with poor rural socio-economic status, with the magnitudes being higher in higher socio-economic groups residing in urban regions (de Onis et al. 2001; Kapil et al. 2001; Chhatwal et al. 2004; Sidhu et al. 2006; Jain et al. 2010; Goyal et al. 2010, 2011; Debnath et al. 2018a).

Based on the NFHS-III data, Parasuraman et al. (2009) observed prevalence of overweight in 15-19 years to be 2.40% among boys and 1.70% among girls. Low prevalence of overweight was reported among rural adolescents from rural Wardha (2.00%) (Deshmukhet al. 2006), Assam (0.30%) (Medhi et al. 2007), rural Darjeeling of West Bengal (0.30%) (Mondal and Sen 2010b), tribal children of Tripura (0.80%) (Sil et al. 2011). A marginally higher prevalence of overweight (5.00%) has been reported in Bengali adolescents by de Onis et al. (2001). Goyal et al. (2010) reported the prevalence of overweight to be 14.30% (in boys) and 9.20% (in girls) among urban adolescents of Ahmadabad. Jain et al. (2010) have reported prevalence of overweight and obesity to be 19.70% and 5.30% (in girls) and 18.36%and 10.82% (in boys) among the affluent adolescents of Meerut. A relatively greater prevalence of overweight and obesity have been reported among Khasi girls as compared to Khasi boys aged 11-17 years of Meghalaya, North East India (Basu et al. 2013). Sharma and Mondal (2014) have observed overall prevalence of overweight to be 8.13% among adolescent girls of Assam. The prevalence of overweight and obesity were observed to be 6.25% and 5.72%, respectively Sinha and Singh (2016). According to Aslam and Durrani (2018) overall prevalence of overweight and obesity among the adolescents of Uttar Pradesh was observed to be 11.80% and 1.00%, respectively.

Table 4: Comparative evaluation of Indian studies assessing prevalence of overweight and obesity

Population	Criteria/ Reference	Prevalence (%)	Reference
Mishing of Assam, North East India	WHO 1995	1.95	Singh and Mishra 2001
Indian adolescent school Children	Cole et al. 2000	16.80	Ramachandran et al. 2002
Pre-adolescent and adolescents of India	WHO 1995	25.3	Chhatwal et al. 2004
Adolescents of rural Wardha	CDC 2000	2.00	Deshmukh et al. 2006
Adolescents from Assam	WHO 1995	0.30	Medhi et al. 2007
School children and adolescents of Wardha	CDC 2000	4.3	Bharati et al. 2008
Affluent adolescents of Meerut	WHO Expert Consultation 2004	26.62	Jain et al. 2010
Tribal children and adolescents of Tripura	WHO 1995	0.80	Sil et al. 2011
Adolescent girls of Assam	Cole et al. 2000	8.13	Sharma and Mondal 2014
Rural and urban adolescent girls of Lucknow	WHO 1995	11.97	Sinha and Singh 2016
Adolescents of Kamrup district, Assam	CDC 2000	14.92	Bibi 2017
Adolescents of Uttar Pradesh	WHO 2007	12.80	Aslam and Durrani 2018
Adolescents of urban Meerut	WHO 2007	24.30	Jain et al. 2018
School-going adolescents of urban Madhya Pradesh	Must et al. 1991a	7.60	Tomar et al. 2018

PREVALENCE OF ANEMIA AMONG ADOLESCENTS IN INDIA

Nutritional anaemia is another result of undernutrition in developing countries and this becomes severe when it occurs among adolescent girls and mothers. Presence of anaemia seriously impedes growth and development during adolescence. Few numbers of studies has assessed the presence of anaemia among Indian adolescent girls and mothers and for boys it is almost absent. As reported by limited numbers of studies, the prevalence of anaemia in

Indian adolescents have ranged from16.25% (Basu et al. 2005) to 96.5% (Bulliyya et al. 2007). Some studies have observed high prevalence of anaemia among adolescent girls and mothers. Rawat et al. (2001) observed that 34.50% of rural adolescent girls of Meerut were suffering from anaemia. The prevalence of anaemia observed by Basu et al. (2005) among the school going adolescents of Chandigarh was 23.90%. In a significant study Toteja et al. (2006) observed that 84.9% of pregnant women and 90.10% of adolescent girls from sixteen districts of India were suffering from severe to moderate anaemia. Prevalence of anaemia was found to be 35.10% among urban adolescent females from Nagpur (Chaudhary and Dhage 2008). School-going adolescent girls (38.89%) of Wardha were also seen to be suffering from higher anaemia as compared to boys (23.75%) (Dambhare et al. 2010). Mittal et al. (2011) have observed the effect of iron supplementation for reduction of iron-deficiency anaemia among the adolescent girls of Maharashtra considering the high prevalence of anaemia among them. Children and adolescents of Tamil Nadu were found to be suffering from a high prevalence of anaemia (52.88%) (Sudhagandhi et al. 2011). Premalatha et al. (2012) observed prevalence of anaemia to be 78.75% among adolescent girls of Tamil Nadu. Thomas et al. (2015) have determined the correlates of nutritional anaemia present among this group. In a very recent study, Gupta et al. (2017) have observed a very high prevalence of anaemia (76.29%) among rural adolescent girls Chhattisgarh. Another recent study by Upadhye and Upadhye (2017) observed prevalence of anaemia among adolescent girls in the country to be exceptionally high (90%). Another recent study among adolescents of Kerala observed to be anaemia to be 44.00% (Rakesh et al., 2018). All these studies point to the fact that suitable nutritional intervention is required for these boys and girls. According to Gillespie (1998) iron and folate supplementation is one of the most important nutritional interventions for adolescent girls.

PREVALENCE OF MICRONUTRIENTS/VITAMIN DEFICIENCIES AMONG ADOLESCENTS IN INDIA

Iron deficiency anaemia (IDA), vitamin A deficiency (VAD), iodine deficiency disorders (IDDs), zinc deficiency and folic acid deficiency are the main types of micronutrient deficiencies (Micronutrient Initiative 2009). Inadequate intake of nutritious food, poor socio-economic status, nutritional deprivation and high proportion of hunger in populations are the principal causes of micronutrient deficiencies. Micronutrient deficiencies are considered to be major nutritional problems in developing countries and adversely affecting the adolescent health and performance leading to major impediments to economic development (Bowley 2008; Popkin et al. 2012). Micronutrients and vitamins play major roles in adolescent growth (Mittal et al. 2011). The relationship between dietary patterns and micronutrients deficiencies has been well established by Deka et al. (2015) among urban adolescents. Some recent studies have also observed the occurrence of micronutrient deficiencies among Indian adolescents, hampering their overall growth (Gupta 2014; Chakraborty et al. 2018; Christian and Smith 2018). However, limited numbers of studies on assessment of micronutrient deficiencies among adolescents and adolescent mothers have been done in India. Here the studies of Seshadri (2001), Pathak et al. (2003) and Akhtar et al. (2013) are mentionable. Pathak et al. (2003) in their study among the adolescent pregnant mothers have observed that

5% of them were suffering from VAD and iron deficiency and IDD was also present among the adolescents. According to Akhtar et al. (2013), deficiency of vitamin D seemed to affect 84% of pregnant women in India.

CAUSES AND CONSEQUENCES OF DOUBLE BURDEN OF NUTRITION

Insufficient intake of food and nutrients hamper the physical growth attainments at adolescent. Poverty, insufficient resource distribution and socio-economic disparities in both underdeveloped and developing countries are the most common causes of undernutrition. Researchers have consistently reported that these are the basic causes of the occurrence of undernutrition in Indian populations (Subramanian et al. 2007; Mondal and Sen 2010; Gupta et al. 2012; Sen and Mondal 2012; Mondal et al. 2015, 2017; Rengma et al. 2016; Debnath et al. 2018a). Undernourishment during adolescence contributes to long-lasting physiological effects, poor growth rate, unattained growth, slow cognitive development and low work efficiency and overall physiological and psychological weakness in adulthood (Ahmed et al. 2012; Gupta 2014; Mahgoub et al. 2017; Chakraborty et al. 2018; Christian and Smith 2018; Masoud et al. 2018). Micronutrient deficiencies during adolescence are also severely affecting rate of growth and susceptibility to infectious diseases. Intake of poor quality food which contains low amounts of essential micronutrients (e.g., zinc, vitamin-A, iron, folate and iodine) and also consumption of less amounts cause such deficiencies. Micronutrient deficiencies and iron deficiencies are considered to be the most prevalent deficiencies among adolescent girls and mothers in India and these increase the high burden of mortality and morbidity during pregnancy and child birth (Ahmed et al. 2012; Masoud et al. 2018). Gender discrimination on girl child, insufficient diet and early marriage are also the contributors of nutrients deficiency among Indian adolescents (Venkaiah et al. 2002; Parasuraman et al. 2009; Mondal and Sen 2010b; Ahmed et al. 2012; Masoud et al. 2018).

Overweight and obesity, coupled with high rate of undernutrition among adolescents, are other causes of concern during the last two decades in India (Mohan et al. 2007; Subramanian et al. 2007; Wang et al. 2009; Popkin et al. 2012; Gupta et al. 2012; Rengma et al. 2016). Prevalence of overweight-obesity was observed to be higher in urban than rural areas among adolescents in India. Moreover, the country is currently undergone to major demographic, nutritional and epidemiological transitions (Lobstein et al. 2004; WHO 2006; Subramanian et al. 2007; Popkin et al. 2012; Pozza andIsidori 2018; Sinha et al. 2018). Rise in household incomes give rise to more sedentary lifestyles, changes in eating behaviour and food patterning (Mohan et al. 2007; Subramanian et al. 2007; Wang et al. 2009; Gupta et al. 2012; Popkin et al. 2012; Rengma et al. 2015). Abnormal adiposity levels among adolescents are results of consumption of fast foods, energy rich foods, nutrient and fat rich foods (Deka et al. 2015; Rathi et al. 2017; Debnath et al. 2018b). The prevalence of overweight-obesity and coupled with several non-communicable diseases increases the relative risks of mortality and morbidities in population.

The contributors of the rapid increase of overweight and obesity in India are:
1. Economic and social changes which in turn have severely changed structure and composition of diets and food habits
2. Sedentary lifestyle has lowered the physical activity therefore resulting in lower energy expenditure
3. Higher socio-economic status and increased per capita income.

Various non-communicable diseases are the results of excess body fat accumulation which give rise to serious health consequences such as cardiovascular disease, type-2 diabetes, osteoarthritis, cancers (endometrial, breast and colon) and hormonal imbalance, polycystic ovary syndrome (PCOS) (Mohan et al. 2007; Popkin 2012; Debnath et al. 2018b). Adolescence is the stage of physical and psychological development which leading from childhood to adulthood. Hence, occurrence of obesity during this period is likely to persist into young adulthood and bear higher risks for obesity in adulthood, metabolic syndrome and a plethora of associated cardio-metabolic diseases (Lobstein et al. 2004). Consumption of high sugar diet, saturated fat and energy content at adolescence increases chances of early occurrence of obesity and cardiovascular diseases in Indian population (Raj et al. 2007; Franks et al. 2010; Ranjani et al. 2014; Kelishadi et al. 2015).

Substantial variations are present across regions and population in the prevalence of adolescent undernutrition and overweight-obesity. There is an increase in the double burden of malnutrition in urban India. The double burden among adolescents increases the public health burden in the country therefore hampering the overall socio-economic growth of the country. The double burden poses a major threat to adolescent health and subsequent disease prevalence. The consequences of this double burden has the potentially to affect the overall population due to related disease burden, illness, poor productivity and poor reproductive outcome (Ramachandran et al. 2002; Debnath et al. 2018; Mondal et al. 2018). The most significant long-term consequences of adolescent overweight and obesity are dyslipidemia, hyper-insulinemia, type-2 diabetes, hypertension, cardiovascular diseases, arthritis, and behavioural problems (Lobstein et al. 2004; Johannsson et al. 2006; Raj et al. 2007; Franks et al. 2010; Ranjani et al. 2014; Kelishadi et al. 2015; Pozza and Isidori 2018).

GOVERNMENT STRATIGIES TO COMBAT/IMPROVE THE ADOLESCENT NUTRITION SITUATION IN INDIA

The Integrated Child Development Services (ICDS) Scheme and Mid-Day Meal (MDM) are the two government schemes introduced in the population level in order to combat/reduced the magnitude of undernutrition among Indian children. The ICDS programme includes the improvement of health and nutritional status of children and pregnant and lactating mothers (Sachdev and Dasgupta 2001). Enhancement of maternal education and capacity are some of the main objectives of the ICDS (Sachdev and Dasgupta 2001). Complementary nutrition, immunization and Growth Monitoring Promotion (GMP) has been included and community participations have also been taken care of in this scheme but more inclusion of adolescent health monitoring is necessary to improve the present situation (Sachdev and Dasgupta 2001;

Malhotra and Passi 2007). The Kishori Shakti Yojana (KSY) is another scheme by the government to improve health status of adolescent girls, to promote awareness of health, hygiene, nutrition and family welfare, home management and child care (Kowli and Dyavarishetty 2013). This includes improvement of nutritional and health status of girls in the age group of 11-18 years (Kowli and Dyavarishetty 2013). The KSY provides the required literacy and numeracy skills through a non-formal stream of education. It also trains the adolescent girls to improve home-based and vocational skills (Kowli and Dyavarishetty 2013). The subsidized food grains through public distribution service (PDS) were also introduced. However, special focus on the adolescent group is lacking and somehow these services and schemes are not working as a proper measure to combat the problem of undernutrition. Need-based supplementation programmes and food based strategies are required so as to control undernutrition among the adolescents. Special focus should also be given in disease prevention, detection and cure so that mortality and morbidity can be combated.

CONCLUSION

The radical shifting diet pattern especially processed and fast food habits and reduced physical activity have increased incidence of overweight-obesity in urban Indian adolescents. Undernutrition in rural adolescents is still a major cause of concern in the country. Several studies have observed presence of a double burden among adolescents in India. Therefore, adolescents should be recognized as a priority target group. They should constitute an integral part of health promotion and optimal nutrition through balanced diet and nutrient supplementation. Factors associated with malnutrition in adolescents need closer examination and prevention of double burden should be taken up as a major need for society by governmental and non-governmental agencies. Community/population specific field studies for assessing the prevalence of dual burden of malnutrition among Indian adolescents will be helpful to generate community specific strategies. Closing gaps between research and action would be beneficial to improve health and nutrition of adolescents.

RECOMMENDATIONS

The present review has discussed the importance of anthropometric measures (i.e., stunting, underweight, thinness and overweight-obesity) in assessment of nutritional status (both undernutrition and overweight-obesity) due to its non-invasive, inexpensive and easy-to-use nature in epidemiological and clinical settings among adolescents. The following recommendations are made:

1. Multi-disciplinary health camps offering comprehensive health-care facilities including varied medical service should be organized at regular intervals in the population/community levels. These camps should provide free medical diagnosis, medicines, counseling and management to prevent timely physical growth and nutritional deficiencies due to infections, diseases and faulty feeding practices.
2. Health-awareness camps by the Government and non-government agencies will be useful to disseminate knowledge on nutritional requirements, appropriate feeding and dietary

practices, health and hygiene practices, physical growth and nutritional risks during infancy, early childhood and pregnancy periods.

3. Lack of recent data on adolescents particularly from the low and middle income countries like India is a challenge for comparison across populations worldwide. Therefore, it is important to generate data from these countries.
4. Economic well-being of Indians should be taken care of by creating more job opportunities so that the underprivileged, economically deprived households can get their adequate share of income from the resources available in the country and can take care of their families in terms of proper food and diet. Measures should be taken to improve the public distribution systems (PDS) so that poor people get the food grains in subsidized rate which will lower their economic burden.
5. Adolescents should be covered through Integrated Child Development Services (ICDS) so that they get proper nutrition from the ICDS centers. The ICDS scheme should be restructured to include the adolescent mothers with special attention.
6. Fortified foods with micronutrients should be distributed among the children and adolescents for combating undernutrition. Moreover, the prices of food commodities, especially of staple food grains should be controlled so that the rural communities with minimum per capita income can purchase foods such as vegetables, fruits and meats rich in micronutrients.

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