CHILD, MATERNAL BODY COMPOSITION AND NUTRITIONAL STATUS AMONG THE BENGALI MUSLIM POPULATION OF DARJEELING DISTRICT, WEST BENGAL

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DECLARATION

I, Sampriti Debnath, Ph.D. research scholar, Department of Anthropology, University of North Bengal, West Bengal hereby declare that the subject matter of this thesis is the record of the original research work and this thesis has not been submitted previously for any research degree or diploma in any other University/Institute. This is submitted to the University of North Bengal, West Bengal for the award of the degree of Doctor of Philosophy in Anthropology.

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112

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ABSTRACT

INTRODUCTION

Malnutrition (undernutrition and overnutrition) undoubtedly is a serious public health challenge in many of the developing countries including India. Child undernutrition has long-term negative influence on all areas of life including health, education and productivity of an individual as well as of a community. Moreover, prevalence of child undernutrition seriously affect the human capital and economy of a country because poor nutritional conditions are strongly associated with faltered growth pattern, delayed mental/cognitive development and depleted intellectual capacity of individuals. Childhood undernutrition has been observed to be interlinked with maternal nutritional status as suggested by research studies. Maternal malnutrition is a prevalent factor for morbidity and mortality in children of the developing countries. Several studies also have observed the prevalence of undernutrition as well as overweight and obesity simultaneously among women/mothers in one population. The contributing factors for maternal malnutrition include inadequate food intake, poor nutrient supply through diets, frequent infections, short inter pregnancy intervals, number of child birth, occupation and husbands occupation etc. The results of poor maternal nutritional status are low weight gain during pregnancy, low birth weight (LBW) of baby and high infant mortality as well as maternal morbidity and mortality. The coexistence of undernutrition and overweight-obesity among the members of a same household raises questions about its cause. According to some researches one of the possibilities is that the economic development and urbanization declines the severe poverty improving household income levels and food availability. In one hand some household members remain undernourished due to the deficiencies of essential nutrients and on the other handsome of them become overweight from excess energy and nutrient intake.

Anthropometry is the universally applicable, inexpensive, non-invasive and easy to handle technique available to researchers for the assessment of nutritional status and body composition of the human body. The most commonly utilised anthropometric measures of nutritional assessment are height-

for-age (stunting), weight-for-height (wasting), weight-for- age (underweight) and BMI-for-age (thinness) among children.

Studies have observed some socio-economic and demographic factors play significant roles in the nutritional status. Such variables include family size, number of siblings, residence, family income, education, clean water supply, hygienic sanitary facility, age, sex, birth intervals and mother's age at childbirth.

Assessment of nutritional status and body composition of individuals is recognized as the most significant indicator of health and wellbeing status of an individual or population. The ultimate objective of nutritional assessment studies is to improve the quality of human health and life conditions by implementing various nutritional intervention programmes.

The objectives of the present study are as follows:

1. To assess the nutritional status of the children (1-5 years) and mothers of the Bengali Muslim population of Darjeeling district, West Bengal using conventional anthropometric measures.
2. To ascertain the effect of maternal body composition and nutritional status on the child nutritional status.
3. To find out the association and effect of certain socio-economic, demographic and lifestyle variables on child and maternal nutritional status.
4. To compare the child and maternal nutritional status of the Bengali Muslim population with the available studies done on different Indian and non-Indian population.

MATERIAL AND METHODS

The present cross-sectional study was carried out among 612 Bengali Muslim children (boys: 325; girls: 287) aged 1-5 years and their mothers (N=612) living in Phansidewa Block of the Darjeeling district of West Bengal, India. The Bengali Muslim is the largest religious minority population in West Bengal and comprises a considerable percentage of the state's population. According to the census of 2011, the Muslim population has 14.2% contribution to total population and is the second largest religious group in India. Muslims constitute 27.10% of West Bengal's total population. West Bengal occupies the second top most position in terms of percentage of Muslim population among all the states and about 12.16% are Muslim women. The Bengali Muslim Population (BMP) is a Bengali speaking ethnic community and by religion faithful to the Islam. They contribute a large share to the social and economic well-being of the state and of the country as a whole. In 2011, religion wise sex ratio for Muslims in India and West Bengal is 951 females for 1000 males. Anthropometric measurements were recorded using standard procedures.

Statistical Analysis

The data of the present study were statistically analyzed utilizing the Statistical Package for Social Sciences (SPSS, Chicago IL, version 16.0). The statistical tests include descriptive statistics (mean and standard deviation), Homogeneity of variance, One way analysis of variance (ANOVA), Pearson correlation coefficient analysis and chi-square test were done to analyse the data. The descriptive statistics (mean and standard deviation) was used to describe the anthropometric measurements of height, weight, MUAC, TSF, SSF, PBF, FM, FFM, FMI, FFMI, TUA, UMA, UFA, AFI, UME, UFE, BMI, PBF-BMI Ratio among children. All the differences were considered to be statistically significant at $p<0.05$ and $p<0.01$ level. Binary logistic regression and multinomial logistic regression analysis have been performed for assessing the association of socio-economic demographic and lifestyle variables with the nutritional status of children and mothers.

RESULTS

The age sex-specific mean weight and height were observed to be higher among boys than girls except in 1 year among children. The age-sex specific mean values of weight and height were observed to be progressively increasing with age in both sexes. The descriptive statistics (mean± SD) of anthropometric measures indicated that there is no statistically significant differences in the age-sex-specific mean of height, weight, MUAC, FM, FFM, FFMI, TUA, BMI. But statistically significant differences were observed in case of HdC, TSF, SSF, PBF, FMI, UMA, UFA, AFI, UME, UFE and PBF-BMI Ratio ($p<0.05$). The sex-specific adiposity pattern and skinfold thicknesses (e.g., TSF, SSF, FMI, AFI, UFA and UFE) and PBF were found to be significantly higher among girls than the boys

($p<0.01$). The sex-specific overall muscularity pattern (e.g., UMA and UME) was observed to be significantly higher among boys than girls ($p<0.05$). Therefore, results showed that there is existence of sexual dimorphism in muscularity and adiposity pattern among Bengali Muslim children. The age-sec specific mean anthropometric variables (e.g., height, weight, HdC, FM, FFM, TUA, UMA, UFA, UME and UFE) were observed to increase with age with few exceptions among Bengali Muslim children. Hence, the results of the present study indicate the attainment of physical growth in anthropometric variables is an age related effect among Bengali Muslim boys and girls. Age-specific mean differences in anthropometric variables of physical growth pattern were found to be statistically significant in case of almost all the anthropometric and body composition variables for boys and girls ($p<0.01$ and $p<0.05$). Most of anthropometric variables of children were significantly correlated with each other ($p<0.01$). The overall prevalence of stunting, underweight, thinness, wasting and low HdC-for- age was observed to be 44.61%, 40.03%, 26.31%, 26.96% and 33.66%, respectively. Statistically significant sex-differences was observed in the prevalence thinness (Low BMI- for-age), wasting (low weight-for-height), low HdC-for-age between boys and girls ($p<0.01$). The high magnitude of undernourishment indicates the high nutritional demand among the children. In case of the mothers of the Bengali Muslim children all the anthropometric and body composition variables were observed to show an age specific increasing trend. Prevalence of a double burden of malnutrition (undernutrition, overweight and obesity) has been observed among the Bengali Muslim mothers. Most of anthropometric variables were highly significantly correlated with each other ($p<0.01$). The results showed that BMI has positive effect on most of the variables (e.g., weight, BSF, TSF, SSF, SISF, MUAC, WC, etc.). The result showed that the overall prevalence of undernutrition was (BMI< 18.50 kg/m^2) 10.29%. The overall prevalence of overweight (BMI= 23.00-24.99 kg/m^2) and obesity (BMI≥ 25.00 kg/m^2) were 21.08% and 15.36%, respectively. Therefore, overall prevalence of overnutrition (BMI≥ 23.00 kg/m^2) was 36.44%. The overall prevalence of undernutrition in terms of low MUAC value was 7.03%. Prevalence of overweight-obesity was 40.85%, 90.20%, 64.05%, 54.41% and 69.61% in terms of WC, WHR, WHtR, PBF and Σ4SKF, respectively. Several socioeconomic and demographic correlates were observed to have statistically significant ($p<0.01$ and $p<0.05$) effect on the nutritional status of the Bengali Muslim children (e.g., family type, family size, number of sibs, fathers occupation, electricity, monthly family expenditure, etc.) and mothers (e.g., age at marriage, age at menarche, family type, house type, etc.).

CONCLUSION

Present study has been conducted among the Bengali Muslim children and their mothers to assess the body composition and nutritional status. The proper evaluation, identification, explanation and understanding of body composition and nutritional status will definitely help the researchers to tackle or answer several unwanted nutritional and health situations (e.g., undernourishment, over nourishment, growth retardation, delayed and poor cognitive development and mortality or morbidity). With the presence of overweight-obesity, India is also a home for undernutrition which is a major cause of child and maternal mortality and morbidity in its populations. The results of the present study established a high prevalence of undernutrition in terms of stunting (low height-for- age), underweight (low weight-for-age), thinness (low BMI-for-age) and wasting (low weight-for-height) and low HdC-for-age among the Bengali Muslim children of Darjeeling district, West Bengal. Moreover, present study has observed double burden of malnutrition (DBM) (i.e., undernutrition and overweight-obesity) among the mothers of these Bengali Muslim children. Associations and effect of several socio-economic and demographic correlates have been observed among the Bengali Muslim children and their mothers. Therefore, present study has proved that the Bengali Muslim children and their mothers are in a critical junction nutritionally. Importance should be given to improve the overall nutritional status of the children and mothers. Present study indicates that the prevalence of undernutrition does not have an age specific trend. Therefore, it is very necessary to give equal importance in improving nutritional condition of the children of all groups. The mothers of Bengali Muslim community should be taken care of for improvement of the condition of malnutrition (undernutrition and overnutrition) so that it does not perpetuate to their future generation. More extensive population specific studies among the Bengali Muslim children and women should be performed to get more insights in the nutrition situation in the population. Moreover, data on diet and food habit should be incorporated in research studies in the studied population which the present study lacks. Both government and non-governmental intervention is very necessary to combat and improve the present poor nutritional situation among the Bengali Muslim children and mothers. There is an urgent need to look into the problem and proper nutritional intervention programmes should be incorporate to ameliorate the nutrition situation among the Bengali Muslims.

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LIST OF ABBREVIATIONS

Σ4SKF: Sum Of Four Skinfold

AFI: Arm Fat Index

ANOVA: One-way Analysis of Variance

BLR: Binary Logistic Regression

BMI: Body Mass Index

BMIAZ: BMI-for-age Z-score

BSF: Biceps Skinfold

CDC: Centre for Disease Control

CED: Chronic Energy Deficiency

HAZ: Height-for-age Z-score

HdC: Head Circumference

HdCAZ: Head circumference-for-age Z-score

HC: Hip Circumference

LBW: Low Birth Weight

MUAC: Mid Upper Arm Circumference

NCHS: National Centre Of Health Statistics

NFHS: National Family Health Survey

PBF: Percent of Body Fat

SES: Socio-economic Status

SISF: Suprailiac Skinfold

SSF: Sub-scapular skinfold

TEM: Technical Errors of Measurements

TSF: Triceps Skinfold

TUA: Total Upper-arm Area

UFA: Upper Arm Fat Area

UMA: Upper Arm Muscle Area

WAZ: Weight-for-age Z-score

WC: Waist Circumference

WHA: Weight-for-height Z-score

WHO: World Health Organization WHR: Waist-Hip Ratio

WHtR: Waist-Height Ratio

CONTENTS

CHAPTERS				Page No.
Acknowledgement				**i**
List of abbreviations				**iii**
CHAPTER I: INTRODUCTION				**1-33**
1.1	Overview			**1**
1.2	Nutrition Situation in India			**6**
1.3.	Methods of Assessing Nutritional Status of Humans			**7-14**
	1.3.1.	Anthropometry		**7**
	1.3.2.	Biochemical Methods		**8**
	1.3.3.	Clinical Examination		**9**
	1.3.4.	Dietary Intake		**11-13**
		a)	Twenty-four-hour recall method	**11**
		b)	Weighed intake method	**11**
		c)	Food frequency questionnaire (FFQ)	**12**
		d)	Food diary	**12**
		e)	Dietary history	**13**
	1.3.5.	Vital and Health Statistics		**13**
	1.3.6.	Ecological Studies		**13**
1.4.	Review of Published Literature			**13-27**
	1.4.1.	Studies done on Body Composition and Nutritional Status Assessment among Non-Indian Population		**14**
	1.4.2.	Studies done on Body Composition and Nutritional Status		**17**

		Assessment among Indian Population	
	1.4.3.	Socio-Economic and Demographic Factors Affecting the Physical Growth and Nutritional Status among Children	**21**
	1.4.4.	Studies done in Biological Anthropology among Different Populations of North Eastern India and North Bengal	**23**
	1.4.5.	Studies on Muslim in North Bengal, West Bengal and India	**26**
1.5.	The Insidious Impact of Maternal Malnutrition on the Health of Child health and Community Health		**27**
1.6.	Statement of the Problem		**30**
1.7.	Objectives of the Present Study		**31**
1.8.	Research Questions of the Present Study		**32**
1.9.	Significance of the Present Research Study		**32**
CHAPTER II: MATERIAL AND METHOD			**34-56**
2.1.	Nature of Subjects and Area		**34**
	2.1.1.	The Bengali Muslims	**34**
2.2.	Sampling		**37**
2.3.	Demographic and Socio-Economic Profile		**38**
2.4.	Anthropometric Measurements Recorded		**40**
2.5.	Collection of Anthropometric Data		**41**
2.6.	Calculation of Technical Error Measurement (TEM) And Calculation of Systematic Error Measurement		**43**
2.7.	Calculation of Anthropometric Indices for Assessment of Nutritional Status and Body Composition of Children and Mothers		**45**
2.8.	Calculation of Anthropometric Variables for Physical Growth Assessment and Nutritional Status of Children		**49**

2.9.	Calculation of Physical Growth Assessment Variables of Children		**51**
2.10.	Assessment of Nutritional Status of Children		**52**
2.11.	Assessment of Nutritional Status of Mothers		**55**
2.12.	Statistical Analysis		**55**
CHAPTER III: RESULTS			**57-139**
3.1.	Demographic, Socio-Economic and Lifestyle Related Variables among the Bengali Muslim Children and Mothers		**57**
	3.1.1.	Population Size:	**57**
	3.1.2.	Mothers age	**58**
	3.1.3.	Mothers age at Menarche	**59**
	3.1.4.	Mothers age at Marriage	**60**
	3.1.5.	Mothers age at First Pregnancy	**60**
	3.1.6.	Family Size	**61**
	3.1.7.	Family Type	**61**
	3.1.8.	Earning Head	**62**
	3.1.9.	Monthly Income	**62**
	3.1.10	Monthly Expenditure	**63**
	3.1.11	Water Supply	**63**
	3.1.12	Toilet Use	**64**
	3.1.13	Electricity Use	**64**
	3.1.14	House Pattern	**65**
	3.1.15	Number of Rooms	**65**
	3.1.16	Birth Weight	**66**
	3.1.17	Duration of Breast Feeding	**66**
	3.1.18	Education of Mother	**67**

	3.1.19	Education of Father	**67**
	3.1.20	Occupation of Mother	**68**
	3.1.21	Occupation of Father	**69**
	3.1.22	Number of Sibs	**69**
3.2.	Descriptive Statistics (Mean ±SD) of Anthropometric Variables among Bengali Muslim Children		**72**
3.3.	Descriptive Statistics (Mean ±SD) of derived Body composition variables and Nutritional Indices of Bengali Muslim Children		**76**
3.4.	Pearson Correlation Coefficient between the anthropometric variables among Bengali Muslim boys		**81**
3.5.	Pearson Correlation Coefficient between the anthropometric variables among Bengali Muslim girls		**81**
3.6.	Assessment of nutritional status among the Bengali Muslim children		**86**
3.7.	Prevalence of overall undernutrition among the children		**86**
3.8.	Prevalence of moderate and severe undernutrition among the Bengali Muslim children		**87**
3.9.	Sex differences in the prevalence of overall and age and sex specific prevalence of overall undernutrition among Bengali Muslim boys and girls		**89**
3.10.	Descriptive statistics (Mean ±SD) of anthropometric variables of Bengali Muslim mothers		**96**
3.11.	Descriptive Statistics (Mean ±SD) of derived body composition variables and nutritional indices Of Bengali Muslim mothers		**98**
3.12.	Pearson Correlation Coefficient between the anthropometric variables among Bengali Muslim mothers		**100**
3.13.	Linear regression analysis of age on the different anthropometric and body		**104**

	composition variables among the Bengali Muslim mothers	
3.14.	Linear regression analyses of BMI on the different anthropometric and body composition variables among the Bengali Muslim mothers	**106**
3.15.	Assessment of nutritional status among the Bengali Muslim mothers using BMI	**108**
3.16.	Assessment of undernutrition among the Bengali Muslim mothers using BMI vs. MUAC	**110**
3.17.	Assessment Of nutritional status among the Bengali Muslim mothers using WC, WHR, WHtR, PBF and Σ4SKF	**112**
3.18.	Linear regression analysis of maternal BMI and MUAC with child HAZ, WAZ, WHA, BMIAZ and HdCAZ	**118**
3.19.	Age-sex specific descriptive statistics of HAZ, WAZ, WHZ, BMIAZ and HdCAZ of the children of undernourished, overweight and obese mothers	**119**
3.20.	Association Of the socio-economic, demographic and life style related variables with the prevalence of stunting, thinness, wasting, underweight and low HdC-for-age among the Bengali Muslim children	**121**
3.21.	Association Of the socio-economic, demographic and life style related variables with the prevalence of undernutrition, overweight and obesity among the Bengali Muslim mothers	**133**
CHAPTER IV: DISCUSSION		**140-218**
4.1.	Overview	**140**
4.2.	Anthropometric Assessment and Body Composition Variation among the Children	**142**
4.3.	Prevalence of Undernutrition among the Bengali Muslim Children	**148**
	4.3.1. Prevalence Of stunting (Low height-for-age)	**152**
	4.3.2. Prevalence Of thinness (Low BMI-for-age)	**156**
	4.3.3. Prevalence Of wasting (Low weight-for-height)	**159**

	4.3.4. Prevalence Of underweight (Low weight-for-age)	**162**
4.4.	Assessment of Maternal Body Composition among The Bengali Muslim Mothers	**178**
4.5.	Prevalence of Undernutrition (BMI< 18.50 Kg/m^2) among Bengali Muslim Mothers	**181**
4.6.	Prevalence of Undernutrition in Terms of MUAC as an Indicator	**191**
4.7.	Prevalence of Overweight and Obesity Among the Bengali Muslim Mothers	**191**
4.8.	Prevalence of Double Burden of Malnutrition Among the Bengali Muslim Children and Their Mothers	**207**
4.9.	Association Between Nutritional Status of Mothers and Children Among Bengali Muslims	**208**
4.10.	Socio-Economic, Demographic Correlates of Nutritional Status Among the Bengali Muslim Children and Mothers	**211**
CHAPTER V: SUMMARY AND CONCLUSION		**219-228**
5.1.	Summary and Conclusion	**219**
5.2.	Limitations of The Present	**224**
5.3.	Recommendations	**225**
5.4.	General Concluding Remarks	**227**
REFERENCE		**229-299**

LIST OF TABLES

Sl. No.	Title	Page No.
1.	**Table 2.1:** Kuppuswami socio-economic scale proposed by Mishra and Singh (2003) and Kumar et al. (2007)	39
2.	**Table 2.2:** Table showing the results of Technical Errors of measurement of the anthropometric measurements recorded in the present study	44
3.	**Table 2.3:** World Health Organization cut-off points and risk of metabolic complications	48
4.	**Table 2.4:** Classification of assessing severity of public health problem of undernutrition based on the percentages among the children.	54
5.	**Table 2.5:** Recommended anthropometric measures/indices used to assess the prevalence of undernutrition status	54
6.	**Table 2.6:** Proposed classification of BMI in Asian Adults (WHO 2004)	55
7.	**Table 3.1:** Demographic, socio-economic profile and lifestyle related factors of Bengali Muslim children	70
8.	**Table 3.2:** Descriptive statistics (mean ± SD) of age Bengali Muslim children and anthropometric variables of	74
9.	**Table 3.3:** Descriptive statistics (mean ± SD) of sex specific anthropometric variables of Bengali Muslim children	75
10.	**Table 3.4:** Descriptive statistics (mean ± SD) of the derived anthropometric indices relating to body composition and nutritional status of Bengali Muslim children	78

11.	**Table 3.5:** Age and sex specific descriptive statistics (mean ± SD) of anthropometric indices relating to body composition and nutritional status of Bengali Muslim children	**79**
12.	**Table 3.6:** Pearson Correlation Coefficient between the anthropometric variables among Bengali Muslim boys	**82**
13.	**Table 3.7:** Pearson Correlation Coefficient between the anthropometric variables among Bengali Muslim girls	**84**
14.	**Table 3.8:** Age-sex specific descriptive statistics of conventional anthropometric measures among Bengali Muslim children	**90**
15.	**Table 3.9:** Age-gender specific prevalence of overall undernutrition among the Bengali Muslim children	**91**
16.	**Table 3.10:** Age-sex specific prevalence of moderate and severe undernutrition among the Bengali Muslim boys	**92**
17.	**Table 3.11:** Age-gender specific prevalence of Moderate and severe undernutrition among the Bengali Muslim girls	**93**
18.	**Table 3.12:** Sex differences in the prevalence of overall and age and sex specific prevalence of overall undernutrition among Bengali Muslim boys and girls	**94**
19.	**Table 3.13:** Sex differences in the prevalence of overall and age and sex specific prevalence of different grades (moderate and severe) of undernutrition among Bengali Muslim boys and girls	**95**
20.	**Table 3.14:** Descriptive statistics (mean ± SD) of age and sex specific anthropometric variables of Bengali Muslim mothers	**97**

21.	**Table 3.15:** Descriptive statistics (mean ± SD) of the derived anthropometric indices relating to body composition and nutritional status of mothers	**99**
22.	**Table 3.16:** Pearson Correlation Coefficient between the Anthropometric Variables of mothers	**101**
23.	**Table 3.17:** Linear regression analyses of age on the different anthropometric and body composition variables among the Bengali Muslim mothers	**105**
24.	**Table 3.18:** Linear regression analyses of BMI on the different anthropometric and body composition variables among the Bengali Muslim mothers	**107**
25.	**Table 3.19:** Nutritional status of the Bengali Muslim mothers based on internationally accepted cut-offs of BMI for Asian Indians (WHO 2004)	**109**
26.	**Table 3.20:** Assessment of undernutrition among the Bengali Muslim mothers using BMI vs. MUAC	**111**
27.	**Table 3.21:** Prevalence of overweight, obesity and adiposity among the Bengali Muslim mothers using WC, WHR, WHtR, PBF and Σ4SKF	**113**
28.	**Table 3.22:** Age-specific prevalence of overweight, obesity and adiposity among the Bengali Muslim mothers using WC, WHR, WHtR, PBF and Σ4SKF	**114**
29.	**Table 3.23:** Assessment of overweight-obesity and excess adiposity among the Bengali Muslim mothers using BMI vs. WC, WHR, WHtR, PBF and Σ4SKF	**115**
30.	**Table 3.24:** Age specific assessment of overweight-obesity and excess adiposity among the Bengali Muslim mothers using BMI vs. WC, WHR, WHtR, PBF and Σ4SKF	**116**

31.	**Table 3.25:** Linear regression analysis of maternal BMI with child HAZ, WAZ, WHA, BMIAZ and HdCAZ	**118**
32.	**Table 3.26:** Linear regression analysis of maternal MUAC with child HAZ, WAZ, WHA, BMIAZ and HdCAZ	**118**
33.	**Table 3.27:** Linear regression analysis of Maternal BMI and MUAC with child HAZ, WAZ, WHA, BMIAZ and HdCAZ	**119**
34.	**Table 3.28:** Age specific descriptive statistics of HAZ, WAZ, WHZ, BMIAZ and HdCAZ of the children of undernourished mothers	**120**
35.	**Table 3.29:** Age specific descriptive statistics of HAZ, WAZ, WHZ, BMIAZ and HdCAZ of the children of overweight mothers	**121**
36.	**Table 3.30:** Age specific descriptive statistics of HAZ, WAZ, WHZ, BMIAZ and HdCAZ of the children of obese mothers	**121**
37.	**Table 3.31:** Binary logistic regression analysis and associate risk factors in the prevalence of stunting and thinness and demographic variables among children with socio-economic	**126**
38.	**Table 3.32:** Binary logistic regression analysis and associate risk factors in prevalence of wasting, underweight and low HdC-for -age with socio-economic and demographic variables among children	**129**
39.	**Table 3.33:** Multinomial logistic regression analysis and associate risk factors in prevalence of undernutrition, overweight, obesity socio- economic and demographic variables among Bengali Muslim mothers	**136**

40.	**Table 4.1:** Comparison of prevalence of undernutrition among the Bengali Muslim children with the other Indian studies	**166**
41.	**Table 4.2:** Comparison of prevalence of undernutrition among the Bengali Muslim children with non-Indian studies	**173**
42.	**Table 4.3:** Comparison of the prevalence of undernutrition among the Bengali Muslim mothers in present study with other Indian studies	**185**
43.	**Table 4.4:** Comparison of the prevalence of undernutrition among the Bengali Muslim mothers in present study with other non-Indian studies	**189**
44.	**Table 4.5:** Comparison of the prevalence of overweight, obesity and overall overweight-obesity among the Bengali Muslim mothers in present study with other Indian studies	**197**
45.	**Table 4.6:** Comparison of the prevalence of overweight, obesity and overall overweight-obesity among the Bengali Muslim mothers in present study with other non-Indian studies	**202**

LIST OF FIGURES

Sl. No.	Title	Page No.
1.	**Figure 2.1.** Map showing the location of study area Phansidewa Block in Darjeeling district of West Bengal, India	36
2.	**Figure 3.1.** Pie chart showing sex specific distribution of Bengali Muslim boys and girls	57
3.	**Figure 3.2.** Bar diagram showing the age distribution of children	58
4.	**Figure 3.3.** Bar diagram showing age and sex specific distribution of children	58
5.	**Figure 3.4.** Bar diagram showing age specific distribution of Bengali Muslim mothers	59
6.	**Figure 3.5.** Bar diagram showing distribution of mother's at menarche	59
7.	**Figure 3.6.** Bar diagram showing the distribution of mother's age at marriage	60
8.	**Figure 3.7.** Bar diagram showing the distribution of mother's age at first pregnancy	60
9.	**Figure 3.8.** Pie chart showing the overall distribution of family size	61
10.	**Figure 3.9.** Pie chart showing the overall distribution of family type	61
11.	**Figure 3.10.** Pie chart showing the overall distribution of number of earning heads in families	62
12.	**Figure 3.11.** Bar diagram showing overall distribution of monthly income	63
13.	**Figure 3.12.** Bar diagram showing the overall distribution of monthly expenditure	63

14.	**Figure 3.13.** Pie chart showing the overall distribution of water supply	**64**
15.	**Figure 3.14.** Pie chart showing the overall distribution of toilet use	**64**
16.	**Figure 3.15.** Pie chart showing the overall distribution of electricity use	**65**
17.	**Figure 3.16.** Pie chart showing the overall distribution of house pattern	**65**
18.	**Figure 3.17.** Bar diagram showing the overall distribution of number of rooms	**66**
19.	**Figure 3.18.** Bar diagram showing the overall distribution of birth weight of the children	**66**
20.	**Figure 3.19.** Bar diagram showing the overall distribution of breast feeding of children	**67**
21.	**Figure 3.20.** Bar diagram showing the overall educational status of mothers	**67**
22.	**Figure 3.21.** Bar diagram showing the overall educational status of fathers	**68**
23.	**Figure 3.22.** Pie chart showing the overall distribution occupational status of mothers	**68**
24.	**Figure 3.23.** Bar diagram showing the overall distribution of occupational status of fathers	**69**
25.	**Figure 3.24.** Bar diagram showing the overall distribution of number of sibs of children	**69**

CHAPTER- I:

INTRODUCTION

1.1. OVERVIEW

Worldwide observations have established the fact that inadequate diet and poor nutritional condition can hamper overall growth of a child and severe irreversible physical and cognitive damage can occur during childhood (Akhter 2016; de Onis and Branca 2016). Child undernutrition has long-term negative influence on all areas of life including health, education and productivity of an individual as well as of a community. Moreover, prevalence of child undernutrition seriously affect the human capital and economy of a country because poor nutritional conditions are strongly associated with faltered growth pattern, delayed mental/cognitive development and depleted intellectual capacity of individuals (Zere and McIntyre 2003; Shrimpton et al. 2011; Dessie et al.2019). Those children who suffer from undernutrition (e.g., stunting) in children may also suffer from overweight-obesity, insulin resistance and chronic non-communicable diseases during adulthood due to over-accumulation of adipose tissue in the body (Judith 2011). Childhood undernutrition has been observed to be interlinked with maternal nutritional status as suggested by several research studies. Malnutrition is associated with both undernutrition and overnutrition causes great amount of human suffering (both physical and emotional) which is also a violation of the child's human rights (Smith and Haddad 2000). Maternal nutrition and health conditions significantly influence the nutritional status and health of children as observed in several research studies. Maternal malnutrition is a prevalent factor for morbidity and mortality in children of the developing countries. Several studies also have observed the prevalence of undernutrition as well as overweight and obesity simultaneously among women/mothers in one population. The contributing factors for maternal malnutrition include inadequate food intake, poor nutrient supply through diets, frequent infections, short inter pregnancy intervals, number of child birth, occupation and husbands occupation etc. The results of poor maternal nutritional status are low weight gain during pregnancy, low birth weight (LBW) of baby and high infant mortality as well as maternal morbidity and mortality (WHO 1995; Ramachandran 2014).

The quality of nutrient consumption and the body's ability to utilize them for its metabolic needs are important factors in an individual's nutritional status. In developing countries like India high prevalence of undernutrition is considered as a major public health problem (Nandy et al. 2005; Ramachandran 2007, 2014; Mondal and Sen 2010a,b; Khambalia et al. 2012; Islam et al. 2014; Bhargava et al. 2015; Corsi et al. 2015; Tigga et al. 2015a,b; Akhter 2016; Debnath and Bhattacharjee 2016;Madrid and Traisci-Marandola 2016; Asim and Nawaz 2018; Debnath et al. 2018a,b,c,d; Huda et al. 2018; Sharma and Mondal 2018, 2020). Child undernutrition plays a major role in physical growth attainment, premature mortality and morbidity of millions of children in the developing countries like India (Nandy et al. 2005; Ahmed et al. 2012; Madrid and Traisci-Marandola 2016; Asim and Nawaz 2018; Debnath et al. 2018a,b,c,d; Huda et al. 2018; Sharma and Mondal 2018, 2020; Sen et al. 2020). Undernourished children who survive to adulthood suffer from poor cognitive growth and adverse health related diseases (Black et al. 2008). Even if it does not cause death, it accounts for several vulnerable infections, diseases and blighting the quality of lives millions of children (Nandy and Miranda 2008; Black et al. 2013; Ramachandran 2014; Smith and Haddad 2015). Prevalence of undernutrition is estimated to be the largest contributor to global burden of disease, effecting millions of children (i.e., morbidity) in the developing countries and causing heavy health expenditures in developing countries (Black et al. 2003; Lenoir-Wijnkoop et al. 2013; Sen et al. 2020). Gender discriminations and gender related nutritional trends are also observed in South Asia where girls are more likely to be undernourished than boys (UNICEF 2007, 2013). The prevalence of undernutrition was estimated to be the cause of 45.0 % of all deaths among children <5 years (Black et al. 2013). India contributes 38.0 % of the global burden of stunting (low height-for-age) (nearly 62 million children) (UNICEF

2013). In India with the large population size, widespread poverty and significant economic and social disparities, majority of individuals are underprivileged and undernourished (Ramachandran 2007; Antony and Laxmaiah 2008; Varadharajan et al. 2013; Debnath et al. 2019). Maternal and child undernutrition account for almost 11% of the total global burden of disease (Black et al. 2008). Maternal nutritional status has significant impact on the children as the WHO estimated in 1998 that between half and two-thirds of deaths among children less than five years of age in developing countries can be attributed to undernutrition (Son and Menchavez 2008). India is the largest country in the region is also home to the largest number of undernourished children in the world (Khor 2008; Ramachandran 2014; Corsi et al. 2015; Smith and Haddad 2015; Aguayo et al. 2016; Ali et al. 2016; Dhok and Thakre 2016; Saxton et al. 2016; Mandal et al. 2017; Patil et al. 2017; Debnath et al. 2018a,b,c,d; Sharma and Mondal 2018).

Health status of individuals and populations are determined by assessing nutritional status and body composition of people (Peter et al. 2015; Shidfar et al. 2016; Alamgir et al. 2018). Determination of nutritional status and body composition of individuals/populations has immense application in human biology, biological anthropology, public health and primary health care (Park 2009; BDA 2012). Body composition studies are particularly important to understand the amount of fat content (i.e., fat mass) and non-fat (i.e., fat-free mass) content in human body. Such data is useful in assessing the nutritional deficiencies and excesses of body adiposity. Useful insight on health risks like, on heart disease, diabetes, cancer and minimal energy stores, poor cardiovascular function, starvation, prone to illness, low hormonal levels, weak muscles, osteoporosis and other related morbidity can be obtained from such investigations (Howley and Franks 2007; Zhao et al. 2008; Speakman and Westerterp 2013; Kalyani et al. 2014; Falsarella et al. 2015; Preto et al. 2017; Boseet al. 2019).

Studies have observed some socio-economic and demographic factors play significant roles in the nutritional status. Such variables include family size, number of siblings, residence, family income, education, clean water supply, hygienic sanitary facility, age, sex, birth intervals and mother's age at childbirth (Zere and McIntyre 2003; Hien and Kam 2008; Mondal and Sen 2010a; Mondal et al. 2015; Tigga et al. 2015a,b; Debnath et al. 2018c; Sen et al. 2020).

Anthropometry is the universally applicable, inexpensive, non-invasive and easy to handle technique available to researchers for the assessment of nutritional status and body composition of the human body (WHO 1995; Gibson 2005; Lee and Neiman 2005; Hall et al. 2007). The body mass index (BMI=weight/height, kg/m^2) is a derived proxy anthropometric index to assess the under- or overnutrition in children and adults (WHO 1995, 2007; Wells 2007). The most commonly utilised anthropometric measures of nutritional assessment are height-for-age (stunting), weight-for-height (wasting), weight-for-age (underweight) and BMI-for-age (thinness)among children (WHO 1995; 2007; Hall et al. 2007). The interpretation of these nutritional indices is based on Z-score classification and children found to be below −2 Z-score of any nutritional indices is considered to be undernourished (WHO 1995, 2007). These anthropometric measures reflects distinct biological processes but poses major methodological limitation in assessment of actual magnitude of undernutrition in population level (Svedberg 2000; Nandy et al. 2005; Nandy and Svedberg 2012; Sen and Mondal 2013; Savanur and Ghugre 2015).The coexistence of maternal overnutrition (overweight and obesity) is an emerging phenomenon present mostly in developing countries which are undergoing the epidemiological and nutritional transition (Popkin et al. 1996; Garret and Ruel 2003; Barquera et al. 2007).

Several researchers have studied nutritional transitions in different countries and have observed unique features in terms of prevalence of undernutrition and overnutrition across populations (Adair and Popkin 2005; Popkin 2006). Recent trends showed that populations tend to shift from undernutrition to overnutrition due to the change in dietary and demographic patterns associated with socio-economic status change (Popkin 1998, 2001; Doak et al. 2000; Barquera et al. 2007). Epidemiological studies have observed that body mass index (BMI) is an adequate surrogate anthropometric measure of adiposity (Horlick 2001; Weber et al. 2012; Little et al. 2016; Verma et al. 2016; Debnath et al. 2019).

Assessments of child and maternal nutritional status are important because they contribute to the negative health consequences in human populations. Adult obesity and child stunting are critical health conditions as they contribute to the burden of non-communicable diseases such as cardiovascular disease, type-2 diabetes, osteoarthritis and certain types of cancer among adults (Lee et al. 2008, 2010; Debnath et al. 2019) with stunting contributing to the poor cognitive development, poor attainment of linear growth and poor overall growth among children (Berkman et al. 2002; Sawaya et al. 2003). The dual burden households of undernutrition and overnutrition demand particular attention. Some recent studies indicate that undernutrition and overnutrition can co-exist not only in the same population, but in the same household (Doak et al. 2000a,b, 2002; Garrett and Ruel 2005).

The coexistence of undernutrition and overweight-obesity among the members of a same household raises questions about its cause. According to some researches one of the possibilities is that the economic development and urbanization declines the severe poverty improving household income levels and food availability. In one hand some household members remain undernourished due to the deficiencies of essential nutrients and on the other handsome of them become overweight from excess energy and nutrient intake. A somewhat different possibility as proposed by researchers is that at higher levels of economic development the physical energy is sufficient for both adults and children, but low intake of micronutrients leads to undernourishment in children and overweight-obesity among adults.

1.2. NUTRITION SITUATION IN INDIA

Inspite of the high economic growth of India is unable to ensure food security of the entire population. According to Ramachandran (2014), food security of people depends on three major factors:

1. Food Availability— in a sustainable manner throughout the year.

2. Food Accessibility— the economic ability or purchasing power.

3. Food Absorption— the ability to absorb micronutrients which are essential for superior nutrition which depends on the availability of other supportive measures like supply of clean drinking water, access to sanitation facilities, hygienic environment.

There are existing endemic pockets of hunger, mainly in the tribal areas, less developed rural areas and among the unemployed and homeless migrants living in large cities (Ramachandran, 2014). The most poverty affected areas in India are rural Odisha, West Bengal, Kerala, Assam and Bihar and it usually peaks in late summer or the monsoons when household food grain supplies are exhausted and both on-farm and off farm employment is unavailable (Ramachandran 2004). According to the National Census data of 2011, as many as 8.6 million people are facing chronic hunger (Census 2011). In rural and underdeveloped regions of the country, men, women and children continue to exhibit unacceptably high rates of undernutrition (Ramachandran 2014). Among children this undernutrition is observed in terms of underweight, stunting, wasting and thinness. Malnutrition among mothers are also prevalent in the country and has been assessed by several research studies (Radhakrishna and Ravi 2004; Abdullah 2015).

Although economic growth in India has been taking place for a long time but the improvement of nutrition situation is not directly proportional to economic growth and a large proportion of children and adolescents in India is remaining undernourished which gives rise to undernourished adults. The United Nations Children’s Fund (UNICEF) has estimated that one in every three malnourished children observed globally lives in India and 47% of children under age three are underweight, 46% are stunted and 16% are wasted in the country (UNICEF 2013). Even though India is becoming the world's third largest economy (Dre`ze and Sen 2013), but its child and infant mortality rates rank among the worst 50 nations (Lozano et al. 2011). The country has one of the highest rates of child malnutrition in the world which is almost double of sub-Saharan Africa and five times that of China. Nearly annually 50.0% of the 2.5 million child deaths occur in India and this can be attributed directly or indirectly to malnutrition (Klasen 2008). While a major portion of Indian children is suffering from undernutrition, there is an increasing trend in the prevalence of overweight and obesity among them (Gupta et al. 2012). In the lower income groups underweight remains a major concern, overweight and obesity rates among children are increasing mainly among the higher socio-economic groups (Ranjani et al. 2016). It has been observed that the issue of malnutrition in the country appears to be a concentrated phenomenon and a relatively small number of states, districts and villages account for a large share of the malnutrition burden. Only five states and 50.0% of villages account for about 80% of the malnutrition burden (Gragnolati et al. 2006).

1.3. METHODS OF ASSESSING NUTRITIONAL STATUS OF HUMANS

1.3.1. Anthropometry

Anthropometry has been widely and successfully applied to the assessment of health and nutritional risk. It is a useful technique to assess nutritional status and body composition of an individual or population (WHO 1995, 2007; Hamieda and Billot 2002;Lee and Neiman 2005; Hall et al. 2007). The most commonly utilized measurements are as follows:

a) Height/length

b) Weight

c) Mid-upper arm circumference (MUAC)

d) Head circumference

f) Waist circumference

g) Hip circumference

h) Skin fold thicknesses

As the present study is based on anthropometric measurements, this section is discussed in details subsequently.

1.3.2. Biochemical Methods

The underlying principle of this method is that any changes in the quantity and composition of the diet is reflected by variations in the concentrations of nutrients or their associated compounds in different body tissues and fluids along with the appearance or disappearance of metabolites. Haemoglobin estimation is the most important test to interpret the overall state of nutrition. This indicates prevalence of anaemia and deficiencies in proteins and trace elements. Stool examination is utilized to test for the presence of ova and/or intestinal parasites. Urine examination can be used for albumin and sugar tests. Vitamins promote other metabolic reactions in the body that produce energy (Campbell 2017; Saltveit 2019). This in turn leads to better maintenance of cells and tissues, along with promoting growth and development. Hence, a determination of the levels of these vitamins of different body tissues (biomarkers) can help to ascertain deficiencies. The important vitamins needed by the body are vitamins A, B, C, D, E, and K.

Vitamin A deficiency is indicated by plasma ß-carotene levels and fasting plasma amino acid pattern, which in turn indicate a deficiency of plasma retinol. Deficiency in vitamin B1 (thiamine) is determined by thiamine levels in urine. The long term result is an impaired red cell transketolase enzyme function. The biomarker for riboflavin or vitamin B2 deficiency is urinary riboflavin and the function of the enzyme red cell gluthione reductase is impaired. The biomarker for the determination of vitamin B6 deficiency is urinary 4-pyridoxic acid, indicating plasma pyridoxal 5' phosphate dysfunction. Deficiency in vitamin B12 is indicated in plasma holotranscobalamin II levels which in turn show a deficiency in the function of the enzymes plasma vitamin B12 and plasma methyl malonate. Analysis of plasma and urinary ascorbate levels is associated with a deficiency in vitamin C. There is a cell depletion of leucocyte ascorbate in the long term. Vitamin D deficiency is documented by the analysis of 25-hydroxy-vitamin D in the plasma. The deficiency results in the improper function of the enzyme plasma alkaline phosphatase. The ratio of plasma tocopherol to cholesterol + triglyceride is the biomarker to determine deficiency in vitamin E status. Vitamin K deficiency is determined by the plasma analysis of phyllo Quinone. This deficiency results in the impairment in the function of plasma prothrombin. Proteins are responsible for maintaining fluid balance, blood clotting, cell growth and repair, and immunity. Proteins also provide fuel for the body and glucose for the synthesis of sugar. Diets low in energy and proteins lead to a situation known as protein-energy malnutrition (PEM) and kwashiorkor. Analysis of urinary nitrogen indicates reduced intake of proteins. The principal advantages of the biochemical method are that it is precise, accurate, reliable and extremely useful in assessing in detecting early cases of malnutrition before the appearance of the clinical signs. The biochemical measurements usually reflect the immediate past intake of nutrients or the changes produced by a long-standing deficient intake of a nutrient.

1.3.3. Clinical Examination

Clinical examination is a simple, yet objective method to assess nutritional status. The signs and symptoms can be in the skin, mouth, gums, nails, lips, eyes and hair of the subjects under study. The 1963 WHO Expert Committee on Medical Assessment of Nutritional Status provided a classification of the physical signs that can be utilized for nutritional assessment. This classification was subsequently updated in the World Health Organization Monograph Series No. 53 entitled “The Assessment of the Nutritional Status of the Community” published in the year 1966. The WHO classification is very helpful when a rapid nutritional screening of a population is required within a stipulated time frame and also for specific research studies that needs to evaluate certain signs and symptoms. Physical signs and symptoms need to be recorded in a precise manner. The signs of malnutrition can be multiple. An experienced observer should possess the inherent capability of going for a more precise assessment of the body, after the initial findings based on a single sign. He/she also has to take into account the physical environment of the subject, along with the cultural features that can contribute to malnutrition. The age of the subject also plays an important role as the signs of a particular deficiency. The two aspects that are vital for proper and objective diagnosis are the reliability of the signs of symptoms and the experience of the investigator.

For convenience, the signs and symptoms are being classified into two categories. The categories are

a) Physical signs and general appearance

b) Internal signs

The physical signs and symptoms need to be recorded as accurately and possible. This can only be attained by the nutritionist/health worker by constant practice. The age of the individual under study is also related to the signs and their interpretation. Any physical finding that is indicative of malnutrition should be a clue that needs to be pursued more precisely. The physical signs and symptoms are strongly related to the ethnic features of the population under study. In a diverse country such as India, this is even more evident. The main advantages of this method are that it is inexpensive, rapid, reliable and easy to perform in any situation. It is also non-invasive and do not require the collection, transportation and analysis of any biologically active material. No specialized laboratory is required as such.

The main disadvantages of this method is that it is often not possible to detect early cases of malnutrition and that some of the clinical signs may not be specific to a particular nutrient deficiency and often one sign is an indicator of two or more such deficiencies. Moreover, the prevalence of the different clinical signs of malnutrition is quite low. There also can be differences in the assessment of the clinical signs by different observers (inter-observer error). The physical signs and symptoms can also vary over time periods.

1.3.4. Dietary Intake

Dietary surveys are extensively used in the areas of nutritional epidemiology, clinical assessment, population surveillance and experimental research.

a) Twenty-four hour recall

b) Weighed intake

c) Food frequency questionnaire

d) Food diary

e) Dietary history

a) Twenty-four hour recall method

All the food items that were consumed during the last 24 hours are recorded ("24-hour recall method"). This method is utilized in large-scale nutritional surveys. The subject is usually asked to recall and describe in as much detail as possible his/her food intake during the last 24-hours either through an interview or by a questionnaire.

The most widely preferred subject for this method is the housewife. The investigator asks her to recall the kind and amount of the food used, the preparations actually made and distributed to the family members. Standard measuring containers such as cups, glasses, saucers and spoons are used to help the subject in recalling the information. To get proper information, the investigator may use several stages in which each data obtained are checked and verified, and each recall may therefore take almost 45 minutes.

The main advantages of this method are that it is inexpensive, quick, easy and relies on short-term memory.

b) Weighed intake method

The main difference between the 24-hour recall method and the weighed intake method is that in the case of the latter, the investigator remains actually present when the subject is eating and the food amounts are weighed before serving, during serving and subsequently the left-over (food not consumed). The differences between them give the amount of food actually consumed by the individual.

c) Food frequency questionnaire (FFQ)

The FFQ method tries to obtain long-term dietary habits. The individuals generally complete the FFQ themselves. The detailed instructions are sent by post along with the questionnaires. However, in the developing countries such as India, it is advisable for the investigator to fill up the questionnaire after interviewing the subjects. In the FFQ method the individual is asked about how often specific food item are consumed. The responses of the subjects are standardized as the subjects just need to tick mark on the responses. The frequency is generally calculated as per week/fortnight/month. The list of food items should not generally exceed 150 items. Up to 10 categories ranging from never to six times per day are the usual format. The FFQ method has been used in large epidemiological studies to assess food patterns associated with inadequate intake of nutrients and descriptive information of the food and diet.

The FFQ check list has two main parts, namely, a list of different food items and the frequency of consumption of these food items.

d) Food diary

The subject is required to keep a record in written form (diary) and photographs of all the food and beverages consumed over a certain period of time. This method is generally utilized when interviewing all the members regarding their dietary intakes is not possible due to some practical constraints. A time period of one week can be used in the diary to estimate the dietary intake. The subjects are initially tutored to describe and weigh/estimate the amount food immediately prior to eating and subsequently to record left overs, if any. Standardized bowls and utensils are given to them prior to writing the diary. Even though the subject burden appears to be the highest while using this method, the food diary method has been effectively used in a number of large prospective epidemiological studies and for validating the results obtained from other methods of dietary assessment.

e) Dietary history

Dietary history records the dietary practices of the respondents over a prolonged period of time. The investigator obtains a retrospective estimate of the food intake using this method. The time duration covered is 3 months to one year. The information is recorded either through interviews and/or questionnaires addressed to the subject. This method is not used in large scale epidemiological surveys.

1.3.5. Vital and Health Statistics

Analysis of the mortality and morbidity data, along with the infant mortality rate, second year child mortality rate, rate of low birth weight and the life expectancy can also identify the at-risk groups with regards to nutritional status. The data of morbidity in the clinical settings or community health and morbidity surveys particularly those in relation to the protein energy malnutrition (PEM) and vitamin deficiencies are valuable in providing additional information with regards to the nutritional status of populations.

1.3.6. Ecological Studies

Malnutrition can be the end result of many interacting ecological factors. In many nutritional surveys it becomes necessary to collect the ecological information of the given community in order to make a complete nutritional assessment. A study of the ecological factors comprises of food balance sheets, socio-economic factors, health and educational services and finally conditioning influences.

1.4. REVIEW OF PUBLISHED LITERATURE

1.4.1. Studies done on Body Composition and Nutritional Status Assessment among Non-Indian Populations

Several studies have been done on the assessment of body composition and percent of body fat (PBF) by measuring skin-fold thickness (Slaughter et al. 1988; Rolland-Cachera 1993; Deurenberg et al. 1998; Gibson 2005; Wells 2007; Sen and Mondal 2013; Debnath et al. 2018a). Studies have been done on body composition assessment using recently developed advanced methods includes DXA, BIA among children and adolescents. Studies on whole body bone mineral content, FFM and FM have been done by Boot et al. (1997) among the Dutch children and adolescents; Bolanowski and Nilsson (2001), Eisenko¨lbl et al. (2001), Kontogianni et al. (2005) also used DXA for studying body composition among children and adolescents. Sala et al. (2007) reported that body composition among Canadian children and adolescents. A study was done by Wickramasinghe (2011) to assess the body composition among Sri Lankan children. Some studies have also been published using the indices like FM, FFM, FMI and FFMI on the issue of body composition among children among both non-Indian children (Musaiger and Gregory 2000; Nakao and Komiya 2003; Freedman et al. 2005; Gu¨ltekin et al. 2005; Ghosh et al. 2009; Leonard et al. 2010; Weber et al. 2012; Giri et al. 2017a; Debnath et al. 2018a). Several non-Indian studies have been done on the body composition assessment of children using Dual-energy x-ray absorptiometry (DXA) (Goran et al. 1996; Huang et al. 2003; McDonald et al. 2007; Hoffman et al. 2012; Kuzawa et al. 2012; Xiong et al. 2012; De Moraes et al. 2013; Tanvig et al. 2014; Marra et al. 2019; Alburquerque-Sendín et al. 2020).

Yanovski et al. (2011) conducted a study on body composition among children and adolescents of United States. Pereira et al. (2014) studied body composition using PBF as an indicator among female adolescents of Brazil. Weber et al. (2013) also studied body composition using body fat and BMI among children and adolescents. Stanfield et al. (2012)

reported another study among the mother and baby in London. Kim et al. (2013) reported body composition using body fat among Korean children. A study on body fat using DXA is reported by Ackerman et al. (2011). Studies using DXA were also reported by Wells et al. (2010) and Bauer et al. (2012) .

A number of studies have been done on the assessment of body composition and percent of body fat (PBF) by measuring skin-fold thickness (eg., Gibson 2005; Kontogianni et al. 2005; Wells 2006; Basu et al. 2010; Xiong et al. 2012; Weber et al. 2013). Studies have also been done using indices like fat mass, fat free mass and fat mass index to estimate body composition among children (Freedman et al. 2005; Gu¨ltekin et al. 2005; Sala et al. 2007; Wickramasinghe 2011). Several non-Indian studies have been done on the body composition assessment of children using bio-electrical impedance methods (Ackerman et al. 2011; Yanovski et al. 2011; Kuzawa et al. 2012; Tanvig et al. 2014; Wendel et al. 2016). A number of studies have been done world-wide on the measurements of nutritional status among under-five years age. Some studies in this respect are by Kosti and Panagiotakos (2006), Cole et al. (2007), Edris (2007), Tienboon and Wangpakapattanawong (2007), Amsalu and Tigabu (2008), Mashal et al. (2008), Bomela (2009), de Onis et al. (2010), Emina et al. (2011), Kamiya (2011), Abubakar and van de Vijver (2012), Abuya et al. (2012), Massad et al. (2012), Mugo (2012), Nketiah-Amponsah et al. (2012), Sufiyan et al. (2012), Ghazi et al. (2013), Akorede and Abiola (2013), Bhandari and Chhetri (2013), Flax (2013), Islam et al. (2013), Owoaje et al. (2014), Aheto (2015), Chirande et al. (2015), Iannotti et al. (2015), Aguayo et al. (2016), Ahmed et al. (2016), Devkota et al. (2016), Rachmi et al. (2016), Rakotomanana et al. (2016), Valente et al. (2016) and Karra et al. (2017).

Studies on maternal body composition and nutritional status have been published. Some recent studies on the field are by Lewycka et al. (2013), Keino et al. (2014) and Tebekaw et al. (2014). There are also studies on maternal nutritional status and its association with the child nutrition and socio-economic factors (Black et al. 2008; Davidson et al. 2008; Lartey 2008; Victora et al. 2008; Oken 2009; Padilha et al. 2009a,b; Lampl et al. 2010; Limwattananon et al. 2010; Peiris and Wijesinghe 2011; Khan and Khan 2012; Målqvist et al. 2012). Studies on assessment of maternal nutritional status include those of Drehmer et al. (2010), Young et al. (2012), Haileslassie et al. (2013), Li et al. (2013), Ma˚lqvist et al. (2013), Felisbino-Mendes et al. (2014), Hambidge et al. (2014), Jayawardena (2014), Restrepo-Mesa et al. (2014), Abrha et al. (2016), Bhandari et al. (2016), Gyenes et al. (2016), Mohsena et al. (2016), Veena et al. (2016), Jomaa et al. (2017) and Tanwi et al. (2019).

A number of studies have been done world-wide on the measurements of growth among various populations. One of the earliest significant studies in this regard is that of Partington and Roberts (1969) on height and weight of Indian and Eskimo school children. Other notable studies include those of Johnston et al. (1973) on height, weight and their growth velocities in Guatemalan private school children, that of Hartaman et al. (1973) on height of school children in Bandung that of Shephard and Rode (1995) on the growth patterns of Canadian Inuit children that of Merola et al. (1998) on height, weight, height velocity of primary school children in Italy and that of Kamal et al. (2004) on height, weight, height velocity of Qatari preschool children.

Studies have also been initiated on establishment of growth reference values such as that among Belgian children of 3-18 years of age (Hauspie et al. 1993). Sutphen (1985) discussed the common anthropometric techniques and emphasizes the inference of nutritional status from such measurements. Many of the studies on human growth were initiated in the early part of the 20th century and most of them were long-term. As a background for the International Growth Reference for Children and Adolescents, 21 long-term longitudinal studies of physical growth were reviewed by Himes (2006). Seidell et al. (2006) opined in another review that normative data are necessary to create a reference that indicates optimal development of weight in relation to height and age, particularly in the face of the unfolding obesity epidemic in many developed and developing countries around the world. Ideally, a reference would be based on longitudinal data in populations with little underweight, overweight and obesity. Cole et al. (2000) have reported reference population for assessing the prevalence of overweight and obesity among children and adolescent. Childhood overweight and obesity is worldwide trend. A number of studies have reported the prevalence of overweight and obesity among children from different populations (Kosti and Panagiotakos 2006; de Onis et al. 2010; Evans et al. 2010).

In a recent study, a high prevalence of malnutrition among Karen children has been observed by Tienboon and Wangpakapattanawong (2007) involving anthropometric measurements. Sex differences in different anthropometric measurements were also studied. In a study done in Libya, it was reported that there was a marked difference in anthropometric measurements between boys and girls at the age of 14 years (Shamssain 1989). In another significant study, Huque and Hussain (1991) showed that it was possible to detect of low birth-weight among new born babies by anthropometric measurements. Ben Salem et al. (2006) evaluated weight-for-age, height-for-age and weight-for-height in infants in Tunisia and compared them with the National Centre of Health Statistics (NCHS) reference. Secular trends in various anthropometric measures have also been studied (Ayatollahi et al. 2006; Matton et al. 2007).

1.4.2. Studies done on Body Composition and Nutritional Status Assessment among Indian Populations

Anthropometry is the single universally applicable, inexpensive and non-invasive technique available to researchers for the assessment of the size and proportion of the human body, physical growth pattern and nutritional status (WHO 1995, 2007; Lee and Neiman 2005; Hall et al. 2007). It is considered to be very useful tool in the assessment of growth and nutrition of individuals (Lee and Neiman 2005). The technique of anthropometry has been successfully utilized by different researchers to assess and document the growth and nutritional status of various populations. Several research studies have reported that prevalence of undernutrition is considered to be the one of the major public health concerns among children (George et al. 2000; Rajaram et al. 2003; Rao et al. 2004; Nandy et al. 2005; Som et al. 2006, 2007; Bose et a. 2007a; Mondal and Sen 2010a,b; Sen and Mondal 2012; Singh and Mondal 2013; Mondal 2014; Islam et al. 2014; Sharma and Mondal 2014; Mondal et al. 2015; Sharrma and Mondal 2018; Debnath et al. 2018a,b,c).

A sizeable number of these studies have been done on pre-school children (Khongsdier 2001; Som et al. 2006; Mondal and Sen 2010a,b; Sen and Mondal 2012; Tigga et al. 2015a,b; Singh et al. 2016; Debnath et al. 2017a; Debnath et al. 2018a,b,c; Kramsapi et al. 2018; Sharma and Mondal 2018). The anthropometric parameters (e.g., mid-upper arm circumference (MUAC), head circumference (HC), height-for-age, weight-for-height, weight-for-age) that are used are widely to assess physical growth and nutritional status of children (WHO 1995; Nandy et al. 2005; Bose et al. 2007; Mondal and Sen 2010a,b; Debnath et al. 2018; Sharma and Mondal 2018, 2020). Extensive studies have also been done in assessment of nutritional status using anthropometry among children, particularly in the age group below 12 years using conventional anthropometric measurements and indices (e.g., stunting, underweight and wasting) (e.g., Rao et al. 2005; Rajaram et al. 2003; Som et al. 2006, 2007; Mittal and Srivastava 2006; Bose et al. 2007a; Mitra et al. 2007a,b; Bisai et al. 2008a; Chowdhury et al. 2008; Mondal and Sen 2010a,b; Bisai and Mallick 2011; Sen and Mondal 2012; Mondal et al. 2015; Debnath et al. 2018a,b,c).

The inadequate/poor physical growth attainment in weight and height were also reported in other tribal and non-tribal children and adolescents in India (Reddy and Rao 1995, 2000; Mitra et al. 2002; Rao et al. 2006; Medhi et al. 2007; Mondal and Terangpi 2014; Singh and Mondal 2014; Roy et al. 2016; Mondal et al. 2017; Sharma and Mondal 2018) compared to the recommended international growth references (e.g., WHO and CDC) (Frisancho 1990; Kuczmarski et al. 2002; WHO 2007). The population/ethnic specific physical growth and nutritional studies were also assessed using anthropometric measurements (e.g., height and weight) among Indian children and Indian adolescents (ICMR 1972). Here, the studies on Bengali boys of West Bengal (Dasgupta and Das 1997), Assamese Muslim of Kamrup, Assam (Begum and Choudhury 1999), Sugalis tribal adolescents of Andhra Pradesh(Reddy and Rao 2000), Kamar tribal of Chhattisgarh (Mitra et al. 2002), School children of Assam (Medhi et al. 2006), Khasi adolescents Meghalaya (Khongsdier and Mukherjee 2003), Tribal adolescents of Assam (Medhi et al. 2007), Santal tribe of Orissa (Chowdhury et al. 2008), Shabar tribe of Orissa (Chakrabarty and Bharati 2008, 2010), Bengali adolescents (Banerjee et al. 2009), SonowalKachari tribe of Assam (Singh and Mondal 2014), Indian adolescents (Khadilkar et al. 2015), Rajbanshi (Roy et al. 2016), Karbi adolescents (Mondal and Terangpi 2014; Sharma and Mondal 2018, 2020) are mentionable.

Several studies have been done using upper arm composition which includes the indices of upper arm muscle area (UMA), total upper arm area (TUA), upper arm fat area (UFA), arm fat index (AFI), upper arm fat area estimate (UFE) and upper arm muscle area estimate (UME) to assess body composition of children and adults. Several studies during the last decade have established the usefulness of upper arm composition in the assessment of body composition among them (e.g. Bolzan et al. 1999; Chowdhury and Ghosh 2009; Sen et al. 2011a; Senbanjo et al. 2014; Singh and Mondal 2014; Sen et al. 2015; Debnath et al. 2017b), although not adopted for routine assessment of body composition and nutritional status. Several studies have been conducted among children using UMA and UFA as reliable indicator of body composition and nutritional status (e.g., Erfan et al. 2003; Chowdhury and

Ghosh 2009; Çiçek et al. 2009; Basu et al. 2010; Sen et al. 2011, 2015; Sikdar 2012a,b; Singh and Mondal 2014; Debnath et al. 2017b).

There are a number of Indian studies available on FMI, FFMI (Bhat et al. 2005; Bose et al. 2008; Khongsdier 2005; Rao et al. 2012; Bose et al. 2006; Verma et al. 2016) and MUAC (Bose et al. 2007; Bose et al. 2006; Bisai et al. 2009; Chakraborty et al. 2009; Das et al. 2012a; Mallick and Roy 2019). Studies on West Bengal have also been reported (Ghosh et al. 2001; Das and Bose 2006; Bisai et al. 2008; Datta Banik 2011; Das et al. 2012a; Das and Bose 2012; Sen and Mondal 2013; Kuiti and Bose 2015; Pratiharp et al. 2016; Bose et al. 2019; Mallick and Roy 2019).

Composite Index of Anthropometric failures (CIAF) is more useful over the conventional anthropometric indices (i.e., stunting, underweight and wasting) in assessing the overall magnitude of undernutrition and identifying children with multiple anthropometric failures (Nandy et al. 2005; Nandy and Miranda 2008; Nandy and Svedberg 2012; Sen and Mondal 2012; Dasgupta et al. 2014; Savanur and Ghugre 2015; Goswami 2016; Kramsapi et al. 2018; Sen et al. 2020). The CIAF comprises typical anthropometric indicators and their combination into seven categories and proposes an additional measure to study malnutrition as an alternative to the evaluation of stunting, wasting and underweight as the separate measure (Nandy et al. 2005; Nandy and Svedberg 2012; Sen and Mondal 2012). Several researchers have reported that conventional anthropometric indices could not provide the overall prevalence of undernutrition as the researcher had to 'choose' a certain category of anthropometric failure when assessing nutritional status among preschool children (Nandy et al. 2005; Seetharaman et al. 2007; Berger et al. 2008; Nandy and Miranda 2008; Nandy and Svedberg 2012; Kramsapi et al. 2018). Several research studies have reported the overall magnitude of undernutrition status using CIAF among Indian preschool children and children residing in both rural and urban population (Nandy et al. 2007; Seetharaman et al. 2007; Das and Bose 2009; Sen and Mondal 2012; Dasgupta et al. 2014; Savanur and Ghugre 2015; Dhok and Thakre 2016; Goswami 2016; Gupta et al. 2017; Kramsapi et al. 2018; Sen et al., 2020).

A significant number of contributions have observed that the prevalence of chronic energy deficiency (CED) is the important nutritional issue among Indian adults (e.g., Khongsdier 2001, 2005; Gautam et al. 2006; Bose et al. 2006; Subramanian and Smith 2006; Bharati et al. 2007; Subramanian et al. 2007; Sengupta 2014). In a very significant study involving 81,712 rural women from 26 states and 6 zones, Bharati et al. (2007) reported that 31.20% of them were suffering from CED. Here, the studies among the Oraon (Mittal and Srivastava 2006) and Santal (Bose et al. 2006) may be also mentioned. Using body mass index (BMI) and mid upper arm circumference (MUAC), Bose et al. (2006c) reported a high prevalence of undernutrition among adult Santals of Odisha (26.20% males and 33.70% females).

The current nutritional trends have shown that the prevalence of overweight and obesity has increased among Indian populations residing in the urban areas of the country (Subramanian and Smith 2006; Subramanian et al. 2007; Mungreiphy and Kapoor 2010; Sen et al. 2013; Sengupta et al. 2014; Rengma et al. 2016; Tigga et al. 2018). Studies on waist-circumference (WC) (Ghosh and Bandypadhyay 2007; Chakraborty and Bose 2009; Singh et al. 2014; Banik et al. 2016; Ghosh and Bose 2018), waist-to-height ratio (WHtR) (DeNino et al. 2001; Despres and Lemieux 2006; Abdelaal et al. 2017) and human physical variation in body dimension (Dewangan et al. 2005; Singh et al. 2014; Banik et al. 2016; Ghosh and Bose 2018) has also been published.

1.4.3. Socio-Economic and Demographic Factors Affecting Physical Growth and Nutritional Status among Children

Socio-economic and demographic factors are considered to be the major contributors to the prevalence of undernutrition, mortality and morbidity among children around the world

(Jafari et al. 2010; Zsakai and Bodzsar 2014; Tigga et al. 2015; Choy et al. 2017; Galgamuwa et al. 2017; Wang et al. 2017; Debnath et al. 2018c). Zsakai and Badzsar (2014) have observed a significant relationship between physical growth and socio-economic status among children. Studies have reported poor feeding practices (Lindsay et al. 2012), low household income and illiteracy, improper care during childhood triggers the prevalence of undernutrition among the children and decreases the cognitive abilities and makes them less productive (WHO 1995; Black et al. 2013; Mondal et al. 2015; Tigga et al. 2015; Wang et al. 2017). Specific nutritional deficiencies in terms of protective foods (i.e., micronutrient deficiency such as vitamin-A, zinc deficiency and iron deficiency) caused due to inadequate intake of food can be attributed to the greater prevalence of undernutrition and morbidities among children (Alaofe 2017; Chengezi and Lindberg 2017). The existence of low socio-economic status, poor environmental, unhygienic conditions and unavailability or inaccessibility of the healthcare degrades health status of women and often makes them prone to deliver an undernourished child (Alaofe et al. 2017). The relationship between nutritional status (e.g., undernutrition) and dental eruption chronology has been evaluated by many studies (Barbería et al. 1988; Psoter et al. 2008; Must et al. 2012; Heinrich-Weltzien et al. 2013; Juliana et al. 2017).

Several socio-economic, demographic and lifestyle determinant have shown significant effects on the prevalence of undernutrition (e.g., stunting or thinness) and that poverty highly affects the linear growth mechanism than body weight of the children (Black et al. 2008; Janevic et al. 2010; Agostoni and Fattore 2013; Meshram et al. 2016). A number of studies have showed that poor children tend to be at higher risk of being undernourished and having restricted growth. Therefore, economic inequality remains an independent determinant for childhood undernutrition (Zere and McIntyre 2003; Janevic et al. 2010; Meshram et al. 2016; Roy et al. 2016). These determinants include poor socio-economic status, poverty, income, hygiene and adverse environments (e.g., rural), including low income

(Choudhury et al. 2000; Mahgoub et al. 2006; Tigga et al. 2015a,b; Roy et al. 2016). Physical growth attainment, health status and nutritional benefits from economic growth tend to be concentrated only among the economically advantaged groups (Vardharajan et al. 2013; Mushtaq et al. 2011; Meshram et al. 2015). Moreover, the developing countries remain vulnerable to food insecurity, poor access to health services, undernutrition (e.g., stinting) and increased morbidity and mortality (Zere and McIntyre 2003; Nandy et al. 2005; Nandy et al. 2008; Smith and Haddad 2015; Akseer et al. 2017; Dondi et al. 2020). The major factors affecting the prevalence of undernutrition in the developing countries are poor socio-economic and environmental conditions, ethnic, socio-economic and demographic disparities (Mahgoub et al. 2006; Ramachandran 2007, 2014; Antony and Laxmaiah 2008; Mondal and Sen 2010; Ahmed et al. 2012; Varadharajan et al. 2013; Tigga et al. 2015; Huda et al. 2017; Debnath et al. 2018c, 2019). The consequences of such undernourishment are poor growth associated with greater risk of morbidity and mortality from infectious diseases, adverse long-term consequences of delayed linear growth (e.g., stunting) (Black et al. 2013; Ramachandran 2014; Smith and Haddad 2015). Most of the studies documenting nutritional status in India have observed that girls were more affected by undernutrition than boys (Bose et al. 2007; Mondal and Sen 2010; Sen and Mondal 2012; Tigga et al. 2015; Pal and Bose 2017; Sinha et al. 2017; Debnath et al. 2018c,d; Seshadri and Ramakrishna 2018; Sharma and Mondal 2018). Several researchers have also reported existence of sharp sex/gender disparities, with rural girls were more likely to be severely undernourished than rural boys (Choudhury et al. 2000; Mondal and Sen 2010; Bhargava et al. 2015; Pal and Bose 2017; Sinha et al. 2017; Debnath et al. 2018; Seshadri and Ramakrishna 2018).

1.4.4. Studies done in Biological Anthropology among Different Populations of North-Eastern India and North Bengal

Northeast India is comprised of eight states, namely Assam, Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura. The region has international boundaries with China, Bhutan, Myanmar and Bangladesh. This region of India is the most interior and inaccessible part of the country as a result of mountainous terrain and poor communication means. Noteworthy studies have been reported in the field of nutrition assessment among communities of Northeast India. The high prevalence undernutrition is considered to be a serious problem among adult populations of Northeast India. Several studies have reported that chronic energy deficiency (CED) is widely prevalent and causing various form mortality and morbidity among individuals. Khongsdeir (2001) using data from 12 populations of Northeast India reported that the prevalence CED of was significantly lower in tribal than Hinduized and caste populations. The prevalence of CED was also found to be 21.43% among Dibongiya Deoris of Assam (Gogoi and Sengupta 2002) and 35.00% among male War Khasi individuals (Khongsdier 2002). When the population specific prevalence of undernutrition (e.g., CED) was taken into consideration the data shows a lower prevalence among tribal populations such as Boro Kachari (11.22%), Mech Kachari (6.00%) and Pnar Khasi (14.28%) than the tribes like Lalung (34.69%) and Mishing/Miri (34.00%). The prevalence of CED was found to be higher in the Hinduized Mongoloid groups like Ahom (52.00%), Koch (50.00%) and Rajbanshi (42.00%) (Khongsdier 2001). Khongsdier et al. (2005) further reported excess chronic energy deficiency (CED) was observed among male adolescents in the context of patrilineal and matrilineal societies in Northeast India. Other significant contributions in the field of nutritional assessment and growth studies among children and adolescents are also available among diverse ethnic populations of Northeast India (e.g., Devi et al. 1997; Sharma and Bora 1998; Begum and Choudhury 1999; Khongsdier and Mukherjee 2003a,b; Agrahar-Murugkar 2005; Som et al. 2006; Medhi et al. 2007; Basu et al. 2010; Sil et al. 2011; Islam et al. 2014; Mondal and Terangpi 2014; Sharma and Mondal

2014; Singh and Mondal 2014; Mondal et al. 2015; Sharma and Mondal 2018, 2020). Recent studies of Basu et al. (2010) and Singh and Mondal (2014) have reported that upper arm composition and nutritional status among Khasi adolescent and Sonowal Kachari children remained nutritionally deficient with gender specific muscle and fat proportion, respectively. Recent trends suggested that the prevalence of overweight and obesity also apparent among the adult individuals of Northeast India (Mungreiphy and Kapoor 2010; Rengma et al. 2015).

Several research studies were also conducted on different anthropological and health related issues of non-communicable diseases (Misra et al. 2014), malnutrition (Sikdar 2012), healing practices and folk medicine (Shankar et al. 2012), Obesity (Rengma et al. 2015) and ABO and PTC sensitivity (Das et al. 1985a,b) among the Mishing tribal population and among Muslims of Northeast India. Significant contributions have been made in the field of nutritional assessment and growth studies in the different population of North-east India (Devi et al. 1997; Sharma and Bora 1998; Khongsdier and Mukherjee 2003; Agrahar-Murugkar 2005; Medhi et al. 2006; Som et al. 2007; Bharati et al. 2008; Sharma and Mondal 2014; Singh and Mondal 2014; Mondal et al. 2016; Rengam et al. 2017; Kransapi et al. 2018). Medhi et al. (2007) reported the very high prevalence of stunting (47.40% boys; 51.90% girls) and thinness (59.50% boys; 41.30% girls) among the adolescent working in the tea gardens of Dibrugarh district of Assam. Basu et al. (2010) reported the in upper arm composition and nutritional status among Khasi adolescent children remain nutritionally deficient with gender dimorphic muscle and fat proportion. Sil et al. (2011), reported the prevalence stunting (23.70%), thinness (23.70%) among the rural tribal children in Tripura. Some studies have been initiated in the field of Hbopathies among populations of North Bengal (e.g., Bhattacharyya et al. 2013; Goswami et al. 2014; Ghosh et al. 2015). Some other studies on nutritional status and body composition among children have been done in North Bengal are that of Debnath et al. (2017a, 2018a,b,c,).

1.4.5. Studies on Muslim in North Bengal, West Bengal and India

Population specific studies among the Indian Muslims are rare in the field of nutritional status and body composition. In the field of body composition two significant studies were reported from North Bengal using the upper arm composition and FM and FFM among the Bengalee Muslim children by Sen et al. (2011) and Sen and Mondal (2012), respectively. Studies have assessed nutritional status among the Muslim children and women simultaneously with other Indian populations or religious groups. One population specific study among the Muslim adolescents of Deganga, North 24 Parganas has been reported by Khatun et al. (2017).

In West Bengal studies on the assessment of nutritional status includes that among school going Muslim adolescent girls in a semi urbon area of West Bengal (31.36%) (Pramanik et al. 2014), among Muslim adolescent school girls (16.00%) (Sarkar et al. 2015), among adolescent girls in a slum area of Kolkata that includes 30.28% of Muslims (Pal and Pal 2017). Some of the other studies in West Bengal which have included Muslims in the study population are by Pal (1999) and Bisai et al. (2010). Several studies have been done by Debnath et al. (2017, 2018a,b,c,d, 2019) who included Bengali Muslim children. Sen et al. (2020) have reported a study on Composite Index of Anthropometric failure (CIAF) which included Bengali Muslim children.

A population specific study among Muslim women in Assam has been done by Haloi and Limbu (2013). Indian studies which have included Muslims as the study population include that of adult males of different social groups (includes 13.15% Muslims) in Odisha and Bihar (Chakrabarty et al. 2008), under five children (Muslim 13.90%) of rural area of Western Maharashtra (Avachat et al. 2011), young children in Mumbai slums (Muslims 43.00%) (Das et al. 2012), adolescents in northern Karnataka (Rajaretnam and Hallad 2012), school going children (6-9 years) (includes 5% of Muslims) in rural area of Bhopal district, Madhya Pradesh (Murugkar et al. 2013), urban slum children (Muslim 24.20%) (Lohia and Udipi 2014), children aged 1-6 years in rural Lucknow, Uttar Pradesh (Muslims 29.50%) (Prasot et al. 2014), rural adolescents of 10-19 years age (includes 61.34% Muslims) in Bareilly, Uttar Pradesh (Singh et al. 2014), school children (includes 29.00% Muslims) in Sullia town, South India (Amruth et al. 2015), adults in urban slums of Delhi (Muslim 49.80%) (Singh et al. 2015), adolescents in rural school of Unokoti District of Tripura (Uddin et al. 2015), women (includes 15.50% Muslims) in a rural population of North Karnataka (Mastiholi et al. 2018), women of reproductive age in India (Al Kibria 2019), school children (includes 11.60% Muslims) in Udupi, Karnataka (Gautam and Jeong 2019), elderly adults in Patna (Kumari 2019) and adolescent girls aged 10-19 years (includes 26.67% Muslims) in urban slums of Agra in Uttar Pradesh (Kumar and Mishra 2019).

Some of the other studies which included Muslims were that among Indian women (Bharati et al. 2008), children (Bose 2011; Griffiths et al. 2002; Imai et al. 2014; Viramgami et al. 2014; Puttaraju and Uma 2015; Joe et al. 2019; Pakrashi and Saha 2020), among adults (Dutta et al. 2019), Indian Muslims in general (Ismail and Mustaquim 2013) and females of reproductive age group of Azamgarh district, Uttar Pradesh (Mishra et al. 2011). Studies on assessing the low birth weight situation in India (Muslims 13.10%) (Chakraborty and Anderson 2011) and prevalence of anemia in Muslim (92.3%) and non-Muslim pregnant women of western Rajasthan (Bansal et al. 2013) are also mentionable. Paul and Mondal (2020) have reported the prevalence morbidity and mortality among Indian children which included 16.80% of Muslims in the study population.

1.5. The Insidious Impact of Maternal Malnutrition on the Health of Child health and Community Health

Maternal health has an important link with the health of the individual, family and society (Gill et al. 2007; Delisle 2008). Mothers/Women's nutritional status impacts all these levels of society in present and future generations and their health and well-being is connected with their own socio-economic and lifestyle status, their education, occupation and on the power to make decisions. Maternal health affects women's survival as well as the health and survival of their children and future generations (Smith et al. 2003; Delisle 2008). Women's good health and better nutritional status can be directly reflected in better nutrition and health of their children (Smith et al. 2003; Delisle 2008). Maternal undernutrition is associated with CED status of mother, fetal growth restriction, low-birth weight for gestational age and child birth with a high risk of undernourishment among those who survive (Delisle 2008). The nutritional status of children is adversely influenced by the health and nutritional conditions of the mother. There are various Problems caused by poor maternal health and nutritional conditions.

The prevalence of LBW (Low Birth Weight) which is a significant public health concern in the developing countries including India (Sen et al. 2011; Shastri et al. 2014; Mondal et al. 2018; Dey et al. 2019; Laopaiboon et al. 2019). Significant interaction between the allocation group and maternal pre-pregnant BMI has been reported by Potdar et al. (2014). The factors associated with LBW among new-born babies in an urban slum community in Bhopal has been reported by Choudhary et al. (2013) where the mean birthweight of new-borns was 2.57± 0.36 kg and 105 (36.2%) new-borns had a birthweight lesser than 2500 gm. Some of the other studies on risk factors for LBW and pregnant women are those by Bharati et al. (2011), Negandhi et al. (2014). Study on the variability in survival of very LBW neonates in hospitals of India has been done by Chawla et al. (2015). Studies have observed the relationship between neonatal, peri-natal mortality and maternal nutritional status in Indian states (Bamji et al. 2008; Kumar et al. 2014; Siddalingappa et al. 2014). Sethuraman et al. (2006) has observed that malnutrition continues to affect 46% of children under five years of age and 47% in rural women in South India. According to the study done by Udipi et al. (2000)

maternal nutrition is very important for the course and outcome of pregnancy. In another study Kulkarni et al. (2011) observed regional body composition changes during lactation in Indian women from the low-income group and have assessed relationship to the growth of their infants. It has also been observed in several studies that when maternal income is higher than that of men's income then it is directly reflected among their children (Smith et al. 2005; Delisle 2008). Studies have pointed out the relationship of gender inequality and deprivation among and the health expenses of these for the whole population (Osmani and Sen 2003; Subramanium and Smith 2006; Delisle 2008). Some adverse consequences of women's poor health and nutrition harm the entire population because the offspring are affected as children and as well as future adults. Although women's physiological processes (that is, their childbearing and hormone functions) require an excess of essential fat i.e., the "sex-specific fat" but overnourishment among mothers (i.e., overweight-obesity) can also give birth to children who become malnourished (e.g., stunted) on later age as suggested by several studies on obesogenic environment. The presence of maternal overweight-obesity also exposes the child to increased risk of gestational diabetes and macrosomia (ESHRE Capri workshop group 2006). Moreover, the female off-springs of malnourished mothers are at higher risk of becoming stunted and undernourished women themselves and also to have low-birth weight babies, thereby perpetuating the vicious cycle of undernourishment (Delisle 2008). Socio-economic inequalities denote the degree of prevalence of malnutrition in population and the forms differ between more and less socially and economically advantaged groups (Van de Poel et al. 2008; Mazariegos 2019). The National Family Health Survey-3 2005–2006 data showed that combined prevalence of overweight and obesity 12.6% among women aged 15–49 years and the NNMB 2005–2006 data showed that in rural areas the combined prevalence was 10.9% among adult women aged 18–60 years (Wang et al. 2009). On the other hand the prevalence of child undernutrition is persistently high in India (Khor 2008; Ali et al. 2016;

Dhok and Thakre 2016; Saxton et al. 2016; Mandal 2017; Patil et al. 2017; Debnath et al. 2018a,b,c). Although causes of child undernutrition and maternal overnutrition are different but the both of them can coexist. Several studies (e.g., Doak et al. 2005; Garrett and Ruel 2005; Dieffenbach and Stein 2012; Doak et al. 2016; Jayalakshmi and Kannan 2019), have observed such a coexistence. Chronic undernutrition such as stunting among children and maternal undernutrition in terms of CED are serious health issues in poor income and developing countries. Moreover, the nutrition transition, lifestyle changes and economic disparities in these countries are contributing towards the occurrence of overweight and obesity in population. But occurrence of childhood stunting and maternal obesity present in the same households is more serious issue than occurrence of undernutrition and overnutrition separately in different households. Therefore, the occurrence and contribution of the obesogenic environment needs special attention.

Several socio-economic and demographic indicators e.g., maternal age, maternal age at menarche, family size, family type, earning head, monthly income, monthly expenditure, toilet use and fathers occupation have been observed to be significantly associated with the obesogenic environment.

1.6. STATEMENT OF THE PROBLEM

Childhood malnutrition is the underlying cause of death in an estimated 35% of all deaths among children, under the age of five years. More than two million children die each year as a result of undernutrition before the age of five years and iron-deficiency anaemia is estimated to contribute to a significant number of maternal deaths every year in low- and middle-income countries (WHO-UNICEF 2014). India has the highest occurrence of child undernutrition in the world and it has been estimated that more than half of the Indian children remain undernourished (Ahmed et al. 2012). It has also been reported that the country has more than 47 million stunted children and that nearly 20% of children are born with LBW

(Bharati et al. 2011; Kader and Perera 2014). The effect of undernutrition among Indian children and mothers are high. High rates of infant mortality, under-five mortality and maternal mortality are observed in India, which are higher than those of some of the developing countries of South-East Asia. There is also a scarcity of the scientific studies on maternal and child nutritional status in the selected area. Undernutrition was identified to be the principal underlying cause of mortality among children and the WHO has estimated that, in the year 2012, a total of 6.60 million deaths occurred among children aged under-five years (WHO 2014). The relationship between maternal and child undernutrition is affected by biological consequences during child birth and lactation. Poor nutritional condition among children and mothers perpetuates generation after generation in human population. Therefore, it is very important to assess the nutritional status of such children and their mothers. Interventions by improving maternal nutritional status could have a significant role in the prevention of childhood malnutrition. Keeping the above-issues in mind, the present study aims to assess the nutritional status of children (1-5 years) and their mother.

1.7. OBJECTIVES OF THE PRESENT STUDY

Assessment of nutritional status and body composition of individuals is recognized as the most significant indicator of health and wellbeing status of an individual or population. The ultimate objective of nutritional assessment studies is to improve the quality of human health and life conditions by implementing various nutritional intervention programmes.

The objectives of the present study are as follows:

1. To assess the nutritional status of the children (1-5 years) and mothers of the Bengali Muslim population of Darjeeling district, West Bengal using conventional anthropometric measures.
2. To ascertain the effect of maternal body composition and nutritional status on the child nutritional status.

3. To find out the association and effect of certain socio-economic, demographic and lifestyle variables on child and maternal nutritional status.
4. To compare the child and maternal nutritional status of the Bengali Muslim population with the available studies done on different Indian and non-Indian population.

1.8. RESEARCH QUESTIONS OF THE PRESENT STUDY

It is evident from the above discussion that nutritional status and body composition is generally influenced by several biological, physical, socio-economic, demographic and lifestyle determinant factors. It is considered to be one of major factor affecting the physical growth, delay in developmental processes and increases the mortality and morbidity conditions. As established by several research studies, women suffering from chronic energy deficiency (CED) (e.g., undernutrition) and poor body composition will continue the vicious cycle of undernutrition and such issues have the direct influence on the reproductive outcome and the prevalence of undernutrition among children in the population. Therefore, the present study is proposed on the basis of the following research questions:

1. What is the present condition of body composition and nutritional status of of the Bengali Muslim children and mothers?
2. What is the extent of prevalence of malnutrition among the Bengali Muslim children and mothers?
3. How maternal nutritional status is affecting the nutritional status of children?
4. Does socio-economic, demographic and lifestyle conditions have any effect on the child and maternal nutritional status?

1.9. SIGNIFICANCE OF THE PRESENT RESEARCH STUDY

The poor physical growth attainment and undernutrition are considered to be major causes of ill-health conditions among nutritionally vulnerable segments (e.g., children) of the population. Children are the worst affected individuals due to their rapid physical growth and development. Maternal nutritional status has important effect on child health, growth and development. In the field and clinical investigations, anthropometric measurements and indices (e.g., stunting, underweight, wasting or thinness) play major roles in the assessment of the physical growth pattern and development, body composition and nutritional status of an individual/ populations, mainly because the technique is widely utilized, easy-to-use, non-invasive and inexpensive in nature. Due to its immense population size, socio-economic disparities, demographic composition, illiteracy and inadequate access to health facilities the Indian populations are undernourished and underprivileged. The overall health and nutritional scenario are found to be similar in the populations of North-east, India. The present study will provide insight to understand the possible mechanism and interaction of the determinant factors (e.g., poverty, illiteracy, occupation, low socio-economic conditions, unavailability of clean drinking water, inadequate food intake, inadequate dietary knowledge and unavailability of health-care facilities) with physical growth and nutritional status (e.g., undernutrition) among children residing in rural environments. The findings of the present research study will help to identify the ethnic/population variations of physical growth and nutrition status. The outcomes of the present study may be helpful to the Government and other public health organizations to formulate the suitable health intervention strategies for the overall improvement of the physical growth pattern and nutritional status of the under study population. Further, the data of the present study will be helpful for comparison of physical growth pattern, body composition and nutritional status (e.g., undernutrition) with other populations of India, as well as with national and international data. The results will also evaluate the efficacy of ongoing the nutritional intervention programme or need of any appropriate public health strategies to ameliorate the nutritional conditions of the population concern.

CHAPTER- II:

MATERIAL AND METHOD

2.1. NATURE OF SUBJECTS AND AREA

The present study has been undertaken among rural Bengali Muslim children and their mothers residing in the Phansidewa block of Darjeeling district of North Bengal, West Bengal, India. Ethnically, the Bengali Muslim Population is a Bengali-speaking ethnic community and by religion faithful to Islam (Das Chaudhuri et al. 1993) and constitutes 20.20 million individuals or 25.30% of the total population of the state of West Bengal. The proposed study area is located under Siliguri, sub-division of Darjeeling district. The community block (Latitude 26º 34´59´´ N, Longitude 88º 22´00´´ E) covers an area of 308.65 km^2. and has a total population of 204,522 individuals (males: 103,719; females: 100,803) with the literacy rate of 41.59% (males: 51.85%; females: 30.80%)(Census 2011).The Phansidewa block has a Muslim population of 48,202 (males: 24,640; females: 23,562) (23%) individuals (Census, 2011). The region is situated near the Indo Bangladesh border region and ~35– 40 km from the sub-divisional town of Siliguri. The residents of the block have access to all the basic amenities, such as hospitals, schools, post office, markets and government offices (Mondal and Sen 2010; Sen and Mondal 2013; Debnath et al. 2018).

2.1.1. The Bengali Muslims

The Bengali Muslim constitute the largest religious minority population in West Bengal and comprises a considerable percentage of the state's population. According to the census of 2011, the Muslim population has 14.2% contribution to the total population and is the second largest religious group in India. Muslims constitute 27.10% of West Bengal's total population. West Bengal occupies the second top most position in terms of percentage of Muslim population among all the states and about 12.16% are Muslim women (Census 2011). Ethnically, the Bengali Muslim Population (BMP) is a Bengali-speaking ethnic community and by religion faithful to the Islam. They contribute a large share to the social and economic well-being of the state and of the country as a whole. In 2011, religion wise sex ratio for

Muslims in India and West Bengal was 951 females for 1000 males (Census 2011). The growth rate of population in the decade 2001-2011 was 24.6%. Work participation rate of Muslims in India was 31.3%, 47.5% and 14.1% for overall, male and female work participation (Census 2011). Forty-seven percent of Indian Muslims were aged below 20 years which was the highest among all the religious communities (Census 2011). The literacy rate in West Bengal Muslims was 57.47% (male: 64.61% and female: 49.75%). In rural areas Muslim literacy rate was about 56% compared to urban Muslims 66% (Census 2001).

Women Empowerment among Muslims

The two of the most important reform movements which have been witnessed by the nineteenth century Muslim society are the revival to Islam and the education for menand women. The most prominent Muslim social reformers of Muslim women education, girls school education and rigidity of Parda system were Sir Syed Ahmed Khan, Badru Tayabji, Haji Mohhamad Mohsin and Syed Imam. In Bengal there were many eminent women literate reformers like Sush Sundari Thakur, Sarala Devi Chowdhurani, Begum Roquiah, Khujista Akhtar Banu, Ashalata Sen, Nalini Das, SushamaSengupta, Amina Tyabji, and Begum Abdullah who improved the social status of women and made significant contribution in empowerment for the Muslim women (Roy 2020). Only after independence the socio-economic situation of Muslim women has come to light of the development authorities, academicians, and policy makers of India. It has been observed that the Muslim women are the most deprived group of the Indian population (Roy 2020). Due to various reasons the gender disparity and marginalization still exist within the Muslim society (Roy 2020).

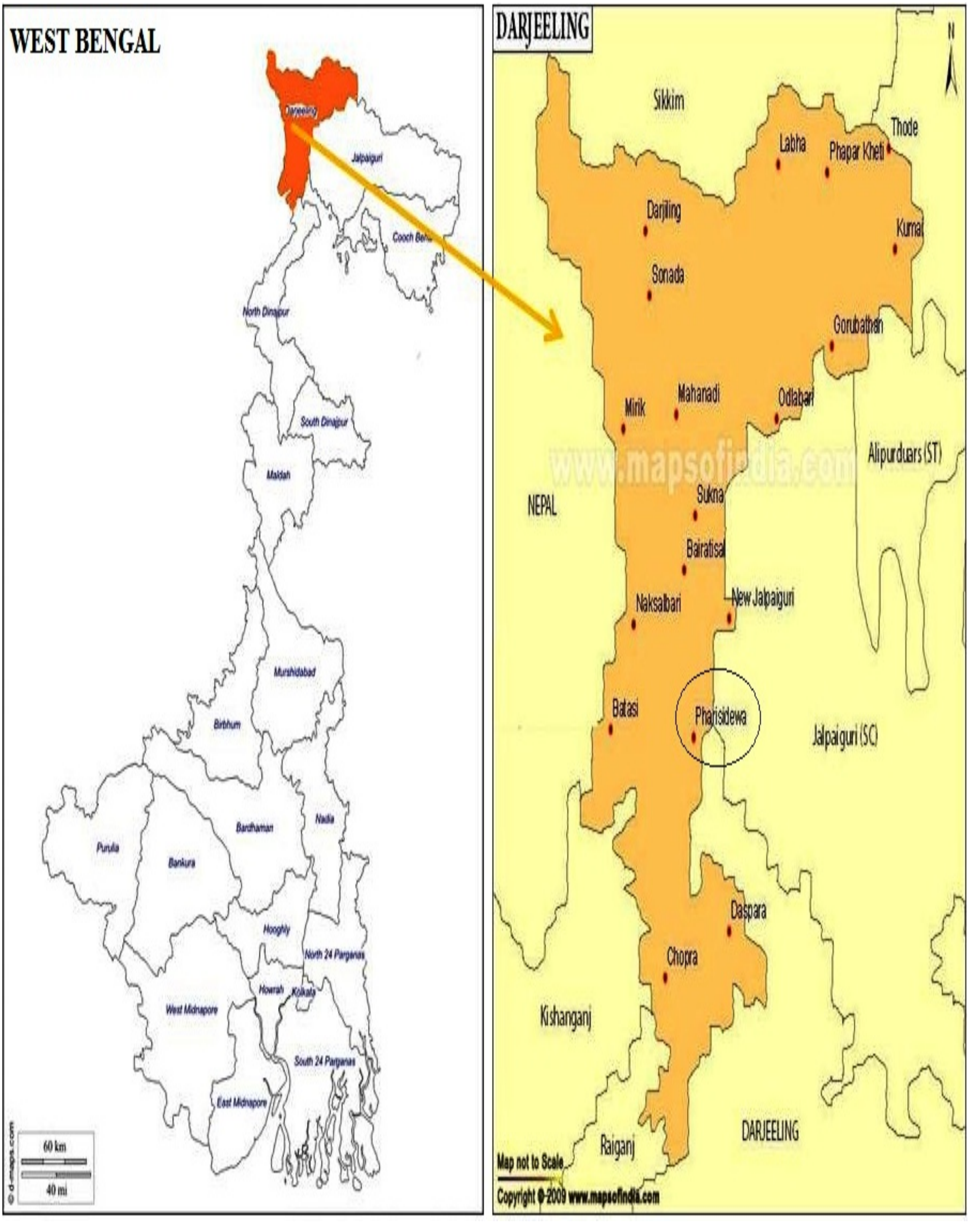

Figure 2.1. Map showing the location of study area Phansidewa Block in Darjeeling district of West Bengal, India

2.2. SAMPLING

The present cross-sectional study was carried out among 612 Bengali Muslim children (boys: 325; girls: 287) aged 1-5 years and their mothers (N=612) living in Phansidewa Block of the Darjeeling district of West Bengal, India. The minimum number of individuals required for reliably estimating the prevalence of undernutrition has calculated following the standard sample size estimation method of Lwanga and Lemeshow (1991). In this method, the anticipated population proportion of 50%, absolute precision of 5% and confidence interval of 95% are taken into consideration. The minimum sample size thus estimated was 384 children and their mothers. Subsequently the individuals were selected using a stratified random sampling method.

The children were selected using the stratified random sampling method. The study was based on the representative sample of children across the Phansidewa block. Initially 750 children (boys: 325; girls: 287) in the age group of 1–5 years were identified so as to participate in the study. Initially, 12 Bengali Muslim dominated villages were identified and listed from the official records of the respective Block and Gram Panchayets. These villages were physically visited to ascertain the actual existence of Muslim individuals. The villages were surveyed to explore the number of Bengali Muslim families' in each village. Special attention was given to those villages which were convenient for data collection, subjects' availability and easy accessibility, so that the actual sample size of the present study could be met. Finally the 10 villages mentioned above were selected for the study. The villages were situated at a distance of about 15 km to 20 km from the Phansidewa Block office.

Parents of the children were informed about the objectives of the study prior to data collection. An informed consent was obtained from them and participation in the study was purely voluntary. The study was conducted in accordance with the ethical guidelines for human experiments, as laid down in the Helsinki Declaration of 2000 (Touitou et al. 2004).

The selected villages were surveyed to collect the data on anthropometric, demographic, socio-economic and lifestyle related factors. The selections of the Bengali Muslim children were done based on the surnames and cultural and religious practices. The ethnicity was subsequently verified from the official records of the block and Gram Panchayets. The ICDS centers were also surveyed for identifying the children and their mothers. Verbal consent of the mothers has been taken for the collection of anthropometric measurements of the children and the mothers. Age of the children and mothers was collected from available official records, birth certificates, polio cards and voter identity cards.

2.3. DEMOGRAPHIC AND SOCIO-ECONOMIC PROFILE

Demographic and socio-economic data were collected from mothers using a pre-structured schedule. The data to be recorded are age of the child, birth orderof the child, number of sibsof the child, family size, age of mother, age at marriage and age at menarche of mother, marital status of mother, education of mother, education of father, occupational of mother, occupation of father, number of children of the mother, family type, water supply, electricity facility, toilet facility, number of rooms, monthly income, monthly expenditure and disease prevalence of children and mothers. These data were be collected by interviewing the mothers and guardians of the children by the household visits. The socio-economic status of the subjects was assessed by utilizing the modified scale of Kuppuswami (Singh et al., 2007). Relevant data on family income, education and nature of occupation were used to determine the socio-economic status of the children. The different variables used for measuring the SES include family income, education, and nature of occupation. These socio-economic variables were classified arbitrarily into different groups or categories with a view to understanding their influence on demographic characteristics i.e. growth, health, and nutritional status of the studied population. The scale has been used in a number of studies dealing with assessment of nutritional status (e.g., Sen and Mondal 2012; Tigga et al. 2015; Debnath et al. 2018).

Table 2.1: Kuppuswami socio-economic scale proposed by Mishra and Singh (2003) and Kumar et al. (2007)

(A) Education	**Score**
1. Professional or Honours	7
2. Graduate or post graduate	6
3. Intermediate or post high school diploma	5
4. High school certificate	4
5. Middle school certificate	3
6. Primary school certificate	2
7. Illiterate	1
(B) Occupation	**Score**
1. Professional	10
2. Semi-professional	6
3. Clerical,shop owner and farmer	5
4. Skilled worker	4
5. Semi-skilled worker	3
6. Unskilled worker	2
7. Unemployment	1
(C) Income per month (in Rs.) (as modified by Kumar et al. 2007)	**Score**
1. 19,575>	12
2. 9,788-19,574	10
3. 7,323-9,787	6

4. 4,894-7,322	4
5. 2,936-4,893	3
6. 980-2,935	2
7. <979	1
Socio-economic status	**Total score**
Upper (I)	**26-29**
Upper-middle (II)	**16-25**
Lower-middle (III) (Middle)	**11-15**
Upper lower (Lower)	**5-10**
Lower	**<5**

2.4. ANTHROPOMETRIC MEASUREMENTS RECORDED

Anthropometric measurements were collected using the standard procedures of anthropometric data collection (Weiner and Lourie 1981; Hall et al. 2007). The anthropometric measurements of children of weight, height, mid-upper arm circumference (MUAC), head circumference (HdC), triceps skinfold (TSF) and Sub-scapular skinfold (SSF) were collected to assess the body composition and nutritional status of children. Collected anthropometric measurements of mothers were weight, height, mid-upper arm circumference (MUAC), hip circumference (HC), waist circumference (WC), biceps skinfold (BSF), triceps skinfold (TSF), sub-scapular skinfold (SSF) and supra-iliac skinfold (SISF) thickness to assess the body composition and nutritional status of mothers. The skinfold measurements were taken using Holtain skinfold caliper.

2.5. COLLECTION OF ANTHROPOMETRIC DATA

1. Height

Height was taken with the help of the anthropometer rod to the nearest 0.1 cm. The subjects were made to stand on a horizontal platform with both heels together. The head was hold stretched upward to the fullest extent in the Frankfurt horizontal plane. The horizontal arm of the anthropometer was brought down lightly to touch the vertex and the measurement was recorded in linear distance from floor to vertex.

2. Weight

Body weight of the subjects was recorded using a portable weighing scale. The children/individuals were barefooted and wearing minimum clothing at the time of measurement. Body weight was recorded to the nearest 0.5 kg. The weighing scale was cross-checked with known weight after regular interval and the scale needle was set zero before obtaining the data.

3. Mid-Upper Arm Circumference (MUAC)

The mid-upper arm circumference (MUAC) was measured on the left arm of each individual with the arm hanging relaxed. It was measured midway between tip of the acromion and the olecranon process. The measurement points were marked by a marker and the measurements taken with the help of a non-stretchable plastic coated measuring tape to the nearest 1mm.The measurement were recorded in such a way that the tape was touching the skin but not compressing the tissue. The sometime repeated measurements were taken using the same procedures to validate/check the values obtained in first measurement.

4. Head Circumference (HdC)

Brain size and head circumference can be affected with under-nutrition, especially in case of protein energy malnutrition. The greatest circumference is to be measured for head circumference.

5. Hip circumference (HC)

HC was measured as the maximum circumference or elevation of the buttocksie, at the level of the greater trochanters with the individual standing erect with his feet placed together. Two consecutive readings were recorded to the nearest of 0.1 cm using a non-stretchable measuring tape without compressing the skin.

6. Waist circumference (WC)

Waist measurement can be used to assess central obesity. Waist circumference was measured at the level halfway between the iliac crest and the coastal margin in the mid-axillary line after exhaling with the subject in the standing position. Two consecutive readings were recorded to the nearest of 0.1 cm using a non-stretchable measuring tape without compressing the skin.

7. Biceps skin fold (BSF)

BSF was recorded in the middle of the upper arm between the acromian and the olecranon process at the level of nipple line. The elbow was placed at right angles to the middle of upper arm and marked. The skinfold was pinched vertically and lifted off the muscle about 1 cm above the marked line. The measurement was then recorded.

8. Triceps Skin Fold (TSF)

The triceps skinfold (TSF) site is on the posterior aspect of the right arm, over the TSF muscles midway between the lateral projection of the acromion process of the scapula and inferior margin of the Olecranon process of the ulna. The midpoint between the acromion and olecranon processes is marked along the lateral side of the arm with the elbow flexed 90 degrees. The subject's arm is now hanging loosely at the side with the palm of the hand facing anterior to posteriors determine the posterior midline of the upper arm at the same level as the previously marked midpoint. The skinfold is now grasped with the thumb and index finger of the left hand about 1cm proximal to the skinfold site. The caliper is placed on the site where the sides of the skinfold are approximately parallel and 1cm distal to where the skinfold is grasped. The caliper is positioned so that it can be read easily. The measurement is obtained about 4 seconds after placing the caliper tips on the skinfold.

9. Sub-Scapular Skinfold (SSF)

The sub-scapular skinfold (SSF) is 1cm below the lowest or inferior angle of the scapula. The long axis of the skinfold is on a 45 degree angle directed down and to the right side. The site can be located by gently feeling for the inferior angle of the scapula or by having the subject place his or her right arm behind the back sides. The skin is grasped 1cm above and medial to the site along the axis. The caliper is held in the right hand, perpendicular to the long axis of the skinfold and with the caliper's dial facing up and easily readable. The dial is read approximately 4 seconds after the pressure from the measurer's hand has been released on the lever arm of the caliper. The skinfolds measurements were taken with great care and special care was given to identify the landmarks of the measurements. The skinfolds measurements were measured very carefully by separating the muscle and fat folds among children. Two repeated measurements were taken on each subject and mean of the measurements were recorded in order avoid any measurement errors.

10. Supra-Iliac Skinfold (SISF)

SISF was recorded on the superiority portion of the iliac crest directly on the mid-auxiliary line slanting and directly on top of the iliac crest. The skinfold was pinched vertically and the measurement taken about l cm above the marked point.

2.6. CALCULATION OF TECHNICAL ERROR MEASUREMENT (TEM) AND CALCULATION OF SYSTEMATIC ERROR MEASUREMENT

The technical error measurement (TEM) was calculated following the method of Ulijaszek and Kerr (1999) to determine the accuracy of the measurements. The intra-observer TEM were observed to be within the cut-offs values of 0.95 as suggested by Ulijaszek and

Kerr (1999), hence the measurements recorded in the present study was considered to be reliable and reproducible. The TEM was calculated using the following equations:

TEM=√(∑D2/2N), D=Difference between the measurements, N=number of individuals. The co-efficient of reliability (R) was subsequently calculated from TEM using the following equation: R={1-(TEM)^2/SD^2}, SD=Standard deviation of the measurements.

For calculating TEM, height, weight, MUAC, HdC, TSF and SSF were recorded from 50 children aged 1-5 years other than those selected for the investigation. High values of R (>0.95) were recorded for height and weight. The values were observed being within the acceptable limits of 0.95 as recommended by Ulijaszek and Kerr (1999). Hence, the measurements recorded were reliable and reproducible. Systematic errors are errors that affect the accuracy of measurements. Systematic errors are 'one-sided' errors, because, in the absence of other types of errors, repeated measurements yield results that differ from the true or accepted value by the same amount. The accuracy of measurements subject to systematic errors cannot be improved by repeating those measurements. The systematic errors cannot easily be analyzed by statistical analysis. Systematic errors can be difficult to detect, but once detected can be reduced only by refining the measurement method or technique. Common sources of systematic errors are faulty calibration of measuring instruments, poorly maintained instruments or faulty reading of instruments (Harris and Smith 2008).

Table 2.2: Table showing the results of Technical Errors of measurement of the anthropometric measurements recorded in the present study

Name of the Measurement	Intra--observer	
	TEM	Coefficient of Reliability
Height	**0.070**	**0.995**

Weight	**0.107**	**0.995**
MUAC	**0.077**	**0.997**
HdC	**0.129**	**0.998**
TSF	**0.125**	**0.999**
SSF	**0.015**	**0.997**

2.7. CALCULATION OF ANTHROPOMETRIC INDICES FOR ASSESSMENT OF NUTRITIONAL STATUS AND BODY COMPOSITION OF CHILDREN AND MOTHERS

1. Body Mass Index (BMI)

The body mass index (BMI) was calculated using the standard equation of WHOM (1995). The BMI is widely used index to study the physical growth pattern and nutritional status as recommended by WHO (1995; 2007).

BMI (kg/m^2) =Weight (kg)/$Height^2$ (m^2)

2. Percent of Body Fat (PBF)

The percent of body fat following equations of Slaughter et al. (1988) were used to estimate the percent of body fat (PBF) of children:

Boys = 1.21 (TSF +SSF) − 0.008 $(TSF+SSF)^2$ − 1.7

Girls =1.33 (TSF + SSF) − 0.013 $(TSF+SSF)^2$ − 2.5

The present study evaluated PBF content in order to evaluate the body composition characteristics of rural school-going children using the equation of Slaughter et al. (1988). Furthermore, several studies have assessed body composition characteristics in children utilizing these equations for estimation of PBF among children from both non-Indian

(Musaiger and Gregory 2000; Gültekin et al. 2005; Ghosh et al. 2009; Laurson et al. 2011; Aguirre et al. 2015; Noradilah et al. 2016; González-Agüero et al. 2017) and Indian ethnic populations (Mukhopadhyay et al. 2005; Chowdhury et al. 2007; Sen and Mondal 2013; Debnath et al. 2018; Sharma and Mondal2018).

The following standard equation of Siri (1956) was used to assess PBF for Bengali Muslim Mothers in the present study.

PBF = (4.95/ Body density - 4.50) x 100

The body density values of mothers after calculating them from the Durnin and Womersely equations (1974) were used in the PBF equations. Several researchers have utilized Siri 's equation in order to estimate the bodv fat content in different Indian ethnic populations (Dudeja et al. 2001; Das and Bose 2006; Chakrabarty and Bharati 2010).

3. Body Density

The body density of the Bengali Muslim Mothers was calculated in order to assess PBF. The sum of four skinfold thickness (e.g ., BSF, TSF, SSF, SISF) were also utilized for calculation of body density. Sex specific standard equations of Durnin and Womersely(1974) were utilized for the purpose. These equations have been validated in different Indian populations by Dudeja et al. (2001), Das and Bose (2006) and Chakraborty and Bharati (2010). The following equation of Dumin and Womersely (1974) were utilized to assess the body density of mothers:

Female body density = 1.1567-0.0717 X $\log_{10}$ (BSF+TSF+SSF+SISF)

4. Fat Mass (FM) and Fat Free Mass (FFM)

The body mass consists of both fat mass (FM) and fat free mass (FFM). The standard equations of Van Itallie (1990) and Eckhardt et al. (2003) have been utilized to assess the amount of FM and FFM among children and mothers. Several researchers have utilized these equations to assess the FM and FFM among different Indian populations (Bhadra et al. 2005a;

Choudhury et al. 2007; Das and Bose. 2006; Debnath et al. 2018). The equations are as follows:

Fat Mass (FM) (kg)= (PBF/100) X Weight (kg)

Fat Free Mass (FFM) (kg)= Weight (kg)/ FM (kg)

5. **Fat Mass Index (FMI) and Fat Free Mass Index (FFMI)**

The indices of fat mass index (FMI) and fat free mass index (FFMI) were calculated from the equations of Van Itallie et al. (1990). The indices are given below:

Fat Mass Index (FM) (kg/m^2) = FM/ $Height^2$ (m^2)

Fat Free Mass Index (FFMI) (kg/m^2) = FFMI/ $Height^2$ (m^2)

6. **Upper Arm Composition**

The upper arm compositions of the children were evaluated using the anthropometric measure of TSF and MUAC by following the standard equations (Frisancho 1974, 1989): The upper arm composition of the individuals was evaluated in terms of total Upper Arm Area (TUA), Upper Arm Muscle Area (UMA), Upper Arm Fat Area (UFA) and Arm Fat Index (AFI).

Following upper-arm composition variables were calculated:

Total upper arm area (TUA cm^2) = $(MUAC)^2/4\pi$

Upper arm muscle area (UMA cm^2) = $[MUAC-(TSF\times\pi)^2]/(4\pi)$

Upper arm fat area (UFA) (cm^2) = $\{(MUAC)^2/(4\pi)\}-UMA$

Arm Fat Index (AFI) = $UFA/\{(MUAC)^2/(4\times\pi)\}\times 100$

7. **Waist circumference (WC)**

Waist circumference cut-offs were taken as >90 for males and >80 for females to define overweight (WHO 2000).

Table 2.3: World Health Organization cut-off points and risk of metabolic complications

Indicator	Cut-off points	Risk of metabolic complications
Waist circumference	>94 cm (M); >80 cm (W)	Increased
Waist circumference	>102 cm (M); >88 cm (W)	Substantially increased
Waist–hip ratio	≥0.90 cm (M); ≥0.85 cm (W)	Substantially increased

M, men; W, women

8. Waist-Hip Ratio (WHR)

The WHR has been calculated using the measurements of WC and HC using the following equation:

WHR = Waist circumference (cm) / Hip circumference (cm).

A high WHR is defined as >0.9 in males and >0.8 in females by Webb (2002) and Huxley et al. (2008). These cutoffs are used to assess the amount or' higher regional adiposity among the individuals.

9. Waist-height ratio (WHtR)

The WHtR has been calculated using the measurements of WC and height using the following equation:

WHR = Waist circumference (cm) / height (cm).

For WHtR, the cut-offs used was 0.5 (<0.5; ≥0.50) for both sexes (Hsieh and Muto 2004).

10. Sum of four skinfold (Σ4SKF)

The skinfold measurement can be utilized to assess of fat proportion and fat distribution in an individual or population so as to assess body composition. The sum of four skinfold thicknesses (Σ4SKF) has been calculated to assess the fat proportion among Bengali Muslim mothers.

Sum of four skinfold (Σ4SKF)= BSF+ TSF+ SSF+ SISF

For **Σ**4SKF cut off is>50 nm for both sexes (Dudeja et al. 2001)

11. BODY ADIPOSITY INDEX (BAI)

The body adiposity index (BAI) is used as a tool to evaluate body adiposity. BAI can be calculated from the hip circumference and height and it can be used to assess the body fat percentage in adults (Bergman et al. 2011). The following formula has been used to calculate BAI among Bengali Muslim mothers.

BAI= {(hip circumference)/[(height^1.5)- 18]}

2.8. CALCULATION OF ANTHROPOMETRIC VARIABLES FOR PHYSICAL GROWTH ASSESSMENT AND NUTRITIONAL STATUS OF CHILDREN

Growth references are very important tools for determining the nutritional status in a population and are valuable indicators of attained size and physical growth in children at each specific age. A variety of growth references were developed and used in the United States since the early 1900s. Most of the earlier references have considerable limitations, including lack of coverage for infants and pre-school children with limited representation of ethnic, genetic, socio-economic, environmental, and geographic variability. The Centre for Disease Control and Prevention (CDC 2000) Growth Charts released in 2000 is the updated and revised version of the National Centre for Health Statistics (NCHS) growth charts (WHO, 1995).The 2000 CDC growth charts consists of a set of charts for infants, births to 36 months of age and a set of charts for children and adolescents from ages 2 to 20 years. The charts for infants includes sex-specific smoothed percentile curves for weight-for-age, recumbent length-for-age, head circumference-for-age and weight-for-recumbent length, the charts for children and adolescents include weight-for-age, stature-for-age and body mass index (BMI)-for-age charts represents a new tool that can be used by health care providers for the early identification of children who are at risk for becoming overweight at older ages. The CDC (2000) growth charts also include weight-for-stature charts for statures ranging from 77 to 121 cm, primarily intended for use among children from ages 2 to 5 years (CDC 2000). There are three widely known and used versions of the 1978 WHO/NCHS Growth references (for children upto age 10), WHO Growth References (for children and adolescents upto age 19), and the 2006 WHO Growth standards (for pre-school children, under 6 years of age. Most of the earlier versions are based on the national survey data collected in the 1960s and 1970s.These NCHS Growth Charts included anthropometric measurements such as weight –for-height, weight-for-age, height-for-age, and head circumference –for-age. They were developed based on several national surveys (namely NHAES II, NHAES III, and NHANES I) and a local study for infants. In 1978, the WHO/CDC produced a normalized version of the US CDC/NCHS growth curves, showing Z-scores instead of absolute anthropometric values. It was called the 1978 WHO/NCHS Growth References, and has been widely used all over the world since then. In 1995, a WHO Expert Committee reviewed existing growth references and research findings, and then re-endorsed the use of the 1978 WHO/NCHS Growth Charts. The 2006 WHO Growth Standards include anthropometric indicators such as length/height –for-age, weight –for-age, weight-for-length/height, BMI-for-age, head circumference-for-age, arm circumference –for-age, Sub scapular skin fold-for-age, and triceps skin fold-for-age. Recumbent length-for-age was used for indicators of stature from birth to age of 24 months, while standing height –for-age from 2 to 5 years old. Due to differential measurements of body length and body height, a 0.7cm in length at 24 –month –old was observed. To address this issue, weight-for-length for 0-2 year –old children and weight-for-height for 2-5 year –

old children were presented on separate charts. The WHO provides growth charts and tables of percentiles and Z-Scores, separately for girls and boys.

2.9. CALCULATION OF PHYSICAL GROWTH ASSESSMENT VARIABLES OF CHILDREN

The anthropometric measures of height, weight and BMI was used to respect to age were used to calculate the Z-score values in order to assess the physical growth. A Z-score is a measure of how many standard deviations below or above the population mean a raw score is. A Z-score is also known as standard score and it can be placed on a normal distribution curve. Z-score range from -3 standard deviation (which would fall to the far left of the normal distribution curve) to +3 standard deviation (which would fall to the right of the normal distribution curve). WHO (2006, 2007) recently proposed growth references was used to calculate the age-sex specific z-score values. L, M and S method was used to calculate the age-sex specific Z-score values among children. A child with Z-score of <-2SD was considered to be undernourished in any nutritional status indicators as described below:

1. Height-For-Age Z-Score (HAZ)

A height-for-age Z-score (HAZ) is the number of standard deviation of the actual height of a child from the median height of the children of his/her age as determined from the standard sample. This is prefixed by a positive sign (+) or a negative sign (-) depending on whether the child's actual height is more than the median height or less than the median weight. When actual height of a child is exactly equal to the median, the resultant HAZ is 0 (zero).

2. Weight-For-Age Z-Score (WAZ)

It is the number of standard deviations of the actual weight of a child from the median weight of the child of his/her age as determined from the standard sample. This is prefixed by a positive sign (+) or a negative sign (-) depending on whether the child's actual weight is more than the median weight or less than the median weight. When the actual weight of a child is exactly equal to the median, the resultant WAZ is 0 (zero).

3. Weight-For-Height Z-Score (WHZ)

A weight-for-height Z-score (WHZ) is the number of standard deviation of the actual weight of a child from the median weight of the children of his/her age as determined from the standard sample. This is prefixed by a positive sign (+) or a negative sign (-) depending on whether the child's actual weight is more than the median weight or less than the median weight. When actual weight of a child is exactly equal to the median, the resultant HAZ is 0 (zero).

4. BMI-For-Age Z-Score (BMIAZ)

A BMI-for-age Z-score (BMIAZ) is the number of standard deviation of the actual height of a child from the median BMI of the children of his/her age as determined from the standard sample. This is prefixed by a positive (+) sign or a negative sign (+) depending on whether the child's actual BMI is more than the median BMI or less than the median BMI. When actual BMI of a child is exactly equal to the median, the resultant BMI is zero.

5. Head Circumference-For-Age Z-Score (HdCAZ)

A head circumference-for-age Z-score (HdCAZ) is the number of standard deviation of the actual height of a child from the median height of the children of his/her age as determined from the standard sample. This is prefixed by a positive sign (+) or a negative sign (-) depending on whether the child's actual height is more than the median height or less than the median weight. When actual height of a child is exactly equal to the median, the resultant HdCAZ is 0 (zero).

2.10. Assessment of Nutritional Status of Children

The anthropometric indices of stunting, underweight, wasting and thinness were widely used to assess the undernutrition in children and adolescents. The anthropometric indices reflect certain distinct biological process and their use is necessary for determining appropriate nutritional interventions (WHO 1995, 2006, 2007). The indices of low height-for-age (i.e., stunting) and low weight-for-height (i.e., wasting) reflects long-term chronic and short-term acute undernutrition among children, respectively. The low weight-for age (i.e., underweight) or low BMI-for-age (i.e., thinness) were used to assess the magnitude in terms of composite measure to assess the both the chronic and acute undernutrition. The interpretation of the four indices involves a comparison with an international reference population to determine undernutrition as recommended by the WHO (WHO, 1995, 2006, 2007). The justification for the use of a reference population is the empirical finding that well-nourished children in all communities follow very similar growth patterns (de Onis et al., 2006). The Nutrition Foundation of India had also advocated the use of the WHO standard to be applied among Indian children. Hence, the reference values from the WHO (WHO 1995, 2006, 2007) will be used in the course to calculate the magnitude of undernutrition among children. Recently, WHO (2006, 2007) has recommended low BMI-for-age (Thinness) to assess the nutritional status of children. To determine the nutritional status of children, the WHO has recommended the use of Z-score indicators. Children with a Z-score value below –2 for any indices are considered to be undernourished (WHO, 2006, 2007). Thus, boys and girls with Z-score values of <–2 of HAZ, WAZ, BMIAZ, WHZ were classified as suffering from stunting, underweight, thinness, wasting, respectively. The nutritional status of the children was assessed using the conventional anthropometric nutritional status of stunting (low height-for-age), underweight (low height-for-age), thinness (low BMI-for-age), wasting (low weight-for-height) and low Head circumference-for-age (low HdC-for-age) as recommended by the WHO (1995, 2007).

Furthermore, the severity of undernutrition was assessed among children by three conventional anthropometric measures of stunting, underweight and wasting was classified according to the proposed classifications of public health problem (WHO 1995). The proposed classification to assess the severity of public health problem of undernutrition based on the percentages among the children is depicted in Table 2.2.

Table 2.4: Classification of assessing severity of public health problem of undernutrition based on the percentages among the children.

Index	Low (%)	Medium (%)	High (%)	Very High (%)
Stunting	< 20	20-29	30-39	≥ 40
Underweight	<10	10-19	20-29	≥30
Wasting	< 5	5-9	10-14	≥15

Source: WHO (1995)

The different nutritional indices used to assess the undernutrition among children are depicted in Table 2.3.

Table 2.5: Recommended anthropometric measures/indices used to assess the prevalence of undernutrition status

Children	Anthropometric/ Nutritional variables	Cut-off/ Reference	Undernutrition categories/measures
Children (0-5 years)	**Height-for-age**	<−2SD	Stunting
	Weight-for-age	<−2SD	Underweight
	BMI-for-age	<−2SD	Thinness
	Weight-for-height	<−2SD	Wasting
	Head circumference-for-age	<−2SD	Low-Hdc-for-age

Source: WHO (1995, 2006, 2007)

2.11. Assessment of Nutritional Status of Mothers

Nutritional status has been assessed in terms of BMI. The BMI was calculated using the following standard equation of WHO (WHO 1995):

BMI= Weight/Height² (kg/m²)

The BMI cut-off points proposed by WHO (2004) for Asian Indians have been utilized for the assessment of under-nutrition, overweight and obesity (Table 2.5).

2.6: Proposed classification of BMI in Asian Adults (WHO 2004)

Classification		BMI (kg/m^2)	Risk of co-morbidities
Underweight		< 18.5	Low (but increased risk of other clinical problems)
Normal range		18.5-22.9	Average
Overweight		23-24.9	Increased
Obese	**Obese I**	25-29.9	Moderate
	Obese II	≥ 30	Severe

Nutritional status of mothers has also been assessed using sex specific MUAC cut-off for females. Value of MUAC<22 cm indicates undernutrition as proposed by James et al. (1994).

2.12. Statistical Analysis

The data of the present study were statistically analyzed utilizing the Statistical Package for Social Sciences (SPSS, Chicago IL, version 16.0). The statistical constants include descriptive statistics (mean and standard deviation), Homogeneity of variance (i.e., Levene statistics), One-way analysis of variance (ANOVA) and chi-square analysis was done to analyze data and test the study hypothesis. The descriptive statistics (mean and standard deviation) was used to describe the anthropometric measurements of height, weight, MUAC, TSF, SSF, PBF, FM, FFM, FMI, FFMI, TUA, UMA, UFA, AFI, UME, UFE, BMI, PBF-BMI Ratio among children. The sex specific mean difference in anthropometric measures and variables was assessed using ANOVA between boys and girls. The overall and age-sex specific homogeneity of variance (Levene statistics) was used to determine the probability distribution of the continuous anthropometric data. The one-way ANOVA was done to determine the age specific mean different in anthropometric measures measure among boys and girls. Two-way ANOVA was performed for the continuous anthropometric variables to assess the combined effect of age and sexes. Pearson correlation coefficient analysis was done to ascertain the relationships between the anthropometric variables among boys and girls, separately. The derived nutritional indices of HAZ, WAZ, WHZ, BMIAZ and HdCAZ were also presented using the descriptive statistics among children. Similarly, age-sex specific mean differences were assessed using ANOVA among children. The prevalence of undernutrition status in different nutritional indices was depicted in terms of frequency and percentages among boys and girls. Chi-square (X^2) analysis was utilized to assess the differences in the nutritional indices between and within communities and between sexes in the different nutritional categories of stunting, underweight, thinness and wasting. The Yates correction term was taken into consideration in the case of chi-square tests where the cells possessed less than five individuals. This correction term adds to the accuracy of X^2 determinations when the numbers of classes are small. Binary logistic regression and multinomial logistic regression analysis have been performed for assessing the association of socio-economic demographic and lifestyle variables with the nutritional status of children and mothers. All the differences were considered to be statistically significant at $p < 0.05$ and $p < 0.01$ level.

CHAPTER- III:

RESULTS

3.1. Demographic, Socio-Economic and Lifestyle Related Variables among the Bengali Muslim Children and Mothers

3.1.1. Population Size

The age and sex distribution of Bengali Muslim children were depicted in Table 3.1. The results showed that 53.10% were boys and 46.90% were girls (Figure 3.1). The overall age group distribution showed that 38.40% and 61.60% of children were in 1-2 years and 3-5 years age group (Figure 3.2). The age and sex specific distribution showed in Figure 3.3.

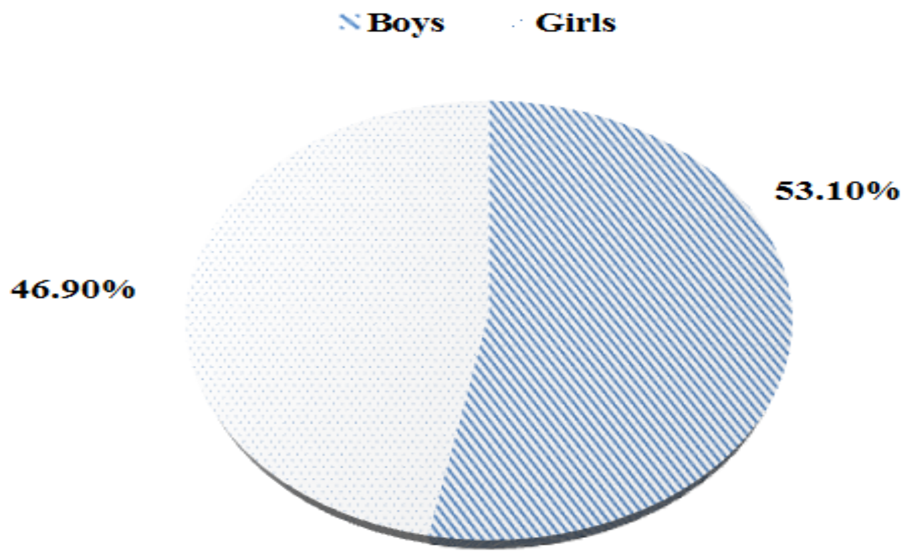

Figure 3.1. Pie chart showing sex specific distribution of Bengali Muslim boys and girls

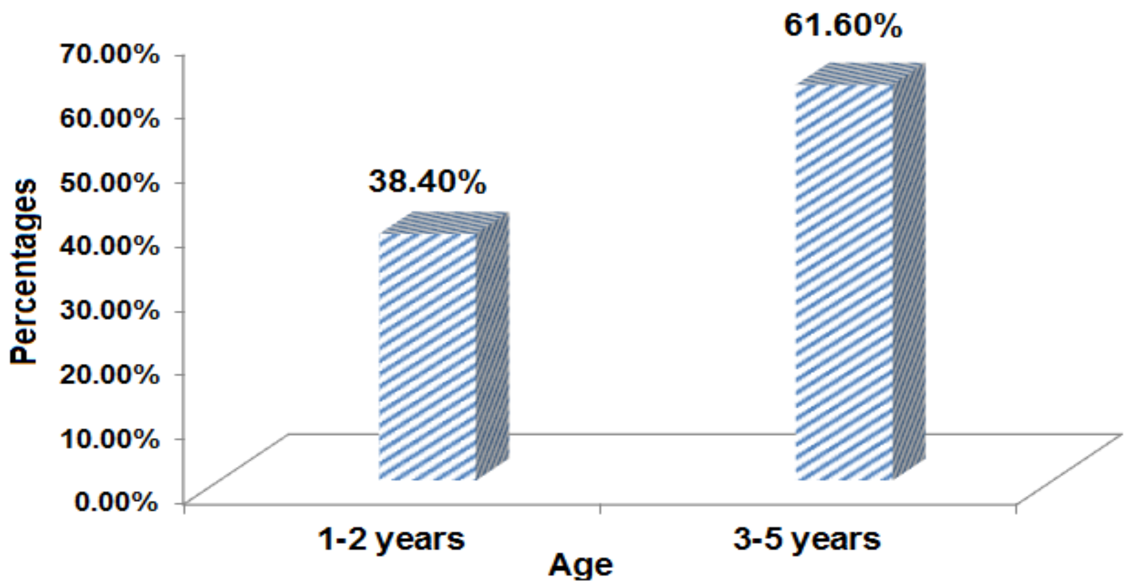

Figure 3.2. Bar diagram showing the age distribution of children

Figure 3.3. Bar diagram showing age and sex specific distribution of children

3.1.2. Mothers age

Age specific distribution of Bengali Muslim mothers was depicted in Table 3.1 and Figure 3.4. Results showed that 35.62%, 47.06% and 17.32% of Bengali Muslim mothers were in the age groups of 20-24 years, 25-29 years and 30-34 years (Figure 3.4).

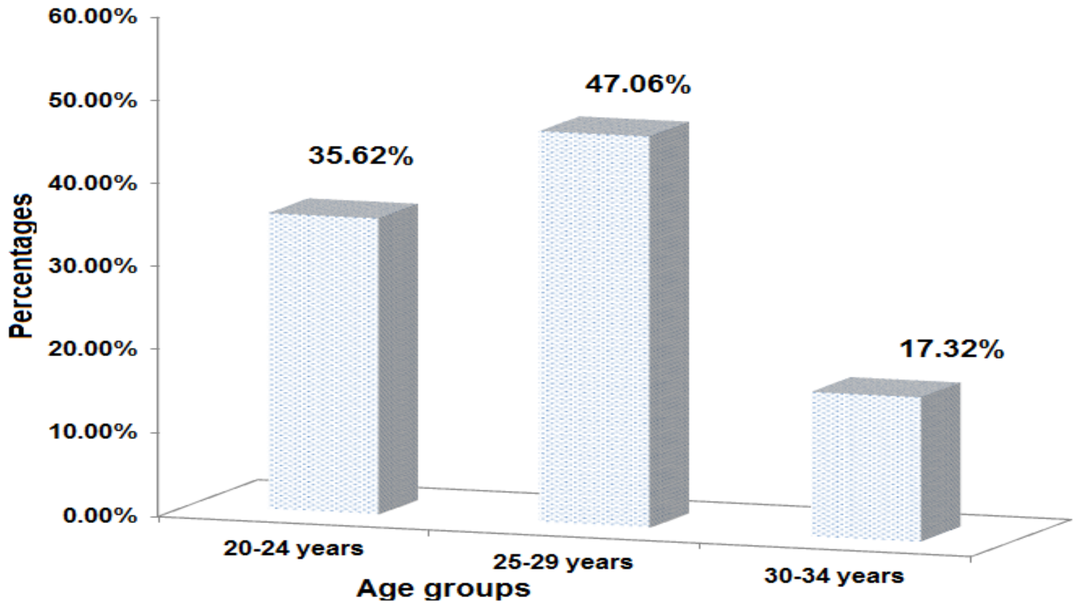

Figure 3.4. Bar diagram showing age specific distribution of Bengali Muslim mothers

3.1.3. Mothers age at Menarche

Age specific distribution of age at menarche of Bengali Muslim mothers was depicted in Table 3.1 and Figure 3.5. Results showed that 53.43% mothers have at menarche between 9 years to 12 years and 46.57% mothers have age at menarche at 13 years and above (Figure 3.5).

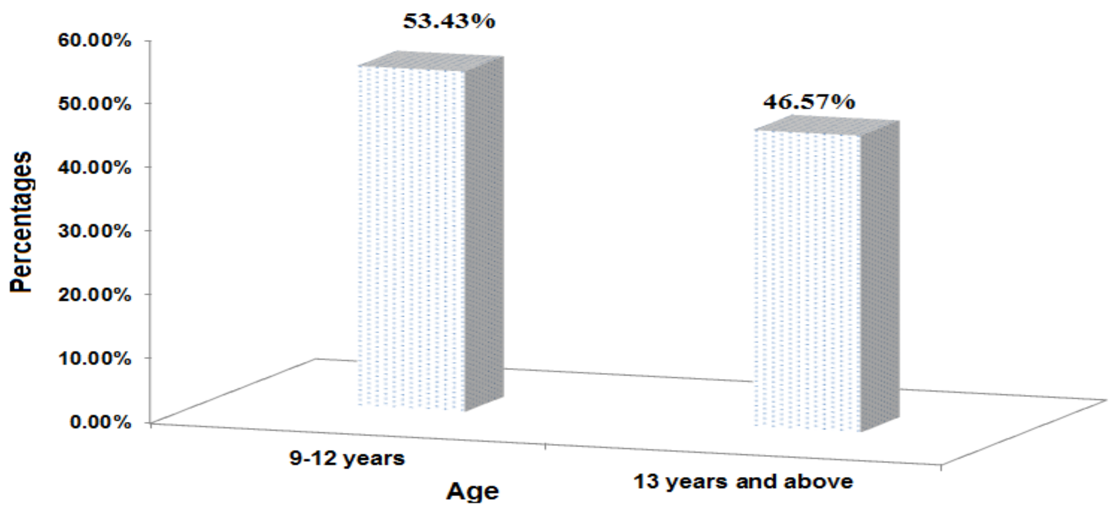

Figure 3.5. Bar diagram showing distribution of mother's at menarche

3.1.4. Mothers age at Marriage

Distribution of mother's age at marriage was depicted in Table 3.1 and Figure 3.6. The results showed that 41.83% of mothers have age at marriage upto 17 years of age and 58.17% of mothers have age at marriage 18 years and above (Figure 3.6).

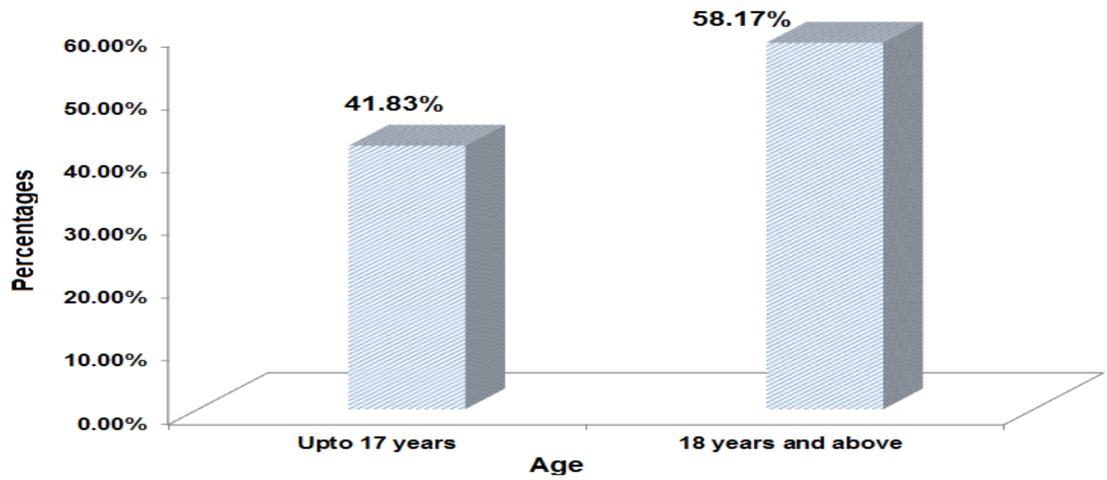

Figure 3.6. Bar diagram showing the distribution of mother's age at marriage

3.1.5. Mothers age at First Pregnancy

Mother's age at first pregnancy was depicted in Table 3.1 and Figure 3.7. Results showed that 42.81% mothers have age at first pregnancy upto 18 years of age and 57.19% mothers have age at first pregnancy at 19 years or above age group (Figure 3.7).

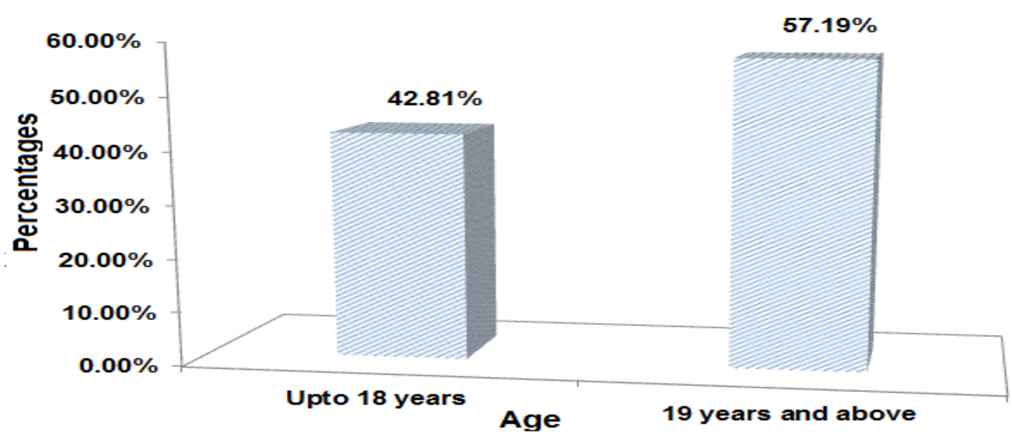

Figure 3.7. Bar diagram showing the distribution of mother's age at first pregnancy

3.1.6. Family Size

Distribution of family has been depicted in Table 3.1 and Figure 3.8. Results showed that 52.29% children have family size upto 4 members and 47.71% children have family size 5 and above (Figure 3.8)

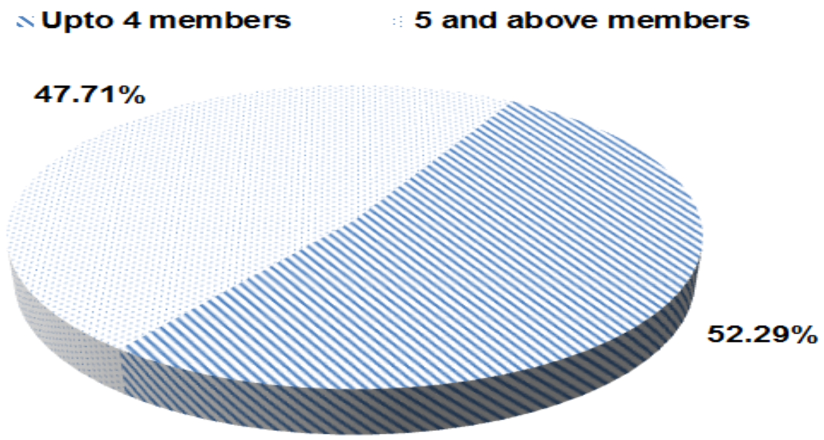

Figure 3.8. Pie chart showing the overall distribution of family size

3.1.7. Family Type

Distribution of family type has been depicted in Table 3.1 and Figure 3.9. Results have showed that 71.08% families were nuclear and 28.92% families were in the category of extended, joint and broken (Figure 3.9).

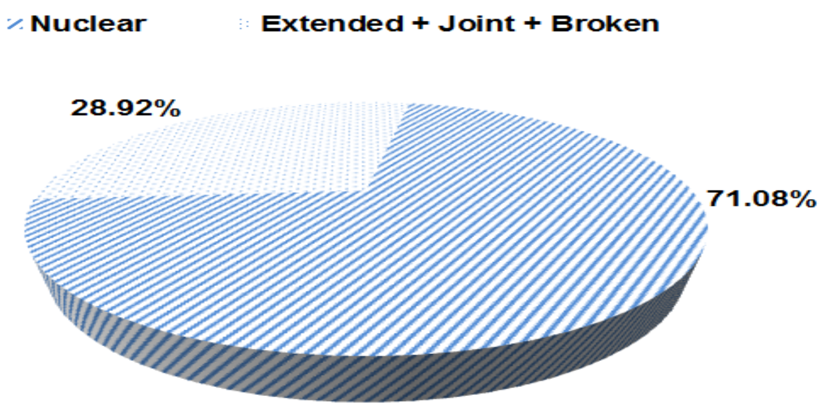

Figure 3.9. Pie chart showing the overall distribution of family type

3.1.8. Earning Head

Distribution of earning head in the families of Bengali Muslim children was depicted in Table 3.1 and Figure 3.10. Results showed that 86.44% children have earning head only 1 and 13.56% children have number of earning 2 and above (Figure 3.10).

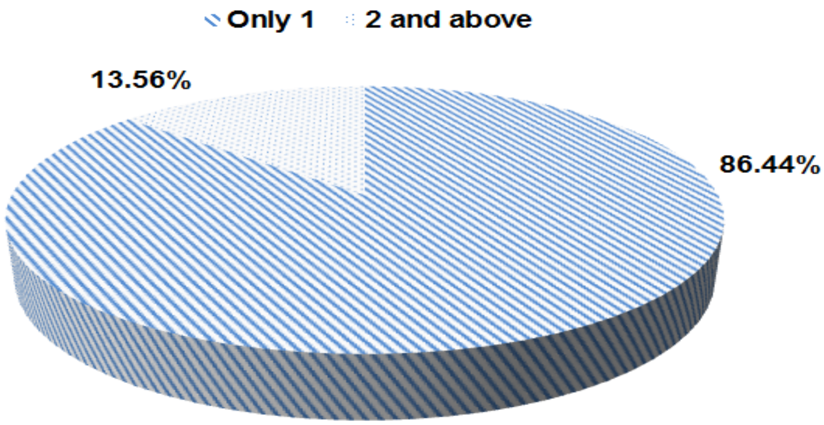

Figure 3.10. Pie chart showing the overall distribution of number of earning heads in families

3.1.9. Monthly Income

Distribution of monthly family income of the children was depicted in Table 3.1 and Figure 3.11. Results showed that 65.36% children have monthly family income of Rs. 7000/- or less and 34.64% children have monthly family income of Rs. 7001/- and above (Figure 3.11).

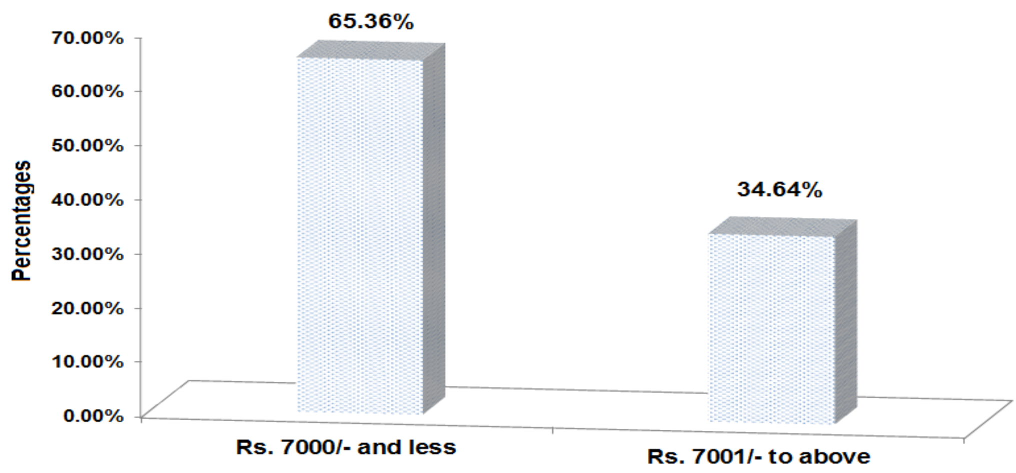

Figure 3.11: Bar diagram showing overall distribution of monthly income

3.1.10. Monthly Expenditure

Distribution of monthly family expenditure of the children was depicted in Table 3.1 and Figure 3.12. Results showed that 70.26% children have monthly family income of Rs. 7000/- or less and 29.74% children have monthly family expenditure of Rs. 7001/- and above (Figure 3.12).

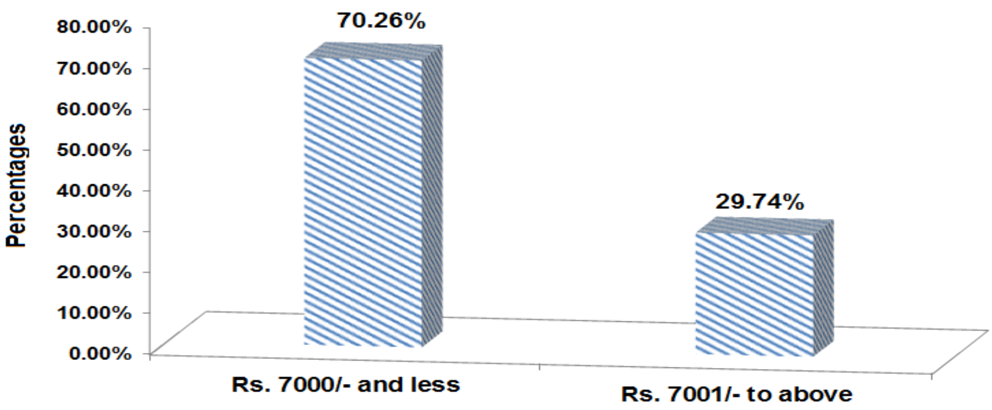

Figure 3.12. Bar diagram showing the overall distribution of monthly expenditure

3.1.11. Water Supply

Distribution of nature of water supply of the children was depicted in Table 3.1 and Figure 3.13. Results showed that 66.34% children use the water of tube well and water supply and 33.66% children use well water (Figure 3.13).

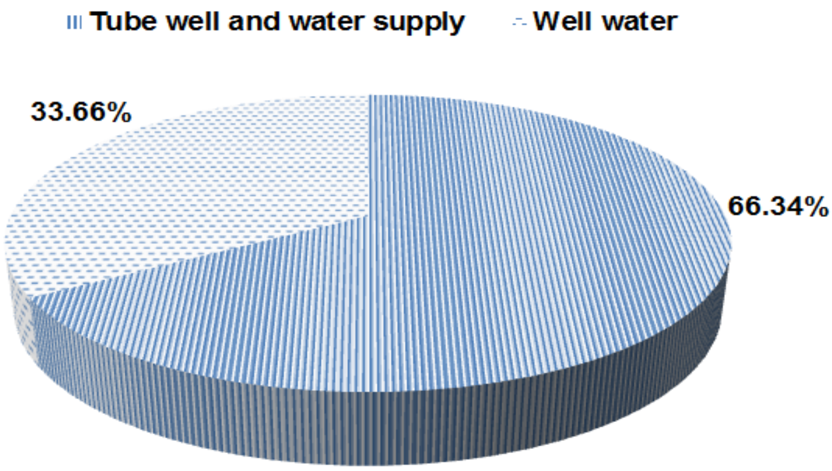

Figure 3.13. Pie chart showing the overall distribution of water supply

3.1.12. Toilet Use

Distribution of toilet of the children was depicted in Table 3.1 and Figure 3.14. Results showed that 77.61% children use toilet and 22.39% children do not use toilet (Figure 3.14).

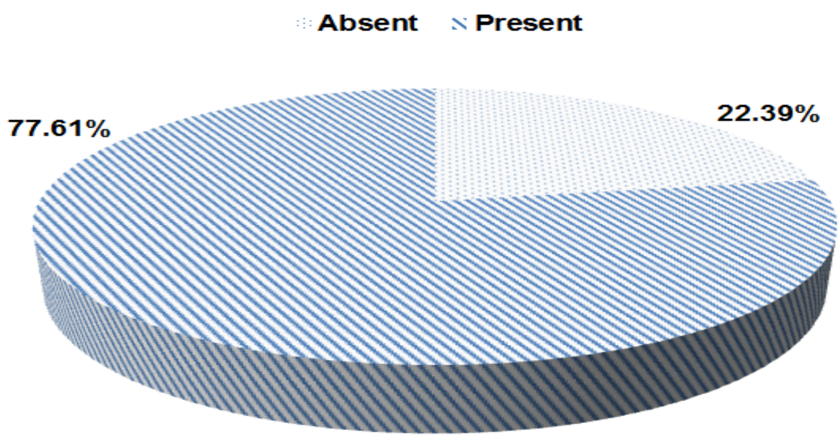

Figure 3.14. Pie chart showing the overall distribution of toilet use

3.1.13. Electricity Use

Distribution of electricity use of the children was depicted in Table 3.1 and Figure 3.15. Results showed that 89.71% children have electricity present in their houses and 10.29% children do not have electricity in their houses (Figure 3.15).

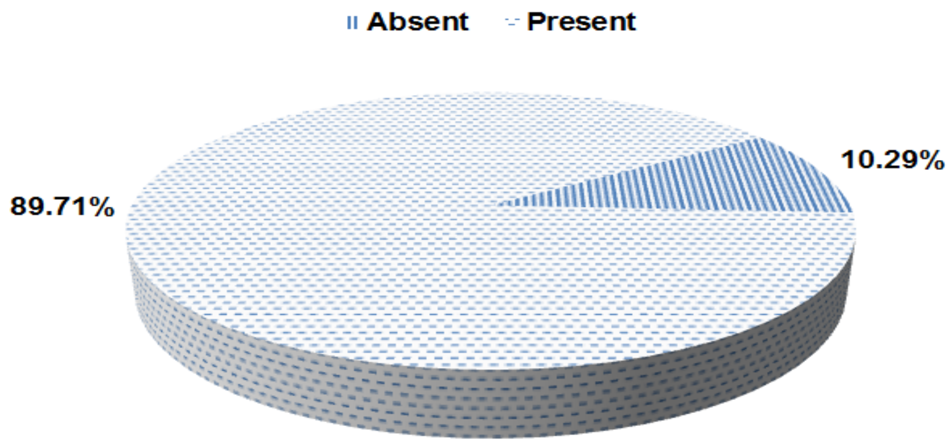

Figure 3.15. Pie chart showing the overall distribution of electricity use

3.1.14. House Pattern

Distribution of house pattern of the children was depicted in Table 3.1 and Figure 3.16. Results showed that 58.82% children have non-bricked house and 41.17% children have bricked house (Figure 3.16).

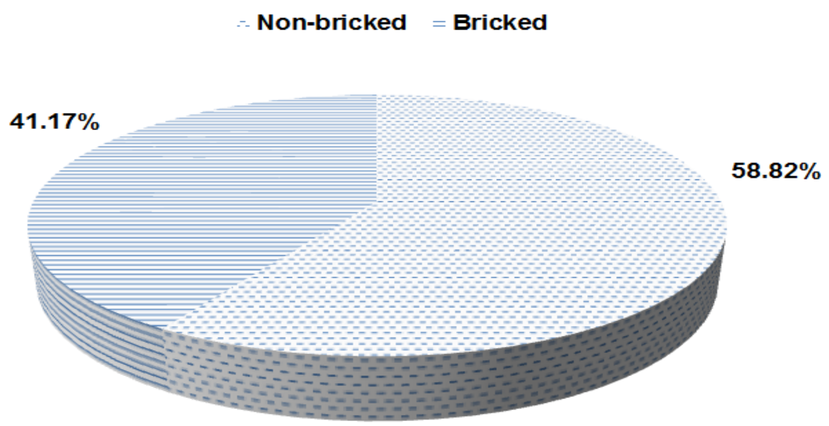

Figure 3.16. Pie chart showing the overall distribution of house pattern

3.1.15. Number of Rooms

Distribution of number of rooms in houses of the children was depicted in Table 3.1 and Figure 3.17. Results showed that 65.03% of children have 1 to 2 numbers of rooms in their households and 34.97% children have 3 and more numbers of rooms in their houses (Figure 3.17).

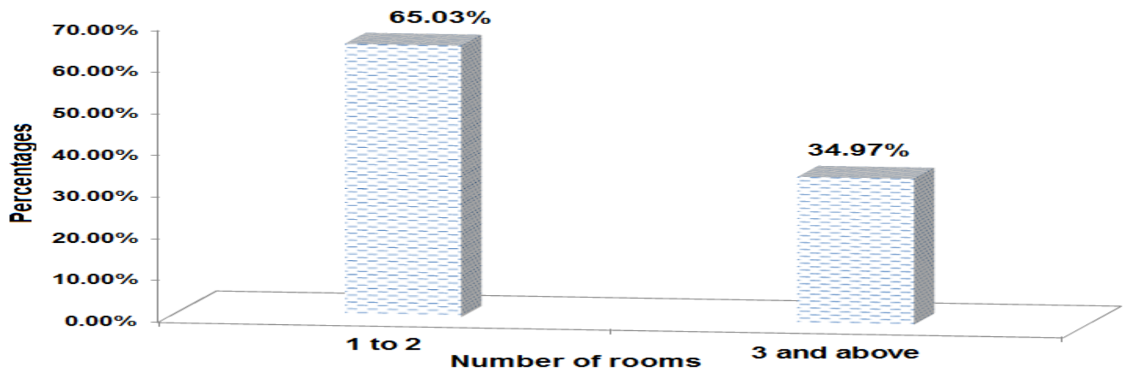

Figure 3.17. Bar diagram showing the overall distribution of number of rooms

3.1.16. Birth Weight

Distribution of birth weight of the children was depicted in Table 3.1 and Figure 3.18. Results showed that 43.95% children have birth weight of 2.8 kg and more, 38.56% children have birth weight from 2.5 kg to 2.7 kg and 17.48% children birth weight of less than 2.5 kg (Figure 3.18).

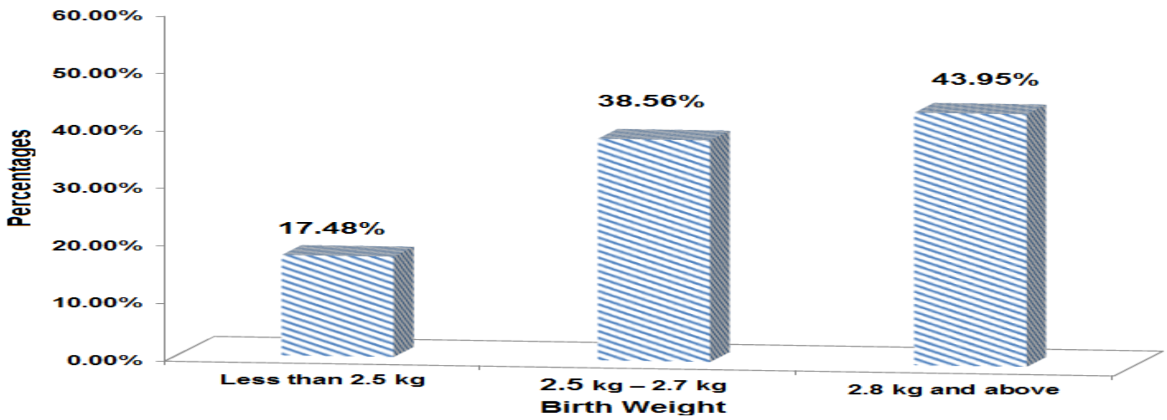

Figure 3.18. Bar diagram showing the overall distribution of birth weight of the children

3.1.17. Duration of Breast Feeding

Distribution of duration of breast feeding of the children was depicted in Table 3.1 and Figure 3.19. Results showed that 51.80% children have duration of breast feeding of 3 years to 4 years and 48.20% children have duration of breast feeding of 2 years and 11 months (Figure 3.19).

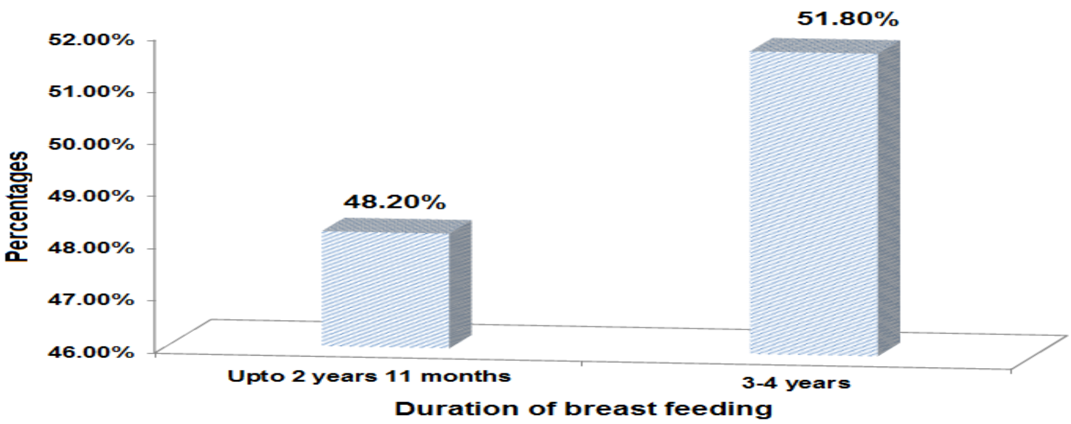

Figure 3.19. Bar diagram showing the overall distribution of breast feeding of children

3.1.18. Education of Mother

Distribution of mother's education of the children was depicted in Table 3.1 and Figure 3.20. Results showed that 39.05% of mothers do not have formal education, 32.35% mothers have education upto class V and 28.59% mothers have education level of class VI and above (Figure 3.19).

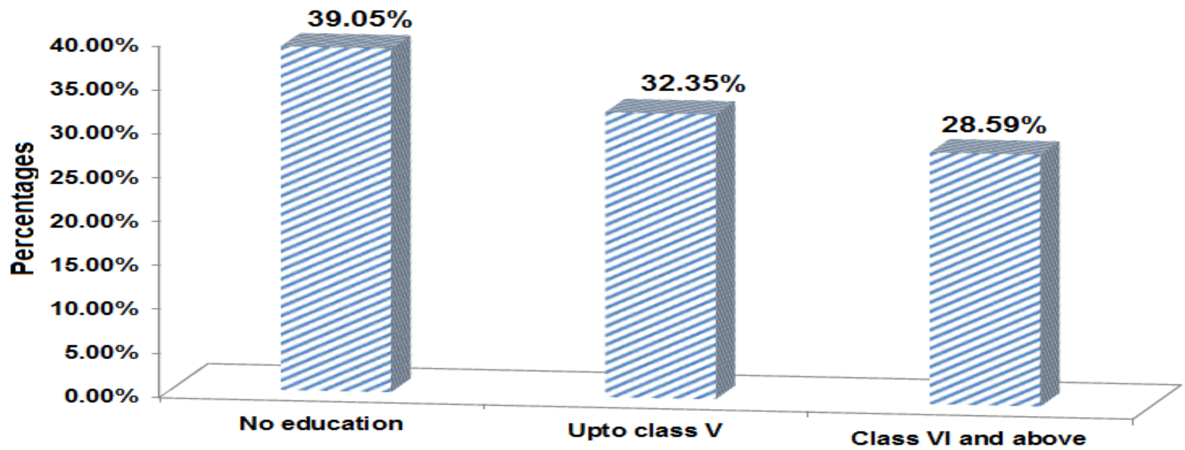

Figure 3.20. Bar diagram showing the overall educational status of mothers

3.1.19. Education of Father

Distribution of father's education of the children was depicted in Table 3.1 and Figure 3.21. Results showed that 22.55% of fathers do not have formal education, 45.10% fathers have education upto class V and 32.35% fathers have education level of class VIand above (Figure 3.19).

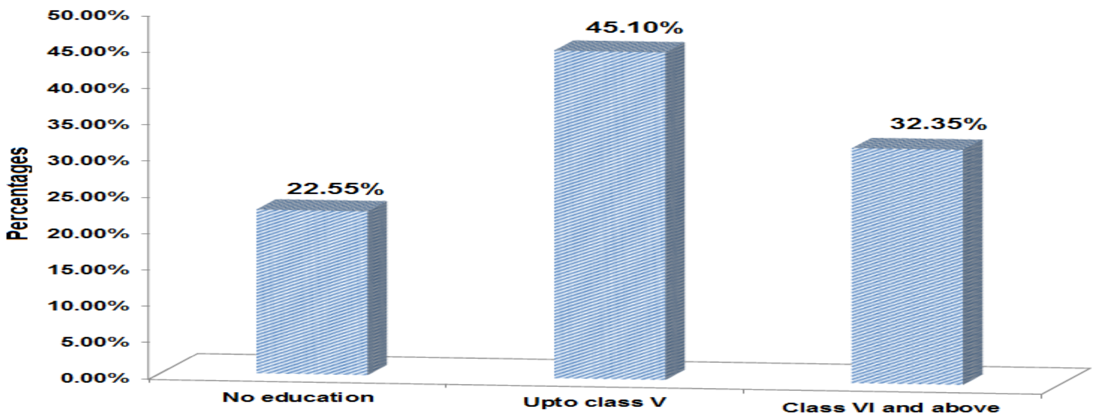

Figure 3.21. Bar diagram showing the overall educational status of fathers

3.1.20. Occupation of Mother

Distribution of mother's occupation of the children was depicted in Table 3.1 and Figure 3.22. Results showed that only 2.12% of mothers were working outside home and 97.88% mothers were housewives (Figure 3.22).

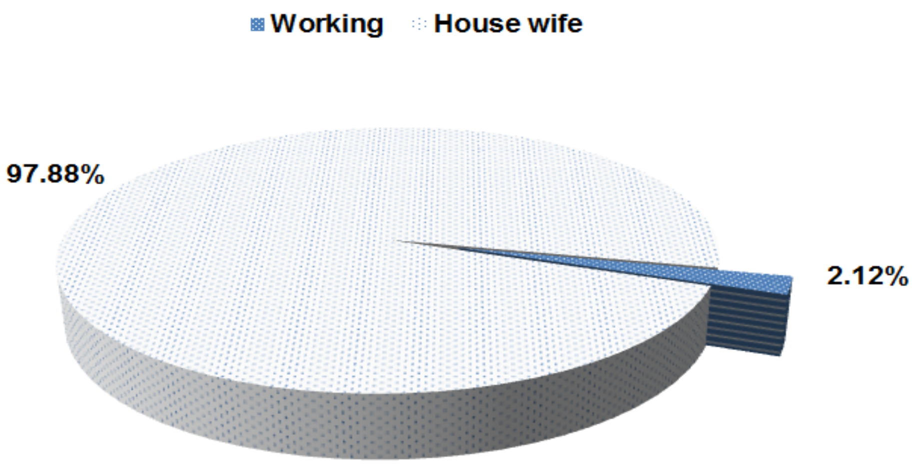

Figure 3.22. Pie chart showing the overall distribution occupational status of mothers

3.1.21. Occupation of Father

Distribution of father's occupation of the children was depicted in Table 3.1 and Figure 3.23. Results showed that 66.67% of fathers were labours and farmers, 23.37% of fathers were businessmen and 9.97% of fathers were from other occupations (Figure 3.23).

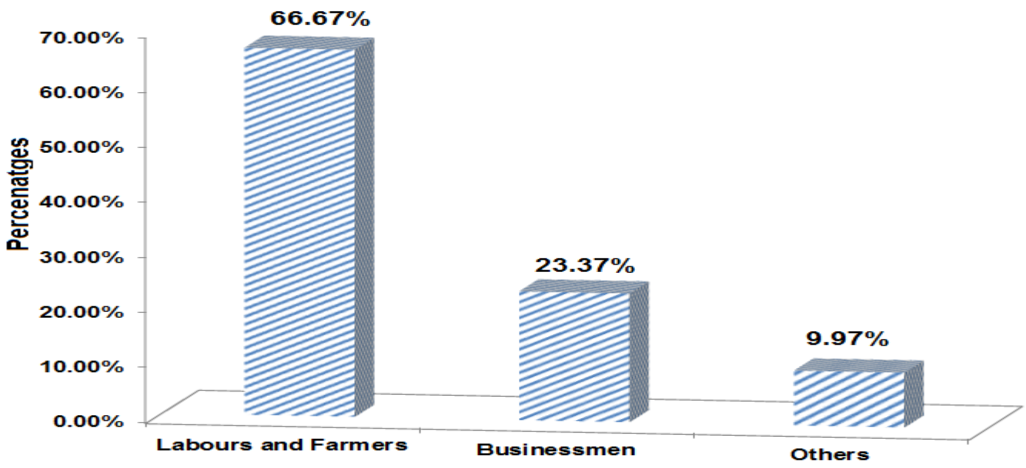

Figure 3.23. Bar diagram showing the overall distribution of occupational status of fathers

3.1.22. Number of Sibs

Distribution of number of sibs of the children was depicted in Table 3.1 and Figure 3.24. Results showed that 34.97% children have number of sibs 1, 39.87% children have number of sibs 2 and 25.16% children have number of sibs 3 and more (Figure 3.24).

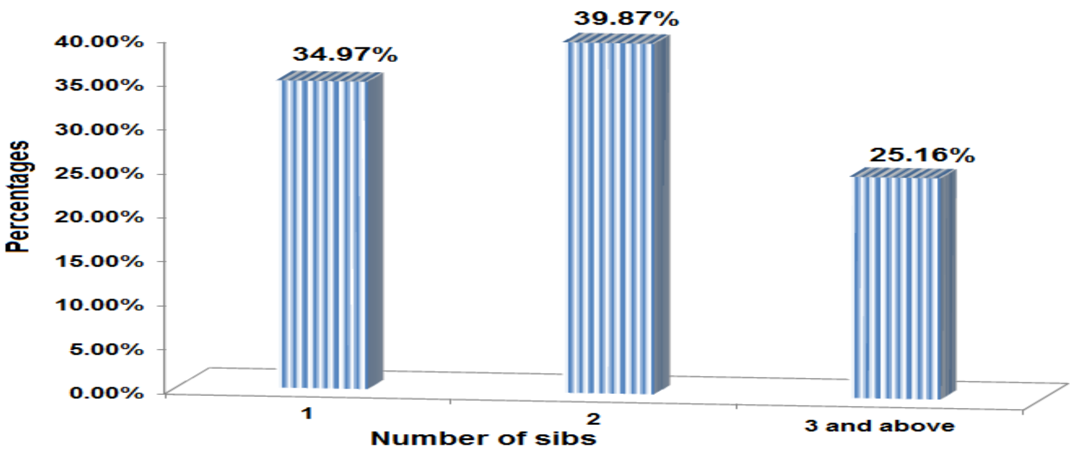

Figure 3.24. Bar diagram showing the overall distribution of number of sibs of children

Table. 3.1: Demographic, socio-economic profile and lifestyle related factors of Bengali Muslim children

Variables		**Total (N= 612)**
Age	**1-2 years**	235 (38.40)
	3-5 years	377 (61.60)
Sex	**Boys**	325 (53.10)
	Girls	287 (46.90)
Mothers age	**20-27 years**	413 (67.48)
	28 and above	199 (32.52)
Mothers age at menarche	**9-12 years**	327 (53.43)
	13 and higher age	285 (46.57)
Mothers age at marriage	**Upto 17 years**	256 (41.83)
	18 years and above	356 (58.17)
Mothers age at first pregnancy	**Upto 18 years**	262 (42.81)
	19 years and above	350 (57.19)
Family size	**Upto 4 members**	320 (52.29)
	5 and above members	292 (47.71)
Family type	**Nuclear**	435 (71.08)
	Extended, joint and broken	177 (28.92)
Earning head	**1**	529 (86.44)
	2 and above	83 (13.56)
Monthly income	**Rs. 7000/- and less**	400 (65.36)
	Rs. 7001/- to above	212 (34.64)
Monthly expenditure	**Rs. 7000/- and less**	430 (70.26)
	Rs. 7001/- to above	182 (29.74)
Water supply	**Tube well and water supply**	406 (66.34)
	Well water	206 (33.66)
Toilet use	**Absent**	137 (22.39)
	Present	475 (77.61)

Electricity use	**Absent**	63 (10.29)
	Present	549 (89.71)
House pattern	**Non-bricked**	360 (58.82)
	Bricked	252 (41.17)
Number of rooms	**1-2**	398 (65.03)
	3 and above	214 (34.97)
Birth weight	**Less than 2.5 kg**	107 (17.48)
	2.6 kg – 2.7 kg	236 (38.56)
	2.8 kg and above	269 (43.95)
Duration of breast feeding	**Upto 2 years 11 months**	295 (48.20)
	3-4 years	317 (51.80)
Education of mother	**No education**	239 (39.05)
	Upto class V	198 (32.35)
	Class VI and above	175 (28.59)
Education of father	**No education**	138 (22.55)
	Upto class V	276 (45.10)
	Class VI and above	198 (32.35)
Occupation of mother	**Working**	13 (2.12)
	House wife	599 (97.88)
Occupation of father	**Labours and Farmers**	408 (66.67)
	Business	143 (23.37)
	Others	61 (9.97)
Number of sibs	**1**	214 (34.97)
	2	244 (39.87)
	3 and above	154 (25.16)

3.2. Descriptive Statistics (Mean ±SD) of Anthropometric Variables among Bengali Muslim Children

The age-sex specific descriptive statistics (mean ± standard deviation) of anthropometric variables of height (cm), weight (kg), MUAC (cm), HdC (cm), TSF (mm), SSF (mm) among Bengali Muslim children (aged 1-5 years) children is depicted in Table 3.2 and in Table 3.3. The age sex-specific mean weight and height were observed to be higher among boys than girls except in 1 year. The age-sex specific mean values of weight and height were observed to be progressively increasing with age in both sexes. The age-specific mean height and weight among boys range from 72.49 cm (in 1 year) to 110.64 cm (5 years) and 8.05 kg (1 year) to 16.82 kg (5 years), respectively. The mean height and weight among girls range from 74.26 cm (1 year) to 106.75 cm (5 years) and 8.14 kg (1 year) to 16.57 kg (5 years), respectively. The age-sex specific mean MUAC values gradually increased with age in both sexes except in girls of 2 years and 3 years. The age sex-specific mean values were observed to be significantly higher among boy than the girls except in 1 year and 5 years. The age sex-specific mean MUAC range from 13.80 cm (in 1 year) to 15.38 cm (in 5 years) (in boys) and 13.89 cm (in 2 years) to 15.47 (in 5 years) (in girls). The age sex-specific mean HdC showed age-specific gradual increase among the children except among the boys in 5 years (in boys). The age-sex specific mean TSF did not show any age specific trend among boys and girls. The age sex-specific mean values of TSF ranged from 8.11 mm (in 5 years) to 8.90 mm (in 4 years) (in boys) and 8.25 mm (in 2 years) to 9.41 mm (in 1 year) (in girls). The age-sex specific mean SSF showed a decreasing trend from lower age groups to higher age groups among the children. The age sex-specific mean SSF values ranged from 5.02 mm (in 5 years) to 5.64 mm (in 1 year) (in boys) and 5.22 mm (in 5 years) to 6.66 mm (in 1 year) (in girls) among children. The results of the anthropometric measures of height, weight, MUAC, HdC, TSF, SSF and SSF have shown a sexual dimorphism in children and the age sex-specific mean skinfold thicknesses were observed to be significantly higher among girls than boys in most cases ($p<0.01$).

Table 3.2: Descriptive statistics (mean ± SD) of age and anthropometric variables of Bengali Muslim children

Variable	Boys (N=325)	Girls (N=287)	F-value	d.f.	p-value
Age (years)	3.03±1.42	3.10±1.48	0.329	1, 611	0.567
Height (cm)	90.01±14.91	89.39±13.57	0.288	1, 611	0.592
Weight (kg)	11.99±3.74	11.85±3.70	0.203	1, 611	0.653
MUAC (cm)	14.46±1.33	14.47±1.29	0.013	1, 611	0.908
HdC (cm)	46.87±2.16	46.43±1.80	7.196^{**}	1, 611	0.008
TSF (mm)	8.32±1.91	8.96±1.84	17.54^{**}	1, 611	0.000
SSF (mm)	5.41±1.47	5.77±1.51	8.877^{**}	1, 611	0.003

Table 3.3: Descriptive statistics (mean ± SD) of sex specific anthropometric variables of Bengali Muslim children

Variable	Boys (N=325)								Girls (N=287)							
	1 year (N=64)	2 years (N=60)	3 years (N=71)	4 years (N=61)	5 years (N=69)	F-value	d.f.	p-value	1 year (N=58)	2 years (N=53)	3 years (N=50)	4 years (N=54)	5 years (N=72)	F-value	d.f.	p-value
Height (cm)	72.49 ±5.64	80.88 ±7.53	88.41 ±6.33	95.90 ±7.18	110.64 ±8.15	285.54	4,324	0.000	74.26 ±5.77	80.24 ±5.61	86.20 ±7.42	94.41 ±5.55	106.75 ±7.06	255.40	4,286	0.000
Weight (kg)	8.05 ±1.58	9.70 ±1.86	11.51 ±2.26	13.46 ±1.62	16.82 ±2.95	167.41	4,324	0.000	8.14 ±1.64	9.51 ±1.51	10.94 ±1.95	12.71 ±1.76	16.57 ±2.68	172.83	4,286	0.000
MUAC (cm)	13.80 ±1.59	14.04 ±1.15	14.42 ±1.76	14.60 ±0.88	15.38 ±1.17	16.68	4,324	0.000	14.14 ±1.31	13.89 ±1.04	14.08 ±0.89	14.45 ±1.39	15.47 ±1.06	19.41	4,286	0.000
HdC (cm)	44.48 ±2.56	46.31 ±1.47	47.20 ±1.57	48.41 ±1.32	47.86 ±1.57	53.33	4,324	0.000	44.50 ±1.79	45.80 ±1.28	46.45 ±1.29	47.58 ±1.24	47.58 ±1.14	54.31	4,286	0.000
TSF (mm)	8.13 ±2.33	8.17 ±2.21	8.33 ±1.82	8.90 ±1.62	8.11 ±1.40	1.91	4,324	0.108	9.41 ±1.95	8.25 ±1.34	8.83 ±2.02	9.13 ±1.79	9.08 ±1.89	3.18	4,286	0.014
SSF (mm)	5.64 ±1.51	5.52 ±1.87	5.52 ±1.48	5.37 ±1.23	5.02 ±1.14	1.83	4,324	0.12	6.66 ±1.99	5.75 ±1.32	5.72 ±1.09	5.60 ±1.62	5.22 ±0.98	8.37	4,286	0.000

3.3. Descriptive Statistics (Mean ±SD) of derived Body composition variables and Nutritional Indices of Bengali Muslim Children

The age-sex specific descriptive statistics (mean ± standard deviation) of derived body composition variables and nutritional indices of PBF, FM, FFM, FMI, FFMI, TUA, UMA, UFA, AFI, UME, UFE, BMI, PBF-BMI Ratio of the Bengali Muslim children are depicted in Table 3.4 and Table 3.5. The sex-specific mean PBF, FFM, FFMI, UMA, UME and BMI were observed to be higher among boys than girls. The sex-specific mean values of FM, FMI,TUA, UFA, AFI, UFE and PBF-BMI Ratio were observed to be higher among girls than boys. The age sex-specific mean PBF of children did not show any specific trend. Among boys, age specific mean value of PBF ranged from 12.78 (in 5 years) to 13.89 (in 4 years). Among girls age specific mean value of PBF ranged from 13.50 (in 2 years) to 15.37 (in 1 year). Age specific mean FM and FFM showed an age wise increasing trend among both sexes. Among boys, age specific mean FM and FFM ranged from 1.08 (in 1 year) to 2.15 (in 5 years) and from 6.97 (in 1 year) to 14.67 (in 5 years), respectively. Among girls age specific mean FM and FFM ranged from 1.26 (in 1 year) to 2.29 (in 5 years) and from 6.88 (in 1 year) to 14.27 (in 5 years), respectively.

The mean FMI and FFMI among boys ranged from 1.75 (in 5 year) to 2.07 (in 1 year) and 11.95 (in 5 years) to 13.27 (1 year), respectively. The mean FMI and FFMI among girls ranged from 2.00 (in 2 years) to 2.30 (in 1 year) and 12.22 (in 4 years) to 12.78 (2 years), respectively. Age and sex-specific TUA showed and age wise increasing trend among boys and girls except in girls of 1 year age group. The age-specific mean TUA of boys and girls ranged from 15.34 (in 1 year) to 18.93 (in 5 years) and from 15.44 (in 2 years) to 19.12 (in 5 years), respectively. Age sex-specific mean values of UMA, UFA, AFI, UME, UFE, BMI and PBF-BMI Ratio did not show any age specific trend. Age-specific mean values of UMA and UFA among boys ranged from 10.29 (in 1 year) to 13.22 (in 5 years) and 5.05 (in 1 year) to

5.89 (in 4 years), respectively. Age-specific mean values of UMA and UFA among girls ranged from 10.07 (in 1 year) to 12.74 (in 5 years) and 5.20 (in 2 years) to 12.68 (in 5 years), respectively. Age-specific mean values of AFI, UME and UFE among boys ranged from 30.45 (in 5 years) to 34.57 (in 4 years), from 9.73 (in 1 year) to 12.68 (in 5 years), from 5.61 (in 1 year) to 6.53 (in 4 years), respectively. Age-specific mean values of AFI, UME and UFE among girls ranged from 33.38 (in 5 years) to 37.35 (in 1 years), from 9.34 (in 1 year) to 12.07 (in 5 years), from 5.74 (in 2 years) to 7.05 (in 5 years), respectively. Age-specific mean values of BMI and PBF-BMI ratio among boys ranged from 13.71 (in 5 years) to 15.34 (in 1 year) and 0.89 (in 1 year) to 0.95 (in 4 years), respectively. Age-specific mean values of BMI and PBF-BMI Ratio among girls ranged from 14.24 (in 4 years) to 14.78 (in 1 year and 2 years) and 0.93 (in 2 years) to 1.07 (in 1 year), respectively. The sex specific mean difference in PBF (F-value: 14.467; d.f.,1, 611) ($p<0.01$), FMI (F-value: 6.307 ; d.f.,1, 611) ($p<0.01$), UMA (F-value: 4.030; d.f.,1, 611) ($p<0.05$), UFA (F-value: 12.438; d.f.,1, 611) ($p<0.01$), AFI (F-value: 16.468; d.f.,1, 611) ($p<0.01$), UME (F-value: 5.749; d.f.,1, 611) ($p<0.01$), UFE (F-value: 13.324; d.f.,1, 611) ($p<0.01$) and PBF-BMI Ratio (F-value: 12.33; d.f.,1, 611) ($p<0.01$) were observed to be statistically significant using ANOVA. Two way ANOVA showed that there were statistically significant mean differences between the groups with respect to age and sex in case of height (F-value= 3.177; $p<0.01$), MUAC (F= 7.378; $p<0.01$), HdC (F-value= 15.957; $p<0.01$), SSF (F-value= 3.918; $p<0.05$), FFMI (F= 2.467; $p<0.05$), TUA (F= 8.282; $p<0.01$), UMA (F= 6.471; $p<0.01$), UFA (F-value= 4.231; $p<0.05$), UME (F= 5.838; $p<0.01$), UFE (F= 3.742; $p<0.01$), BMI (F= 2.339; $p<0.05$). The Post-Hoc test showed significant effect of age on height, weight, MUAC, HdC, SSF, PBF, FM, FFM, FMI, TUA, UMA.

Table 3.4: Descriptive statistics (mean ± SD) of the derived anthropometric indices relating to body composition and nutritional status of Bengali Muslim children

Indices	Boys (N=325)	Girls (N=287)	F-value	d.f.	p-value
PBF (%)	13.34±2.80	14.17±2.55	14.467	1, 611	0.000
FM (kg)	1.60±0.58	1.68±0.60	2.460	1, 611	0.117
FFM (kg)	10.39±3.26	10.18±3.19	0.650	1, 611	0.420
FMI (kg/m^2)	1.97±0.57	2.08±0.53	6.307	1, 611	0.012
FFMI (kg/m^2)	12.67±1.88	12.51±1.60	1.262	1, 611	0.262
TUA (cm^2)	16.78±2.97	16.80±2.89	0.008	1, 611	0.930
UMA (cm^2)	11.31±2.35	10.93±2.22	4.030	1, 611	0.045
UFA (cm^2)	5.48±1.38	5.87±1.37	12.438	1, 611	0.000
AFI (%)	32.85±7.29	35.06±6.01	16.468	1, 611	0.000
UME (cm^2)	10.73±2.42	10.28±2.27	5.749	1, 611	0.017
UFE (cm^2)	6.05±1.60	6.53±1.63	13.324	1, 611	0.000
BMI (kg/m^2)	14.64±2.22	14.59±1.94	0.078	1, 611	0.780
PBF-BMI Ratio	0.92±0.21	0.98±0.213	12.33	1, 611	0.000

Table 3.5: Age and sex specific descriptive statistics (mean ± SD) of anthropometric indices relating to body composition and nutritional status of Bengali Muslim children

Variable	Boys (N=325)								Girls (N=287)							
	1 year (N=64)	2 years (N=60)	3 years (N=71)	4 years (N=61)	5 years (N=69)	F-value	d.f.	p-value	1 year (N=58)	2 years (N=53)	3 years (N=50)	4 years (N=54)	5 years (N=72)	F-value	d.f.	p-value
PBF (%)	13.34 ±3.50	13.28 ±3.34	13.47 ±2.68	13.89 ±2.40	12.78 ±1.79	1.33	4,324	0.259	15.37 ±2.96	13.50 ±2.22	14.02 ±2.31	14.19 ±2.47	13.78 ±2.35	4.860	4,286	0.001
FM (kg)	1.08 ±0.38	1.30 ±0.43	1.56 ±0.46	1.87 ±0.42	2.15 ±0.49	62.06	4,324	0.000	1.26 ±0.35	1.30 ±0.35	1.55 ±0.42	1.81 ±0.41	2.29 ±0.58	60.456	4,286	0.000
FFM (kg)	6.97 ±1.35	8.40 ±1.57	9.95 ±1.92	11.59 ±1.40	14.67 ±2.57	173.50	4,324	0.000	6.88 ±1.40	8.21 ±1.24	9.39 ±1.61	10.91 ±1.52	14.27 ±2.27	183.864	4,286	0.000
FMI (kg/m^2)	2.07 ±0.74	1.99 ±0.65	1.98 ±0.50	2.06 ±0.52	1.75 ±0.34	3.462	4,324	0.009	2.30 ±0.72	2.00 ±0.47	2.06 ±0.42	2.02 ±0.44	2.02 ±0.49	3.215	4,286	0.013
FFMI (kg/m^2)	13.27 ±2.31	12.88 ±2.07	12.68 ±1.86	12.65 ±1.39	11.95 ±1.40	4.568	4,324	0.001	12.48 ±2.10	12.78 ±1.68	12.62 ±1.43	12.22 ±1.35	12.49 ±1.33	.879	4,286	0.477
TUA (cm^2)	15.34 ±3.15	15.77 ±2.58	16.64 ±2.71	17.03 ±2.03	18.93 ±2.86	17.670	4,324	0.000	16.05 ±3.00	15.44 ±2.15	15.83 ±1.98	16.77 ±2.69	19.12 ±2.63	21.973	4,286	0.000

UMA (cm^2)	10.29 ±2.48	10.54 ±1.89	11.15 ±1.88	11.15 ±1.63	13.22 ±2.50	19.913	4,324	0.000	10.07 ±2.21	10.24 ±1.72	10.22 ±1.62	10.79 ±1.95	12.74 ±2.10	21.673	4,286	0.000
UFA (cm^2)	5.05 ±1.57	5.24 ±1.53	5.50 ±1.40	5.89 ±1.15	5.71 ±1.04	3.984	4,324	0.004	5.98 ±1.44	5.20 ±0.95	5.61 ±1.35	5.98 ±1.34	6.38 ±1.41	6.877	4,286	0.000
AFI (%)	33.75 ±11.10	32.96 ±7.39	32.82 ±5.58	34.57 ±5.26	30.45 ±5.09	3.044	4,324	0.017	37.35 ±6.21	33.91 ±5.35	35.35 ±6.62	35.71 ±5.31	33.38 ±5.79	4.399	4,286	0.002
UME (cm^2)	9.73 ±2.61	9.98 ±1.96	10.57 ±1.88	10.50 ±1.71	12.68 ±2.56	19.239	4,324	0.000	9.34 ±2.26	9.69 ±1.77	9.58 ±1.74	10.11 ±1.98	12.07 ±2.19	19.890	4,286	0.000
UFE (cm^2)	5.61 ±1.80	5.79 ±1.81	6.06 ±1.63	6.53 ±1.38	6.24 ±1.21	3.278	4,324	0.012	6.70 ±1.72	5.74 ±1.11	6.25 ±1.64	6.66 ±1.60	7.05 ±1.68	5.951	4,286	0.000
BMI (kg/m^2)	15.34 ±2.73	14.86 ±2.42	14.67 ±2.14	14.72 ±1.76	13.71 ±1.61	5.078	4,324	0.001	14.78 ±2.65	14.78 ±1.98	14.68 ±1.62	14.24 ±1.57	14.51 ±1.68	.755	4,286	0.555
PBF-BMI Ratio	0.89 ±0.25	0.90 ±0.23	0.93 ±0.22	0.95 ±0.15	0.94 ±0.17	0.98	4,324	0.417	1.07 ±0.27	0.93 ±0.19	0.97 ±0.19	1.01 ±0.23	0.95 ±0.15	3.95	4,286	0.004

3.4.Pearson Correlation Coefficient between the anthropometric variables among Bengali Muslim boys

Table 3.6 depicts the Pearson correlation coefficients between the anthropometric variables among Bengali Muslim boys. Most of anthropometric variables were significantly correlated with each other ($p<0.01$). Age showed significantly strong correlations with all variables like height, weight, HdC, MUAC, BMI, PBF, FM, FFM, TUA, UMA, UFA, UFE and UME ($p<0.01$) except TSF and AFI. BMI has showed significant correlation with height, TSF, SSF, PBF, FM, UFA, AFI and UFE ($p<0.01$). PBF also showed significant correlation with TSF, SSF, MUAC, BMI, TUA, UMA, UFA, AFI, UFE and UME ($p<0.01$). FM showed significant correlation with all other variables ($p<0.01$).

3.5.Pearson Correlation Coefficient between the anthropometric variables among Bengali Muslim girls

Table 3.7 depicts the Pearson correlation coefficients between the anthropometric variables among Bengali Muslim girls. Most of anthropometric variables were highly significantly correlated with each other ($p<0.01$). Age showed highly significant correlation with all variables like height, weight, MUAC, FM, FFM, TUA, UMA, UFA, AFI and UME ($p<0.01$) except TSF and BMI. BMI has showed highly significant correlation with height, weight, TSF, SSF,PBF, FM, FFM, FMI, FFMI, TUA, UFA and UFE ($p<0.01$). PBF also showed significant correlation with TSF, SSF, MUAC, BMI, FM, FMI, TUA,UMA, UFA, AFI, UFE and UME ($p<0.01$). FM showed significant correlation with all other variables ($p<0.01$).

Table 3.6: Pearson Correlation Coefficient between the anthropometric variables among Bengali Muslim boys

	Age	Height	Weight	TSF	SSF	HdC	MUAC	BMI	PBF	FM	FFM	TUA	UMA	UFA	AFI	UFE	UME
Age	1	0.874**	0.813**	0.046	-0.137*	0.574**	0.403**	-0.223**	-0.031	0.660**	0.815**	0.407**	0.398**	0.200**	-0.104	0.173**	0.386**
Height	0.874**	1	0.904**	0.053	-0.208**	0.566**	0.426**	-0.328**	-0.060	0.723**	0.909**	0.435**	0.425**	0.214**	-0.098	0.185**	0.413**
Weight	0.813**	0.904**	1	0.148**	-0.154**	0.549**	0.497**	0.080	0.031	0.853**	0.996**	0.511**	0.460**	0.318**	-0.034	0.291**	0.436**
TSF	0.046	0.053	0.148**	1	0.422**	0.163**	0.242**	0.219**	0.893**	0.579**	0.066	0.262**	-0.194**	0.896**	0.886**	0.926**	-0.291**
SSF	-0.137*	-0.208**	-0.154**	0.422**	1	-0.127*	0.047	0.158**	0.784**	0.244**	-0.221**	0.058	-0.130*	0.347**	0.401**	0.367**	-0.172**
HdC	0.574**	0.566**	0.549**	0.163**	-0.127*	1	0.292**	-0.039	0.054	0.499**	0.541**	0.289**	0.218**	0.251**	0.042	0.237**	0.198**
MUAC	0.403**	0.426**	0.497**	0.242**	0.047	0.292**	1	0.113*	0.195**	0.511**	0.479**	0.993**	0.886**	0.632**	-0.199**	0.576**	0.840**
BMI	-0.223**	-0.328**	0.080	0.219**	0.158**	-0.039	0.113*	1	0.225**	0.182**	0.059	0.118*	0.022	0.217**	0.168**	0.224**	-0.003
PBF	-0.031	-0.060	0.031	0.893**	0.784**	0.054	0.195**	0.225**	1	0.522**	-0.058	0.214**	-0.192**	0.788**	0.802**	0.817**	-0.279**

FM	0.660**	0.723**	0.853**	0.579**	0.244**	0.499**	0.511**	0.182**	0.522**	1	0.800**	0.531**	0.278**	0.672**	0.373**	0.665**	0.213**
FFM	0.815**	0.909**	0.996**	0.066	-0.221**	0.541**	0.479**	0.059	-0.058	0.800**	1	0.492**	0.478**	0.245**	-0.106	0.215**	0.462**
TUA	0.407**	0.435**	0.511**	0.262**	0.058	0.289**	0.993**	0.118*	0.214**	0.531**	0.492**	1	0.892**	0.636**	-0.160**	0.583**	0.843**
UMA	0.398**	0.425**	0.460**	-0.194**	-0.130*	0.218**	0.886**	0.022	-0.192**	0.278**	0.478**	0.892**	1	0.217**	-0.549**	0.153**	0.995**
UFA	0.200**	0.214**	0.318**	0.896**	0.347**	0.251**	0.632**	0.217**	0.788**	0.672**	0.245**	0.636**	0.217**	1	0.592**	0.997**	0.121*
AFI	-0.104	-0.098	-0.034	0.886**	0.401**	0.042	-0.199**	0.168**	0.802**	0.373**	-0.106	-0.160**	-0.549**	0.592**	1	0.649**	-0.625**
UFE	0.173**	0.185**	0.291**	0.926**	0.367**	0.237**	0.576**	0.224**	0.817**	0.665**	0.215**	0.583**	0.153**	0.997**	0.649**	1	0.054
UME	0.386**	0.413**	0.436**	-0.291**	-0.172**	0.198**	0.840**	-0.003	-0.279**	0.213**	0.462**	0.843**	0.995**	0.121*	-0.625**	0.054	1

Table 3.7: Pearson Correlation Coefficient between the anthropometric variables among Bengali Muslim girls

	Age	Height	Weight	TSF	SSF	HdC	MUAC	BMI	PBF	FM	FFM	FMI	FFMI	TUA	UMA	UFA	AFI	UFE	UME
Age	1	0.874**	0.820**	0.015	-0.298**	0.637**	0.387**	-0.077	-0.148*	0.653**	0.828**	-0.148*	-0.043	0.403**	0.416**	0.177**	-0.162**	0.151*	0.404**
Height	0.874**	1	0.914**	0.032	-0.287**	0.638**	0.457**	-0.165**	-0.125*	0.741**	0.921**	-0.181**	-0.139*	0.476**	0.486**	0.218**	-0.171**	0.186**	0.471**
Weight	0.820**	0.914**	1	0.112	-0.199**	0.631**	0.512**	0.225**	-0.025	0.871**	0.996**	0.100	0.240**	0.534**	0.507**	0.306**	-0.114	0.274**	0.482**
TSF	0.015	0.032	0.112	1	0.368**	-0.002	0.341**	0.185**	0.865**	0.513**	0.033	0.714**	-0.013	0.340**	-0.129*	0.923**	0.885**	0.947**	-0.248**
SSF	-0.298**	-0.287**	-0.199**	0.368**	1	-0.201**	0.004	0.219**	0.781**	0.176**	-0.263**	0.681**	0.038	0.025	-0.156**	0.304**	0.384**	0.322**	-0.199**
HdC	0.637**	0.638**	0.631**	-0.002	-0.201**	1	0.262**	0.075	-0.106	0.528**	0.632**	-0.044	0.106	0.285**	0.293**	0.125*	-0.134*	0.108	0.284**
MUAC	0.387**	0.457**	0.512**	0.341**	0.004	0.262**	1	0.151*	0.230**	0.544**	0.491**	0.248**	0.101	0.993**	0.881**	0.666**	-0.125*	0.616**	0.820**
BMI	-0.077	-0.165**	0.225**	0.185**	0.219**	0.075	0.151*	1	0.239**	0.318**	0.201**	0.716**	0.973**	0.155**	0.071	0.211**	0.120*	0.210**	0.046
PBF	-0.148*	-0.125*	-0.025	0.865**	0.781**	-0.106	0.230**	0.239**	1	0.446**	-0.113	0.840**	0.010	0.241**	-0.169**	0.781**	0.801**	0.804**	-0.271**

FM	0.653**	0.741**	0.871**	0.513**	0.176**	0.528**	0.544**	0.318**	0.446**	1	0.821**	0.487**	0.224**	0.571**	0.346**	0.642**	0.288**	0.626**	0.275**
FFM	0.828**	0.921**	0.996**	0.033	-0.263**	0.632**	0.491**	0.201**	-0.113	0.821**	1	0.024	0.236**	0.512**	0.523**	0.234**	-0.186**	0.201**	0.507**
FMI	-0.148*	-0.181**	0.100	0.714**	0.681**	-0.044	0.248**	0.716**	0.840**	0.487**	0.024	1	0.534**	0.257**	-0.079	0.669**	0.629**	0.686**	-0.165**
FFMI	-0.043	-0.139*	0.240**	-0.013	0.038	0.106	0.101	0.973**	0.010	0.224**	0.236**	0.534**	1	0.102	0.112	0.033	-0.063	0.027	0.111
TUA	0.403**	0.476**	0.534**	0.340**	0.025	0.285**	0.993**	0.155**	0.241**	0.571**	0.512**	0.257**	0.102	1	0.888**	0.670**	-0.117*	0.619**	0.826**
UMA	0.416**	0.486**	0.507**	-0.129*	-0.156**	0.293**	0.881**	0.071	-0.169**	0.346**	0.523**	-0.079	0.112	0.888**	1	0.253**	-0.553**	0.189**	0.992**
UFA	0.177**	0.218**	0.306**	0.923**	0.304**	0.125*	0.666**	0.211**	0.781**	0.642**	0.234**	0.669**	0.033	0.670**	0.253**	1	0.648**	0.997**	0.135*
AFI	-0.162**	-0.171**	-0.114	0.885**	0.384**	-0.134*	-0.125*	0.120*	0.801**	0.288**	-0.186**	0.629**	-0.063	-0.117*	-0.553**	0.648**	1	0.695**	-0.647**
UFE	0.151*	0.186**	0.274**	0.947**	0.322**	0.108	0.616**	0.210**	0.804**	0.626**	0.201**	0.686**	0.027	0.619**	0.189**	0.997**	0.695**	1	0.069
UME	0.404**	0.471**	0.482**	-0.248**	-0.199**	0.284**	0.820**	0.046	-0.271**	0.275**	0.507**	-0.165**	0.111	0.826**	0.992**	0.135*	-0.647**	0.069	1

3.6.Assessment of nutritional status among the Bengali Muslim children

The age-sex specific descriptive statistics of height-for age z-score (HAZ), weight-for-age (WAZ), weight-for-height z-score (WHZ), BMI-for-age z-score (BMIAZ) and head circumference-for-age z-score (HdCAZ) values and overall prevalence of stunting (low height-for-age) (<-2SD), underweight (low weight-for-age) (<-2SD), wasting (low weight-for-height) (<-2SD), thinness (low BMI-for-age) (<-2SD) and low head circumference-for-age (low HdC-for-age) among the children using the WHO (2011) reference population is depicted in Table 3.8. The overall mean HAZ value was observed to be higher among boys (--1.44 ±2.19) than girls (-1.25±1.97) ($p<0.01$). The overall mean WAZ value was observed to be higher among boys (-1.68 ±1.62) than girls (-1.43±1.53). The overall sex-specific mean values of WHZ (-1.21±1.83 vs. -0.94±1.66), BMIAZ (-1.09±1.88 vs. -0.86±1.68) and HdCAZ (-1.42±1.87 vs. -0.96±1.10) were observed to be higher among boys than girls. The age-sex specific mean HAZ, WAZ, WHZ, BMIAZ and HdCAZ values did not show any age specific trend. The age specific mean differences were significant in HAZ (F-value= 15.333; $p<0.01$) and WAZ (F-value= 8.633; $p<0.01$) and HdCAZ (F-value= 54.458; $p<0.01$) among boys. The age specific mean differences were significant in HAZ (F-value= 19.800; $p<0.01$) and WAZ (F-value= 9.374; $p<0.01$), HdCAZ (F-value= 38.433; $p<0.01$) and BMIAZ (F-value= 2.483; $p<0.05$) among girls (Table 3.8).

3.7. Prevalence of overall undernutrition among the children

The overall prevalence of stunting, underweight, thinness, wasting and low HdC-for-age was observed to be 44.61% (boys: 45.54%; girls: 43.55%), 40.03% (boys: 40.00%; girls: 40.07%), 26.31% (boys: 32.92%; boys: 18.82%), 26.96% (boys: 33.54%; girls: 19.51%) and 33.66% (boys: 45.23; girls: 20.56%), respectively.

The age and sex specific prevalence of stunting was observed to be highest among boys (61.97%) aged 3 years and among girls (66.04) aged 2 years. The lowest prevalence of stunting of 15.94% (in 5 years) and 18.97% (in 1 year) was observed among boys and girls, respectively (Table 3.9). The age and sex specific prevalence of underweight was highest in 3 years (boys: 56.34% and girls: 52.00%) among boys and girls. The lower prevalence of underweight was observed to be 20.29% and 22.22% (in 5 years) among boys and girls, respectively (Table 3.9). The age and sex specific prevalence of wasting was highest in 2 years (43.33%) and in 1 year (32.76%) among boys and girls, respectively. The lowest prevalence of wasting was observed to be 19.67% and 12.96 in 4 years among boys and girls, respectively (Table 3.9). The age and sex specific prevalence of thinness was highest in 1 year (boys: 42.19% and girls: 32.76%) among boys and girls. The lowest prevalence of thinness was observed to be 18.03% in boys aged 4 years and 11.32% in girls aged 2 years (Table 3.9). The age and sex specific prevalence of low HdC-for-age was highest in 5 years (boys: 72.46 and girls: 45.83) among boys and girls. The lowest prevalence of low HdC-for-age was observed to be 6.25% among boys aged 1 year and 0.00% among girls aged in 2 years (Table 3.9).

3.8. Prevalence of moderate and severe undernutrition among the Bengali Muslim children

The age and sex specific prevalence of moderate (-2SD to -3SD) and severe (<-3SD) grades of stunting, underweight, thinness, wasting and low HdC-for-age is depicted in Table 3.10 and Table 3.11. The overall prevalence of moderate stunting was observed to be higher among girls (20.91%) than boys (19.69%), but severe stunting was found to be higher among boys (25.85%) than girls (22.65%) ($p>0.05$). The overall prevalence of moderate underweight also was observed to be higher among girls (23.69%) than boys (21.54%), but severe underweight was found to be higher among boys (18.46%) than girls (16.38%) ($p>0.05$).

The overall prevalence of moderate wasting was observed to be higher among boys (22.77%) than girls (11.50%). Severe wasting was found to be higher among boys (10.77%) than girls (8.01%) ($p>0.05$). The overall prevalence of moderate thinness was observed to be higher among boys (21.23%) than girls (10.45%). Severe thinness was higher among boys (11.69%) than girls (8.36%) ($p>0.05$). The overall prevalence of moderate low HdC-for-age was observed to be higher among boys (28.92%) than girls (17.42%). Severe low HdC-for-age was found to be higher among boys (16.31%) than girls (3.14%) ($p>0.05$). The age and sex-specific prevalence of moderate and severe grades of stunting, underweight, thinness, wasting and low HdC-for-age did not show any age specific trend among the children.

The age and sex specific prevalence of moderate grade of stunting was highest among 3 years (36.62%) and 4 years (31.48%) boys and girls, respectively. The age and sex specific prevalence of moderate grade of underweight was observed to be highest among 3 years (26.76%) and 4 years (33.33%) boys and girls, respectively. The age and sex specific prevalence of moderate grade of wasting was found to be highest among 2 years (30.00%) and 5 years (15.28%) boys and girls, respectively.

The age and sex specific prevalence of moderate grade of thinness was observed to be highest among 5 years (boys: 27.54% and girls: 13.89%) boys and girls. The age and sex specific prevalence of moderate grade of low HdC-for-age was highest among 5 years (boys: 43.48% and girls: 44.44%) boys and girls.

The age and sex specific prevalence of severe grade of stunting was highest among 2 years (41.67%) and 3 years (40.00%) boys and girls, respectively. The age and sex specific prevalence of severe grade of underweight was highest among 2 years (30.00%) and 3 years (26.00%) boys and girls, respectively. The age and sex specific prevalence of severe grade of wasting was highest among 1-year (boys: 14.06% and girls: 20.69%) boys and girls. The age and sex specific prevalence of severe grade of thinness was higher among 1-year (boys: 18.75% and girls: 20.69%) boys and girls. The age and sex specific prevalence of severe grade of low HdC-for-age was observed higher among 5 years (28.99%) and 3 years (10.00%) boys and girls, respectively.

3.9. Sex differences in the prevalence of overall and age and sex specific prevalence of overall undernutrition among Bengali Muslim boys and girls

Sex differences in the prevalence of overall and sex specific prevalence of stunting and underweight were statistically not significant between boys and girls ($p>0.05$) using chi-square analysis (Table 3.12). Sex differences in the prevalence of overall and sex specific prevalence of thinness, wasting and low HdC-for-age were statistically significant between boys and girls ($p<0.01$) using chi-square analysis (Table 3.11). Statistically significant sex differences have been observed in overall stunting in 1 year ($p<0.01$)(χ^2-value= 6.765), overall thinness in 2 years (χ^2-value= 5.984) ($p<0.01$) and 5 years (χ^2-value= 5.056) ($p<0.05$), overall wasting in 2 years (χ^2-value= 5.881) and 5 years (χ^2-value= 4.311) ($p<0.05$) and in overall low HdC-for-age in 2 years (χ^2-value=11.589) ($p<0.01$), 3 years (χ^2-value= 4.700) ($p<0.05$) and 4 years (χ^2-value= 9.559) ($p<0.01$) among boys and girls. Sex differences in the prevalence of overall and age and sex specific prevalence of different grades (moderate and severe) of undernutrition were statistically not significant in most of the categories, except in case of moderate thinness (χ^2-value= 9.496) ($p<0.01$) and moderate and severe low HdC-for-age (χ^2-value= 6.992) ($p<0.01$)(Table 3.13).

Sex specific differences in the different categories of undernutrition have been observed in case of moderate stunting in 4 years (χ^2-value= 3.638) and severe stunting in 1 year (χ^2-value= 4.246) ($p<0.05$), moderate wasting (χ^2-value= 3.972) and moderate thinness (χ^2-value= 4.63) in 2 years ($p<0.05$). Statistically significant sex differences have been observed in moderate low HdC-for-age in 2 years (χ^2-value= 6.44) ($p<0.01$), 3 years (χ^2-value= 17.008) ($p<0.01$) and 4 years (χ^2-value= 4.064) ($p<0.05$) of boys and girls. Statistically significant sex differences have been observed in severe low HdC-for-age in 2 years (χ^2-value= 4.132) ($p<0.05$), 4 years (χ^2-value= 6.799) ($p<0.01$) and 5 years (χ^2-value= 14.013) ($p<0.01$) of boys and girls (Table 3.13).

Table 3.8: Age-sex specific descriptive statistics of conventional anthropometric measures among Bengali Muslim children

Age Group	Sample size (N= 612)		HAZ		WAZ		WHZ		BMIAZ		HdCAZ	
	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
1 year	64	58	-1.37 ±2.38	0.09 ±2.24	-1.82 ±1.86	-0.99 ±1.75	-1.31 ±2.42	-1.33 ±2.37	-1.45 ±2.38	-1.45 ±2.28	0.73 ±1.61	-0.29 ±1.317
2years	60	53	-2.27 ±2.47	-1.91 ±1.74	-2.13 ±1.68	-1.70 ±1.40	-1.31 ±1.72	-0.93 ±1.57	-0.98 ±1.86	-0.67 ±1.72	-0.96 ±1.60	-0.02 ±0.02
3years	71	50	-2.07 ±1.71	-2.33 ±1.95	-2.10 ±1.73	-2.08 ±1.59	-1.22 ±1.97	-0.82 ±1.29	-0.97 ±1.96	-0.68 ±1.37	-1.92 ±1.25	-1.46 ±0.91
4years	61	54	-1.77 ±1.71	-1.93 ±1.29	-1.61 ±1.03	-1.88 ±1.35	-0.78 ±1.42	-0.99 ±1.55	-0.63 ±1.55	-0.90 ±1.57	-2.23 ±1.43	-1.23 ±0.87
5years	69	72	0.15 ±1.76	-0.58 ±1.46	-0.77 ±1.30	-0.77 ±1.13	-1.38 ±1.40	-0.66 ±1.28	-1.37 ±1.46	-0.63 ±1.21	-2.58 ±1.35	-1.65 ±0.81
Total	325	287	-1.44 ±2.19	-1.25 ±1.97	-1.68 ±1.62	-1.43 ±1.53	-1.21 ±1.83	-0.94 ±1.66	-1.09 ±1.88	-0.86 ±1.68	-1.42 ±1.87	-0.96 ±1.10
F-value			15.333	19.800	8.633	9.374	1.068	1.400	2.020	2.483	54.458	38.433
p- value			0.000	0.000	0.000	0.000	0.372	0.234	0.091	0.044	0.000	0.000

Table 3.9: Age-gender specific prevalence of overall undernutrition among the Bengali Muslim children

Age Group	Sample size (N= 612)		Stunting (Low height-for-age)		Underweight (Low weight-for-age)		Wasting (Low weight-for-height)		Thinness (Low BMI-for-age)		Low HdC-for-age	
	Boys	**Girls**	**Boys**	**Girls**	**Boys**	**Girls**	**Boys**	**Girls**	**Boys**	**Girls**	**Boys**	**Girls**
1 year	64	58	33 (51.56)	11 (18.97)	22 (34.38)	19 (32.76)	24 (37.50)	19 (32.76)	27 (42.19)	19 (32.76)	4 (6.25)	4 (6.90)
2years	60	53	33 (55.00)	35 (66.04)	31 (51.67)	26 (49.06)	26 (43.33)	8 (15.09)	22 (36.67)	6 (11.32)	17 (28.33)	0 (0.00)
3years	71	50	44 (61.97)	31 (62.00)	40 (56.34)	26 (52.00)	20 (28.17)	9 (18.00)	20 (28.17)	10 (20.00)	36 (50.70)	11 (22.00)
4years	61	54	27 (44.26)	33 (61.11)	23 (37.70)	28 (51.85)	12 (19.67)	7 (12.96)	11 (18.03)	7 (12.96)	40 (65.57)	11 (20.37)
5years	69	72	11 (15.94)	15 (20.83)	14 (20.29)	16 (22.22)	27 (39.13)	13 (18.06)	27 (39.13)	12 (16.67)	50 (72.46)	33 (45.83)
Total	325	287	148 (45.54)	125 (43.55)	130 (40.00)	115 (40.07)	109 (33.54)	56 (19.51)	107 (32.92)	54 (18.82)	147 (45.23)	59 (20.56)

Values in parenthesis indicates percentage

Table 3.10: Age-sex specific prevalence of moderate and severe undernutrition among the Bengali Muslim boys

Age Group	Sample Size	Stunting (Low height-for-age)		Underweight (Low weight-for-age)		Wasting (Low weight-for-height)		Thinness (Low BMI-for-age)		Low HdC-for-age	
		Moderate (<−2 SD to −3 SD)	Severe (<−3SD)	Moderate (<−2 SD to −3 SD)	Severe (<−3SD)	Moderate (−2 SD to −3 SD)	Severe (<−3SD)	Moderate (−2 SD to −3 SD)	Severe (<−3SD)	Moderate (−2 SD to −3 SD)	Severe (<−3SD)
1 years	64	15 (23.44)	18 (28.13)	12 (18.75)	10 (15.63)	15 (23.44)	9 (14.06)	15 (23.44)	12 (18.75)	3 (4.69)	1 (1.56)
2years	60	8 (13.33)	25 (41.67)	13 (21.67)	18 (30.00)	18 (30.00)	8 (13.33)	15 (25.00)	7 (11.67)	10 (16.67)	7 (11.67)
3years	71	26 (36.62)	18 (25.35)	19 (26.76)	21 (29.58)	11 (15.49)	9 (12.68)	11 (15.49)	9 (12.68)	27 (38.03)	9 (12.68)
4years	61	8 (13.11)	19 (31.15)	16 (26.23)	7 (11.48)	10 (16.39)	2 (3.28)	9 (14.75)	2 (3.28)	24 (39.34)	16 (26.23)
5years	69	7 (10.14)	4 (5.80)	10 (14.49)	4 (5.80)	20 (28.99)	7 (10.14)	19 (27.54)	8 (11.59)	30 (43.48)	20 (28.99)
Total	325	64 (19.69)	84 (25.85)	70 (21.54)	60 (18.46)	74 (22.77)	35 (10.77)	69 (21.23)	38 (11.69)	94 (28.92)	53 (16.31)

Values in parenthesis indicates percentage

Table 3.11: Age-gender specific prevalence of Moderate and severe undernutrition among the Bengali Muslim girls

Age Group	Sample Size	Stunting (Low height-for-age)		Underweight (Low weight-for-age)		Wasting (Low weight-for-height)		Thinness (Low BMI-for-age)		Low HdC-for-age	
		Moderate (<−2 SD to −3 SD)	Severe (<−3SD)	Moderate (<−2 SD to −3 SD)	Severe (<−3SD)	Moderate (−2 SD to−3 SD)	Severe (<−3SD)	Moderate (−2 SD to−3 SD)	Severe (<−3SD)	Moderate (−2 SD to−3 SD)	Severe (<−3SD)
1 years	58	6 (10.34)	5 (8.62)	8 (13.79)	11 (18.97)	7 (12.07)	12 (20.69)	7 (12.07)	12 (20.69)	3 (5.17)	1 (1.72)
2years	53	16 (30.19)	19 (35.85)	17 (32.08)	9 (16.98)	5 (9.43)	3 (5.66)	3 (5.66)	3 (5.66)	0 (0.00)	0 (0.00)
3years	50	11 (22.00)	20 (40.00)	13 (26.00)	13 (26.00)	5 (10.00)	4 (8.00)	5 (10.00)	5 (10.00)	6 (12.00)	5 (10.00)
4years	54	17 (31.48)	16 (29.63)	18 (33.33)	10 (18.52)	5 (9.26)	2 (3.70)	5 (9.26)	2 (3.70)	9 (16.67)	2 (3.70)
5years	72	10 (13.89)	5 (6.94)	12 (16.67)	4 (5.56)	11 (15.28)	2 (2.78)	10 (13.89)	2 (2.78)	32 (44.44)	1 (1.39)
Total	287	60 (20.91)	65 (22.65)	68 (23.69)	47 (16.38)	33 (11.50)	23 (8.01)	30 (10.45)	24 (8.36)	50 (17.42)	9 (3.14)

Values are in parenthesis indicates percentages

Table 3.12: Sex differences in the prevalence of overall and age and sex specific prevalence of overall undernutrition among Bengali Muslim boys and girls

Age Group	Sample size (N= 612)		Stunting (Low height-for-age)		Underweight (Low weight-for-age)		Thinness (Low BMI-for-age)		Wasting (Low weight-for-height)		Low HdC-for-age	
	Boys	Girls	χ^2-value	p-value	χ^2-value	p-value	χ^2-value	p-value	χ^2-value	p-value	χ^2-value	p-value
1 year	64	58	6.765	0.009**	0.018	0.893	0.523	0.469	0.144	0.704	0.053	0.818
2years	60	53	0.355	0.661	0.025	0.874	5.984	0.014**	5.881	0.015*	11.589	0.000**
3years	71	50	0.00	1.000	0.066	0.797	0.641	0.423	1.038	0.308	4.700	0.030*
4years	61	54	1.02	0.313	0.892	0.345	0.408	0.523	0.673	0.412	9.559	0.002**
5years	69	72	0.386	0.534	0.051	0.821	5.056	0.025*	4.311	0.038*	2.681	0.102
Total	325	287	0.093	0.760	0.000	1.000	9.222	0.002**	8.847	0.003**	21.043	0.000**

Table 3.13: Sex differences in the prevalence of overall and age and sex specific prevalence of different grades (moderate and severe) of undernutrition among Bengali Muslim boys and girls

Age Group	Stunting (Low height-for-age)				Underweight (Low weight-for-age)				Thinness (Low BMI-for-age)				Wasting (Low weight-for-height)				Low HdC-for-age			
	Moderate (<−2 SD to −3 SD)		Severe (<−3SD)		Moderate (<−2 SD to −3 SD)		Severe (<−3SD)		Moderate (<−2 SD to −3 SD)		Severe (<−3SD)		Moderate (<−2 SD to −3 SD)		Severe (<−3SD)		Moderate (<−2 SD to −3 SD)		Severe (<−3SD)	
	χ^2-value	p-value	χ^2-value	p-value	χ^2-value	p-value	χ^2-value	p-value	χ^2-value	p-value	χ^2-value	p-value	χ^2-value	p-value	χ^2-value	p-value	χ^2-value	p-value	χ^2-value	p-value
1 year	2.607	0.106	4.246	0.039*	0.393	0.531	0.168	0.682	1.861	0.173	0.049	0.825	1.861	0.173	0.661	0.416	0.091	0.763	0.416	0.519
2years	3.093	0.079	0.177	0.674	0.904	0.341	1.626	0.202	4.63	0.031*	0.487	0.485	3.972	0.046*	0.868	0.352	6.44	0.011**	4.132	0.042*
3years	1.607	0.205	1.501	0.221	0.005	0.944	0.004	0.950	0.251	0.616	0.014	0.906	0.251	0.616	0.193	0.660	17.008	0.000**	0.014	0.906
4years	3.638	0.056*	0.017	0.896	0.376	0.540	0.835	0.361	0.263	0.608	0.152	0.697	0.52	0.471	0.152	0.697	4.064	0.044*	6.799	0.009**
5years	0.366	0.545	0.007	0.933	0.092	0.762	0.093	0.760	2.648	0.104	2.47	0.116	2.47	0.116	1.78	0.182	0.005	0.944	14.013	0.000**
Total	0.092	0.762	0.516	0.473	0.256	0.613	0.323	0.570	9.496	0.002**	1.518	0.218	9.504	0.002	1.117	0.291	6.992	0.008**	23.964	0.000**

3.10. Descriptive statistics (Mean ±SD) of anthropometric variables of Bengali Muslim mothers

Descriptive statistics (mean ±SD) of anthropometric variables of mothers is depicted in Table 3.14. Overall mean values of height, weight, MUAC, WC, HC, BSF, TSF, SSF and SISF are 150.54, 50.33, 25.48, 79.16, 88.78, 10.20, 15.00, 18.41 and 19.00 respectively. Age group specific mean height, weight, weight, MUAC, WC and HC ranged from 150.08 cm (20-24 years) to 151.30 cm (30-34 years), from 49.50 kg (20-24 years) to 50.30 kg (30-34 years), from 25.17 cm (20-24 years) to 26.30 cm (30-34 years), from 77.60 cm (20-24 years) to 81.19 cm (30-34 years) and from 87.27 cm (20-24 years) to 91.09 cm (30-34 years), respectively. Age group specific mean BSF, TSF, SSF and SISF ranged from 9.94 (25-29 years) to 11.03 mm (30-34 years), from 14.54 mm (20-24 years) to 15.92 mm (30-34 years), from 17.64 mm (20-24 years) to 20.86 mm (30-34 years) and from 18.37 mm (25-29 years) to 21.52 mm (30-34 years), respectively. Statistically significant differences have been observed in MUAC (F-value=6.75), WC (F- value=6.51), HC (F- value=8.74), SSF (F- value=6.49) and SISF (F-value=9.19) between age groups ($p<0.01$) (Table 3.14).

Table 3.14: Descriptive statistics (mean ± SD) of age and sex specific anthropometric variables of Bengali Muslim mothers

Variable	Females (N=612)					
	20-24 years (N=218)	25-29 years (N=288)	30-34 years (N=106)	F- value	p- value	Total
Height (cm)	150.08±5.21	150.61±5.23	151.30±5.88	1.88	0.153	150.54±5.35
Weight (kg)	49.50±10.34	50.59±7.13	51.30±7.88	1.85	0.159	50.33±8.54
MUAC (cm)	25.17±2.72	25.42±2.47	26.30±2.90	6.75	0.001	25.48±2.66
WC (cm)	77.60±7.34	79.60±9.11	81.19±10.92	6.51	0.002	79.16±8.96
HC (cm)	87.27±7.09	89.08±7.92	91.09±9.21	8.74	0.000	88.78±7.98
BSF (mm)	10.13±6.18	9.94±4.51	11.03±4.49	1.75	0.174	10.20±5.17
TSF (mm)	14.54±5.04	14.98±5.06	15.92±5.41	2.58	0.077	15.00±5.12
SSF (mm)	17.64±7.65	18.08±7.78	20.86±8.35	6.49	0.002	18.41±7.91
SISF (mm)	18.58±6.73	18.37±6.50	21.52±7.15	9.19	0.000	19.00±6.79

3.11. Descriptive Statistics (Mean ±SD) of derived body composition variables and nutritional indices of Bengali Muslim mothers

Descriptive statistics (mean ±SD) of derived body composition variables and nutritional indices of mothers is depicted in Table 3.15. Overall mean values of PBF, FM, FFM, FMI, FFMI, TUA, UMA, UFA, AFI, UME, UFE, BMI, WHR, BAI, Σ4SKF and WHtR are 30.80, 15.70, 34.63, 6.90, 15.30, 52.22, 34.86, 17.37, 33.18, 32.88, 19.34, 22.20, 0.89, 30.12, 62.59 and 0.53, respectively. Age group specific mean PBF, FM, FFM, FMI and FFMI ranged from 30.37% (20-24 years) to 32.37% (30-34 years), from 15.26 kg (20-24 years) to 16.81 kg (30-34 years), from 34.24 kg (20-24 years) to 34.49 kg (30-34 years), from 6.75 kg/m^2 (20-24 years) to 7.30 kg/m^2 (30-34 years) and from 15.23 kg/m^2 (20-24 years) to 15.06 kg/m^2 (30-34 years), respectively. Age group specific mean TUA, UMA, UFA, AFI, UME, UFE ranged from 50.97 cm^2 (20-24 years) to 55.69 cm^2 (30-34 years), from 34.30 cm^2 (20-24 years) to 36.63 cm^2 (30-34 years), from 16.66 cm^2 (20-24 years) to 19.06 cm^2 (30-34 years), from 32.68% (20-24 years) to 33.98% (30-34 years), from 32.44 cm^2 (20-24 years) to 34.41cm^2 (30-34 years) and from 18.52 cm^2 (20-24 years) to 21.28 cm^2, respectively. Age group specific mean BMI, WHR, BAI (%) and Σ4SKF ranged from 21.98 kg/m^2 (20-24 years) to 22.36 kg/m^2 (30-34 years), from 87.27 (20-24 years) to 91.09 (30-34 years), from 29.50% (20-24 years) to 30.99% (30-34 years) and from 60.90 mm (20-24 years) to 69.33 mm (30-34 years), respectively. Age specific mean WHtR ranged from 0.52 (20-24 years) to 0.54 (30-34 years). Statistically significant differences have been observed in PBF (F- value=6.55) ($p<0.01$), FM (F-value=4.56) ($p<0.01$), FMI (F- value=3.45) ($p<0.05$), TUA (F- value=7.04)($p<0.01$), UMA (F-value=2.83) ($p<0.05$), UFA (F- value= 4.98) ($p<0.01$), UFE (F- value=4.48) ($p<0.01$), BAI (F- value=4.60) ($p<0.01$), Σ4SKF (F- value= 7.20) ($p<0.01$) and WHtR (F- value= 5.13) ($p<0.01$) between age groups (Table 3.15).

Table 3.15: Descriptive statistics (mean ± SD) of the derived anthropometric indices relating to body composition and nutritional status of mothers

Indices	20-24 years (N=218)	25-29 years (N=288)	30-34 years (N=106)	F-value	p-value	Total
PBF (%)	30.37±5.10	30.56±4.81	32.37±4.86	6.55	0.002	30.80±5.00
FM (kg)	15.26±4.74	15.62±4.04	16.81±4.47	4.56	0.011	15.70±4.40
FFM (kg)	34.24±6.60	34.97±4.33	34.49±4.35	1.25	0.287	34.63±5.26
FMI (kg/m^2)	6.75±1.97	6.86±1.66	7.30±1.72	3.45	0.032	6.90±1.79
FFMI (kg/m^2)	15.23±3.04	15.44±1.92	15.06±1.65	1.15	0.318	15.30±2.35
TUA (cm^2)	50.97±10.94	51.90±10.10	55.69±12.31	7.04	0.001	52.22±10.92
UMA (cm^2)	34.30±8.68	34.62±8.29	36.63±9.13	2.83	0.060	34.86±8.61
UFA (cm^2)	16.66±6.25	17.28±6.25	19.06±7.32	4.98	0.007	17.37±6.48
AFI (%)	32.68±9.49	33.27±9.14	33.98±9.08	0.72	0.486	33.18±9.25
UME (cm^2)	32.44±9.10	32.66±8.80	34.41±9.45	1.87	0.155	32.88±9.04
UFE (cm^2)	18.52±7.53	19.25±7.61	21.28±8.79	4.48	0.012	19.34±7.84
BMI (kg/m^2)	21.98±4.52	22.30±2.93	22.36±2.81	0.65	0.521	22.20±3.56
WHR	87.27±7.09	89.08±7.92	91.09±9.21	0.27	0.762	0.89±0.66
BAI (%)	29.50±3.73	30.26±4.50	30.99±4.80	4.60	0.010	30.12±4.32
Σ4SKF (mm)	60.90±20.31	61.38±19.82	69.33±20.80	7.20	0.001	62.59±20.37
WHtR	0.52±0.04	0.53±0.06	0.54±0.07	5.13	0.006	0.53±0.05

3.12. Pearson Correlation Coefficient between the anthropometric variables among Bengali Muslim mothers

Table 3.16 depicts the Pearson correlation coefficients between the anthropometric variables among Bengali Muslim mothers. Most of anthropometric variables were highly significantly correlated with each other ($p<0.01$). Age showed highly significant correlation with the variables like height, weight, MUAC, WC, HC, TSF, SSF, SISF, PBF, FM, FMI, TUA, UMA, UFA, UFE, BAI and WHtR ($p<0.01$ and $p<0.05$) except BSF, FFM, FFMI, AFI, UME, BMI and WHR. PBF has showed statistically significant correlation with most of the variables ($p<0.01$ and $p<0.05$) except FFM, UMA and UME ($p>0.05$). BMI has showed highly significant correlation with weight, MUAC, WC, HC, BSF, TSF, SSF, SISF, PBF, FM, FFM, FMI, FFMI, TUA, UFA, AFI, UFE and BAI ($p<0.01$). WHR showed highly significant correlation with height, weight, MUAC, WC, HC, BSF, SSF, SISF, PBF, FM, FMI, TUA, UMA, UME and BAI ($p<0.01$). WHR also showed significant correlation with UFA ($p<0.05$). BAI showed statistically highly significant correlation with all other variables ($p<0.01$) except BSF and FFM ($p>0.05$) (Table 3.16).

Table 3.16: Pearson Correlation Coefficient between the Anthropometric Variables of mothers

	Age	Height	Weight	MUAC	WC	HC	BSF	TSF	SSF	SISF	PBF	FM	FFM	FMI	FFMI	TUA	UMA	UFA	AFI	UME	UFE	BMI	WHR	BAI	WHtR
Age	**1**	0.078*	0.077*	0.136**	0.144**	0.167**	0.046	0.089*	0.126**	0.122**	0.122**	0.113**	0.031	0.097*	-0.009	0.136**	0.083*	0.119**	0.049	0.066	0.113**	0.042	0.009	0.122**	0.122**
Height	0.078*	1	0.353**	0.291**	0.351**	0.290**	0.201**	0.097*	0.396**	0.334**	0.321**	0.404**	0.236**	0.153**	-0.224**	0.295**	0.240**	0.178**	0.004	0.214**	0.165**	-0.071	0.185**	-0.301**	0.040
Weight	0.077	0.353**	1	0.367**	0.343**	0.343**	0.291**	0.384**	0.406**	0.420**	0.460**	0.861**	0.905**	0.831**	0.741**	0.371**	0.139**	0.442**	0.278**	0.071	0.435**	0.906**	0.140**	0.131**	0.338**
MUAC	0.136**	0.291**	0.367**	1	0.601**	0.563**	0.263**	0.354**	0.398**	0.450**	0.449**	0.484**	0.191**	0.438**	0.054	0.997**	0.808**	0.608**	0.028	0.711**	0.570**	0.256**	0.242**	0.388**	0.543**
WC	0.144**	0.351**	0.365**	0.601**	1	0.761**	0.278**	0.348**	0.432**	0.440**	0.456**	0.491**	0.183**	0.430**	0.016	0.604**	0.402**	0.484**	0.155**	0.326**	0.466**	0.227**	0.604**	0.511**	0.949**
HC	0.167**	0.290**	0.343**	0.563**	0.761**	1	0.152**	0.415**	0.341**	0.311**	0.355**	0.425**	0.201**	0.379**	0.058	0.571**	0.321**	0.536**	0.231**	0.237**	0.522**	0.229**	-0.053	0.824**	0.824**
BSF	0.046	0.201**	0.291**	0.263**	0.278**	0.152**	1	0.361**	0.523**	0.519**	0.699**	0.570**	-0.004	0.562**	-0.099*	0.271**	0.056	0.382**	0.306**	0.000	0.378**	0.218**	0.245**	0.039	0.229**
TSF	0.089*	0.097*	0.384**	0.354**	0.348**	0.415**	0.361**	1	0.475**	0.508**	0.689**	0.630**	0.096*	0.658**	0.048	0.362**	-0.258**	0.951**	0.938**	-0.400**	0.964**	0.363**	0.023	0.358**	0.338**
SSF	0.126**	0.396**	0.406**	0.398**	0.432**	0.341**	0.523**	0.475**	1	0.756**	0.864**	0.745**	0.037	0.688**	-0.143**	0.404**	0.122**	0.519**	0.379**	0.044	0.512**	0.252**	0.247**	0.117**	0.330**
SISF	0.122**	0.334**	0.420**	0.450**	0.440**	0.311**	0.519**	0.508**	0.756**	1	0.893**	0.758**	0.049	0.722**	-0.104*	0.453**	0.152**	0.560**	0.401**	0.069	0.551**	0.295**	0.297**	0.119**	0.359**
PBF	0.122**	0.321**	0.460**	0.449**	0.456**	0.355**	0.699**	0.689**	0.864**	0.893**	1	0.838**	0.046	0.816**	-0.102*	0.452**	0.040	0.708**	0.603**	-0.062	0.701**	0.343**	0.269**	0.171**	0.380**

FM	0.113**	0.404**	0.861**	0.484**	0.491**	0.425**	0.570**	0.630**	0.745**	0.758**	0.838**	1	0.563**	0.963**	0.373**	0.491**	0.110**	0.682**	0.508**	0.008	0.675**	0.730**	0.233**	0.188**	0.414**
FFM	0.031	0.236**	0.905**	0.191**	0.183**	0.201**	-0.004	0.096*	0.037	0.049	0.046	0.563**	1	0.544**	0.892**	0.193**	0.133**	0.147**	0.027	0.109**	0.142**	0.862**	0.032	0.055	0.180**
FMI	0.097*	0.153**	0.831**	0.438**	0.430**	0.379**	0.562**	0.658**	0.688**	0.722**	0.816**	0.963**	0.544**	1	0.471**	0.443**	0.044	0.688**	0.556**	-0.059	0.684**	0.814**	0.197**	0.290**	0.442**
FFMI	-0.009	-0.224**	0.741**	0.054	0.016	0.058	-0.099*	0.048	-0.143**	-0.104*	-0.102	0.373**	0.892**	0.471**	1	0.054	0.022	0.061	0.022	0.011	0.062	0.896**	0.049	0.186**	0.160**
TUA	0.136**	0.295**	0.371**	0.997**	0.604**	0.571**	0.271**	0.362**	0.404**	0.453**	0.452**	0.491**	0.193**	0.443**	0.054	1	0.805**	0.616**	0.038	0.706**	0.579**	0.258**	0.237**	0.393**	0.545**
UMA	0.083*	0.240**	0.139**	0.808**	0.402**	0.321**	0.056	-0.258**	0.122**	0.152**	0.040	0.110**	0.133**	0.044	0.022	0.805**	1	0.029	-0.547**	0.988**	-0.018	0.037	0.235**	0.175**	0.347**
UFA	0.119**	0.178**	0.442**	0.608**	0.484**	0.536**	0.382**	0.951**	0.519**	0.560**	0.708**	0.682**	0.147**	0.688**	0.061	0.616**	0.029	1	0.789**	-0.122**	0.998**	0.386**	0.086*	0.430**	0.457**
AFI	0.049	0.004	0.278**	0.028	0.155**	0.231**	0.306**	0.938**	0.379**	0.401**	0.603**	0.508**	0.027	0.556**	0.022	0.038	-0.547**	0.789**	1	-0.661**	0.814**	0.294**	-0.051	0.229**	0.164**
UME	0.066	0.214**	0.071	0.711**	0.326**	0.237**	0.000	-0.400**	0.044	0.069	-0.062	0.008	0.109**	-0.059	0.011	0.706**	0.988**	-0.122	-0.661**	1	-0.169**	-0.022	0.221**	0.107**	0.164**
UFE	0.113**	0.165**	0.435**	0.570**	0.466**	0.522**	0.378**	0.964**	0.512**	0.551**	0.701**	0.675**	0.142**	0.684**	0.062	0.579**	-0.018	0.998**	0.814**	-0.169**	1	0.385**	0.075	0.425**	0.275**
BMI	0.042	-0.071	0.906**	0.256**	0.227**	0.229**	0.218**	0.363**	0.252**	0.295**	0.343**	0.730**	0.862**	0.814**	0.896**	0.258**	0.037	0.386**	0.294**	-0.022	0.385**	1	0.067	0.268**	0.442**
WHR	0.009	0.185**	0.140**	0.242**	0.604**	-0.053**	0.245**	0.023	0.247**	0.297**	0.269**	0.233**	0.032	0.197**	-0.049	0.237**	0.235**	0.086*	-0.051	0.221**	0.075	0.067	1	-0.160**	0.442**

BAI	0.122**	-0.301**	0.131**	0.388**	0.511**	0.824**	0.039	0.358**	0.117**	0.119**	0.171**	0.188**	0.055	0.290**	0.186**	0.393**	0.175**	0.430**	0.229**	0.107**	0.425**	0.268**	-0.160**	1	0.583**
WHtR	0.122**	0.040	0.338**	0.543**	0.949**	0.715**	0.229**	0.338**	0.330**	0.359**	0.380**	0.414**	0.180**	0.442**	0.160**	0.545**	0.347**	0.457**	0.164**	0.275**	0.442**	0.353**	0.583**	0.690**	0.690**

3.13. Linear regression analysis of age on the different anthropometric and body composition variables among the Bengali Muslim mothers

Linear regression analysis was done to assess the effect of age on the different anthropometric and body composition variables among the Bengali Muslim mothers. The results of linear regression analysis is depicted in Table 3.17. The results showed that age had a positive effect on most of the variables (e.g., height, weight, BSF, TSF, SSF, SISF, MUAC, WC, HC, PBF, FM, FFM, FMI etc.) but a negative effect on FFMI. The age dependency was statistically significant on height (t= 1.933) ($p<0.05$), weight (t= 1.904) ($p<0.05$), TSF (t= 2.197) ($p<0.05$), SSF (t= 3.125) ($p<0.01$), SISF (t= 3.039) ($p<0.01$), MUAC (t= 3.393) ($p<0.01$), WC (t= 3.600) ($p<0.01$), HC (t= 4.181) ($p<0.01$), PBF (t= 3.030) ($p<0.01$), FM (t= 2.798) ($p<0.01$), FMI (t=2.401) ($p<0.01$), TUA (t= 3.401) ($p<0.01$)UMA (t= 2.064) ($p<0.05$), UFA (t= 2.965) ($p<0.01$), UFE (t= 2.821) ($p<0.01$), BAI (t= 3.034) ($p<0.01$), **Σ**4SKF (t= 3.073) ($p<0.01$) and WHtR (t= 3.028) ($p<0.01$). The effect of age was statistically insignificant in case of BSF (t= 1.147), FFM (t= 0.759), FFMI (t= -0.233), AFI (t= 1.201), UME (t= 1.642), BMI (t= 1.049) and WHR (t= 0.216) ($p>0.05$) (Table 3.17).

Table 3.17: Linear regression analyses of age on the different anthropometric and body composition variables among the Bengali Muslim mothers

Indices	B	S.E	Beta	Adjusted R^2	t	p-value
Height	0.010	0.005	0.078	0.004	1.933	0.054
Weight	0.006	0.003	0.007	0.004	1.904	0.057
BSF	0.006	0.006	0.046	0.001	1.147	0.252
TSF	0.012	0.006	0.089	0.006	2.197	0.028
SSF	0.011	0.004	0.126	0.014	3.125	0.002
SISF	0.013	0.004	0.122	0.013	3.039	0.002
MUAC	0.036	0.011	0.136	0.017	3.393	0.001
WC	0.011	0.003	0.144	0.019	3.600	0.000
HC	0.015	0.004	0.167	0.026	4.181	0.000
PBF	0.017	0.006	0.122	0.013	3.030	0.003
FM	0.018	0.006	0.113	0.011	2.798	0.005
FFM	0.004	0.005	0.031	-0.001	0.759	0.448
FMI	0.038	0.016	0.097	0.008	2.401	0.017
FFMI	-0.003	0.012	-0.009	-0.002	-0.233	0.816
TUA	0.009	0.003	0.136	0.017	3.401	0.001
UMA	0.007	0.003	0.083	0.005	2.064	0.039
UFA	0.013	0.004	0.119	0.013	2.965	0.003
AFI	0.004	0.003	0.049	0.001	1.201	0.230
UME	0.005	0.003	0.066	0.003	1.642	0.101
UFE	0.010	0.004	0.113	0.011	2.821	0.005
BMI	0.008	0.008	0.042	0.000	1.049	0.294
WHR	0.093	0.430	0.009	-0.002	0.216	0.829
BAI	0.020	0.007	0.122	0.013	3.034	0.003
Σ4SKF	0.004	0.001	0.123	0.014	3.073	0.002
WHtR	7.729	2.553	0.122	0.013	3.028	0.003

3.14. Linear regression analyses of BMI on the different anthropometric and body composition variables among the Bengali Muslim mothers

Linear regression analysis was done to assess the effect of BMI on the different anthropometric and body composition variables among the Bengali Muslim mothers. The results of linear regression analysis is depicted in Table 3.18. The results showed that BMI had a positive effect on most of the variables (e.g., weight, BSF, TSF, SSF, SISF, MUAC, WC, HC, PBF, FM, FFM, FMI etc.) but a negative effect on height (t= -1.749) and UME (t= -0.551). The BMI dependency was statistically significant ($p<0.01$) on weight (t= 52.939), BSF (t= 5.513), TSF (t= 9.612), SSF (t= 6.428), SISF (t= 7.628), MUAC (t= 6.563), WC (t= 5.764), HC (t= 5.811), PBF (t= 9.026), FM (t= 26.409), FFM (t= 41.975), FMI (t= 34.569), FFMI (t= 49.863), TUA (t= 6.606), UFA (t= 10.344), AFI (t= 7.609), UFE (t= 10.317), BAI (t= 6.879), **Σ**4SKF (t=9.006) and WHtR (t= 9.330). The effect of age was statistically insignificant in case of height (t= -1.749), UMA (t= 0.911), UME (t= -0.551) and WHR (t= 1.652) ($p>0.05$) (Table 3.18).

Table 3.18: Linear regression analyses of BMI on the different anthropometric and body composition variables among the Bengali Muslim mothers

Indices	B	S.E	Beta	Adjusted R^2	t	p-value
Height	-0.047	0.027	-0.071	0.003	-1.749	0.081
Weight	0.378	0.007	0.906	0.821	52.939	0.000
BSF	0.150	0.027	0.218	0.046	5.513	0.000
TSF	0.252	0.026	0.363	0.130	9.612	0.000
SSF	0.113	0.018	0.252	0.062	6.428	0.000
SISF	0.155	0.020	0.295	0.086	7.628	0.000
MUAC	0.343	0.052	0.256	0.064	6.563	0.000
WC	0.090	0.016	0.227	0.050	5.764	0.000
HC	0.102	0.018	0.229	0.051	5.811	0.000
PBF	0.246	0.027	0.343	0.116	9.026	0.000
FM	0.591	0.022	0.730	0.533	26.409	0.000
FFM	0.584	0.014	0.862	0.742	41.975	0.000
FMI	1.617	0.047	0.814	0.661	34.569	0.000
FFMI	1.360	0.027	0.896	0.803	49.863	0.000
TUA	0.084	0.013	0.258	0.065	6.606	0.000
UMA	0.015	0.017	0.037	0.000	0.911	0.362
UFA	0.212	0.021	0.386	0.148	10.344	0.000
AFI	0.113	0.015	0.294	0.085	7.609	0.000
UME	-0.009	0.016	-0.022	-0.001	-0.551	0.582
UFE	0.175	0.017	0.385	0.147	10.317	0.000
WHR	3.585	2.170	0.067	0.003	1.652	0.099
BAI	0.221	0.032	0.268	0.070	6.879	0.000
Σ4SKF	0.060	0.007	0.343	0.116	9.006	0.000
WHtR	19.053	2.042	0.353	0.123	9.330	0.000

3.15. Assessment of nutritional status among the Bengali Muslim mothers using BMI

The nutritional status of the Bengali Muslim mothers based on standard BMI cut-off points of WHO (2004) for Asian Indians is shown in Table 3.19. The result showed that the overall prevalence of undernutrition was (BMI< 18.50 kg/m^2)10.29%. The overall prevalence of overweight (BMI= 23.00-24.99 kg/m^2) and obesity (BMI≥ 25.00 kg/m^2) were 21.08% and 15.36%, respectively. Therefore, overall prevalence of overnutrition (BMI≥23.00 kg/m^2) was 36.44%. Age group specific prevalence of undernutrition among the mothers ranged from 4.72% (30-34 years) to 17.89% (20-24 years). Age group specific prevalence of overweight among the mothers ranged from 16.67% (25-29 years) to 32.08% (30-34 years).Age group specific prevalence of obesity among the mothers ranged from 11.81% (25-29 years) to 24.53% (30-34 years).

χ^2- analysis showed that there were age-specific statistically significant differences in the prevalence of undernutrition (χ^2- value= 15.425, p<0.01), overweight (χ^2- value= 6.904, p<0.01) and combined overnutrition (χ^2- value= 11.480, p<0.01) between the age groups of mothers. Age-specific differences were not significant in the prevalence of obesity (χ^2- value= 6.784, p>0.05).

Table 3.19: Nutritional status of the Bengali Muslim mothers based on internationally accepted cut-offs of BMI for Asian Indians (WHO 2004)

Age group	Sample Size	Undernutrition (BMI< 18.50 kg/m^2)	Overweight (BMI= 23.00-24.99 kg/m^2)	Obese (BMI≥ 25.00 kg/m^2)	Combined Overnutrition (BMI≥ 23.00 kg/m^2)
20-24 years	218	39 (17.89)	47 (21.56)	34 (15.60)	81 (37.16)
25-29 years	288	19 (6.60)	48 (16.67)	34 (11.81)	82 (28.47)
30-34 years	106	5 (4.72)	34 (32.08)	26 (24.53)	60 (56.60)
Total	612	63 (10.29)	129 (21.08)	94 (15.36)	223 (36.44)
χ^2- value		15.425	6.904	6.784	11.480
p-value		0.000	0.032	6.009	0.003

Values in parenthesis indicates percentages

3.16. Assessment of undernutrition among the Bengali Muslim mothers using BMI vs. MUAC

Nutritional status was also assessed used using the sex specific MUAC cut-off points of <22 cm for mothers as specified by James et al. (1994). The results are shown in Table 3.20. The overall prevalence of undernutrition in terms of low MUAC value was 7.03%. The nutritional status of the Bengali Muslim mothers was classified using the combination of MUAC with BMI (Table 3.19). It has been observed that 8.17% of mothers were undernourished in terms of BMI with normal MUAC and 4.90% mothers were undernourished (ie., having MUAC <22 cm) with normal BMI values.

Table 3.20: Assessment of undernutrition among the Bengali Muslim mothers using BMI vs. MUAC

Nutritional status	Normal (BMI≥ 18.50 kg/m^2)	Undernutrition (BMI< 18.50 kg/m^2)	Total
Normal (MUAC ≥22.00 cm)	519 (84.80)	50 (8.17)	569 (92.97)
Undernutrition (MUAC<22.00 cm)	30 (4.90)	13 (2.12)	43 (7.03)
Total	549 (89.71)	63 (10.29)	612 (100.00)

Values in parenthesis indicates percentages

3.17. Assessment of nutritional status among the Bengali Muslim mothers using WC, WHR, WHtR, PBF and Σ4SKF

The prevalence of overweight-obesity of the mothers was also assessed using the cut off values of WC, WHR, WHtR, PBF and Σ4SKF and is depicted in Table 3.21 and Table 3.22. Prevalence of overweight-obesity was 40.85%, 90.20%, 64.05%, 54.41% and 69.61% in terms of WC, WHR, WHtR, PBF and Σ4SKF, respectively. Age specific highest prevalence of overweight-obesity has been observed in the middle age groups (25-29 years) of mothers (Table 3.21). The nutritional status of the Bengali Muslim mothers was classified using the combination of BMI with WC, WHR, WHtR, PBF and Σ4SKF in Table 3.23. It is evident from Table 3.24 that the prevalence of higher levels of regional adiposity was 20.26% in WC (>80 cm) and BMI (≥ 23.00 kg/m^2), 34.31% in WHR (>0.8) and BMI (≥ 23.00 kg/m^2), 27.29% in WHtR (>0.5) and BMl (≥ 23.00 kg/m^2), and 26.14% in PBF (>30.00%) and BMl (≥ 23.00 kg/m^2), and 30.88% in Σ4SKF (< 50mm) and BMl (≥ 23.00 kg/m^2).

Table 3.21: Prevalence of overweight, obesity and adiposity among the Bengali Muslim mothers using WC, WHR, WHtR, PBF and Σ4SKF

Index		**Females**
WC	**Obesity (WC> 80 cm)**	250 (40.85)
	Normal (WC< 80 cm)	362 (59.15)
WHR	**Obesity (WHR> 0.8)**	552 (90.20)
	Normal (WHR< 0.8)	60 (9.80)
WHtR	**Obesity (WHtR> 0.5)**	392 (64.05)
	Normal (WHtR< 0.5)	220 (35.95)
PBF	**Obesity (PBF> 30.00%)**	333 (54.41)
	Normal (PBF< 30.00%)	279 (45.59)
Σ4SKF	**High (Σ4SKF> 50mm)**	426 (69.61)
	Normal (Σ4SKF< 50mm)	186 (30.39)

Values in parenthesis indicates percentages

Table 3.22: Age-specific prevalence of overweight, obesity and adiposity among the Bengali Muslim mothers using WC, WHR, WHtR, PBF and Σ4SKF

Index		**Bengali Muslim Mothers**		
		20-24 years (N= 218)	**25-29 years (N= 288)**	**30-34 years (N= 106)**
WC	**Obesity (WC> 80 cm)**	72 (33.03)	126 (43.75)	52 (49.06)
	Normal (WC< 80 cm)	146 (66.97)	162 (56.25)	54 (50.94)
WHR	**Obesity (WHR> 0.8)**	203 (93.12)	256 (88.89)	93 (87.74)
	Normal (WHR< 0.8)	15 (6.88)	32 (11.11)	13 (12.26)
WHtR	**Obesity (WHtR> 0.5)**	130 (59.63)	185 (64.24)	77 (72.64)
	Normal (WHtR< 0.5)	88 (40.37)	103 (35.76)	29 (27.36)
PBF	**Obesity (PBF> 30.00%)**	112 (51.38)	149 (51.74)	72 (67.92)
	Normal (PBF< 30.00%)	106 (48.62)	139 (48.26)	34 (32.08)
Σ4SKF	**High (Σ4SKF> 50mm)**	151 (69.27)	193 (67.01)	82 (77.36)
	Normal (Σ4SKF< 50mm)	67 (30.73)	95 (32.99)	24 (22.64)

Table 3.23: Assessment of overweight-obesity and excess adiposity among the Bengali Muslim mothers using BMI vs. WC, WHR, WHtR, PBF and Σ4SKF

Nutritional status		Normal (BMI< 23.00 kg/m^2)	Overweight-obesity (BMI≥ 23.00 kg/m^2)	Total
WC	**Normal (WC <80 cm)**	263 (42.97)	99 (16.18)	362 (59.15)
	Obesity (WC >80 cm)	126 (20.59)	124 (20.26)	250 (40.85)
	Total	389 (63.56)	223 (36.44)	612 (100.00)
WHR	**Normal (WHR <0.8)**	47 (7.68)	13 (2.12)	60 (9.80)
	Obesity (WHR >0.8)	342 (55.88)	210 (34.31)	552 (90.20)
	Total	389 (63.56)	223 (36.44)	612 (100.00)
WHtR	**Normal (WHtR<0.5)**	164 (26.80)	56 (9.15)	220 (35.95)
	Obesity (WHtR>0.5)	225 (36.76)	167 (27.29)	392 (64.05)
	Total	389 (63.56)	223 (36.44)	612 (100.00)
PBF	**Normal (PBF<30.00%)**	216 (35.29)	63 (10.29)	279 (45.59)
	Obesity (PBF>30.00%)	173 (28.27)	160 (26.14)	333 (54.41)
	Total	389 (63.56)	223 (36.44)	612 (100.00)
Σ4SKF	**Normal (Σ4SKF< 50mm)**	152 (24.84)	34 (5.56)	186 (30.39)
	High (Σ4SKF> 50mm)	237 (38.73)	189 (30.88)	426 (69.61)
	Total	389 (63.56)	223 (36.44)	612 (100.00)

Values in parenthesis indicates percentages

Table 3.24: Age specific assessment of overweight-obesity and excess adiposity among the Bengali Muslim mothers using BMI vs. WC, WHR, WHtR, PBF and Σ4SKF

Nutritional status		20-24 years (N= 218)			25-29 years (N= 288)			30-34 years (N= 106)		
		Normal (BMI< 23.00 kg/m^2)	Overweight-obesity (BMI≥ 23.00 kg/m^2)	Total	Normal (BMI< 23.00 kg/m^2)	Overweight-obesity (BMI≥ 23.00 kg/m^2)	Total	Normal (BMI< 23.00 kg/m^2)	Overweight-obesity (BMI≥ 23.00 kg/m^2)	Total
WC	**Normal (WC <80 cm)**	91 (41.74)	55 (25.23)	146 (66.97)	103 (35.76)	59 (20.49)	162 (56.25)	34 (32.08)	20 (18.87)	54 (50.94)
	Obesity (WC >80 cm)	55 (25.23)	17 (7.80)	72 (33.03)	71 (24.65)	55 (19.10)	126 (43.75)	35 (33.02)	17 (16.04)	52 (49.06)
	Total	146 (66.97)	72 (33.03)	218 (100.00)	174 (60.42)	114 (39.58)	288 (100.00)	69 (65.09)	37 (34.91)	106 (100.00)
WHR	**Normal (WHR <0.8)**	10 (4.59)	5 (2.29)	15 (6.88)	26 (9.03)	6 (2.08)	32 (11.11)	7 (6.60)	6 (5.66)	13 (12.26)
	Obesity (WHR >0.8)	136 (62.39)	67 (30.73)	203 (93.12)	148 (51.39)	108 (37.50)	256 (88.88)	62 (58.49)	31 (29.25)	93 (87.74)
	Total	146 (66.97)	72 (33.03)	218 (100.00)	174 (60.42)	114 (39.58)	288 (100.00)	69 (65.09)	37 (34.91)	106 (100.00)
WHtR	**Normal (WHtR<0.5)**	60 (27.52)	28 (12.84)	88 (40.37)	64 (22.22)	39 (13.54)	103 (35.76)	19 (17.92)	10 (9.43)	29 (27.36)

	Obesity (WHtR>0.5)	86 (39.45)	44 (20.18)	130 (59.63)	110 (38.19)	75 (26.04)	185 (64.24)	50 (47.17)	27 (25.47)	77 (72.64)
	Total	146 (66.97)	72 (33.03)	218 (100.00)	174 (60.42)	114 (39.58)	288 (100.00)	69 (65.09)	37 (34.91)	106 (100.00)
PBF	**Normal (PBF<30.00%)**	66 (30.28)	40 (18.35)	106 (48.62)	82 (28.47)	57 (19.79)	139 (48.26)	23 (21.70)	11 (10.38)	34 (32.08)
	Obesity (PBF>30.00%)	80 (36.70)	32 (14.68)	112 (51.38)	92 (31.94)	57 (19.79)	149 (51.74)	46 (43.40)	24.53 (34)	72 (67.92)
	Total	146 (66.97)	72 (33.03)	218 (100.00)	174 (60.42)	114 (39.58)	288 (100.00)	69 (65.09)	37 (34.91)	106 (100.00)
Σ4SKF	**Normal (Σ4SKF< 50mm)**	41 (18.81)	26 (11.93)	67 (30.73)	55 (19.10)	40 (13.89)	95 (32.99)	18 (16.98)	6 (5.66)	24 (22.64)
	High (Σ4SKF> 50mm)	105 (48.17)	46 (21.10)	151 (69.27)	119 (41.32)	74 (25.69)	193 (67.01)	51 (48.11)	31 (29.25)	82 (77.36)
	Total	146 (66.97)	72 (33.03)	218 (100.00)	174 (60.42)	114 (39.58)	288 (100.00)	69 (65.09)	37 (34.91)	106 (100.00)

Values in parenthesis indicates percentages

3.18 Linear regression analysis of maternal BMI and MUAC with child HAZ, WAZ, WHA, BMIAZ and HdCAZ

Results of linear regression analysis have shown that maternal BMI has statistically significant ($p<0.05$) effect on wasting (WHZ), underweight (WAZ) and thinness (BMIAZ) among Bengali Muslim children (Table 3.25). It has also been observed that maternal MUAC has statistically significantly ($p<0.05$) effected the prevalence of wasting (WHZ), underweight (WAZ) and thinness (BMIAZ) among Bengali Muslim children (Table 3.26). Moreover, present study has observed that there is a combined effect of maternal BMI and MUAC on the prevalence of wasting (WHZ) and thinness (BMIAZ) among the Bengali Muslim children (Table 3.27).

Table 3.25: Linear regression analysis of maternal BMI with child HAZ, WAZ, WHA, BMIAZ and HdCAZ

Dependent variable	Independent variable	B	S.E	Beta	Adjusted R^2	t	p-value
HAZ	Maternal BMI	-0.012	0.012	-0.038	0.000	-0.937	0.349
WAZ	Maternal BMI	0.018	0.009	0.077	0.004	1.906	0.057
WHZ	Maternal BMI	0.034	0.010	0.132	0.016	3.278	0.001
BMIAZ	Maternal BMI	0.036	0.011	0.137	0.017	3.421	0.001
HdCAZ	Maternal BMI	0.032	0.037	0.036	0.000	0.885	0.376

Table 3.26: Linear regression analysis of maternal MUAC with child HAZ, WAZ, WHA, BMIAZ and HdCAZ

Dependent variable	Independent variable	B	S.E	Beta	Adjusted R^2	t	p-value
HAZ	Maternal MUAC	0.005	0.032	0.007	-0.002	0.165	0.869
WAZ	Maternal MUAC	0.054	0.024	0.091	0.007	2.263	0.024
WHZ	Maternal MUAC	0.067	0.027	0.102	0.009	2.537	0.011
BMIAZ	Maternal MUAC	0.080	0.027	0.118	0.012	2.942	0.003
HdCAZ	Maternal MUAC	0.126	0.094	0.054	0.001	1.348	0.178

Table 3.27: Linear regression analysis of Maternal BMI and MUAC with child HAZ, WAZ, WHA, BMIAZ and HdCAZ

Dependent variable	Independent variable	B	S.E	Beta	Adjusted R^2	t	p-value
HAZ	Maternal BMI and MUAC	-0.012	0.013	-0.040	-0.002	-0.981	0.327
WAZ	Maternal BMI and MUAC	0.015	0.010	0.063	0.009	1.533	0.126
WHZ	Maternal BMI and MUAC	0.030	0.010	0.117	0.021	2.879	0.004
BMIAZ	Maternal BMI and MUAC	0.032	0.011	0.120	0.025	2.957	0.003
HdCAZ	Maternal BMI and MUAC	0.024	0.037	0.027	0.000	0.657	0.511

3.19. Age-sex specific descriptive statistics of HAZ, WAZ, WHZ, BMIAZ and HdCAZ of the children of undernourished, overweight and obese mothers

Age-sex specific descriptive statistics of HAZ, WAZ, WHZ, BMIAZ and HdCAZ of the children of undernourished, overweight and obese mothers have been depicted in Table 3.28, Table 3.29 and Table 3.30. Age-specific differences are not observed among the children of undernourished mothers (Table 3.28). Statistically significant age-specific differences ($p<0.05$) have been observed in the z-score values of stunting (HAZ), underweight (WAZ) and thinness (BMIAZ) among the children of overweight mothers (Table 3.29). Statistically significant age specific differences ($p<0.05$) also have been observed in the z-score values of stunting (HAZ) and underweight (WAZ) of the children of obese mothers (Table 3.30).

Table 3.28: Age specific descriptive statistics of HAZ, WAZ, WHZ, BMIAZ and HdCAZ of the children of undernourished mothers

Age Group	HAZ	WAZ	WHZ	BMIAZ	HdCAZ
1 year	-0.31±2.36	-0.69±1.35	-0.57±1.87	-0.71±2.03	0.40±1.68
2years	-2.18±2.59	-2.01±1.88	-1.18±1.40	-0.84±1.43	1.73±4.39
3years	-1.26±2.20	-1.98±2.13	-1.71±1.96	-1.62±1.81	-0.18±2.08
4years	-1.63±1.13	-1.77±0.72	-1.18±0.56	-1.05±0.57	-0.23±1.09
5years	-0.48±1.63	-0.93±0.80	-1.01±1.12	-0.98±1.12	-1.06±1.29
Total	-1.24±2.17	-1.53±1.61	-1.16±1.50	-1.05±1.49	0.23±2.73
F-value	1.79	1.95	0.92	0.72	2.19
p- value	0.143	0.115	0.461	0.584	0.082

Table 3.29: Age specific descriptive statistics of HAZ, WAZ, WHZ, BMIAZ and HdCAZ of the children of overweight mothers

Age Group	HAZ	WAZ	WHZ	BMIAZ	HdCAZ
1 year	-0.70±2.80	-1.72±2.03	-1.74±2.81	-1.82±2.19	0.56±1.26
2 years	-1.92±1.89	-1.61±1.51	-0.85±1.23	-0.53±1.29	0.58±1.13
3 years	-0.73±1.58	-1.89±1.48	-2.17±2.10	-0.30±1.83	-0.52±1.69
4 years	-1.84±1.66	-1.83±1.14	-1.04±1.02	-0.88±1.07	1.59±8.93
5 years	-0.72±1.63	-0.79±1.36	-0.55±1.09	-0.48±1.08	-0.70±1.33
Total	-1.55±2.06	-1.59±1.51	-0.94±1.58	-0.79±1.51	0.38±4.64
F-value	3.03	2.38	1.77	2.99	1.05
p- value	0.020	0.055	0.140	0.021	0.382

Table 3.30: Age specific descriptive statistics of HAZ, WAZ, WHZ, BMIAZ and HdCAZ of the children of obese mothers

Age Group	HAZ	WAZ	WHZ	BMIAZ	HdCAZ
1 year	-0.49±2.21	-1.29±1.24	-1.33±1.53	-1.41±1.73	-1.03±4.64
2 years	-1.83±2.16	-1.88±1.40	-1.29±2.10	-1.05±2.38	2.71±12.75
3 years	-1.22±1.24	-2.40±1.44	-2.51±1.38	-1.00±1.21	-0.31±1.41
4 years	-1.98±1.51	-2.06±1.96	-1.20±2.31	-1.08±2.38	-1.64±3.16
5 years	-0.08±1.56	-0.59±1.06	-0.87±1.53	-0.87±1.51	-2.34±5.32
Total	-1.31±1.98	-1.57±1.56	-1.15±1.77	-1.05±1.88	-0.60±7.02
F-value	6.82	5.30	0.23	0.18	1.68
p- value	0.000	0.001	0.920	0.950	0.162

3.20. Association of the socio-economic, demographic and life style related variables with the prevalence of stunting, thinness, wasting, underweight and low HdC-for-age among the Bengali Muslim children

Association of socio-economic, demographic and life style related variables with the indicator of undernutrition (stunting, thinness, wasting, underweight and low HdC- for-age) has been analysed using binary logistic regression analysis and is depicted in Table 3.31 and Table 3.32. Bengali Muslim boys were in higher risk of stunting (odds ratio: 1.084) (p>0.05), thinness (odds ratio: 2.238) (p<0.01), wasting (odds ratio: 2.392) (p<0.01) and low HdC-for-age (odds ratio: 3.191) (p<0.01) than their girl counterparts as the boys showed higher odds ratios in these categories. Girls were in higher risk of underweight (odds ratio: 1.003) (p>0.05) than boys. Higher age groups (3-5 years) were in higher risk of stunting (odds ratio: 1.222) (p>0.05), thinness (odds ratio: 1.087) (p>0.05) and low HdC-for-age (odds ratio: 7.757) (p<0.01). Lower age groups (1-2 years) were in higher risk of wasting (odds ratio: 1.579)(p<0.01) and underweight (odds ratio: 1.119) (p>0.05). The children whose mothers were of higher age groups (28-34 years) were in two fold higher risk of stunting (odds ratio: 2.078) (p<0.01), 1.4 times higher risk of wasting (odds ratio: 1.421) (p>0.05), 1.8 times higher risk of underweight (odds ratio: 1.810) (p<0.01) and 1.4 times higher risk of low HdC-for-age (odds ratio: 1.810) (p<0.05) than the children whose mothers were of lower age groups (20-27 years). Children whose mothers were of lower age groups were in higher risks of thinness (odds ratio: 1.025) (p>0.05), than the children of mothers of lower age groups. Children whose mothers have lower age (9-12 years) at menarche were observed to be in higher risks of stunting (odds ratio: 2.458) (p<0.01), wasting (odds ratio: 1.414) and underweight (odds ratio: 1.898) (p<0.01) than the children whose mothers have higher age at menarche (13 years and above). Children of mothers having higher age (13 years and above) at menarche were in higher risk of thinness (odds ratio: 1.005) (p>0.05) and low HdC-for-age (odds ratio: 1.231) (p>0.05) than the children whose mothers have lower age at menarche (9-12 years). Children of mothers with higher age at marriage (18 years and above) have showed higher risk of stunting (odds ratio: 1.217), thinness (odds ratio: 1.072), wasting (odds ratio: 1.131) and low HdC for-age (odds ratio: 1.036) than the children whose mothers have lower age at marriage (Less than 18 years). Risk of underweight (odds ratio: 1.200) was higher among the children whose mothers have a lower age at marriage (Less than 18 years). Children with higher family size (5 and above) were in higher risk of thinness (odds ratio: 1.408) ($p>0.05$), wasting (odds ratio: 1.365) ($p>0.05$) and low HdC-for-age (odds ratio: 1.182) ($p>0.05$) than children of lower family size (Upto 4). On the others hand children with lower family size (Upto 4) were in higher risk of stunting (odds ratio: 1.672) ($p<0.01$) and underweight (odds ratio: 1.175) ($p>0.05$) than the children of higher family size (5 and above). Children of nuclear families showed higher risk of stunting (odds ratio: 1.747) ($p<0.01$) and underweight (odds ratio: 1.394)($p>0.05$) than the children of the extended, joint and broken families. Children of extended, joint and broken families were in higher risk of thinness (odds ratio: 1.233)($p>0.05$), wasting (odds ratio: 1.177)($p>0.05$) and low HdC-for-age (odds ratio:1.297) ($p>0.05$) than the children of nuclear families. Children of families with lower number of earning head (earning head- 1) were in higher risk of stunting (odds ratio: 1.695) ($p<0.05$) and underweight (odds ratio: 1.454) ($p>0.05$). Children of families with earning head two and above were in higher risk of thinness (odds ratio: 1.457) ($p>0.05$) and low HdC-for-age (odds ratio: 1.527) ($p>0.05$). Children with lower monthly family income (Rs. 7000/- and less) were in higher risk of stunting (odds ratio: 4.393) ($p<0.01$), thinness (odds ratio: 1.874) ($p<0.01$), wasting (odds ratio: 1.821) ($p<0.01$) and underweight (odds ratio: 2.973) ($p<0.01$) than the children with higher monthly income of family (Rs. 7001/- to above). Children with lower monthly family expenditure (Rs. 7000/- and less) were in higher risk of stunting (odds ratio: 7.284) ($p<0.01$), thinness (odds ratio: 1.588) ($p<0.05$), wasting (odds ratio: 1.702) ($p<0.01$) and underweight (odds ratio: 3.372) ($p<0.01$)

than the children with higher monthly family expenditure (Rs. 7001/- to above). Children using tube well and supply water were in higher risk of stunting (odds ratio: 1.265) ($p>0.05$) and underweight (odds ratio: 1.147) ($p>0.05$) than the children using well water. Children using well water were in higher risk of thinness (odds ratio: 1.267) ($p>0.05$), wasting (odds ratio: 1.098) ($p>0.05$) and low HdC-for-age (odds ratio: 1.323) ($p>0.05$). Children who do not have toilet facility were in higher risk of stunting (odds ratio: 1.074) ($p>0.05$), thinness (odds ratio: 1.209) ($p>0.05$), wasting (odds ratio: 1.177) ($p>0.05$) and underweight (odds ratio: 1.046) ($p>0.05$). Children who do not have electricity in their houses were in higher risk of thinness (odds ratio: 1.922) ($p<0.01$) and wasting (odds ratio: 1.489) ($p>0.05$). Children having electricity in their house were in higher risk of stunting (odds ratio: 1.252) ($p>0.05$), underweight (odds ratio: 1.095) ($p>0.05$) and low HdC-for-age (odds ratio: 1.882) ($p<0.01$). Children having kaccha house were in higher risk of stunting (odds ratio: 1.068) ($p>0.05$) and underweight (odds ratio: 1.054)($p>0.05$). Children having semi pucca and pucca house were in higher risk of thinness (odds ratio: 1.037) ($p>0.05$), low HdC-for-age (odds ratio: 1.485) ($p<0.05$). Children with number of rooms one or two were in higher risk of stunting (odds ratio: 1.074) ($p>0.05$), underweight (odds ratio: 1.117)($p>0.05$), low HdC-for-age (odds ratio: 1.177) ($p>0.05$). Children with low birth weight (<2.5 kg) were in higher risk of thinness (odds ratio: 1.124) ($p>0.05$), wasting (odds ratio: 1.037) ($p>0.05$), underweight (odds ratio: 1.337) ($p>0.05$) and low HdC-for-age (odds ratio: 1.034) ($p>0.05$) than the children with higher birth weight (2.8 kg and above). Children with lesser number of years of breast feeding were observed to be in higher risk of stunting (odds ratio: 1.038) ($p>0.05$), thinness (odds ratio: 1.160) ($p>0.05$), underweight (odds ratio: 1.082) ($p>0.05$) and low HdC-for-age (odds ratio: 1.217) ($p>0.05$). Children whose mothers were without education were in higher risk of stunting (odds ratio: 1.197) ($p>0.05$), wasting (odds ratio: 1.075) ($p>0.05$), underweight (odds ratio: 1.272) ($p>0.05$) and low HdC-for-age (odds ratio: 1.182)($p>0.05$) than the educated mothers. Children of uneducated fathers were in higher risk of stunting (odds ratio: 1.380) ($p>0.05$), wasting (odds ratio: 1.073) ($p>0.05$), underweight (odds ratio: 1.164) ($p>0.05$) and low HdC-for-age (odds ratio: 1.117) ($p>0.05$). Children whose mothers were working outside were in higher risk of stunting (odds ratio: 1.461), thinness (odds ratio: 1.715) ($p>0.05$), and wasting (odds ratio: 1.273) ($p>0.05$) than the children of housewife mothers. Children of housewife mothers were in higher risk of underweight (odds ratio: 3.754) and low HdC-for-age (odds ratio: 2.841) than the children of working mothers. Children of labourer and Farmer fathers were in higher risk of stunting (odds ratio: 2.800) ($p<0.01$), thinness (odds ratio: 3.276) ($p<0.01$), wasting (odds ratio: 1.985) ($p<0.05$) and underweight (odds ratio: 1.822) ($p<0.05$). Children with lower number of sibs were in higher risk of stunting (odds ratio: 1.194 in number of sib = 1 and odds ratio: 1.428 in number of sibs = 2), thinness (odds ratio: 1.029 in number of sib = 1), wasting (odds ratio: 1.627 in number of sib = 1) ($p<0.05$) and underweight (odds ratio: 1.539 in number of sib = 1 and odds ratio: 1.545 in number of sib = 2) ($p<0.05$) than the children with higher number of sibs.

Table 3.31: Binary logistic regression analysis and associate risk factors in the prevalence of stunting and thinness with socio-economic and demographic variables among children

Characteristics		Frequency (n= 612)	Stunting			Thinness		
			Wald	Odds ratio	95% CI	Wald	Odds ratio	95% CI
Sex	**Boys**	**325**	0.243	1.084	0.787-1.492	17.785	2.238**	1.539-3.254
	Girls	**287**	-	-	-	-	-	-
Age	**1-2 years**	**235**	-	-	-	-	-	-
	3-5 years	**377**	1.436	1.222	0.881-1.695	0.195	1.087	0.751-1.571
Mothers age	**20-27 years**	**413**	-	-	-	0.016	1.025	0.700-1.502
	28-34 years	**199**	17.429	2.078**	1.474-2.929	-	-	-
Mothers age at menarche	**9-12 years**	**327**	28.652	2.458**	1.768-3.416	-	-	-
	13 years and above	**285**	-	-	-	0.001	1.005	0.703-1.438
Mothers age at marriage	**Less than 18 years**	**256**	-	-	-	-	-	-
	18 years and above	**356**	1.406	1.217	0.880-1.682	0.139	1.072	0.745-1.540
Mothers age at first pregnancy	**18 years or less**	**262**	-	-	-	-	-	-
	19 years and above	**350**	0.095	1.052	0.762-1.452	0.014	1.022	0.712-1.466
Family size	**Upto 4**	**320**	9.771	1.672**	1.211-2.308	-	-	-
	5 and above	**292**	-	-	-	3.497	1.408	0.984-2.014

Family type	**Nuclear**	**435**	**9.150**	1.747**	1.217-2.508	-	-	-
	Extended, joint and broken	**177**	-	-	-	1.123	1.233	0.837-1.815
Earning head	**1**	**529**	4.523	1.695*	1.042-2.755	-	-	-
	2 and more	**83**	-	-	-	2.220	1.457	0.888-2.389
Monthly income	**Rs. 7000/- and less**	**400**	59.055	4.393**	3.012-6.407	9.406	1.874**	1.254-2.799
	Rs. 7001/- to above	**212**	-	-	-	-	-	-
Monthly expenditure	**Rs. 7000/- and less**	**430**	76.271	7.284**	4.665-11.373	4.818	1.588*	1.051-2.401
	Rs. 7001/- to above	**182**	-	-	-	-	-	-
Water supply	**Tube well and supply water**	**406**	1.842	1.265	0.901-1.776	-	-	-
	Well water	**206**	-	-	-	1.548	1.267	0.873-1.838
Toilet	**Absent**	**137**	0.136	1.074	0.733-1.574	0.787	1.209	0.795-1.838
	Present	**475**	-	-	-	-	-	-
Electricity	**Absent**	**63**	-	-	-	5.624	1.922**	1.120-3.298
	Present	**549**	0.687	1.252	0.736-2.132	-	-	-
House type	**Kaccha**	**360**	0.159	1.068	0.772-1.477	-	-	-
	Semi pucca and pucca	**252**	-	-	-	0.038	1.037	0.722-1.490
No. of rooms	**1-2**	**398**	0.176	1.074	0.769-1.501	-	-	-
	3 and above	**214**	-	-	-	0.003	1.011	0.696-1.470
Birth weight of child	**< 2.5 kg**	**107**	0.024	0.965	0.614-1.517	0.217	1.124	0.687-1.840

	2.5 kg-2.7 kg	**236**	0.273	1.098	0.773-1.561	0.408	0.878	0.590-1.308
	2.8 kg and above	**269**	-	-	-	-	-	-
Duration of breast feeding	**Upto 2 years 11 months**	**295**	0.052	1.038	0.754-1.428	0.662	1.160	0.811-1.658
	3-4 years	**317**	-	-	-	-	-	-
Education of mother	**No education**	**239**	0.817	1.197	0.810-1.770	0.093	0.933	0.599-1.454
	Class I to V	**198**	2.995	0.694	0.458-1.050	0.172	1.101	0.699-1.734
	Class VI and above	**175**	-	-	-	-	-	-
Education of father	**No education**	**138**	2.094	1.380	0.891-2.135	0.108	0.918	0.551-1.529
	Class I to V	**276**	0.093	0.944	0.635-1.365	1.842	1.330	0.881-2.009
	Class VI and above	**198**	-	-	-	-	-	-
Mothers occupation	**Working outside**	**13**	0.454	1.461	0.485-4.398	0.872	1.715	0.553-5.319
	House wife	**599**	-	-	-	-	-	-
Fathers occupation	**Labours and Farmers**	**408**	12.272	2.800**	1.574-4.981	9.088	3.276**	1.515-7.086
	Business	**143**	4.093	0.049*	0.247-0.978	0.175	1.205	0.504-2.879
	Others	**61**	-	-	-	-	-	-
No. of sibs	**1**	**214**	0.683	1.194	0.784-1.819	0.015	1.029	0.649-1.631
	2	**244**	2.912	1.428	0.948-2.149	0.417	0.860	0.545-1.358
	3 and above	**154**	-	-	-	-	-	-

***p<0.05; **p<0.01**

Table 3.32: Binary logistic regression analysis and associate risk factors in prevalence of wasting, underweight and low HdC-for -age with socio-economic and demographic variables among children

Characteristics		Frequency (n= 612)	Wasting			Underweight			Low HdC-for -age		
			Wald	Odds ratio	95% CI	Wald	Odds ratio	95% CI	Wald	Odds ratio	95% CI
Sex	Boys	325	20.003	2.392**	1.632-3.505	-	-	-	39.894	3.191**	2.226-4.575
	Girls	287	-	-	-	0.000	1.003	0.725-1.387	-	-	-
Age	1-2 years	235	5.976	1.579**	1.095-2.277	0.443	1.119	0.803-1.560	-	-	-
	3-5 years	377	-	-	-	-	-	-	75.770	7.757**	4.891-12.304
Mothers age	20-27 years	413	-	-	-	-	-	-	-	-	-
	28-34 years	199	3.332	1.421	0.974-2.072	11.479	1.810**	1.284-2.552	4.791	1.483*	1.042-2.109
Mothers age at menarche	9-12 years	327	3.430	1.414	0.980-2.040	14.443	1.898**	1.364-2.641	-	-	-
	13 years and above	285	-	-	-	-	-	-	1.468	1.231	0.880-1.722
Mothers age at marriage	Less than 18 years	256	-	-	-	1.175	1.200	0.863-1.667	-	-	-
	18 years and above	356	0.430	1.131	0.783-1.635	-	-	-	0.041	1.036	0.737-1.456
	18 years or less	262	-	-	-	0.124	1.060	0.765-1.470	0.236	1.087	0.775-1.525

Mothers age at first pregnancy	**19 years and above**	**350**	0.040	1.038	0.720-1.496	-	-	-	-	-	-
Family size	**Upto 4**	**320**	**-**	-	-	0.948	1.175	0.849-1.625	-	-	-
	5 and above	**292**	2.834	1.365	0.950-1.961	-	-	-	0.956	1.182	0.845-1.654
Family type	**Nuclear**	**435**	**-**	-	-	3.205	1.394	0.969-2.005	-	-	-
	Extended, joint and broken	**177**	0.665	1.177	0.795-1.744	-	-	-	1.956	1.297	0.901-1.868
Earning head	**1**	**529**	0.429	0.842	0.504-1.407	2.234	1.454	0.890-2.375	-	-	-
	2 and more	**83**	-	-	-	-	-	-	3.083	1.527	0.952-2.448
Monthly income	**Rs. 7000/- and less**	**400**	8.399	1.821**	1.214-2.731	33.134	2.973**	2.052-4.308	-	-	-
	Rs. 7001/- to above	**212**	-	-	-	-	-	-	1.027	1.198	0.845-1.700
Monthly expenditure	**Rs. 7000/- and less**	**430**	6.055	1.702**	1.114-2.600	35.218	3.372**	2.257-5.038	-	-	-
	Rs. 7001/- to above	**182**	-	-	-	-	-	-	1.152	1.220	0.849-1.753
Water supply	**Tube well and supply water**	**406**	-	-	-	0.608	1.147	0.813-1.617	-	-	-
	Well water	**206**	0.234	1.098	0.751-1.605	-	-	-	2.451	1.323	0.932-1.880

Toilet	**Absent**	**137**	0.567	1.177	0.770-1.801	0.052	1.046	0.710-1.541	2.757	0.701	0.461-1.066
	Present	**475**	-	-	-	-	-	-	-	-	-
Electricity	**Absent**	**63**	1.955	1.489	0.852-2.602	-	-	-	-	-	-
	Present	**549**	-	-	-	0.110	1.095	0.640-1.872	4.007	1.882*	1.013-3.497
House type	**Kccha**	**360**	0.437	0.884	0.613-1.274	0.100	1.054	0.759-1.465	-	-	-
	Semi pucca and pucca	**252**	-	-	-	-	-	-	5.222	1.485*	1.058-2.084
No. of rooms	**1-2**	**398**	0.432	0.882	0.605-1.284	0.403	1.117	0.794-1.569	0.814	1.177	0.826-1.679
	3 and above	**214**	-	-	-	-	-	-	-	-	-
Birth weight of child	**< 2.5 kg**	**107**	0.020	1.037	0.626-1.718	1.556	1.337	0.847-2.111	0.019	1.034	0.645-1.657
	2.5 kg-2.7 kg	**236**	0.128	0.930	0.623-1.387	2.694	1.350	0.943-1.931	0.034	0.966	0.667-1.399
	2.8 kg and above	**269**	-	-	-	-	-	-	-	-	-
Duration of breast feeding	**Upto 2 years 11 months**	**295**	-	-	-	0.230	1.082	0.783-1.496	1.315	1.217	0.870-1.703
	3-4 years	**317**	0.238	1.094	0.762-1.571	-	-	-	-	-	-
Education of mother	**No education**	**239**	0.100	1.075	0.686-1.686	1.402	1.272	0.854-1.895	0.626	1.182	0.781-1.791
	Class I to V	**198**	0.352	1.151	0.723-1.833	0.001	1.007	0.662-1.532	0.245	1.116	0.723-1.723
	Class VI and above	**175**	-	-	-	-	-	-	-	-	-

Education of father	**No education**	**138**	0.077	1.073	0.652-1.767	0.450	1.164	0.747-1.813	0.221	1.117	0.705-1.769
	Class I to V	**276**	0.256	1.114	0.733-1.693	0.162	1.080	0.743-1.570	0.156	1.081	0.734-1.594
	Class VI and above	**198**	-	-	-	-	-	-	-	-	-
Mothers occupation	**Working outside**	**13**	0.158	1.273	0.387-4.193	-	-	-	-	-	-
	House wife	**599**	-	-	-	2.927	3.754	0.825-17.087	1.822	2.841	0.624-12.937
Fathers occupation	**Labours and Farmers**	**408**	3.835	1.985*	0.999-3.941	4.275	1.822*	1.032-3.218	-	-	-
	Business	**143**	0.047	0.917	0.418-2.013	2.077	0.615	0.318-1.191	0.447	1.146	0.768-1.710
	Others	**61**	-	-	-	-	-	-	0.288	1.166	0.665-2.046
No. of sibs	**1**	**214**	3.834	1.627*	1.000-2.647	3.812	1.539*	0.998-2.372	-	-	-
	2	**244**	1.316	1.327	0.818-2.152	4.083	1.545*	1.013-2.357	0.003	0.990	0.667-1.469
	3 and above	**154**	-	-	-	-	-	-	2.407	1.408	0.914-2.170

***p<0.05; **p<0.01**

3.21. Association of the socio-economic, demographic and life style related variables with the prevalence of undernutrition, overweight and obesity among the Bengali Muslim mothers

Association of socio-economic, demographic and life style related variables with the indicator of undernutrition, overweight and obesity has been analysed using multinomial logistic regression analysis and is depicted in Table 3.33. Bengali Muslim mothers of higher age group (28-34 years) were in higher risk of undernutrition (odds ratio: 1.613) ($p>0.05$), lower age groups (20-27 years) were in higher risk of overweight (odds ratio: 1.544) ($p<0.05$) and obesity (odds ratio: 1.085) ($p>0.05$). Risk of prevalence of undernutrition (odds ratio: 1.125) ($p>0.05$) and obesity (odds ratio: 1.176) ($p>0.05$) were observed to be higher among the mothers who had a lower age at menarche (9-12 years). Risk of being overweight was higher among the mothers with higher age at menarche (odds ratio: 1.380) ($p<0.05$).Mothers with lower age at marriage were in higher risk of undernutrition (odds ratio: 1.384) ($p>0.05$) and obesity (odds ratio: 1.748) ($p<0.05$) and mothers with higher age at marriage were in higher risk of overweight (odds ratio: 1.894) ($p<0.01$). Mothers with higher age at first pregnancy were in higher risk of undernutrition (odds ratio: 1.432) ($p>0.05$) and overweight (odds ratio: 1.948) ($p<0.01$) and mothers with lower age at first pregnancy were in higher risk of obesity (odds ratio: 1.942) ($p<0.01$). Mothers with higher education level were in higher risk of undernutrition (odds ratio: 1.037) ($p>0.05$) and overweight (odds ratio: 1.650) ($p<0.05$). Mothers in the category of no education were in higher risk of obesity (odds ratio: 1.388) ($p>0.05$). Mothers with earning head two or more were observed to be in higher risk of undernutrition (odds ratio: 3.412) ($p<0.05$) and overweight (odds ratio: 1.512) ($p>0.05$). Mothers of the families with higher family income (Rs. 7001/- to above) were in higher risk of overweight (odds ratio: 1.125) ($p>0.05$). Mothers of the families with higher family expenditure (Rs. 7001/- to above) were in higher risk of overweight (odds ratio: 1.119) ($p>0.05$)

than the mothers with lower family expenditure. Mothers with lesser number of living children (upto 4) were in higher risk of undernutrition (odds ratio: 1.526) ($p>0.05$) and overweight (odds ratio: 1.145) ($p>0.05$) and mothers with higher number of living children were in higher risk obesity (odds ratio: 1.279) ($p>0.05$). Mothers of extended, joint and broken families were in higher risk of undernutrition (odds ratio: 5.292) ($p<0.01$) and overweight (odds ratio: 1.236) ($p>0.05$) and mothers of nuclear families were in higher risk of obesity (odds ratio: 1.051) ($p>0.05$). Mothers using well water were in higher risk of undernutrition (odds ratio: 1.555) ($p>0.05$) and mothers using tube-well and supply water were in higher risk of overweight (odds ratio: 1.327) ($p>0.05$) and obesity (odds ratio: 1.655) ($p<0.05$). Mothers using toilets were in higher risk of undernutrition (odds ratio: 1.866) ($p<0.05$) and mothers without toilet facility were in higher risk of overweight (odds ratio: 2.361) ($p<0.01$) and obesity (odds ratio: 1.080) ($p>0.05$).Mothers of the house type category semi pucca and pucca were in higher risk of undernutrition (odds ratio: 1.857) ($p<0.05$) and overweight (odds ratio: 1.184) ($p>0.05$). Mothers having higher number of rooms (3 and above) were in higher risk of overweight (odds ratio: 1.096) ($p>0.05$) and mothers having lesser number of rooms were in higher risk of obesity (odds ratio: 1.251) ($p>0.05$). Women whose husbands were in the category of no education and with education upto class V were in higher risk of undernutrition (odds ratio: 1.766 in No education; Odds ratio: 1.175 in Upto class V) ($p>0.05$). Women whose husbands were in the categories of education level class I to class V and class VI and above were in higher risk of overweight (odds ratio: 1.327 in class I to class V and Odds ratio: 1.644 in class VI and above) ($p>0.05$). Women whose husbands were in the category of no education were also in higher risk of obesity (odds ratio: 1.054) ($p>0.05$). Women whose husbands were farmers were in higher risk of undernutrition (odds ratio: 1.072) ($p>0.05$) and whose husbands were businessmen were in higher risk of overweight (odds ratio: 1.223) ($p>0.05$). Mothers having higher number of children (3 and above) were in higher risk of undernutrition (odds ratio: 1.062) (p>0.05) and mothers having lower number of children were in higher risk of overweight (odds ratio: 4.903 in no. of living children 1, p<0.05; Odds ratio: 5.507 in no. of living children 2, p<0.01). Mothers with number of living children 2 were in higher risk of obesity (odds ratio: 1.249) (p>0.05). Mothers with duration of breast feeding upto 2 years 11 months i.e., lesser duration of breast feeding were in higher risk of obesity (odds ratio: 1.611) (p<0.05). Mothers with longer duration of breast feeding (3-4 years) were in higher risk of undernutrition (odds ratio: 1.493) (p>0.05) and overweight (odds ratio: 1.533) (p<0.05).

Table 3.33: Multinomial logistic regression analysis and associate risk factors in prevalence of undernutrition, overweight, obesity socio-economic and demographic variables among Bengali Muslim mothers

Characteristics		Frequency (n= 612)	Undernutrition			Overweight			Obesity		
			Wald	Odds ratio	95% CI	Wald	Odds ratio	95% CI	Wald	Odds ratio	95% CI
Age	**20-27 years**	**413**	-	-	-	4.487	1.544*	1.033-2.037	0.118	1.085	0.682-1.727
	28-34 years	**199**	2.390	1.613	0.880-2.958	-	-	-	-	-	-
Age at menarche	**9-12 years**	**327**	0.196	1.125	0.668-1.896	-	-	-	0.525	1.176	0.758-1.826
	13 years and above	**285**	-	-	-	2.562	1.380	0.930-2.048	-	-	-
Age at marriage	**17 years and less**	**256**	1.369	1.384	0.803-2.387	-	-	-	5.409	1.748*	1.092-2.800
	18 years and above	**356**	-	-	-	10.212	1.894**	1.280-2.803	-	-	-
Age at first pregnancy	**18 years or less**	**262**	-	-	-	-	-	-	7.511	1.942**	1.208-3.122
	19 years and above	**350**	1.814	1.432	0.849-2.413	11.084	1.948**	1.316-2.884	-	-	-
Education	**No education**	**239**	-	-	-	-	-	-	1.392	1.388	0.805-2.394

	Class I to V	**198**	0.131	0.893	0.484-1.647	0.970	1.255	0.798-1.973	0.015	1.034	0.601-1.779
	Class VI and above	**175**	0.012	1.037	0.539-1.996	3.930	1.650*	1.006-2.708	-	-	-
Earning head	**1**	**529**	-	-	-	-	-	-	0.542	1.257	0.684-2.308
	2 and more	**83**	4.130	3.412*	1.045-11.141	1.674	1.512	0.808-2.830	-	-	-
Monthly income	**Rs. 7000/- and less**	**400**	0.260	0.865	0.495-1.512	-	-	-	-	-	-
	Rs. 7001/- to above	**212**	-	-	-	0.313	1.125	0.744-1.700	3.046	0.671	0.429-1.050
Monthly expenditure	**Rs. 7000/- and less**	**430**	0.046	0.939	0.528-1.671	-	-	-	-	-	-
	Rs. 7001/- to above	**182**	-	-	-	0.262	1.119	0.727-1.722	4.855	0.599*	0.380-0.945
Family size	**Upto 4**	**320**	2.477	1.526	0.901-2.583	0.469	1.145	0.777-1.689	-	-	-
	5 and above	**292**	-	-	-	-	-	-	1.181	1.279	0.821-1.993
Family type	**Nuclear**	**435**	-	-	-	-	-	-	0.040	1.051	0.649-1.700
	Extended, joint and broken	**177**	12.301	5.292**	2.086-13.429	0.885	1.236	0.795-1.921	-	-	-

Water supply	**Tube well and supply water**	**406**	-	-	-	1.897	1.327	0.887-1.984	4.867	1.655*	1.058-2.589
	Well water	**206**	2.120	1.555	0.858-2.816	-	-	-	-	-	-
Toilet	**Absent**	**137**	-	-	-	8.956	2.361**	1.345-4.143	0.079	1.080	0.632-1.844
	Present	**475**	4.728	1.866*	1.063-3.276	-	-	-	-	-	-
Electricity	**Absent**	**63**	1.196	0.655	0.306-1.399	-	-	-	-	-	-
	Present	**549**	**-**	**-**	**-**	2.879	0.515	0.239-1.110	0.963	0.664	0.293-1.505
House type	**Kccha**	**360**	**-**	**-**	**-**	-	-	-	-	-	-
	Semi pucca and pucca	**252**	4.496	1.857*	1.084-3.291	0.687	1.184	0.794-1.764	3.538	0.655*	0.421-1.018
No. of rooms	**1-2**	**398**	0.000	0.998	0.577-1.724	-	-	-	0.941	1.251	0.796-1.965
	3 and above	**214**	-	-	-	0.192	1.096	0.727-1.653	-	-	-
Education of husband	**No education**	**138**	2.082	1.766	0.816-3.822	-	-	-	0.028	1.054	0.571-1.944
	Class I to V	**276**	0.302	1.175	0.661-2.087	1.344	1.327	0.823-2.139	0.055	0.942	0.568-1.560

	Class VI and above	**198**	-	-	-	3.416	1.644	0.970-2.784	-	-	-
Occupation of husband	**Labours and Farmers**	**408**	0.026	1.072	0.460-2.502	0.083	1.099	0.578-2.089	0.000	1.004	0.470-2.144
	Business	**143**	0.478	1.415	0.529-3.788	0.297	1.223	0.592-2.528	0.229	0.357	0.357-1.871
	Others	**61**	-	-	-	-	-	-	-	-	-
No. of living children	**1**	**214**	-	-	-	4.903*	1.740	1.066-2.841	-	-	-
	2	**244**	0.017	0.961	0.527-1.751	5.507**	1.769	1.099-2.848	0.733	1.249	0.751-2.079
	3 and above	**154**	0.029	1.062	0.532-2.120	-	-	-	0.101	1.096	0.623-1.925
Duration of breast feeding	**Upto 2 years 11 months**	**295**	-	-	-	-	-	-	4.313	1.611*	1.027-2.527
	3-4 years	**317**	2.227	1.493	0.882-2.527	4.570	1.533*	1.036-2.267	**-**	**-**	**-**

***p<0.05; **p<0.01**

CHAPTER- IV:

DISCUSSION

4.1. OVERVIEW

Assessments of body composition and nutritional status among individuals and/or populations bear significant importance in developing countries such as India where the vast majority of the populations are malnourished and underprivileged. Studies among different Indian populations have reported that major segments are malnourished (undernourished or overnourished) and it is the major public health concern with the central attention being given to children less than 5 years, adolescents and women. The coexistence of undernutrition, overweight and obesity in a population is known as "double burden of malnutrition" (DBM). Therefore, the assessment of DBM in populations is important for the improvement of overall health and development of country and its citizens. The occurrence of childhood undernutrition in terms of stunting, thinness, wasting, underweight and low HdC-for-age among children have detrimental effects on their life and is a major concern in public health and continues to be a cause of ill-health and premature mortality among children (Nandy et al. 2005). Physical growth, development and body composition assessment can play an important role in nutritional status for the effect of age, sex, ethnic, geographic, environmental, socio-economic conditions, sedentary behaviour, physical activity, disease and genotype or genetic factors and provides a useful sign of the health and nutritional status (Eveleth and Tanner 1990; Rolland-Cachera 1993; Rogol et al. 2002; Hall et al. 2007; Rogol 2010; Wells 2010; Sen and Mondal 2013; Xue et al. 2016; Griffiths et al. 2016; Rengma et al. 2016; Debnath et al. 2017; Debnath et al. 2018). The presence of undernutrition and overweight and obesity in adult population has been observed by several studies. Maternal malnutrition is a major factor for morbidity and mortality among women of the developing countries. The contributing factors include inadequate food intake, poor nutritional quality of diets, frequent infections, and short inter pregnancy intervals. The consequences of poor maternal nutritional status contribute to the low pregnancy weight gain and high infant and maternal morbidity and mortality. Studies also have observed the prevalence of overweight and obesity simultaneously in one population. Several studies have observed that South Asian populations have 3%-5% of greater body-adiposity levels than Caucasians at any given BMI including low adipokine production and lower levels lean body mass and it is called the "Asian Indian Phenotype" (Little et al. 2016; Debnath et al. 2019). Obesity is observed as the 'first wave of a defined cluster of non-communicable diseases' called "New World Syndrome" creating an enormous socio-economic and public health burden in low and middle income developing countries (WHO 2000; Bharati et al. 2008).

The WHO has described overweight-obesity as one of the most neglected public health issue (Bharati et al. 2008). Several internal and external factors e.g., ethnic or genetic environment, socio-cultural, socioeconomic and demographic factors are potential contributors to the occurrence of overweight and obesity in populations. Overweight and obesity are associated with increased risk of non-communicable diseases such as metabolic syndrome, high cholesterol, type-2 diabetes mellitus, high blood pressure, and cardiovascular disease; conditions that are already serious public health concerns in rural and urban India alike (Misra et al. 2011; Zaman et al. 2012). The co-occurrence of undernutrition and overnutrition in rural villages and households, termed the 'double burden' of disease is much more troubling which worsen poverty and limit overall economic growth (Doak et al. 2005; Little et al. 2016).

For assessing the nutritional status of children the conventional anthropometric measures (e.g., stunting, thinness, wasting and underweight) are generally recommended for (WHO 1995; 2007). These reflect a failure to reach linear growth optimal potential, as a result of achieving a sub-optimal health and nutritional condition. The assessment of body composition is of interest to human biologists because of the impact of nutritional status, specific diet, exercise, disease and genetic factors. It reflects nutritional intakes, losses and needs over time (i.e., FFM and FFMI loss) and the prevalence of undernutrition. It is also associated with decreased survival, worse clinical outcome, quality of life and disease prevalence in individuals or populations (Thibault and Pichard 2012; Thibault et al. 2012). Therefore, body composition evaluations should be integrated into routine clinical practice for the initial assessment and sequential follow-up of nutritional status (e.g., undernutrition or excess weight gain) (Wells 2010; Weber et al. 2012; Sen and Mondal 2013). Assessment of nutritional status and body composition of mothers is done using the BMI cut offs for undernutrition and overnutrition (overweight and obesity) and WC, WHR, WHtR, MUAC, PBF and sum of four skinfolds.

4.2. ANTHROPOMETRIC ASSESSMENT AND BODY COMPOSITION VARIATION AMONG THE CHILDREN

Measurement of body composition is proving increasingly important in epidemiological and clinical investigations, where skin-fold thicknesses (e.g., TSF and SSF) and MUAC are preferably used to estimate the body composition in children and adolescents (Reilly et al. 1995; Gerver and de Bruin 1996; Gibson 2005; Wells 2010; Sen and Mondal 2013; Debnath et al. 2017). The results of the present study showed significant age and sex specific differences among the children ($p<0.05$). Several studies validated different skin-fold equations and recommended usage of the equations of Slaughter et al. (1988) for evaluation of body fat among pre-pubertal children (Reilly et al. 1995; Goran et al. 1996; Boot et al. 1997; Rodrı´guez et al. 2005; Sala et al. 2007). More accurate estimates of PBF can be calculated by the equations of Slaughter et al. (1988), than most currently available methods that considered the use of a multi-component approach to body composition. It has been shown from previous reliable data that skin-fold thickness equations, such as those proposed by Slaughter et al. (1988) predicted fatness with negligible bias in groups of children (Rodrı´guez et al. 2005). Hence, the present study evaluated PBF content among the children in order to evaluate their body composition characteristics using the equation of Slaughter et al. (1988). Several researchers have assessed body composition characteristics in children utilizing these equations for estimation of body fat percentages among children from both non-Indian (Musaiger and Gregory 2000; Gültekin et al. 2005; Al-Hazzaa et al. 2007; Aguirre et al. 2015; Gutiérrez et al. 2017; Teo et al. 2019) and Indian populations (Bhadra et al. 2005; Mukhopadhyay et al. 2005; Chowdhury et al. 2007; Ghosh et al. 2009; Debnath et al. 2018). Significant sexual dimorphisms have been observed among the Bengali Muslim children in MUAC, HdC, TSF, SSF, PBF, FM, FFM, FMI, TUA, UMA, UFA, AFI, UME, UFE, PBF-BMI Ratio ($p<0.01$) (Table 3.1, Table 3.2, Table 3.3 and Table 3.4). Similar trends of body composition and adiposity indicators have also been reported in other studies. (Gerver et al. 2000; Webster-Gandy et al. 2003; Gültekin et al. 2005; Wang et al. 2007; Sen and Mondal 2013; Debnath et al. 2017, 2018a,b). Wells (2007) advocated that sexual dimorphism of body composition is evident from foetal life and it mainly emerges during puberty and such differences in body composition are primarily attributed to the action of steroidal hormones. Sex differences appear in body composition prior to the onset of sexual maturation and several studies have reported that fatness showed stability between early infancy and childhood (Weststrate et al. 1989; Gerver et al. 2000; Webster-Gandy et al. 2003; Wells 2010; Kromeyer-Hauschild et al. 2012; Xiong et al. 2012).

The differences in adiposity measures (e.g., TSF, SSF, PBF, UFA, AFI, UME, BMI, PBF-BMI Ratio) were also observed to be more prominent with advancement of age. The sex-specific mean values were greater in girls than boys (Table 3.2 and Table 3.4). Similar trends in the adiposity and body composition characteristics have been reported among children by several researches (Gültekin et al. 2005; Kromeyer-Hauschild et al. 2012; Xiong et al. 2012; Sen and Mondal 2013; Debnath et al. 2018). It has also been reported that the Tanner stages had a significant relationship with body composition in both sexes and were significantly positively related to lean tissue mass and bone mineral content among boys and girls and to PBF and FM in girls in the higher age groups (Boot et al. 1997; Leonard et al. 2010).

Body composition evaluation should be integrated into a routine clinical practice for initial assessment and sequential follow-up of nutritional status. Several studies have already reported that the conventional anthropometric measure such as BMI is commonly used as a simple surrogate anthropometric measure to excess adiposity and body composition in relation to excess weight gain, but nevertheless, there are well-known limitations regarding the use of BMI as it is unable to distinguish FFM and FM, and is not sensitive to changes in adiposity during childhood (Gallagher et al. 1996; Horlick 2001; Weber et al. 2012). BMI is not able to distinguish whether it is an increase in FM or a decrease in FFM that causes increase in body mass of a child, but it can be partitioned into the fat and lean components of FMI (FM index= FM/height^2) and FFMI (FFM index= FFM/height^2) (Wells 2010; Weber et al. 2012). It is therefore desirable to investigate the relationship of both compartments lean mass (e.g., FFM and FFMI) and fat mass (FM and FMI) when analyzing the body composition data.

Moreover, FM and FFM have the advantage that they can provide discrete measures for these two components of weight, each adjusted for an independent component of size, although in some cases a more complex approach is required (VanItallie et al. 1990; Wells 2007, 2010). This could allow for a systematic and early screening of undernutrition and promote rational, early initiation of optimal nutritional support, thereby contributing to reducing malnutrition-induced morbidity, mortality, worsening of the quality-of-life and global healthcare costs (Thibault and Pichard 2012; Thibault et al. 2012). Therefore the indices of FFMI and FMI offer a powerful framework for evaluating within and between-population variability in body composition and address physique (e.g., FFMI) as well as relative adiposity (e.g., FMI). The results also showed that the body composition of school children exhibited higher values compared to the available data. The present study showed that the girls had higher body fat contents than their male counterparts in connection with adiposity indicators such as TSF, SSF, PBF, UFA, AFI , UME, BMI , PBF-BMI Ratio ($p<0.01$). Such differences in adiposity patterns have been reported among Dutch (Weststrate et al. 1989), Indian (Gerver et al. 2000), Chinese (Wang et al. 2007), Santhal (Chowdhury et al. 2007), Nepalese (Ghosh et al. 2009) and Bengalee Muslim (Sen and Mondal 2013), Indian (Debnath et al. 2013) children.

Age sex-specific FM values as observed in the present study were lower than those obtained from Bahraini (Musaiger and Gregory 2000), Turkish (Gültekin et al. 2005), Nepalese (Ghosh et al. 2009), ICDS children (Biswas and Bose 2011) and Bengalee Muslim (Sen and Mondal 2013), Bengalee pre-school children (Giri et al. 2017) children. The age and sex specific mean FFM values were lower than those reported for Bahraini (Musaiger and Gregory 2000), Turkish (Gültekin et al. 2005), Santhal children (Chowdhury et al. 2006), Nepalese (Ghosh et al. 2009), Bengalee Muslim children (Sen and Mondal 2013), Indian children (Debnath et al. 2018). The age and sex specific mean FFM values were higher than those reported for Bengalee pre-school children (Giri et al. 2017), ICDS children (Biswas and Bose 2011) and Santhal (Chowdhury et al. 2007) children. The age-specific mean values of FMI among the children were higher than the values for Nepalese (Ghosh et al. 2009), Bengalee Muslim children (Sen and Mondal 2013) and Indian children (Debnath et al. 2018). The age-specific mean values of FMI among the children were lower than the values for Bengalee pre-school children (Giri et al. 2017) and ICDS children (Biswas and Bose 2011). The age-specific mean values of FFMI among the children were higher than the values for Bengalee pre-school children (Giri et al. 2017), ICDS children (Biswas and Bose 2011), Bengalee Muslim children (Sen and Mondal 2013), Indian children (Debnath et al. 2018) and almost equal with the Nepalese (Ghosh et al. 2009) children.

Several studies have already validated different skinfold equations with alternate methods of estimation and recommended the use of the equations of Slaughter et al. (1988) for the evaluation of body fat among pre-pubertal children (Goran et al. 1996; Boot et al. 1997; Laurson et al. 2011; Sen and Mondal 2013; Almeida et al. 2016; González-Agüero et al. 2017). The present study evaluated PBF content in order to evaluate the body composition characteristics of rural school-going children using the equation of Slaughter et al. (1988).

Furthermore, several studies have assessed body composition characteristics in children utilizing these equations for estimation of PBF among children from both non-Indian (Musaiger and Gregory 2000; Gültekin et al. 2005; Ghosh et al. 2009; Laurson et al. 2011; Aguirre et al. 2015; Noradilah et al. 2016; González-Agüero et al. 2017) and Indian ethnic populations (Mukhopadhyay et al. 2005; Chowdhury et al. 2007; Sen and Mondal 2013; Sharma and Mondal 2018). The results indicated pronounced sexual differences in adiposity and body composition measures (e.g., PBF, FM, FM, FMI and FFMI) between boys and girls ($p<0.01$). Similar trends of body composition and adiposity indicators were reported among Indian (Gerver et al. 2000; Sen and Mondal 2013) and rural Chinese (Wang et al. 2007) children. The differences in adiposity measures (PBF, FM and FFM) were also observed to be more prominent with the advancement of age (Table 1). The sex-specific mean values were greater in girls than boys but were distinctly higher in older age groups (e.g. 9–12 years) ($p<0.05$).

Due to the limitation of expressing body composition data as kilograms (e.g. kg of FM and FFM) and as percentages (e.g. PBF), the FMI (kg of FM/ height^2) and FFMI (kg of FFM/ height^2) appear to be better indicators of body composition (Freedman et al. 2005; Wells 2010; Debnath et al. 2018). The FMI estimates fat mass related to height and the FFMI estimates muscle mass related to height. Such variation in the body compositions might be due to genetic adaptations to ancestral environments and exposure to more contemporary, as it has been reported that variations in FM, FFM, FMI and FFMI between populations can be attributed to their ethnic elements (Musaiger and Gregory 2000; Wells 2010; Sen and Mondal 2013;

Debnath et al. 2018). The present study indicated sexual dimorphism in terms of FM, FMI and PBF. Higher amount of body fat has been observed among the girls counter parts of the sample. Several studies have observed a similar trend in fat accumulation (Reddy and Rao 1995; Mesa et al. 1996; Ghosh et al. 2009; Sen and Mondal 2013; Debnath et al. 2018). In the present study values of FFM have been observed to higher among boys than girls as observed in other studies (Ghosh et al. 2009; Sen and Mondal 2013; Debnath et al. 2018).

The occurrence of sexual dimorphism in fat patterning and body composition is primarily attributed to the effect of sex steroid hormones (He et al. 2004; Wells 2007, 2010; Sen and Mondal 2013; Debnath et al. 2017, 2018a,b). Presence of estrogen increases fat deposition and in contrary presence of testosterone increases fat metabolism, therefore, among females fat storage increases whereas among males fat storage decreases. The accumulation of body fat is important in determining the time of onset of puberty among children. Several studies have proved that gonadotropins and sex steroid hormones gradually increase among pre-pubertal children, which implies that their effects may be more prominent among older group of children than among younger pre-pubertal children (Mitamura et al. 1999, 2000; He et al. 2004; Wells et al. 2007; Debnath et al. 2017, 2018a,b). Such differences can be attributed to the tempo of adipose tissue accumulation which is likely to be greater in girls than boys, and to the onset of pubertal maturation (Wells 2007, 2010). The onset of puberty among children appears to be regulated by a number of complementary mechanisms which include intrauterine conditions, genotype, sex-specific mechanisms, nutritional status and also demographic and environmental conditions (He et al. 2002; Parent et al. 2003; Wells 2007).

Upper arm composition includes the indices of upper arm muscle area (UMA), total upper arm area (TUA), upper arm fat area (UFA), arm fat index (AFI), upper arm fat area estimate (UFE) and upper arm muscle area estimate (UME) for the assessment of body composition of children and adults. Several studies during the last few decades have established the usefulness of upper arm composition in the assessment of body composition of children and adults (e.g. Bolzan et al. 1999; Chowdhury and Ghosh 2009; Sen et al. 2011; Senbanjo et al. 2014; Singh and Mondal 2014; Sen et al. 2015; Debnath et al. 2017), although not adopted for routine assessment of body composition and nutritional status. Several studies have been conducted among children using UMA and UFA as reliable indicator of body composition and nutritional status (e.g., Erfan et al. 2003; Chowdhury and Ghosh 2009; Çiçek et al. 2009; Basu et al. 2010; Sen et al. 2011, 2015; Sikdar 2012; Singh and Mondal 2014; Debnath et al. 2017).

In present study it has been observed that muscularity related to UMA and UME was higher among boys in most of age groups than girls ($p<0.01$). Several studies have reported similar trends Indian (Chowdhury and Ghosh 2009; Basu et al. 2010; Sen et al. 2011; Sen and Mondal 2013; Singh and Mondal 2014; Debnath et al. 2017), Argentinean (Bolzan et al. 1999), South Korean (Kim et al. 1999), Kenyan (Semproli and Gualdi-Russo 2007), Zimbabwean (Olivieri et al. 2008), Turkish (Ozturk et al. 2009) and Nigerian (Senbanjo et al. 2014) children. Sex differences in body composition existed prior to puberty among boys and girls have been reported by several studies and the same trend has been observed in the present study (in UFA, AFI and UFE). Studies that have reported sex specific differences in adiposity measures (i.e., UFA and AFI) and body fat percentages among children are by He et al. (2002), Basu et al. (2010), Sen et al. (2011), Singh and Mondal (2014), Debnath et al. (2017) and Debnath et al. 2018(a,b).

4.3. PREVALENCE OF UNDERNUTRITION AMONG THE BENGALI MUSLIM CHILDREN

The prevalence of undernutrition continues to be major public health issue and principal cause of ill-health, premature mortality and morbidity by increasing the disease burden in the developing countries like India (Pelletier 1998; Nandy et al. 2005; Uthman and Aremu 2008; Akhtar 2015; Debnath et al. 2018c). Reduced cognitive performance, low productivity and non-attainment of physical and psychological growth are observed to be associated with prevalence of undernutrition among children (WHO 1995; Pelletier 1998; Bogale et al. 2013; Sandjaja et al. 2013; Akhtar 2015).

The prevalence of undernutrition was estimated to be cause of death of 45.0 percent of all deaths among children <5 years (Black et al. 2013) and India is accounted for 38.0 percent of the global burden of stunting (low height-for-age) (nearly 62 million children) (UNICEF 2013). Approximately two-thirds of the world's malnourished (undernourished and overnourished) children live in Asia which gives this region the highest concentration of worldwide childhood undernutrition (Ramachandran 2014; UNICEF/WHO 2016; Debnath et al. 2018c). India has unacceptably high rates of undernutrition (Ramachandran 2014) and has the highest prevalence of childhood undernutrition in the world with more than half of Indian children remaining undernourished. The prevalence of childhood undernutrition remains persistently high in India (Khor 2008; Ramachandran 2014; Corsi et al. 2015; Smith and Haddad 2015; Aguayo et al. 2016; Ali et al. 2016; Dhok and Thakre 2016; Saxton et al. 2016; Mandal 2017; Patil et al. 2017).

In India, the large population size, large social and economic disparities and widespread poverty are the main causes of the prevalence of undernutrition (Vella et al. 1992; Sachs and McArthur 2005; Ramachandran 2007; Antony and Laxmaiah 2008; Mondal and Sen 2010; Gopalan 2013; Varadharajan et al. 2013; Akhtar 2015). Moreover, it has been estimated that more than half of Indian children are undernourished which is the highest occurrence of childhood undernutrition in the world (Measham and Chatterjee 1999; Bamji 2003; Bhutia 2014).

The present study assessed prevalence of undernutrition among Bengali Muslim children (aged 1–5 years) of West Bengal, India. The assessment of undernutrition has been done by using low height-for-age (stunting), low BMI-for-age (thinness), low weight-for-height (wasting), low weight-for-age (underweight) and low head circumference-for-age (low HdC-for-age). In the present study the magnitude of stunting, underweight, thinness, wasting and low HdC-for-age was observed to be 44.61% (boys: 45.54%; girls: 43.55%), 40.03% (boys: 40.00%; girls: 40.07%), 26.31% (boys: 32.92%; boys: 18.82%), 26.96% (boys: 33.54%; girls: 19.51%) and 33.66% (boys: 45.23%; girls: 20.56%), respectively. The sex-specific undernutrition showed that the severity of undernourishment was observed to higher among boys than girls in stunting (45.54% vs. 43.55%) ($p>0.05$), underweight (40.00% vs. 40.07%) ($p>0.05$), thinness (32.92% vs. 18.82%) ($p<0.01$), wasting (3.54% vs. 19.51%) ($p<0.01$) and low HdC-for-age (45.23 vs. 20.56%)($p<0.01$) (Table 3.8). However, the age-sex specific prevalence of undernutrition was observed to be statistically not significant in most of the cases ($p>0.05$) (Table 3.11).

High prevalence of undernutrition has been reported from the children of West Bengal (stunting: 45.80%, underweight: 38.89% and wasting: 13.94%), Assam (stunting: 36.17%, underweight: 57.54% and wasting: 14.42%) (Som et al. 2006), Dibrugarh district of Assam (stunting: 30.40%, underweight: 29.00% and wasting: 21.60%) (Islam et al. 2014). Mandal et al., (2008) reported the prevalence of undernutrition was 48.79% (stunting), 58.83% (underweight) and 19.08% (wasting), and 50.82% (stunting), 62.52% (underweight) and 26.87% (wasting) among the boys and girls, respectively of Hooghly district, West Bengal. Moreover, several studies have reported the magnitude of undernutrition was observed to very high among children of North-east India (Som et al. 2006; Islam et al. 2014; Singh and Mondal 2014; Debnath and Bhattacharjee 2016; Sarkar and Sil 2016; Kramsapi et al. 2018). The proposed classification of WHO (1995, 2007) was used to assess the severity of the public health problem of undernutrition based on percentages of conventional nutritional indices. It was observed that high undernutritiion existed among the Bengali Muslim children (1-5 years) of Phansidewa block, Darjeeling, West Bengal. There is an urgent need of nutritional intervention programme is necessary to combat/ameliorate this serious public health problem of undernutrition. It was well established that in India, children from the economically low tribal groups were found to poorer in nutritional status as compared to the general caste children (Radhakrishna and Ravi 2004; Mondal and Sen 2010; Tigga et al. 2015a,b; Debnath et al. 2018).

The decreased availability of food and resources due to increase in population and low production may lead to lowered intake of food in individuals of a population. Lack of proper dietary knowledge also leads to wrong infant feeding practices which in turn cause undernutrition in the population. Moreover, several others factors like low socio-economic status which means lower purchasing power also causes the lack of desired nutrients importanet for the good nutritional and health condition. Poor nutritional status among children triggers the poor cognitive developments and abilities and decreases the productive efficiency of individuals. Illness in childhood, short birth interval, maternal age, weight and anemia has significant contribution to the child's nutritional status (Mittal et al. 2007; Kumar et al. 2010; Tigga et al. 2015a,b; Ansuya et al. 2018).). Poverty is a major cause of the undernutrition among the children in India (Svedberg, 2000; Nandy et al. 2005; Khor 2008; Varadharajan et al. 2013; Ramachandran 2014; Smith and Haddad 2015).

The prevalence of undernutrition leads to a critical nutritional situation for public health among Indian children (Bose et al. 2007; Mondal and Sen 2010; Singh and Mondal 2014; Sharma and Mondal 2014; Gaiha et al. 2012; Islam et al. 2014; Tigga et al. 2015a,b; Asim and Nawaz 2018; Huda et al. 2018; Debnath et al. 2018). In spite of various nutritonal intervention programmes and socio-economic development, the prevalence of undernutrition continues to be a persisting problem which causes widespread mortality and morbidity among Indian children (Nandy et al. 2005; Som et al. 2006; Bose et al. 2007; Bharatati et al. 2008; Black et al. 2013; Ramachandran 2014; Smith and Haddad 2015; Joshi et al. 2016). This prevalence of undernutrition can lead to a vicious cycle of undernourishment which can be inherited to the next generation in the population (WHO 1995; Smith and Haddad 2015).

Studies have observed that children suffering from high undernutrition during their early age are at a higher risk of infectious/communicable diseases, low levels of physical strength, lower working capacity and poor reproductive outcomes during adulthood (e.g., LBW) (WHO 1995; Nandy et al. 2005; Svedberg 2000; Black et al. 2013). Family planning methods have significant role to play in reducing childhood undernutrition (Rana and Goli 2018). Severe Acute Malnutrition in infants hampers the neural development status in the age group of 6 to 30 months (Dwivedi et al. 2018). Dietary diversity is an important factor to be considered as a significant predictor of stunting (Borkotoky et al. 2018; Ahmed et al. 2018). Maternal dietary pattern and nutritional condition are significantly associated with the birth of LBW babies and growth and nutritional condition of children (Tigga et al. 2015a,b; Rammohan et al. 2018). Availability of safe drinking water, adequate water supply and hygiene sanitation are very important factors for the eradication of the infectious disease among the children which can in turn eradicate undernutrition (Gera et al. 2018).

4.3.1. Prevalence of stunting (Low height-for-age)

Comparisons of prevalence of undernutrition among children in terms of stunting, thinness, underweight and wasting have been depicted in Table 4.1 and Table 4.2.

The prevalence of stunting obtained in the present study was observed to be distinctively lower than the prevalence observed in children in Ludhiana, Punjab (74.00%) (Sengupta et al. 2010), Saharia children of Rajasthan (67.80%) (Rao et al. 2006), Kamar children of Chattisgarh (67.40%) (Mitra et al. 2007b), tribal children of Melghat (66.40%) (Talapalliwar and Garg 2014), pre-school tribal children of Maharashtra (61.00%) (Meshram et al. 2011), tribal children of Thane (60.40%) (Khandare et al. 2008), tribal children of 17 tribal districts Bihar (60.00%) (Yadav and Singh 1999), children in urban slums of Pune

(58.70%) (Mamulwar et al. 2014) and tribal children of West Bengal (58.60%) (IIPS and Macro International 2008). The prevalence of stunting was also observed to be lower than the children infected with HIV in South India (58.00%) (Padmapriyadarsini et al. 2009), children residing in slum areas of Bhubaneswar (57.40%) (Panigrahi and Das 2014), Gond children of Chattisgarh (55.60%) (Mitra et al. 2007a), children of Kadukuruba tribes of Mysore district (55.40%) (Manjunath et al. 2014), Santal pre-school children (54.20%) (Bisai 2014), Oraon of North Bengal and tribal children of Bihar (54.00%) (Mittal and Srivastava 2006), and rural adolescents in West Bengal (54.00%) (Pal et al. 2016). Several other studies have observed higher prevalence of stunting among Indian children than in the present study, eg., among tribal children in India (53.90%) (IIPS and Macro International 2007), children of Rajasthan (53.00%) (Singh et al. 2006), children in National Capital Territory of Delhi (53.00%) (Saxena et al. 1997), tribal children of Madhya Pradesh (51.60%) (Rao et al. 2005), Gond children of Madhya Pradesh (51.60%) (Rao et al. 2005), children from urban Allahabad (51.60%) (Kumar et al. 2006), Kora-Mudi children (2-5 years) of Paschim Medinipur, West Bengal (51.10%) (Bisai and Mallick 2011), Kamar tribe of Chhattisgarh (50.00%) (Mitra et al. 2007b) and among the Kora-Mudi children (2-13 years) of Paschim Medinipur, West Bengal (49.60%) (Bisai and Mallick 2011) (Table 4.1).

The prevalence of stunting in present study (44.61%) was observed to be higher than the prevalence of stunting observed among Baiga children of Madhya Pradesh (44.30) (Chakma et al. 2009), children from Bareilly, UP (43.22%) (Singh et al. 2013), Kodaku children in Madhya Pradesh (43.00%) (Dolla et al. 2005), children belonging to tea-labourer community in West Bengal (41.70%) (Mondal and Sen 2010a), children in Maharashtra (40.46%) (Purohit et al. 2017), Bengalee rural pre-school children of ICDS (39.2%) (Biswas and Bose2010), Bengalee Muslim school children of North Bengal (38.5%) (Sen et al. 2011b), Rajbanshi children of North Bengal (35.80%) (Mondal and Sen 2010a), Lodha children of Paschim

Medinipur in West Bengal (35.10%) (Bisai et al. 2008), early adolescent school girls of Paschim Medinipur in West Bengal (34.20%) (Maiti et al. 2011) (Table 4.1).

The prevalence of stunting in present study (44.61%) was observed to be distinctively higher than the prevalence of stunting observed among Bengali Muslim children, W.B (33.70%) (Mondal and Sen 2010a), early adolescent school girls of West Bengal (32.50%) Maiti et al. (2011), rural school-going children of West Bengal (31.80%) (Debnath et al. 2018c), tribal children in riverine areas of Dibrugarh in Assam (30.40%) (Islam et al. 2014), Infants in rural areas of Madhya Pradesh (29.00%) (Meshram et al. 2015), children in a slum area of Kolkata (28.80%) (Mandal et al. 2014), rural pre-school children of Hoogly (26.60%) (Mandal and Bose 2009), ICDS children from West Bengal (26.60%) (Mandal et al. 2008), Santal children from Purulia district West Bengal (26.30%) (Das and Bose 2011a), ICDS children of Nadia District, West Bengal (23.90%) (Bose et al. 2007a), children in orphanages of Odisha (22.90%) (Routray et al. 2015), Santal children of Puruliya district, West Bengal (17.90%) (Chowdhury et al. 2008), rural school children of Onda, Bankura District, West Bengal (17.20%) (Bose et al. 2007b), school children in Army School, Pune (13.81%) (Mukherjee et al. 2008), tribal children, Bankura, West Bengal (12.80%) (Mukhopadhyay and Biswas 2011), school children in Uttar Pradesh (12.50%) (Srivastav et al. 2013), children of Karnataka (9.40%) (Joseph et al. 2002) and among rural school children in Bangalore (7.00%) (Rashmi et al. 2015) (Table 4.1).

In case of non-Indian studies several studies among children from Zambia (69.20%) (Gernaat et al. 1996), children in a rural district of Kelantan in Malaysia (69.00%) (Whye Lian et al. 2012), pre-school children of Terengganu in Malaysia (62.00%) (Wong et al. 2014), children from Central Africa Republic (61.50%) (Wanga et al. 2009), children in North-eastern of Peninsular Malaysia (61.40%) (Ali Naser et al. 2014), children in Ethiopia (58.10%) (Derso et al. 2017), children of Bangladesh (50·70%) (Semba et al. 2008), Indonesian school children

(55.00%) (Hadju et al. 1995), children from Laos (54.00%) (Phengxay et al. 2007), pre-school children of Swabi district, Pakistan (53.00%) (Khan Khattak and Ali 2010), children in Kenya (51.00%) (Adeladza 2009), children of Western Kenya (47.00%) (Bloss et al. 2004), children and adolescents in rural area of Bangladesh (46.60%) (Rahman and Karim 2014) have observed higher prevalence of stunting than it is observed in present study (44.61%). The prevalence of stunting in present study (44.61%) was observed to be higher than the prevalence of stunting observed among children from Vietnam (44.30%) (Hien and Kam 2008), children of Bangladesh (44.00%) (Rahman and Chowdhury 2007), pre-school children in Bangladesh (44.00%) (Rahman and Chowdhury 2006), rural children of Fogera and Libo Kemkem Districts in Ethiopia (42.70%) (Herrador et al. 2014), school-age children in Southern Ethiopia (41.90%) (Tariku et al. 2018), Tibetan children (41.40%) (Dang et al. 2004), pre-school children in Bangladesh (39.50%) (Jesmin et al. 2011), school children in Ethiopia (35.00%) (Mahmud et al. 2013), children of Indonesia (33.20%) (Semba et al. 2008), pre-school age children in Peru (32.10%) (Casapia et al. 2007) and among Kenyan children (30.20%) (Chesire et al. 2008).

The prevalence of stunting in present study (44.61%) was observed to be distinctively higher than the prevalence of stunting observed among children in Nicaragua (30.10%) (Sakisaka et al. 2005), children of Mugu district in Nepal (29.40%) (Thapa et al. 2013), urban children of Fogera and Libo Kemkem Districts in Ethiopia (29.20%) (Herrador et al. 2014), Malaysian children (29.20%) (Marjan et al. 1998), students in Northern Ethiopia (28.50%) (Melaku et al. 2015), rural school going children in Kavre District of Nepal (24.54%) (Mansur et al. 2015), children of Humla district of Nepal (22.40%) (Thapa et al. 2013), pre-school children in Egypt (20.30%) (Seedhom et al. 2014), children in Thailand (19.90%) (Firestone et al. 2011), primary school children in Sub-urban region in Tanzania (16.30%) (Teblick et al. 2017), Chinese children (14.59%) (Zhang et al. 2011), semi-urban Nigerian school children (14.20%) (Fetuga et al. 2011), Chinese children and adolescents (13.80%) (Yan-Ping et al.

2009), adolescent school girls in North Ethiopia (12.20%) (Gebregyorgis et al. 2016), pre-school children in Gaza strip (11.90%) (Kanoa et al. 2011), children in Iran (11.50%) (Mahyar et al. 2010), children from Turkey (10.90%) (Ergin et al. 2007), children from Oman (10.60%) (Alasfoor et al. 2007), children of Nairobi, Kenya (10.60%) (Muchina and Waithaka 2010), children in Brazil (9.90%) (de Souza et al. 2012), children in Iran (9.53%) (Kavosi et al. 2014), school children in Burkina Faso (8.80%) (Daboné et al. 2011), Pakistani primary school children (8.00%) (Mushtaq et al. 2011), Rural school-aged Sudanese children (7.10%) (Mohamed and Hussein 2015), children from Pakistan (6.00%) (Badruddin et al. 2008), Cameroon urban children and adolescents (5.70%) (Wamba et al. 2013), school children in an urban area of Sri Lanka (5.15%) (Wickramasinghe et al. 2004), children in Malaysia (3.90%) (Poh et al. 2012) and among school children from Iran (2.85%) (Rezaeian et al. 2014).

4.3.2. Prevalence of thinness (Low BMI-for-age)

The prevalence of thinness in present study (26.31%) was observed to be distinctively lower than the prevalence of thinness observed among rural children of ICDS scheme (85.21%), Hooghly, West Bengal (Mandal et al. 2009), rural Bengalee pre-school children of ICDS Scheme of Sagar Island, South 24 Parganas, West Bengal (81.25%) (Giri et al. 2017b), rural primary school in Paschim Medinipur, West Bengal (77.00%) (Das et al. 2012), Santal school children Hooghly District, West Bengal (75.95%) (Mandal and Bose 2014), rural primary school-going children residing in Darjeeling, West Bengal (69.40%) (Mondal and Sen 2010b), children of Purba Medinipur, West Bengal (67.74%) (Khanra et al. 2020), Kora-Mudi tribal children of Paschim Medinipur, West Bengal (67.20%) (Bisai et al. 2010), pre-school children of North Bengal, West Bengal (62.00%) (Tigga et al. 2015b), rural pre-school children in Karnataka (61.70%) (Nayak et al. 2015), early adolescent rural school girls of Paschim Medinipur, West Bengal (58.30%) (Maiti et al. 2011), rural children of Darjeeling district, West Bengal (57.36%) (Debnath et al. 2018d), Bhaina tribal girls in Chhattisgarh (57.10)

(Singh et al. 2014), Bengalee Muslim school children in Eastern India (56.70%) (Mondal et al. 2011), Santal Pre-school Children (56.17%) (Das and Bose 2011c), school age children of tea garden worker of Assam (53.90%) (Medhi et al. 2006), Hill Kharia tribal children (52.90) (Das and Bose 2011d), Shabar children in forest habitat, Orissa (52.42%) (Chakrabarty and Bharati 2010), children in Central India (51.10%) (Gupta et al. 2015), rural adolescents in West Bengal (49.00%) (Pal et al. 2016), rural primary school children in Hooghly, West Bengal (48.50%) (Pal and Bose 2020), children of Central Odisha (48.00%) (Mishra and Mishra 2007), Nepali speaking pre-school children of Darjeeling, West Bengal (45.22%) (Das and Datta Banik 2011), Santal tribal children and adolescents of Purulia district, West Bengal (41.30%) (Das and Bose 2011b), early adolescent school girls of Paschim Medinipur, West Bengal (40.94%) (Maiti et al. 2011), Bengalee children of Darjeeling district, West Bengal (40.19%) (Dorjee 2015), Sunni Muslim school girls Delhi (38.37%) (Bansal and Joshi 2013), school going children in Surathkal, Karnataka (37.50%) (Aroor et al. 2014) and among rural school children in Bangalore (34.00%) (Rashmi et al. 2015). The prevalence of thinness in present study (26.31%) was also observed to be lower than the prevalence of thinness observed among Ao Naga tribal children in Nagaland (30.12%) (Longkumar 2013), Santal children of Birbhum district, West Bengal (29.60%) (Ghosh and Sarkar 2013), among the children in a slum area of Kolkata, West Bengal (28.80%) (Mandal et al. 2014) and rural school-going children of West Bengal (27.70%) (Debnath et al. 2018c). The prevalence of thinness in present study (26.31%) was observed to be higher than the prevalence of thinness observed among the Sonowal Kachari tribal children in Assam (25.99%) (Singh and Mondal 2013), school children in Uttar Pradesh (23.20%) (Srivastav et al. 2013), rural school children of Onda, Bankura District, West Bengal (23.10%) (Bose et al. 2007b), children residing in slum areas of Bhubaneswar (22.9) (Panigrahi and Das 2014), urban adolescents of North 24 Parganas and Howrah, West Bengal (21.75%) (Ghosh and Bandyopadhyay 2009), early adolescent school girls of West Bengal

(20.20%) (Maiti et al. 2011), Mising tribal children of North-east India (18.19%) (Sikdar 2012b), school children in South India (12.20%) (Kumaravel et al. 2014), tribal Bodo children of Assam (11.50%) (Mondal et al. 2015) and among urban affluent school children in Gujrat (3.30%) (Chudasama et al. 2017).

In case of non-Indian studies several studies among Children and adolescents North-western Nigeria (60.60%) (Mijinyawa et al. 2014), school children in Nigeria (42.90%) (Akinpelu et al. 2014), children and adolescents in rural area of Bangladesh (42.40%) (Rahman and Karim 2014), children and adolescents in the Seychelles (35.60%) (Bovet et al. 2011), school children in Ethiopia (34.00%) (Mahmud et al. 2013), Garo tribal children in Bangladesh (30.88) (Rana et al. 2012), children in Tamale in Northern Ghana (29.80%) (Mogre et al. 2013) have observed higher prevalence of thinness than it is observed in present study (26.31%).

The prevalence of thinness in present study (26.31%) was observed to be higher than the prevalence of thinness observed among students in Northern Ethiopia (26.10%) (Melaku et al. 2015), adolescent girls in rural Bangladesh (26.00%) (Alam et al. 2010), pre-school children in Norway of South Asian origin (26.00%) (Toftemo et al. 2018), school children in an urban area of Sri Lanka 23.86%) (Wickramasinghe et al. 2004), rural school-aged Sudanese children (23.10%) (Mohamed and Hussein 2015), semi-urban Nigerian school children (22.20%) (Fetuga et al. 2011), Nigerian children and adolescents (21.61%) (Ejike et al. 2013), rural children in Fogera and Libo Kemkem Districts in Ethiopia (21.60%) (Herrador et al. 2014), adolescent school girls in North Ethiopia (21.40%) (Gebregyorgis et al. 2016), children of Humla district in Nepal (21.13%) (Thapa et al. 2013), urban children of Fogera and Libo Kemkem districts in Ethiopia (20.80%) (Herrador et al. 2014), children of Mugu district in Nepal (20.12%) (Thapa et al. 2013), children in China (16.04%) (Chen et al. 2016), school children in Burkina Faso (13.70%) (Daboné et al. 2011), children in Malaysia (13.10%) (Partap et al. 2017), urban school children and adolescents in southern Nigeria (13.00%) (Ene-Obong et al. 2012), children in Mauritius (12.70%) (Caleyachettyet al. 2012), children and adolescents in China (12.42%) (Zhang et al. 2015), Polish school-aged children and adolescents (11.70%) (Gurzkowska et al. 2017), primary school children in rural Sri Lanka (11.51%) (Naotunna et al. 2017), primary school children in Sub-urban region in Tanzania (11.30%) (Teblick et al. 2017), early adolescents in Malaysia (11.10%) (Woon et al. 2014), children in Italian school in Rome (10.9%) (Rosati et al. 2013), pre-school children of European origin in Norway (10.40%)

(Toftemo et al. 2018), rural school going children in Nepal (10.05%) (Mansur et al. 2015), Pakistani primary school children (10.00%) (Mushtaq et al. 2011).

The prevalence of thinness in present study (26.31%) was observed to be distinctively higher than the prevalence of thinness observed among Cameroon urban children and adolescents (9.50%) (Wamba et al. 2013), Malaysian children (5·40%) (Poh et al. 2013), school children and adolescents from Democratic Republic of Congo (8.93%) (Buhendwa et al. 2017), school-age children in Southern Ethiopia (8.00%) (Tariku et al. 2018), Greek children and adolescents (7.43%) (Tambalis et al. 2019), Chinese children and adolescents (7.40%) (Yan-Ping et al. 2009), children in Southwest China (6.30%) (Li et al. 2012), French children (6.00%) (Rolland-Cachera et al. 2002), children in Malaysia (5.80%) (Poh et al. 2012), children and adolescents in England (5.70%) (Whitaker et al. 2011), Portuguese children and adolescents (4.75%) (Marques-Vidal et al. 2008), pre-school children in Gaza strip (4.20%) (Kanoa et al. 2011), children and adolescents from Brazil (4.10%) (Guedes et al. 2013), Brazilian school children (3.20%) (de Assis et al. 2005) and among Portuguese children (1.00%) (Rito et al. 2012).

4.3.3. Prevalence of wasting (Low weight-for-height)

The prevalence of wasting in present study (26.96%) was observed to be distinctively lower than the prevalence of wasting observed among Kamar children in Chattisgarh (85.60%) (Mitra et al. 2007b), children in Uttar Pradesh (60.67%) (Singh et al. 2013), Gond children in

Korba in Chattisgarh (55.00%) (Mitra et al. 2007a), rural pre-school children of Hoogly in West Bengal (50.00%) (Mandal and Bose 2009), Kawar children in Chattisgarh (48.20%) (Mitra et al. 2007a), children of Kadukuruba tribes of Mysore district (43.00%) (Manjunath et al. 2014), children of urban slum in Punjab (42.00%) (Sengupta et al. 2010), Raj Gond children in Madhya Pradesh (41.50%) (Sharma et al. 2006), Baiga children in Madhya Pradesh (37.20%) (Chakma et al. 2009), Kodaku children in Madhya Pradesh (35.00%) (Dolla et al. 2005), Bharia children in Madhya Pradesh (33.90%) (Dolla et al. 2006), Infants in Rural Areas of Madhya Pradesh (33.00%) (Meshram et al. 2015), Gond children in Madhya Pradesh (32.90%) (Rao et al. 2005), slum children of Midnapore in West Bengal (32.70%) (Bisai et al. 2009), tribal children of Maharastra (30.20%) (Khandare et al. 2008), Santal children of Puruliya district in West Bengal (29.40%) (Chowdhury et al. 2008), pre-school tribal children of Maharashtra (29.00%) (Meshram et al. 2011), children in a slum area of Kolkata (28.80%) (Mandal et al. 2014), children of Rajasthan (28.00%) (Singh et al. 2006), Kora-Mudi children of Paschim Medinipur in West Bengal (27.70%) (Bisai and Mallick 2011), tribal children in India (27.60%) (IIPS and Macro International 2007).

The prevalence of wasting in present study (26.96%) was observed to be higher than the prevalence of wasting observed among Bengali Muslim children in West Bengal (26.60%) (Mondal and Sen 2010a), tribal children of 17 tribal districts Bihar (25.00%) (Yadav and Singh 1999), children of Tea-labourer community in W.B (23.50%) (Mondal and Sen 2010a), children Residing in Slum Areas of Bhubaneswar (23.30%) (Panigrahi and Das 2014), Kora-Mudi children of Paschim Medinipur in West Bengal (22.70%) (Bisai and Mallick 2011), National Capital Territory of Delhi (22.50%) (Saxena et al. 1997), tribal children in riverine areas of Dibrugarh in Assam (21.60%) (Islam et al. 2014), tribal children of Khammam in Andhra Pradesh (21.30%) (Laxmaiah et al. 2007), school age children of tea garden workers of Assam (21.20%) (Medhi et al. 2006), tribal children in West Bengal (20.70%) (IIPS and

Macro International 2008), Lodha children of Paschim Medinipur in West Bengal (20.30%) (Bisai et al. 2008), Santal pre-school children (20.10%) (Bisai 2014), tribal children of Melghat in central India (18.80%) (Talapalliwar and Garg 2014), Bengalee Muslim school children of North Bengal (17.40%) (Sen et al. 2011b), children in urban slums of Pune (16.90%) (Mamulwar et al. 2014), children Infected with HIV in South India (16.00%) (Padmapriyadarsini et al. 2009), children in Maharashtra (16.00%) (Purohit et al. 2017), children of Assam (14.42%) (Som et al. 2006), children of West Bengal (13.94%) (Som et al. 2006), Rajbanshi children of North Bengal, West Bengal (13.60%) (Mondal and Sen 2010a), Saharia children in Rajasthan (13.40%) (Rao et al. 2006), children of Punjab (13.00%) (Gupta 2014), Santal Children Purulia District, West Bengal (12.70%) (Das and Bose 2011a), Shabar children in forest habitat in Orissa (12.10%) (Chakrabarty and Bharati 2010), children from urban Allahabad (10.60%) (Kumar et al. 2006), children in Orphanages of Odisha (9.80%) (Routray et al. 2015), ICDS children of Nadia District, W.B (9.40%) (Bose et al. 2007a), school children in Army School in Pune (6.71%) (Mukherjee et al. 2008) and the tribal children of Bankura in West Bengal (3.20) (Mukhopadhyay and Biswas 2011).

Studies non-Indian several studies among children of Western Kenya (70.00%) (Bloss et al. 2004), children from Pakistan (45.00%) (Badruddin et al. 2008), children in a rural district of Kelantan, Malaysia (40.00%) (Whye Lian et al. 2012), pre-school children in Terengganu, Malaysia (38.00%) (Wong et al. 2014), children in North-eastern of Peninsular Malaysia (30.60%) (Ali Naser et al. 2014) have observed higher prevalence of wasting than that in present study (26.96%).

The prevalence of wasting in present study (26.96%) was observed to be higher than the prevalence of wasting observed among pre-school children in Peru (26.60%) (Casapia et al. 2007), children from Burkina Faso (26.00%) (Beiersmann et al. 2013), children in Central Africa Republic (20.20%) (Wanga et al. 2009), children in Sri Lanka (17.10%) (Ubeysekara et al. 2015), children in Ethiopia (17.00%) (Derso et al. 2017), children in Nghean, Vietnam (11.90%) (Hien and Kam 2008), children in rural Cambodia (10.00%) (Reinbott et al. 2015), children of Mugu district, Nepal (9.40%) (Thapa et al. 2013), children of Humla district, Nepal (8.80%) (Thapa et al. 2013), children from Turkey (8.20%) (Ergin et al. 2007), children in Iran (8.19%) (Kavosi et al. 2014), children from Oman (7.00%) (Alasfoor et al. 2007), children from Laos (6.00%) (Phengxay et al. 2007), Cameroon urban children and adolescents (5.20%) (Wamba et al. 2013), children in Granada province, Nicaragua (5.00%) (Sakisaka et al. 2005), Kenyan children (4.50%) (Chesire et al. 2008), children from Zambia (4.40%) (Gernaat et al. 1996), children in Brazil (4.10%) (de Souza et al. 2012), school children from Iran (3.10) (Rezaeian et al. 2014), Chinese children (3.07) (Zhang et al. 2011), children of Nairobi in Kenya (2.10%) (Muchina and Waithaka 2010), children in Iran (0.70%) (Mahyar et al. 2010).

4.3.4. Prevalence of underweight (Low weight-for-age)

The prevalence of underweight in present study (40.03%) was observed to be distinctively lower than the prevalence of underweight observed among Kamar children in Chattisgarh (93.90%) (Mitra et al. 2007b), Gond tribal children of Kalahandi district of Orissa (89.30%) (Balgir et al. 2002), Saharia children, Baran, Rajasthan (72.10%) (Rao et al. 2006), tribal children of Maharastra (68.70%) (Khandare et al. 2008), tribal children of Khammam, Andhra Pradesh (65.40%) (Laxmaiah et al. 2007), Santal pre-school children (65.20%) (Bisai 2014), pre-school tribal children of Maharashtra (64.00%) (Meshram et al. 2011), slum children in Midnapore, West Bengal (63.70%) (Bisai et al. 2009), rural pre-school children of Arambag, Hoogly, West Bengal (63.30%) (Mandal and Bose 2009), children Infected with HIV in South India (63.00%) (Padmapriyadarsini et al. 2009), Kora-Mudi children of Paschim Medinipur, West Bengal (61.70%) (Bisai and Mallick 2011), Gond children in Madhya Pradesh (61.60%) (Rao et al. 2005), Baiga children in Madhya Pradesh (61.00%) (Chakma et al. 2009), tribal children of Melghat in central India (60.90%) (Talapalliwar and Garg 2014), children of

Kadukuruba tribes of Mysore district (60.40%) (Manjunath et al. 2014), Gond children in Korba, Chattisgarh (60.00%) (Mitra et al. 2007a), children of Rajasthan (60.00%) (Singh et al. 2006), Kodaku children in Madhya Pradesh (59.80%) (Dolla et al. 2005), tribal children, West Bengal (59.70%) (IIPS and Macro International 2008), National Capital Territory of Delhi (57.60%) (Saxena et al. 1997), tribal children of 17 tribal districts Bihar (55.00%) (Yadav and Singh 1999), tribal children, India (54.50%) (IIPS and Macro International 2007) children in Uttar Pradesh (53.86%) (Singh et al. 2013), Kora-Mudi children of Paschim Medinipur in West Bengal (52.90%) (Bisai and Mallick 2011), Bharia children in Madhya Pradesh (52.50%) (Dolla et al. 2006), school age children of tea garden workers of Assam (51.70%) (Medhi et al. 2006), children of Tea-labourer community in West Bengal (50.80%) (Mondal and Sen 2010a), Kawar children in Chattisgarh (48.20%) (Mitra et al. 2007a) and Lodha children, Paschim Medinipur, West Bengal (47.30%) (Bisai et al. 2008).

The prevalence of underweight in present study (40.03%) was observed to be slightly lower than the prevalence of underweight observed among Bengalee Muslim school children of North Bengal (47.00%) (Sen et al. 2011b), children residing in slum areas of Bhubaneswar (45.40%) (Panigrahi and Das 2014), Bengali Muslim children, West Bengal (43.80%) (Mondal and Sen 2010a), slum children of Bankura in West Bengal (41.60%) (Shit et al. 2012) and infants in rural areas of Madhya Pradesh (41.00%) (Meshram et al. 2015).

The prevalence of underweight in present study (40.03%) was observed to be higher than the prevalence of underweight observed among Santal Children Purulia District, West Bengal (38.20%) (Das and Bose 2011a), children in Maharashtra (38.15%) (Purohit et al. 2017), Raj Gond children in Madhya Pradesh (37.40%) (Sharma et al. 2006), Rajbanshi children of North Bengal, West Bengal (37.40%) (Mondal and Sen 2010a), children from urban Allahabad (36.40%) (Kumar et al. 2006), children in urban slums of Pune (34.30%) (Mamulwar et al. 2014), Shabar children in forest habitat in Orissa (33.87%) (Chakrabarty and

Bharati 2010), Santal children of Puruliya district, West Bengal (33.70%) (Chowdhury et al. 2008), children of Karnataka (31.20%) (Joseph et al. 2002), Santal children of Birbhum district, W.B (31.10%) (Ghosh and Sarkar 2013), ICDS children of Nadia District, West Bengal (31.00%) (Bose et al. 2007a), children in a slum area of Kolkata, West Bengal (30.50%) (Mandal et al. 2014), children of urban slum in Punjab (29.50%) (Sengupta et al. 2010), tribal children in riverine areas of Dibrugarh in Assam (29.00%) (Islam et al. 2014), early adolescent school girls of West Bengal (27.90%) (Maiti et al. 2011), children in orphanages of Odisha (21.30%) (Routray et al. 2015), rural school children of Bankura in West Bengal (16.90%) (Bose et al. 2007b), school children in army school in Pune (9.87%) (Mukherjee et al. 2008) and among tribal children of Bankura in West Bengal (7.40%) (Mukhopadhyay and Biswas 2011).

In case of non-Indian studies several studies e.g., among pre-school age children in Belen in Peru (28.60%) (Casapia et al. 2007), pre-school children in Terenggan in Malaysia (71.00%) (Wong et al. 2014), children in a rural district of Kelantan in Malaysia (63.40%) (Whye Lian et al. 2012), children in North-eastern of Peninsular in Malaysia (61.00%) (Ali Naser et al. 2014) and pre-school children of Swabi district in Pakistan (49.00%) (Khan Khattak and Ali 2010) have observed higher prevalence of underweight than that in present study (40.03%).

The prevalence of underweight in present study (40.03%) was observed to be higher than the prevalence of underweight observed among children from Laos (35.00%) (Phengxay et al. 2007), children Vietnam (31.80%) (Hien and Kam 2008), rural school going children in Nepal (30.85%) (Mansur et al. 2015), children from Zambia (30.00%) (Gernaat et al. 1996), children of Western Kenya (30.00%) (Bloss et al. 2004), Pakistani children (29.50%) (Mian et al. 2002), children in Thailand (27.80%) (Firestone et al. 2011), Malaysian children (26.10%) (Marjan et al. 1998), semi-urban Nigerian school children (25.50%) (Fetuga et al. 2011), Tibetan children (24.70%) (Dang et al. 2004), children from Pakistan (22.00%) (Badruddin et al. 2008), children from Oman (17.90%) (Alasfoor et al. 2007), Kenyan children (14.90%) (Chesire et al. 2008), children in Qazvin, Iran (11.70%) (Mahyar et al. 2010), children in Granada province, Nicaragua (10.30%) (Sakisaka et al. 2005), children in Iran (9.66%) (Kavosi et al. 2014), school children from Iran (9.48%) (Rezaeian et al. 2014), Chinese children (7.19%) (Zhang et al. 2011), school children in an urban area of Sri Lanka (6.90%) (Wickramasinghe et al. 2004), children of Nairobi, Kenya (6.20%) (Muchina and Waithaka 2010), children from Turkey (4.80%) (Ergin et al. 2007) and Cameroon urban children and adolescents (2.20%) (Wambaetal. 2013).

Table 4.1: Comparison of prevalence of undernutrition among the Bengali Muslim children with the other Indian studies

Population	Age group (Years)	Prevalence (%)				Reference
		Stunting	Thinness	Wasting	Underweight	
National Capital Territory of Delhi	Under 6	53	-	22.50	57.60	Saxena et al. 1997
Tribal children of 17 tribal districts Bihar	0-6	60.0	-	25.00	55.00	Yadav and Singh 1999
Gond tribal children of Kalahandi district of Orissa	6-14	-	-	-	89.30	Balgir et al. 2002
children of Karnataka	1-5	9.40	-	-	31.20	Joseph et al. 2002
Kodaku children, Sarguja, Madhya Pradesh	1-5	43.00	-	35.00	59.80	Dolla et al. 2005
Gond children, Jabalpur, Madhya Pradesh	0-5	51.6	-	32.90	61.60	Rao et al. 2005
Bharia children, Chhindwara, Madhya Pradesh	1-5	48.1	-	33.90	52.50	Dolla et al. 2006
Children from urban Allahabad	Under 5	51.6	-	10.60	36.40	Kumar et al. 2006
School age children of tea garden worker of Assam	6-8	47.4	-	21.20	51.70	Medhi et al. 2006
School age children of tea garden worker of Assam	9-14	-	53.9	-	-	Medhi et al. 2006
Oraon of North Bengal and tribal children of Bihar	6-12	54.00	-	-	-	Mittal and Srivastava 2006
Raj Gond children, Balaghat, Madhya Pradesh	1-5	46.3	-	41.50	37.40	Sharma et al. 2006

Saharia children, Baran, Rajasthan	1-5	67.8	-	13.40	72.10	Rao et al. 2006
Children of W.B	0-5	45.80	-	13.94	-	Som et al. 2006
Children of Assam	0-5	-	-	14.42	-	Som et al. 2006
Children of Rajasthan	0–5	53.00	-	28.00	60.00	Singh et al. 2006
ICDS children of Nadia District, W.B	3-5	23.90	-	9.40	31.00	Bose et al. 2007a
Tribal children, India	Under 5	53.9	-	27.60	54.50	IIPS and Macro International 2007
Tribal children of Khammam, Andhra Pradesh	1-5	46.4	-	21.30	65.40	Laxmaiah et al. 2007
the Kamar tribe of Chhattisgarh	4-12	50.00	-	-	-	Mitra et al. 2007b
Santal children of Puruliya district, W.B	5-12	17.90	-	29.40	33.70	Chowdhury et al. 2008
Tribal children, W.B	Under 5	58.6	-	20.70	59.70	IIPS and Macro International 2008
Tribal children of Thane, Maharastra	0-6	60.4	-	30.20	68.70	Khandare et al. 2008
ICDS children from W.B	2-6	26.60	-	-	-	Mandal et al. 2008
Slum children in Midnapore, W.B	3-6	47.8	-	32.70	63.70	Bisai et al. 2009
Baiga children, Dindori, Madhya Pradesh	1-5	44.30	-	37.20	61.00	Chakma et al. 2009

Urban adolescents of North 24 Parganas and Howrah, W.B	-	-	21.75	-	-	Ghosh and Bandyopadhyay 2009
Rural children of ICDS scheme, Hooghly, W.B	2-6	-	85.21	-	-	Mandal et al. 2009
Rural pre-school children of Arambag, Hoogly, W.B	2-6	26.60	-	50.00	63.30	Mandal and Bose 2009
Children Infected with HIV in South India	0-15	58	-	16.00	63.00	Padmapriyadarsini et al. 2009
Kora-Mudi tribal children of Paschim Medinipur, W.B	2-13	-	67.2	-	-	Bisai et al. 2010
Bengalee rural pre-school children of ICDS	1–5	39.20	-	-	-	Biswas and Bose2010
Shabar children in forest habitat, Orissa	5-19	45.16	52.42	12.10	33.87	Chakrabarty and Bharati 2010
Children of Tea-labourer community, W.B	5–12	41.70	-	23.50	50.80	Mondal and Sen 2010a
Bengali Muslim children, W.B	5–12	33.70	-	26.60	43.80	Mondal and Sen 2010a
Rajbanshi children of North Bengal, W.B	5–12	35.80	-	13.60	37.40	Mondal and Sen 2010a
Rural primary school-going children residing in Darjeeling, W.B	5–12	-	69.40	-	-	Mondal and Sen 2010b
Children of urban slum in Ludhiana, Punjab	0-5	74	-	42.00	29.50	Sengupta et al. 2010

Kora-Mudi children of Paschim Medinipur, W.B	2-5	51.1	-	27.70	61.70	Bisai and Mallick 2011
Kora-Mudi children, Paschim Medinipur, W.B	2-13	49.6	-	22.70	52.90	Bisai and Mallick 2011
Santal Children Purulia District, W.B	2-6	26.30	-	12.70	38.20	Das and Bose 2011a
Santal tribal children and adolescents of Purulia district, W.B	7-18	-	41.3	-	-	Das and Bose 2011b
Santal Preschool Children	2–6	-	56.17	-	-	Das and Bose 2011c
Hill Kharia tribal children	4-18	-	52.9	-	-	Das and Bose 2011d
Nepali speaking pre-school children of Darjeeling, W.B	2-6	-	45.22	-	-	Das and Datta Banik 2011
Early adolescent school girls of W.B	10-14	32.50	20.2	-	27.90	Maiti et al. 2011
Early adolescent rural school girls of Paschim Medinipur, W.B	10–14	-	58.30	-	-	Maiti et al. 2011
Early adolescent school girls of Paschim Medinipur, W.B	10-14	34.20	40.94	-	-	Maiti et al. 2011
Pre-school tribal children of Maharashtra, India	1-5	61	-	29.00	64.00	Meshram et al. 2011
Bengalee Muslim school children in Eastern India	6-16	-	56.70	-	-	Mondal et al. 2011
Tribal children, Bankura, W.B	0.5-5	12.80	-	3.20	7.40	Mukhopadhyay and Biswas 2011

Rural primary school in Paschim Medinipur, W.B	6-12	-	77.0	-	-	Das et al. 2012
Slum children in Bankura, West Bengal	Under 5		-		41.60	Shit et al. 2012
Mising tribal children of North-east India	6-10	-	18.19	-	-	Sikdar 2012b
Sunni Muslim school girls Delhi	6-12	-	38.37	-	-	Bansal and Joshi 2013
Ao Naga tribal children, Nagaland	8-15	-	30.12	-	-	Longkumar 2013
Santal children of Birbhum district, W.B	2-16	47.8	29.6	-	31.10	Ghosh and Sarkar 2013
Sonowal Kachari tribal children in Assam	6-18	-	25.99	-	-	Singh and Mondal 2013
Children in Bareilly, UP	0-5	43.22	-	60.67	53.86	Singh et al. 2013
School children in UP	10-19	12.50	23.20	-	-	Srivastav et al. 2013
School going children in Surathkal, Karnataka	4-16	-	37.5	-	-	Aroor et al. 2014
Santal pre-school children	0-5	54.2	-	20.10	65.20	Bisai 2014
Children of Punjab	0-5	-	-	13.00	-	Gupta 2014
Tribal children in riverine areas of Dibrugarh, Assam	Under 5	30.40	-	21.60	29.00	Islam et al. 2014
School children in South India	5-18	-	12.2	-	-	Kumaravel et al. 2014
Santal school children Hooghly District, W.B	6-10	-	75.95	-	-	Mandal and Bose 2014
Children Residing in Slum Areas of Bhubaneswar	3–9	57.4	22.9	23.30	45.40	Panigrahi and Das 2014

Bhaina tribal girls in Chhattisgarh	6-12	-	57.1	-	-	Singh et al. 2014
Tribal children of Melghat in central India	0–6	66.4	-	18.80	60.90	Talapalliwar and Garg 2014
Children in Central India	6-15	-	51.1	-	-	Gupta et al. 2015
Infants in Rural Areas of Madhya Pradesh	Under 1	29.00	-	33.00	41.00	Meshram et al. 2015
Tribal Bodo children of Assam	5-11	-	11.50	-	-	Mondal et al. 2015
Rural pre-school children in Karnataka	2-5	-	61.7	-	-	Nayak et al. 2015
Rural school children in Bangalore	5-14	7.00	34.00	-	-	Rashmi et al. 2015
Children in Orphanages of Odisha	Under 6	22.90	-	9.80	21.30	Routray et al. 2015
Pre-school children of North Bengal, W.B	2-5	-	62.00	-	-	Tigga et al. 2015b
Rural adolescents in W.B	10-17	54	49	-	-	Pal et al. 2016
Bhaina tribal children in Bilaspur, Chattisgarh	7-12	-	53.8	-	-	Das et al. 2016
Urban affluent school children in Gujrat	8-18	-	3.3	-	-	Chudasama et al. 2017
Rural Bengalee pre-school children of ICDS Scheme of Sagar Island, South 24 Parganas, W.B	3-5.5	-	81.25	-	-	Giri et al. 2017b
Children in Maharashtra	Under 5	40.46	-	16.00	38.15	Purohit et al. 2017
Rural school-going children of W.B	5-12	31.80	27.7	-	-	Debnath et al. 2018c

Rural primary school children in Hooghly, W.B	6-10	-	48.5	-	-	Pal and Bose 2020
Children of Purba Medinipur, W.B	-	-	67.74	-	-	Khanra et al. 2020
Bengali Muslim children	1-5	44.61	26.31	26.96	40.03	Present Study

Table 4.2: Comparison of prevalence of undernutrition among the Bengali Muslim children with non-Indian studies

Population	Age group (Years)	Prevalence (%)				Reference
		Stunting	Thinness	Wasting	Underweight	
Indonesian school children	5-12	55.00	-	-	-	Hadju et al. 1995
Children from Zambia	Under 5	69.2	-	4.40	30.00	Gernaat et al. 1996
Malaysian children	Under 9	29.20	-	-	26.10	Marjan et al. 1998
Pakistani children	5-10	-	-	-	29.50	Mian et al. 2002
French children	7 – 9	-	6.0	-	-	Rolland-Cachera et al. 2002
Children of Western Kenya	Under 5	47	-	70.00	30.00	Bloss et al. 2004
Tibetan children	Under 3	41.40	-	-	24.70	Dang et al. 2004
School children in an urban area of Sri Lanka	8-12	5.15	23.86	-	6.90	Wickramasinghe et al. 2004
Brazilian school children	7–10	-	3.2	-	-	de Assis et al. 2005
Children in Granada province, Nicaragua	0–2	30.1	-	5.0	10.3	Sakisaka et al. 2005
Pre-school children in Bangladesh	Under 5	44	-	-	-	Rahman and Chowdhury 2006

Children from Oman	0-5	10.6	-	7.00	17.90	Alasfoor et al. 2007
Pre-school age children in Belen, Peru	Under 5	32·1	-	26.60	28·60	Casapia et al. 2007
Children from Turkey	Under 5	10.9	-	8.20	4.80	Ergin et al. 2007
Children from Laos	Under 5	54	-	6.00	35.00	Phengxay et al. 2007
Children of Bangladesh	Under 5	44.00	-	-	-	Rahman and Chowdhury 2007
Children from Pakistan	5-12	6	-	45.00	22.00	Badruddin et al. 2008
Kenyan children	6-12	30.20	-	4.50	14.90	Chesire et al. 2008
Children in Nghean, Vietnam	Under 5	44.3	-	11.9	31.8	Hien and Kam 2008
Children of Bangladesh	0–1	50·7	-	-	-	Semba et al. 2008
Children of Indonesia	0–1	33·2	-	-	-	Semba et al. 2008
Children in Kenya	1-2	51	-	-	-	Adeladza 2009
Children in Central Africa Republic	0.5–2	61.5	-	20.2		Wanga et al. 2009
Chinese children and adolescents	5-19	13.80	7.40	-	-	Yan-Ping et al. 2009
Adolescent girls in rural Bangladesh	13-18	-	26	-	-	Alam et al. 2010

Pre-school children of Swabi district, Pakistan	2-5	53	-	-	49	Khan Khattak and Ali 2010
Children in Qazvin, Iran	Under 2	11.5	-	0.70	11.70	Mahyar et al. 2010
Children of Nairobi, Kenya	0-2	10.60	-	2.10	6.20	Muchina and Waithaka 2010
Children and adolescents in the Seychelles	5-16	-	35.6	-	-	Bovet et al. 2011
Semi-urban Nigerian school children	6-10	14.2	22.2	-	25.5	Fetuga et al. 2011
Chinese children	Under 5	14.59	-	3.07	7.19	Zhang et al. 2011
Pre-school children in Gaza strip	5-6	11.9	4.2	-	-	Kanoa et al. 2011
Children and adolescents in England	2-5		5.7	-	-	Whitaker et al. 2011
Children in Mauritius	9–10	-	12.7	-	-	Caleyachettyet al. 2012
Children in Brazil	Under 5	9.9	-	4.10		de Souza et al. 2012
Urban school children and adolescents in southern Nigeria	5-18	-	13.0	-	-	Ene-Obong et al. 2012
Children of Chengdu, Southwest China	9–15	-	6.3	-	-	Li et al. 2012
Children in Klang valley, Malaysia	5-6	3.9	5.8	-	-	Poh et al. 2012
Garo tribal children in Bangladesh	5-10	-	30.88			Rana et al. 2012
Portuguese children	6–8	-	1.0	-	-	Rito et al. 2012

Children from Burkina Faso	0.5–2.5		-	26		Beiersmann et al. 2013
Nigerian children and adolescents	7-17	-	21.61	-	-	Ejike et al. 2013
Children and adolescents from Brazil	7-17		4.1	-	-	Guedes et al. 2013
Children in Tamale, Northern Ghana	5-14	-	29.8	-	-	Mogre et al. 2013
Malaysian children	0.5-12	-	5·4	-	-	Poh et al. 2013
Children in Italian school in Rome	6-19	-	10.9	-	-	Rosati et al. 2013
Children of Mugu district, Nepal	0-5	-	20.12	9.4	-	Thapa et al. 2013
Children of Humla district, Nepal	0-5	-	21.13	8.8	-	Thapa et al. 2013
Cameroon urban children and adolescents	8-15	5.7	9.5	5.2	2.2	Wamba et al. 2013
Children in Iran	0–6	9.53	-	8.19	9.66	Kavosi et al. 2014
Pre-school children in Egypt	0.5-2	20.3	-	-	-	Seedhom et al. 2014
Rural school going children in Kavre District, Nepal	4-16	24.54	10.05	-	30.85	Mansur et al. 2015
Students in Northern Ethiopia	10–19	28.5	26.1	-	-	Melaku et al. 2015
Rural school-aged Sudanese children	6–14	7.1	23.1	-	-	Mohamed and Hussein 2015
Children and adolescents in Shandong, China	7–18	-	12.42	-	-	Zhang et al. 2015
Children in Shanghai, China	3–12	-	16.04	-	-	Chen et al. 2016

Adolescent school girls in North Ethiopia	10–19	12.2	21.4	-	-	Gebregyorgis et al. 2016
School children and adolescents from Democratic Republic of Congo	6-18	-	8.93	-	-	Buhendwa et al. 2017
Children in Ethiopia	0.5–2	58.1	-	17.0		Derso et al. 2017
Polish school-aged children and adolescents	7–18	-	11.7	-	-	Gurzkowska et al. 2017
Primary school children in rural Sri Lanka	5-10	-	11.51	-	-	Naotunna et al. 2017
Children in Johor State, Malaysia	6-18	-	13.1	-	-	Partap et al. 2017
Primary school Children in Sub-urban region in Tanzania	5-19	16.3	11.3	-	-	Teblick et al. 2017
School-age children in Southern Ethiopia	6-14	41.9	8.0	-	-	Tariku et al. 2018
Bengali Muslim children	1-5	44.61	26.31	26.96	40.03	Present Study

4.4. ASSESSMENT OF MATERNAL BODY COMPOSITION AMONG THE BENGALI MUSLIM MOTHERS

Human body is composed of water, protein, minerals and can be divided into two major components i.e., fat component and fat-free component (Kravitz and Heyward 1992). The total fat can be divided into essential fat and storage fat. Fat in muscles, bone marrows, in heart, lungs, liver, spleen, kidneys, intestines and tissues throughout the central nervous system is called the essential fat, on the other hand the fat which accumulates in adipose tissue is called the storage fat. The presence of essential fat is necessary for normal body functioning and it has been found to be higher among women than in men because it includes gender related characteristics which is also related to child-bearing (Kravitz and Heyward, 1992; Das et al. 2012; Mallick and Roy 2019). Overall physical health and health of specific organs are influenced by distribution in body. In terms of location body fat can be divided into two categories ie., subcutaneous fat (under the skin) and visceral fat (around the organs). Excess visceral fat around the vital organs can interfere with proper functioning of them. Fat around the middle body portion is associated with visceral fat and the presence of excess abdominal fat possesses serious health risk in individuals. Body size of adults and status of body composition have important functional implications mainly in developing countries e.g., the lean body mass is an important factor of physical work capacity which can impact productivity in physically demanding works (Haas et al. 1995; Martorell 1995).

Height of mothers can be used to identify the risk of having a difficult delivery, obstructed or prolonged labor because short stature is often related to small pelvic size among women (Howsen et al. 1996; Rush 2000; Sokal et al. 1991). Moreover, the risk of having babies with low birth weight is another problem observed among short statured women (NFHS-3 2007). The presence of short maternal stature and maternal body size and composition is also related to the birth size and survival of infants (Martorell et al. 1996; UNICEF 1998).

The present study have observed that the mean values of all the anthropometric and body composition e.g., height, weight, MUAC, WC, HC, BSF, TSF, SSF, SISF, PBF, FM, FFM, FMI, FFMI, TUA, UMA, UFA, AFI, UME, UFE, BMI, WHR, BAI and WHtR variables showed an increasing trend with age. Although several studies have observed a decreasing trend in body composition variables among adults (Strickland and Ulijaszek 1993; Chilima and Ismail 1998; Pieterse et al. 1998; Kuozmarski et al. 2000; Oguntona and Kuku 2000; Ghosh et al. 2001; Pirlich and Lochs 2001; Bose 2002; Bose and Das Chaudhuri 2003; Ghosh 2004; Santos et al. 2004; Bose et al. 2007b; Bisai et al. 2008; Sarkar and Mukhopadhyay 2008, Bisai et al. 2009; Das et al. 2012). However, some studies also have demonstrated positive age specific trend in anthropometric and body composition measures such as Reddy (1998) and Sadhukan et al. (2007). Several studies have been reported on Body composition and BMI among various populations which have indicated ethnic differences (Misra et al. 2011; Zaman et al. 2012). Such differences depeding on ethnicity may be attributed to genetic factors and many other environmental factors (e.g., obesogenic environment). Several recent studies have investigated the relationship of BMI and body composition. The BMI assesses the entire body mass and not FM or FFM body composition of an individual. Therefore, same BMI levels among individuals does not imply that body composition status (ie., FM, FFM, FMI, FFMI etc.) of those individuals will also be similar. There are several studies on available in India on FMI, FFMI (Bhat et al., 2005; Bose et al., 2008; Khongsdier, 2005; Rao et al., 2012; Bose et al., 2006; Verma et al., 2016) and MUAC (Bose et al., 2007; Bose et al., 2006; Bisai et al., 2009; Chakraborty et al., 2009; Das et al. 2012; Mallick and Roy 2019).

Studies on West Bengal have also been reported (Das and Bose, 2006; Bisai et al., 2008; Das and Bose, 2012; Das et al., 2013; Ghosh et al., 2001; Banik, 2007; Das et al. 2012; Kuiti and Bose, 2015; Mallick and Roy 2019). The present study observed statistically significant correlations between the anthropometric and body composition variables among the Bengali

Muslim mothers. Statistically significant effect of age and BMI on the anthropometric and body composition variables are also observed in the present study.

In ideal conditions the increase in body mass during adulthood and progressive decrease of body mass with old age at a rate of approximately 1 kg per decade has been observed in several researches. It has also been observed in the present study that the younger mothers have lower BMI values than the elder ones ie., mean BMI values have increased with age among the Bengali Muslim mothers. The BMI is a measure of overall adiposity, whereas WC, WHR and WHtR reliable proxy measures of abdominal fat (Bose and Mascie-Taylor 1998; Kopelman 2000).

Sexual dimorphism in age trends in anthropometric and body composition variables have been observed in many research works from India (Singal and Sidhu 1983; Singal et al. 1988; Ghosh et al. 2001; Bose and Chaudhuri 2003; Bisai et al. 2008; Das et al. 2012; Mallick and Roy 2019). The possible causes for this sex difference may be because of the factors like, levels of physical activity and sex hormones (Bowen et al. 2011; Edwards and Sackett 2016; Sood and Bharmoria 2016; Bisai et al. 2008; Das et al. 2012; Ghosh and Bose 2018; Samuel et a. 2015; Corella et al. 2019; Mallick and Roy 2019).

The four skinfold measurements (BSF, TSF, SSF and SISF) and WHR were observed to be statistically significantly correlated correlated with height and weight ($p<0.01$). Also, height and weight were positively correlated with WC and HC which is also statistically significant. Several Indian and non-Indian studies have been done on the assessment of body composition using these above mentioned indicator to assess the health condition of individuals and populations (Khatoon et al. 2008; Bose and Das Chaudhuri 2003; Singh et al. 2014).

Statistically significant effects of age and BMI on PBF and WHtR has been observed among the mothers ($p<0.01$). Statiscally significant correlations of BMI and MUAC, WC, HC, PBF, BAI and WHtR have been observed as observed in other studies (Ghosh and

Bandypadhyay 2007; Singh et al. 2014; Banik et al. 2016; Ghosh and Bose 2018). The WC can predict health status as well as body composition accurately without any involving any other indicator as recommended by severl researches (Ghosh and Bandypadhyay 2007; Singh et al. 2014; Banik et al. 2016; Ghosh and Bose 2018). Moreover, studies have observed that WC has a better association with body fat than any other anthropometric indicator (Chakraborty and Bose 2009; Singh et al. 2014; Singh et al. 2014; Banik et al. 2016; Ghosh and Bose 2018). Several studies have used the waist-to-height ratio (WHtR) as the screening indicator among the individuals who need an assessment of visceral obesity rather than the assessment of body weight as it has been observed to be more useful than other indicators (DeNino et al. 2001; Despres and Lemieux 2006; Abdelaal et al. 2017). Human physical variation in body dimension exists between populations which is also effected by geography and environment (Saha 1985; Gite and Singh 1997; Dewangan et al. 2005; Singh et al. 2014; Banik et al. 2016; Ghosh and Bose 2018). Individuals from the same population group or even members of the same household may differ in their fatness although they are in a similar lifestyle pattern. Obesity is a chronic condition characterized by an excess amount of body fat (Arterburn and Noel 2001) which can be a major risk factor for survival.

4.5. PREVALENCE OF UNDERNUTRITION (BMI< 18.50 kg/m^2) AMONG BENGALI MUSLIM MOTHERS

Several research studies have reported a high amount of undernourishment present among Indian women (Bose and Chakraborty 2005; Subramanium and Smith 2006; Griffiths and Bentley 2005; Mahanta et al. 2012; Kshatriya and Acharya 2016). Prevalence of undernutrition ie., chronic energy deficiency (CED) will increase the disease burden and morbidity in population. Less physical productivity, poor reproductive performances (e.g., low birth weight of children) and per-capita economic development in population are the results of the presence of maternal undernutrition in populations. The prevalence of undernutrition was observed to be higher in the Hinduized Mongoloid groups like Ahom (52.00%), Koch (50.00%) and Rajbanshi (42.00%) (Khongsider 2002). The present study have observed prevalence of undernutrition ie., CED 10.29% which is observed to be lowest as observed by other research studies among women in India.

The prevalence of undernutrition (i.e., CED) is a serious problem among the adult population of Northeast India (Khongsider 2002; Gogoi and Sengupta 2002; Mungreipy and Kapoor 2010; Mahanta et al. 2012). It has also been observed that the prevalence of undernutrition i.e., CED was observed to be significantly lower in the tribal populations than in the Hinduized and caste populations (Khongsider 2001; Gogoi and Sengupta 2002). When the population specific comparison of prevalence of undernutrition (e.g. CED) among Indian and non-Indian women was taken into consideration, the prevalence of maternal undernutrition in the present study showed significantly lower prevalence. Prevalence of maternal undernutrition in the present study is observed to be significantly lower than among the Bathudi women in Odisha, India (64.50%) (Bose and Chakraborty 2005), Oraon tribal women in West Bengal (62.90%) (Kshatriya and Acharya 2016), Bathudi tribal women in Odisha (62.80%) (Kshatriya and Acharya 2016), Orang tribal women Jharkhand (62.50%) (Dutta Banik 2011), Kora tribal women in West Bengal (62.00%) (Kshatriya and Acharya 2016), Kora-Mudi tribal women West Bengal (56.40%) (Bose et al. 2006a), Savar tribal women in Orissa (49.00%) (Bose et al. 2006b), Chaudhari tribal women in Gujarat (48.80%) (Kshatriya and Acharya 2016), rural women Assam (48.00%) (Mahanta et al. 2012), rural women in Karnataka (48.00%) (Griffiths and Bentley 2005), Indian tribes (47.40%) (Kshatriya and Acharya 2016), Sarak women Jharkhand (46.36%) (Dutta Banik 2011), Dhimal tribal women in West Bengal (46.20%) (Banik et al. 2007), Santal tribal women in West Bengal (45.10%) (Kshatriya and Acharya 2016), women from Andhra Pradesh (45.00%) (Griffiths and Bentley 2001), ever-married women in Jharkhand (41.50%) (NFHS-3), ever-married women in Bihar

(41.10) (NFHS-3), Kukna tribal women in Gujarat (40.00%) (Kshatriya and Acharya 2016), ever-married women in Chhattisgarh (39.70%) (NFHS-3), ever-married women in Odisha (39.50%) (NFHS-3), ever-married women in Karnataka (38.80%)(NFHS-3), ever-married women in Madhya Pradesh (38.60%) (NFHS-3), ever-married women in West Bengal (37.10%) (NFHS-3), Bhumij tribal women in Odisha (37.00%) (Kshatriya and Acharya 2016), ever-married women in Assam (35.80%) (NFHS-3), ever-married women in Rajasthan (32.70%) (NFHS-3), ever-married women in Uttar Pradesh (32.60%) (NFHS-3), ever-married women in India (32.20%) (NFHS-3), Indian women (32.10%) (Subramanium and Smith 2006), ever-married women in Maharashtra (32.10%) (NFHS-3), Indian women from 26 states (32.00%) (Ackerson et al. 2008), Indian women in 26 Indian states (31.20%) (Bharati et al. 2007), Santal tribal women in Odisha (31.10%) (Kshatriya and Acharya 2016), ever-married women in Andhra Pradesh (30.30%) (NFHS-3), Dhodia tribal women in Gujarat (29.20%) (Kshatriya and Acharya 2016), ever-married women in Haryana (26.90%) (NFHS-3), ever-married women in Uttaranchal (25.00%) (NFHS-3), ever-married women in Himachal Pradesh (24.20%) (NFHS-3), ever-married women in Tamil Nadu (23.20%) (NFHS-3), ever-married women in Jammu and Kashmir (20.60%) (NFHS-3), women in Kerala (19.00%) (Ramesh and Jareena 2009) and among Punjabi women in Punjab (18.50%) (Singh and Kirchengast 2011) (Table 4.3).

Several non-Indian studies also observed higher prevalence of undernutrition among women (Table 4.4) e.g., among rural Bangladeshi women (38.80%) (Shafique et al. 2007), Bangladeshi women in Bangladesh Demographic and Health Survey (36.00%) (Biswas et al. 2017), urban poor Bangladeshi women (29.70%) (Shafique et al. 2007), women in South/Southeast Asia (29.00%) (Nube and Boom 2003), ever-married women in Bangladesh (24.10%) (Kamal et al. 2015), women in Sub-Saharan Africa (22.99%) (Nube and Boom 2003), women in Dakar (15.70%) (Macia et al. 2010), Colombian pregnant women (14.50%)

(Sarmiento et al. 2012) and among women in Myanmar (14.10%) (Hong et al. 2018) than it is been observed among the Bengali Muslim mothers in present study.

Prevalence of undernutrition among Bengali Muslim mothers has been observed to be higher than it is among the women in northern Nigeria (10.00%) (Bakari et al. 2007), women in Indonesia (9.10%) (Pengpid and Peltzer 2017), women in rural China (7.80%) (He et al. 2016), women in rural Tanzania (7.00%) (Keding et al. 2013), women in eastern Uganda (5.90%) (Kirunda et al. 2015), women in Latin America (5.17%) (Nube and Boom 2003), women of childbearing age in Morocco (4.70%) (Belahsen et al. 2004) and among adult females in Iran (1.00%) (Mohammadi et al. 2013).

Table 4.3: Comparison of the prevalence of undernutrition among the Bengali Muslim mothers in present study with other Indian studies

Population	Age group (Years)	Prevalence of Undernutrition (BMI< 18.50 kg/m^2)	Reference
Indian Women Andhra Pradesh	15-49	45.00	Griffiths and Bentley 2001
Bathudi women in Orissa, India	18 and above	64.5	Bose and Chakraborty 2005
Rural women in Karnataka	15–49	48	Griffiths and Bentley 2005
Ever-married women in Jharkhand	15–49	41.5	NFHS-3
Ever-married women in Bihar	15–49	41.1	NFHS-3
Ever-married women in Chhattisgarh	15–49	39.7	NFHS-3
Ever-married women in Orissa	15–49	39.5	NFHS-3
Ever-married women in Karnataka	15–49	38.8	NFHS-3
Ever-married women in Madhya Pradesh	15–49	38.6	NFHS-3
Ever-married women in West Bengal	15–49	37.1	NFHS-3
Ever-married women in Assam	15–49	35.8	NFHS-3
Ever-married women in Rajasthan	15–49	32.7	NFHS-3

Ever-married women in Uttar Pradesh	15–49	32.6	NFHS-3
Ever-married women in India	15–49	32.2	NFHS-3
Ever-married women in Maharashtra	15–49	32.1	NFHS-3
Ever-married women in Haryana	15–49	26.9	NFHS-3
Ever-married women in Uttaranchal	15–49	25	NFHS-3
Ever-married women in Himachal Pradesh	15–49	24.2	NFHS-3
Ever-married women in Tamil Nadu	15–49	23.2	NFHS-3
Ever-married women in Andhra Pradesh	15–49	30.3	NFHS-3
Ever-married women in Jammu and Kashmir	15–49	20.6	NFHS-3
Ever-married women in Punjab	15–49	13.3	NFHS-3
Ever-married women in Kerala	15–49	12.4	NFHS-3
Ever-married women in Gujarat	15–49	11.1	NFHS-3
Ever-married women in Delhi	15–49	10.7	NFHS-3
Indian Women India	15-49	32.10	Subramanium and Smith 2006
Dhimal tribal women in West Bengal	18 and above	46.20	Banik et al. 2007
Indian women in 26 Indian states	15-49	31.20	Bharati et al. 2007

Kora-Mudi tribal women West Bengal	18-65	56.40	Bose et al. 2006a
Savar tribal women in Orissa	18 and above	49.00	Bose et al. 2006b
Indian women in 26 states	15–49	32	Ackerson et al. 2008
Women in Kerala	15–49	19	Ramesh and Jareena 2009
Tangkhul Naga tribal women in Manipur	20-70	16.20	Mungreiphy and Kapoor 2010
Orang tribal women Jharkhand	39-60	62.50	Dutta Banik 2011
Sarak women Jharkhand	39-60	46.36	Dutta Banik 2011
Punjabi women Punjab	17-80	18.50	Singh and Kirchengast, 2011
Rural women Assam	18 and above	48.00	Mahanta et al. 2012
Oraon tribal women in West Bengal	20–60	62.9	Kshatriya and Acharya 2016
Bathudi tribal women in Odisha	20–60	62.8	Kshatriya and Acharya 2016
Kora tribal women in West Bengal	20–60	62.0	Kshatriya and Acharya 2016
Chaudhari tribal women in Gujarat	20–60	48.8	Kshatriya and Acharya 2016
Indian Tribes	20-60	47.40	Kshatriya and Acharya 2016
Santal tribal women in West Bengal	20–60	45.1	Kshatriya and Acharya 2016
Kukna tribal women in Gujarat	20–60	40.00	Kshatriya and Acharya 2016

Bhumij tribal women in Odisha	20–60	37	Kshatriya and Acharya 2016
Santal tribal women in Odisha	20–60	31.1	Kshatriya and Acharya 2016
Dhodia tribal women in Gujarat	20–60	29.2	Kshatriya and Acharya 2016
Nyishi tribal women of Arunachal Pradesh	15-44	10.50	Bharali et al. 2017
Karbi women residing in rural areas of Diphu, Karbi Anglong, Assam	20-49	10.67	Sharma and Mondal 2020
Bengali Muslim Mothers in West Bengal	20-34	10.29	Present Study

Table 4.4: Comparison of the prevalence of undernutrition among the Bengali Muslim mothers in present study with other non-Indian studies

Population	**Age group (Years)**	**Prevalence of Undernutrition (BMI< 18.50 kg/m^2)**	**Reference**
Women in South/Southeast Asia	15–50	29.00	Nube and Boom 2003
Women in Sub-Saharan Africa	15–50	22.99	Nube and Boom 2003
Women in Latin America	15–50	5.17	Nube and Boom 2003
Women of childbearing age in Morocco	15–49	4.7	Belahsen et al. 2004
Women in northern Nigeria	18 and above	10	Bakari et al. 2007
Rural Bangladeshi women	15–45	38.8	Shafique et al. 2007
Urban poor Bangladeshi women	15–45	29.7	Shafique et al. 2007
Women in Dakar	20 and above	15.7	Macia et al. 2010
Colombian pregnant women	20–49	14.5	Sarmiento et al. 2012
Women in rural Tanzania	17–45	7	Keding et al. 2013
Adult females in Iran	18-49	1.0	Mohammadi et al. 2013

Ever-married women in Bangladesh	15-49	24.1	Kamal et al. 2015
Women in eastern Uganda	18 and above	5.9	Kirunda et al. 2015
Women in rural China	20 to 49	7.8	He et al. 2016
Bangladeshi women in Bangladesh Demographic and Health Survey	35 and above	36.0	Biswas et al. 2017
Women in Indonesia	15–103	9.1	Pengpid and Peltzer 2017
Women in women in Myanmar	18–49	14.1	Hong et al. 2018
Bengali Muslim Mothers in West Bengal	20-34	10.29	Present Study

4.6. PREVALENCE OF UNDERNUTRITION IN TERMS OF MUAC AS AN INDICATOR

MUAC is a useful indicator for the assessment of acute adult undernutrition and is useful for both screening acute adult undernutrition at individual as well as population levels (Collins et al. 2000). Several researchers prefer to use MUAC as a reasonable alternative measure for the detection of undernutrition among adults instead of BMI and subsequently to identify individuals with morbidity risk and mortality (Vella et al. 1994; Das et al. 2012; Bose et al. 2019).

Several studies have observed high prevalence of undernutrition in India using MUAC as a measure. The prevalence of undernutrition in terms of MUAC was 51.2% among 60.4% among Santals of Purulia (Das and Bose 2012), Kora Mudis of Paschim Medinipur (Basu and Banik 2009), 43.5% among slum dwellers of Paschim Medinipur (Bose et al. 2007c), 33.4% among Santals of Bankura (Bose et al. 2006c) and 32.7% among Telegas of Paschim Medinipur (Datta Banik 2007) and 57.73% among Mahalis of Bankura (Bose et al. 2019). In the present study, the prevalence of relative risk of low MUAC with low BMI was 2.12% which was lower prevalence than that observed in other Indian opulations (Bose et al. 2006c; Bose et al. 2007; Datta Banik 2007; Basu and Banik 2009; Bose et al. 2019).

4.7. PREVALENCE OF OVERWEIGHT AND OBESITY AMONG THE BENGALI MUSLIM MOTHERS

Recent studies on the assessment of nutritional status have clearly indicated that a sizable proportion of the population is observed to be affected by overweight and obesity in India (Griffith and Bentley 2001; Subramanian and Smith 2006; Bharati et al. 2007; Subramanian et al. 2007; Mungreipy and Kpoor 2010; Sen et al. 2013; Majumder et al. 2014 Sengupta et al. 2015; Rengma et al. 2015; Giridhar et al. 2016). Prevalence of overweigtht, obesity and overall prevalence of overweight obesity in the present study is observed to be 21.08%, 15.36% and 36.44%, respectively.

Rapid socio-economic and demographic transition are currently undergoing in several developing countries which is leading to the acceleration of several non-communicable diseases and higher prevalence of overweight-obesity and slightly lower prevalence of undernutrition in population (Wang et al. 2009; Popkin et al. 2012; Subramanian et al. 2013; Varadharajan et al. 2013; Mondal and Sen 2014; Bharali et al. 2017).

A comparison of the overweight, obesity and overall overweight-obesity of Bengali Muslim mothers is depicted in Table 4.5. Several Indian studies have observed high prevalence of overall overweight and obseidy (BMI≥ 23.00 kg/m²) among Indian women e.g., Bengali Kayastha women of North Bengal (overweight: 13.33%, obesity: 78.67%, overweight-obesity: 92.00%) (Sarkar et al. 2009), Tangkhul Naga tribal women in Manipur (overweight: 25.10%, obesity: 27.10%, overweight-obesity: 52.20%) (Mungreiphy and Kapoor 2010), Indian Women in Puducherry (overweight: 19.10%, Obesity: 31.80%, overweight-obesity: 50.90%) (Majumdar et al. 2014), Bangalee Hindu caste West Bengal (overweight: 20.33%, obesity: 29.33%, overweight-obesity: 49.66 %) (Sen et al. 2013), urban women in Panjab (overweight: 12.70%, Obesity: 29.60%, overweight-obesity: 42.30%) (Girdhar et al. 2016) and among Regma Naga tribal women Assam (overweight: 25.50%, obesity: 11.63%, overweight-obesity: 37.13%) (Rengma et al. 2015) than it has been observed among Bengali Muslim mothers in the present study (overweight: 21.08%, obesity: 15.36%, overweight-obesity: 36.44%).

Several Indian studies have observed lower prevalence of overall overweight-obesity (BMI≥ 23.00 kg/m²) among women e.g., Punjabi Women Punjab (overweight: 9.20%, obesity: 24.60%, Overweight-obesity: 33.80%) (Singh and Kirchengast 2011), Dhodia tribal women (overweight-obesity: 23.3%) (Kshatriya and Acharya 2016), Nyishi tribal women of Arunachal Pradesh (overweight: 9.94%, Obesity: 9.57%, overweight-obesity: 19.57%)

(Bharali et al. 2017), Young women in Kashmir Valley (overweight: 16.50%, obesity: 2.90%, overweight-obesity: 19.40%) (Masoodi et al. 2010), Santal tribal women in Odisha (overweight-obesity: 15.10%) (Kshatriya and Acharya 2016), Kukna tribal women (overweight-obesity: 15.00%) (Kshatriya and Acharya 2016), Indian Women Andhra Pradesh (overweight: 12.00%, Obesity: 2.00%, overweight-obesity: 14.00 %) (Griffiths and Bentley 2001), Indian Tribes (overweight: 10.90%, obesity: 1.50%, overweight-obesity: 12.40%) (Kshatriya and Acharya 2016), Indian women (overweight: 9.60%, obesity: 2.70%, overweight-obesity: 12.30%) (Subramanium and Smith 2006), Santal women in West Bengal (overweight-obesity: 12.30%) (Kshatriya and Acharya 2016), Indian women in 26 Indian states (overweight: 9.40%, obesity: 2.60%, Overweight-obesity: 12.00%) (Bharati et al. 2007), Bhumij tribal women (overweight-obesity: 10.70%) (Kshatriya and Acharya 2016), Chaudhari tribal women (overweight-obesity: 10.70%) (Kshatriya and Acharya 2016), Oraon tribal women(overweight-obesity: 5.60%) (Kshatriya and Acharya 2016) and among Bathudi tribal women (overweight-obesity: 4.10%) (Kshatriya and Acharya 2016), Kora tribal women (overweight-obesity: 1.70%) (Kshatriya and Acharya 2016) than it has been observed among Bengali Muslim mothers in the present study (overweight: 21.08%, obesity: 15.36%, overweight-obesity: 36.44%).

Several Indian studies have observed high prevalence of overall overweight-obesity using the WHO (2000) cut off (BMI≥ 25.00 kg/m^2) among women e.g., Bengalee Hindu women of Kolkata (54.69%) (Bhadra et al. 2005), ever-married women in Punjab (51.60%) (NFHS-3), ever-married women in Kerala (50.60%) (NFHS-3), ever-married women in Delhi (47.70%) (NFHS-3), urban women in Karnataka (44.00%) (Griffiths and Bentley 2005), ever-married women in Tamil Nadu (37.00%) (NFHS-3), ever-married women in Jammu and Kashmir (35.30%) (NFHS-3), ever-married women in Gujarat (30.90) (NFHS-3), adult women in Punjab (30.80%) (Dewan 2008), ever-married women in Haryana (30.80%) (NFHS-

3), ever-married women in Himachal Pradesh (30.00) (NFHS-3), ever-married women in Karnataka (28.00%) (NFHS-3), ever-married women in Uttaranchal (28.00%) (NFHS-3), ever-married women in Andhra Pradesh (27.90%) (NFHS-3), ever-married women in Maharashtra (27.40%) (NFHS-3), ever-married women in India (24.10%) (NFHS-3), ever-married women in West Bengal (21.60%) (NFHS-3), women in Kerala (21.00%) (Ramesh and Jareena 2009), ever-married women in Uttar Pradesh (20.10%) (NFHS-3), ever-married women in Rajasthan (18.70%) (NFHS-3), ever-married women in Assam (16.70%) (NFHS-3), ever-married women in Madhya Pradesh (15.00%) (NFHS-3), ever-married women in Orissa (14.90%) (NFHS-3), Dhodia tribal women in Gujarat (12.50%) (Kshatriya and Acharya 2016), Indian women in 26 states (12.30%) (Ackerson et al. 2008), ever-married women in Chhattisgarh (12.20%) (NFHS-3), ever-married women in Bihar (11.90%) (NFHS-3), ever-married women in Jharkhand (11.80%) (NFHS-3), Santal tribal women in Odisha (9.20%) (Kshatriya and Acharya 2016), Santal tribal women in West Bengal (7.40%) (Kshatriya and Acharya 2016), Bhumij tribal women in Odisha (5.70%) (Kshatriya and Acharya 2016), Kukna tribal women in Guajarat (4.20%) (Kshatriya and Acharya 2016), Chaudhari tribal women in Guajarat (4.10%) (Kshatriya and Acharya 2016), Oraon tribal women in Jharkhand (3.20%) (Kshatriya and Acharya 2016), Bathudi tribal women in Odisha (2.50%) (Kshatriya and Acharya 2016).

Several non-Indian studies have observed higher overall prevalence of overweight-obesity (BMI≥ 23.00 kg/m²) e.g., adult females in Iran (overweight: 40.30%, obesity: 33.00%, overweight-obesity: 73.30%) (Mohammadi et al. 2013), women in Pakistan (overweight: 27.90%, obesity: 38.80%, overweight-obesity: 66.70%) (Jafar et al. 2006), women in Myanmar (overweight-obesity: 41.20%) (Hong et al. 2018), women in Bangladesh (39.50%) (Bishwajit 2017), women of reproductive age in Bangladesh (overweight: 28.37%, obesity: 10.77%, overweight-obesity: 39.14%) (Chowdhury et al. 2018) than it has been observe in the present study among Bengali Muslim mothers. Some of the non-Indian studies have observed lower prevalence of overweight-obesity (BMI≥23.00 kg/m²) among women e.g., Bangladeshi women of reproductive age (overweight: 25.20%, obesity: 11.20%, overweight-obesity: 36.40%) (Biswas et al. 2017), ever-married women in Bangladesh (overweight: 12.80%, obesity: 16.40%, overweight-obesity: 29.20%) (Kamal et al. 2015), women in Nepal (overweight-obesity: 27.50%) (Bishwajit 2017), Bangladeshi women in BDHS (24.40%) (Biswas et al. 2017) and among women in Nigeria (20.90%) (Kandala and Stranges 2014) than it has been observed in the present study. The presence of excess adiposity levels is considered to increase the risk of non-communicable diseases (e.g., hypertension, diabetes, cardio-metabolic and cardiovascular disorders) (WHO 2000; WHO Expert Consultation 2004). Therefore, the prevalence of overweight-obesity among women in reproductive ages certainly contributes to the mortality and morbidity among women/ mothers in the near future. There are substantial evidences which suggest socioeconomic, demographic, diet and increasing sedentary lifestyle ,subsequent decrease in physical activity, increase in reliance upon processed foods, increased use of edible oils and sugar-sweetened beverages have triggered such prevalence in populations(Subramanian et al. 2007; Mungreiphy and Kapoor 2010; Popkin et al. 2012; Mondal et al. 2015).

Several non-Indian studies have observed high prevalence of overall overweight-obesity using the WHO (2000) cut off (BMI≥ 25.00 kg/m^2) among women e.g., Non-pregnant adult women in Egypt (77.30%) (Eckhardt et al. 2008), Mexican women (72.10%) (Gómez et al. 2009), Malay women in Singapore (65.10%) (Sabanayagam et al. 2009), Peruvian women (63.00%) (Jacoby et al. 2003), Mexican women (62.00%) (Jones et al. 2017), women in Ecuador (61.00%) (Weigel et al. 2016), non-pregnant adult women in Mexico (59.30%) (Eckhardt et al. 2008), Western Sahara refugee women (53.70) (Grijalva-Eternod et al. 2012), non-pregnant adult women in Peru (52.30%) (Eckhardt et al. 2008), Ghana women (49.70%) (Ofori-Asenso et al. 2016), women in Indonesia (48.80%) (Roemling and Qaim 2012), Tz'utujil Maya women in Guatemala (46.90%) (Nagata et al. 2009), women in a slum area in Brazil (46.00%) (Alves et al. 2011), Colombian women of reproductive age (42.30%) (Kordas et al. 2013), women in northern Nigeria (40.40%) (Bakari et al. 2007), women living along the Bolivia (40.30%) (Benefice et al. 2007), Colombian pregnant women (37.30%) (Sarmiento et al. 2012), women in Indonesia (36.20%) (Sohn 2014), women in eastern Uganda (35.80%) (Kirunda et al. 2015), women of childbearing age in Morocco (35.20%) (Belahsen et al. 2004), women in Dakar (34.80%) (Macia et al. 2010), adult Chinese women in Singapore (34.00%) (Sabanayagam et al. 2007), women in low and middle income countries (31.20%) (Popkin and Slining 2013), Kenyan women (29.60%) (Mkuu et al. 2018), women in Indonesia (28.70%) (Sari and Amaliah 2014), women in Bangladesh, India, Indonesia, Thailand and Vietnam (27.90%) (Razzaque et al. 2009), non-pregnant women in Bangladesh (24.50%) (Ghose 2017), women in rural Tanzania (22.00%) (Keding et al. 2013), women in the USA (20.70%) (Martorell et al. 2000).

Table 4.5: Comparison of the prevalence of overweight, obesity and overall overweight-obesity among the Bengali Muslim mothers in present study with other Indian studies

Population	Age group (Years)	Prevalence (%)				Reference
		Overweight (BMI= 23.00-24.99 kg/m²)*	Obese (BMI≥ 25.00 kg/m²)#	Overweight -Obesity (BMI≥ 23.00 kg/m²)*	Overweight-Obesity (BMI≥ 25.00 kg/m²)#	
Indian Women Andhra Pradesh	15-49	12.00	2.00	14.00	-	Griffiths and Bentley 2001
Bengalee Hindu women of Kolkata	20-50	-	-	-	54.69	Bhadra et al. 2005
urban women in Karnataka	15–49	-	-	-	44.00	Griffiths and Bentley 2005
Ever-married women in Punjab	15–49	-	-	-	51.60	NFHS-3
Ever-married women in Kerala	15–49	-	-	-	50.60	NFHS-3
Ever-married women in Delhi	15–49	-	-	-	47.70	NFHS-3
Ever-married women in Tamil Nadu	15–49	-	-	-	37.00	NFHS-3
Ever-married women in Jammu and Kashmir	15–49	-	-	-	35.30	NFHS-3

Ever-married women in Gujarat	15–49	-	-	-	30.90	NFHS-3
Ever-married women in Haryana	15–49	-	-	-	30.80	NFHS-3
Ever-married women in Himachal Pradesh	15–49	-	-	-	30.00	NFHS-3
Ever-married women in Karnataka	15–49	-	-	-	28.00	NFHS-3
Ever-married women in Uttaranchal	15–49	-	-	-	28.00	NFHS-3
Ever-married women in Andhra Pradesh	15–49	-	-	-	27.90	NFHS-3
Ever-married women in Maharashtra	15–49	-	-	-	27.40	NFHS-3
Ever-married women in India	15–49	-	-	-	24.10	NFHS-3
Ever-married women in West Bengal	15–49	-	-	-	21.60	NFHS-3
Ever-married women in Uttar Pradesh	15–49	-	-	-	20.10	NFHS-3
Ever-married women in Rajasthan	15–49	-	-	-	18.70	NFHS-3
Ever-married women in Assam	15–49	-	-	-	16.70	NFHS-3
Ever-married women in Madhya Pradesh	15–49	-	-	-	15.00	NFHS-3
Ever-married women in Orissa	15–49	-	-	-	14.90	NFHS-3
Ever-married women in Chhattisgarh	15–49	-	-	-	12.20	NFHS-3
Ever-married women in Bihar	15–49	-	-	-	11.90	NFHS-3

Ever-married women in Jharkhand	15–49	-	-	-	11.80	NFHS-3
Indian women	15-49	9.60	2.70	12.30	-	Subramanium and Smith 2006
Indian women in 26 Indian states	15-49	9.40	2.60	12.00	-	Bharati et al. 2007
Indian women in 26 states	15–49	-	-	-	12.30	Ackerson et al. 2008
Adult women in Punjab	-	-	-	-	30.80	Dewan 2008
Women in Kerala	15–49	-	-	-	21.00	Ramesh and Jareena 2009
Bengali Kayastha women of North Bengal	30-50	13.33	78.67	92.00	-	Sarkar et al. 2009
Young women in Kashmir Valley	20–40	16.50	2.90	19.40	-	Masoodi et al. 2010
Tangkhul Naga tribal women in Manipur	20-70	25.10	27.10	52.20	-	Mungreiphy and Kapoor 2010
Punjabi Women Punjab	17-80	9.20	24.60	33.80	-	Singh and Kirchengast, 2011
Bangalee Hindu caste West Bengal	20-60	20.33	29.33	49.66	-	Sen et al. 2013
Indian Women in Puducherry	30 and above	19.10	31.80	50.90	-	Majumdar et al. 2014
Regma Naga tribal women Assam	20-49	25.50	11.63	37.13	-	Rengma et al. 2015

Urban women in Panjab	20-60	12.70	29.60	42.30	-	Girdhar et al. 2016
Dhodia tribal women in Gujarat	20–60	-	-	23.30	12.50	Kshatriya and Acharya 2016
Santal tribal women in Odisha	20–60	-	-	-	9.20	Kshatriya and Acharya 2016
Santal tribal women in West Bengal	20–60	-	-	-	7.40	Kshatriya and Acharya 2016
Bhumij tribal women in Odisha	20–60	-	-	10.70	5.70	Kshatriya and Acharya 2016
Kukna tribal women in Guajarat	20–60	-	-	15.00	4.20	Kshatriya and Acharya 2016
Chaudhari tribal women in Guajarat	20–60	-	-	10.70	4.10	Kshatriya and Acharya 2016
Oraon tribal women in Jharkhand	20–60	-	-	5.60	3.20	Kshatriya and Acharya 2016

Bathudi tribal women in Odisha	20–60	-	-	4.10	2.50	Kshatriya and Acharya 2016
Indian Tribes	20-60	10.90	1.50	12.40	-	Kshatriya and Acharya 2016
Kora tribal women in West Bengal	20–60	-	-	1.70	-	Kshatriya and Acharya 2016
Santal tribal women in Odisha	20–60	-	-	15.10	-	Kshatriya and Acharya 2016
Santal women in West Bengal	20–60	-	-	12.30	-	Kshatriya and Acharya 2016
Nyishi tribal women of Arunachal Pradesh	15-44	9.94	9.57	19.57	-	Bharali et al. 2017
Karbi women residing in rural areas of Diphu, Karbi Anglong, Assam	20-49	16.67	34.00	50.67		Sharma and Mondal 2020
Bengali Muslim Mothers in West Bengal	20-34	21.08	15.36	36.44	-	Present Study

*** WHO (2004) (WHO cut off for Asian Indians); # WHO (2000)**

Table 4.6: Comparison of the prevalence of overweight, obesity and overall overweight-obesity among the Bengali Muslim mothers in present study with other non-Indian studies

Population	Age group (Years)	Prevalence (%)				Reference
		Overweight (BMI= 23.00-24.99 kg/m²)*	Obese (BMI≥ 25.00 kg/m²)#	Overweight-Obesity (BMI≥ 23.00 kg/m²)*	Overweight-Obesity (BMI≥ 25.00 kg/m²)#	
Women in the USA	15–49	-	-	-	20.70	Martorell et al. 2000
Women in the Middle East and North Africa	15–49	-	-	-	17.20	Martorell et al. 2000
Women in Central Eastern Europe	15–49	-	-	-	15.40	Martorell et al. 2000
Women in Latin America and the Caribbean	15–49	-	-	-	9.60	Martorell et al. 2000
Women in Sub-Saharan Africa	15–49	-	-	-	2.50	Martorell et al. 2000
Women in South Asia	15–49	-	-	-	0.10	Martorell et al. 2000
Women in NHSP	25-44	-	14.00	-	-	Nanan 2002
Peruvian women	30-60	-	-	-	63.00	Jacoby et al. 2003
Women of childbearing age in Morocco	15–49	-	-	-	35.20	Belahsen et al. 2004

Women in Pakistan	15 and above	27.90	38.80	66.70	-	Jafar et al. 2006
Women in northern Nigeria	18 and above	-	-	-	40.40	Bakari et al. 2007
Women living along the Bolivia	20-49	-	-	-	40.30	Benefice et al. 2007
Urban poor Bangladeshi women	15–45	-	-	-	9.10	Shafique et al. 2007
Rural Bangladeshi women	15–45	-	-	-	4.10	Shafique et al. 2007
Adult Chinese women in Singapore	40-81	-	-	-	34.00	Sabanayagam et al. 2007
Non-pregnant adult women in Mexico	18–49	-	-	-	59.30	Eckhardt et al. 2008
Non-pregnant adult women in Egypt	18–49	-	-	-	77.30	Eckhardt et al. 2008
Non-pregnant adult women in Peru	18–49	-	-	-	52.30	Eckhardt et al. 2008
Mexican women	20-69	-	-	-	72.10	Gómez et al. 2009
Tz’utujil Maya women in Guatemala	18–82	-	-	-	46.90	Nagata et al. 2009
Women in Bangladesh, India, Indonesia, Thailand and Vietnam	25-64	-	-	-	27.90	Razzaque et al. 2009
Malay women in Singapore	40-80	-	-	-	65.10	Sabanayagam et al. 2009

Adult women in Malaysia	20-49	-	-	-	15.30	Sidik and Rampal 2009
Women in Dakar	20 and above	-	-	-	34.80	Macia et al. 2010
Women in a slum area in Brazil	20-60	-	-	-	46.00	Alves et al. 2011
Western Sahara refugee women	15-49	-	-	-	53.70	Grijalva-Eternod et al. 2012
Women in Indonesia	20-75	-	-	-	48.80	Roemling and Qaim 2012
Colombian pregnant women	20–49	-	-	-	37.30	Sarmiento et al. 2012
African immigrant women in Oslo	25 and above	-	66.00	-	-	Gele and Mbalilaki 2013
Women in rural Tanzania	17–45	-	-	-	22.00	Keding et al. 2013
Colombian women of reproductive age	18–49	-	-	-	42.30	Kordas et al. 2013
Adult females in Iran	18-49	40.30	33.00	73.30	-	Mohammadi et al. 2013
Women in low and middle income countries	40 and above	-	-	-	31.20	Popkin and Slining 2013
Ever-married women in Bangladesh	15-49	12.80	16.40	29.20	-	Kamal et al. 2015

Women in Nigeria	15–49	-	-	20.90	-	Kandala and Stranges 2014
Women in Indonesia	19-55	-	-	-	28.70	Sari and Amaliah 2014
Women in Indonesia	40 and above	-	-	-	36.20	Sohn 2014
Women in eastern Uganda	18 and above	-	-	-	35.80	Kirunda et al. 2015
Women in rural China	20-49	-	-	-	16.50	He et al. 2016
Ghana women	18 and above	-	-	-	49.70	Ofori-Asenso et al. 2016
Women in Ecuador	15–49	-	-	-	61.00	Weigel et al. 2016
Women in Bangladesh	15–49	-	-	39.50	-	Bishwajit 2017
Women in Nepal	15–49	-	-	27.50	-	Bishwajit 2017
Bangladeshi women in BDHS	35 and above	-	-	24.40	-	Biswas et al. 2017
Bangladeshi women of reproductive age	15–49	25.20	11.20	36.40	-	Biswas et al. 2017
non-pregnant women in Bangladesh	15-49	-	-	-	24.50	Ghose 2017
Mexican women	15-49	-	-	-	62.00	Jones et al. 2017
Women of reproductive age in Bangladesh	15–49	28.37	10.77	39.14	-	Chowdhury et al. 2018
Women in Myanmar	18–49	-	-	41.2	-	Hong et al. 2018

Kenyan women	15–49	-	-	-	29.60	Mkuu et al. 2018
Bengali Muslim Mothers in West Bengal	20-34	21.08	15.36	36.44	-	Present Study

*** WHO (2004) (WHO cut off for Asian Indians); # WHO (2000)**

4.8. PREVALENCE OF DOUBLE BURDEN OF MALNUTRITION AMONG THE BENGALI MUSLIM CHILDREN AND THEIR MOTHERS

In the present study it has been observed that there is a prevalence of undernutrition among the Bengali Muslim children and their mothers. The present study also showed that Bengali Muslim mothers are also suffering with the prevalence of overweight and obesity. This co-existence of double burden of malnutrition (DBM) (ie., both undernutriton and overnutrition) represents the opposite sides of energy balance equation which is a unique difficulty for public health policy makers in population. The coexistence of undernutrition and overweight-obesity is being considered as a common problem in low and middle-income countries (LMICs) which is due to the lack of proper distribution of social resources and economic resources. The prevalence of DBM contributes to the burden of non-communicable diseases in LMICs. When the prevalence of DBM affects the biological, social and economic development of people then it also hampers the overall growth of a developing nation like India. The problem of DBM rotates in a cyclic process with the economic growth of a country when it is not properly monitored due to its large scale distribution in the population. Several studies have observed the high prevalence of DBM in Indian populations specially among children and women of the country as observed among the Bengali Muslim children and mothers in the present study. The combined prevalence of undernutrition and overweight-obesity is considered as a proxy measure for the total burden of nutritional diseases (Delisle 2008). Chronic energy deficiency (CED) or underweight (BMI < 18.5 kg/m^2) is a major nutritional problem among women of low-income countries and the prevalence of double burden of underweight and overweight-obesity (BMI ≥ 23 kg/m^2) is emerging as a critical health situation in South Asia and sub-Saharan Africa (Delisle 2008). Studies in Bangladesh have observed among the women of reproductive age the prevalence of undernutrition was 38.8% and 29.7% among among rural and urban poor women, respectively. On the other hand there were also the occurrence of overweight-obese of 4.1% and 9.1% among rural and urban poor women, respectively (Shafique et al. 2007; Delisle 2008). Over the period of 5 years the prevalence of CED has declined and overweight-obesity has increased in both rural and urban settings in Bangladesh, but the trend of high BMI among women was more significant in rural settings than in urban areas (Delisle 2008). The adverse effect of inequality in per capita is the occurrence of DBM in populations because children and women belonging to low SES experience the greatest risk of undernutrition, whereas the high SES ones are exposed to higher risk of overweight and obesity. Therefore, the economic transitions focusing on reducing the economic inequalities can address the DBM problem in population.

There are several studies depicting the dual burden of child undernutrition (mainly stunting) and maternal overnutrition in a single household, which implies to the fact that although maternal overweight-obesity and child undernutrition looks like two different problems but they occur from single cause that is the socio-economic inequality or the improper distribution of social and economic resources among populations/households/individuals. That is, the occurrence of undernutrition and overnutrition do not have opposite causes but they appear as responses to the same situations in the country. Several published studies conducted in nutrition-transitioning countries have observed that the occurrence of double burden of malnutrition is more common among women than in men may be due to the gender inequalities that women face from childhood in most of the patriarchal societies/countries (Sawaya et al. 2003; Delisle 2008). Moreover, low birth weight and stunting also occurs as a result of maternal constraint or poor nutrition.

4.9. ASSOCIATION BETWEEN NUTRITIONAL STATUS OF MOTHERS AND CHILDREN AMONG BENGALI MUSLIMS

The present cross-sectional study has shown direct associations between maternal anthropometric characteristics, nutritional status (e.g., BMI) and nutritional status of children (e.g., WAZ, HAZ and BMIAZ) among the Bengali Muslim population of West Bengal, India. The results of the linear regression analysis showed that maternal BMI, MUAC and physical growth/nutritional variables of children ($p<0.05$) are significantly associated (Table 3.24, Table 3.25, Table 3.26, Table 3.27, Table 3.28 and Table 3.29). Several studies have shown a positive association with the maternal anthropometric parameters/body composition (e.g., height, weight or BMI) with physical growth and nutritional variables in children (Subramanian et al. 2009; Mitra et al. 2012; Addo et al. 2013; Felisbino-Mende et al. 2014; Girma and Genebo 2015; Tigga and Sen 2016; Tayade et al. 2018). The results of the linear regression model analysis revealed that maternal BMI and MUAC was the most predictive variable of anthropometric growth parameters (e.g., HAZ, WAZ, and BMIAZ) were proved as statistically significant variations in these three dependent variables in children (Table 3.24, Table 3.25 and Table 3.26). Results showed that correlations between maternal and children anthropometric variables (BMI and MUAC) were observed to be significant with the all the child anthropometric variables WHZ, WAZ, HAZ, BMIAZ of variations in the Z-score among children ($p<0.05$) (Table 3.24, Table 3.25, Table 3.26). The associations of combined maternal anthropometric measures therefore, showed a strong genetic component between maternal and anthropometric physical growth variables among school children. Santos et al. (2009) have reported the direct significant association ($p<0.01$) between maternal BMI and child BMI Z-scores. The results of the present study showed that maternal anthropometric measures and nutritional status has significant effect on children physical growth patterns among Bengali Muslim children (<5 years). Several researchers have reported an increase in maternal body composition (i.e., BMI or MUAC) and/or nutritional status was associated with a lower prevalence of undernutrition in children (<5 years) (Subramaniam et al. 2009; Addo et al. 2013; Felisbino-Mende et al. 2014; Tigga and Sen 2016; Tayade et al. 2018). Several research studies have confirmed the direct association between maternal body composition/nutritional status with physical growth attainments or nutritional status using conventional anthropometric measurements among children. Rahman et al. (1993) reported in a study from Bangladesh that physical growth variables (i.e., WAZ) of children were associated with maternal BMI in ($p<0.001$). In Bangladesh Islam et al. (1994) observed that mothers who were underweight were two times more likely to give birth to an underweight child. Women with poor nutritional status (e.g., BMI) had registered the higher risk of severe stunting (HAZ) and severe underweight (WAZ) (27.10% and 23.30%, respectively) among children as observed in a recent study by Kulasekaran (2012). Positive associations between maternal BMI with BMI of children have been observed by several recent studies (Ajslev et al. 2014; Tigga and Sen 2016). Present investigation also showed similar incidence of maternal undernutrition with lower physical growth attainments among the Bengali Muslim children. Some others investigations also observed the relationship between maternal BMI and child stunting, wasting and thinness (Mitra et al. 2012; Khan and Mohanty 2018).The present study among the Bengali Muslims has confirmed that the anthropometric measurements (e.g., BMI or MUAC) were significantly associated with the child nutritional status (Table 3.24, Table 3.25, Table 3.26).

The prevalence of undernutrition among children will manifest as a long-term effect on the physical growth attainments or reducing growth potentials, health and survivals, cognitive developments, lower attained schooling, decreased economic potential, reproductive performance, and onset of chronic illness in adulthood (Shrimpton et al. 2001; Pelletier and Frongillo 2003; Black et al. 2008, 2013; WHO 2013). Therefore, implementations of appropriate intervention programme and nutrition sensitive approaches are necessary to improve maternal and child nutritional status in the studied population.

4.10. SOCIO-ECONOMIC, DEMOGRAPHIC CORRELATES OF NUTRITIONAL STATUS AMONG THE BENGALI MUSLIM CHILDREN AND MOTHERS

The major underlying factors for the prevalence of double burden of malnutrition (overnutriton and undernutrition) in the developing countries are the disparities in socio-economic and demographic conditions, environmental factors, ethnic and variations (Mahgoub et al. 2006; Mondal and Sen 2010; Ahmed et al. 2012). Studies have reported that in most of the Indian populations gender differences are significant and boys have better access to food and basic amenities than girls and there is a pronounced preference for the male child (Mondal and Sen 2010; Sen and Mondal 2012). Studies also have documented that girls are more affected by chronic undernutrition (e.g., stunting and wasting) whereas boys are more affected by acute undernutrition (e.g., thinness and underweight) (Bose et al. 2007; Mondal and Sen 2010; Sen and Mondal 2012; Som et al. 2006). The present study has observed a higher prevalence of stunting (45.54% vs. 43.55%), wasting (33.54% vs. 19.51%), thinness (32.92% vs. 18.82%) and low HdC-for-age (45.23% vs. 20.56%) among boys than girls and the prevalence of underweight (40.00% vs. 40.07%) was almost similar among both the groups.

The odds were significantly greater among boys than girls in case of stunting ($p>0.05$), thinness ($p<0.01$), wasting ($p<0.01$) and low HdC-for-age ($p<0.01$). Odds in case of underweight were higher among girls. Therefore, the results of BLR analysis showed that boys were in higher risk of of stunting, thinness, wasting and low HdC-for-age and girls were in higher risk of underweight. Studies have reported that rural girls were more likely to be severely undernourished than rural boys (Choudhury et al. 2000; Mondal and Sen 2010). Results of BLR analysis have shown that children of lower age groups (1-2 years) were in higher risk of wasting ($p<0.01$) and underweight whereas children of higher age groups were in higher risk of stunting, thinness and low HdC-for-age ($p<0.01$).

Thus, the present study is in concordance with the other studies among children where prevalence of undernutrition was higher in higher age groups (Biswas et al. 2009; Mandal et al. 2009; Tigga et al. 2015a; Mondal et al. 2015). The significant effects of some other socioeconomic and demographic correlates (i.e., birth order, no. of sibs, mothers' occupation) on prevalence of stunting and thinness among the children can be attributed to the fact that better access to food and amenities may have significant effect on the nutritional status of the children of growing ages. Child birth order, period of breastfeeding initiation, toilet facility, drinking water and mother's education are associated with the prevalence of undernutrition (e.g., stunting and wasting) in children (Panigarhi and Das 2014; Tigga et al. 2015a,b; Mesharam et al. 2012; Dera et al. 2018; Hossain and Khan 2018). Studies have observed that undernutrition is an independent risk factor as the outcome of childhood malignancies (Trehan et al. 2015). Few studies have showed the effect of ethnicity on nutritional status (Choudhury et al. 2000; Som et al. 2007; Mondal and Sen 2010a; Bhargava et al. 2015; Sen and Mondal 2012; Tigga et al. 2015a; Poh et al. 2016; Pal and Bose 2017; Sinha et al. 2017; Venkatraman et al. 2017 Seshadri and Ramakrishna 2018). Researchers have observed that the nutrition levels are not only dependent on the access of nutrition rich foods, but several other factors e.g., clean drinking water, a proper sanitary conditions and appropriate caring practices mainly in case of children are equally impactfull and play major roles in the nutritional levels of children (Ramachandran 2014; Tigga et al. 2015a,b; Venkatraman et al. 2017). Therefore, the proper dissemination of knowledge and awareness related to nutritional requirement, improvement of economic conditions, use of nutrient rich food, improvement of feeding practices among nutritionally vulnerable segments would be helpful to reduced such prevalence. Studies have also observed that rural children are more vulnerable to undernourishment than their urban counterparts (Ramachandran 2014; Tigga et al. 2015a,b; Debnath et al. 2018).

Mothers suffering from undernutrition may give birth to infants with growth retardations which may further lead to ill health condition of the children (WHO 1995; Black et al. 2013). Also overweight-obese mothers tend to give birth to stunted child as observed in some studies. The present study have observed that children of higher mothers age category were in higher risk of stunting ($p<0.01$), underweight ($p<0.01$) and low HdC-for –age ($p<0.05$). Children of mothers with lower age at menarche were in higher risk of stunting ($p<0.01$), wasting, underweight ($p<0.01$).

Children of mothers with higher age at marriage have showed higher risk of stunting, thinness, wasting and low HdC for-age than the children whose mothers have lower age at marriage. Risk of underweight was higher among the children whose mothers have a lower age at marriage. Children with higher family size (5 and above) were in higher risk of thinness, wasting and low HdC-for-age than children of lower family size. A number of studies have observed significant relationship between larger households and occurrence of childhood undernutrition. A large household size suggests an increased competition for availables resources therefore leads to inadequate nutrition among the family members (Greene and Merrick 2005; Cleland et al. 2006; Engebretsen et al. 2008; Darteh et al. 2014; Melaku et al. 2015; Liu and Raine 2016; Debnath et al. 2018c). Children of nuclear families were observed to be in higher risk of stunting and underweight than the children of the extended, joint and broken families. Children of extended, joint and broken families were in higher risk of thinness, wasting and low HdC-for-age than the children of nuclear families. Children of families with lower number of earning head (earning head- 1) were in higher risk of stunting and underweight. Lesser number of earning heads means somehow lower economic condition therefore leading to the prevalence of undernutrition. Children with lower monthly family income were in higher risk of stunting, thinness, wasting than the children with higher monthly income of family. Also children with lower monthly family expenditure were in higher risk of stunting ($p<0.01$), thinness, wasting ($p<0.01$) and underweight ($p<0.01$) than the children with higher monthly family expenditure. Children using tube well and supply water were in higher risk of stunting and underweight than the children using well water. Children using well water were in higher risk of thinness, wasting and low HdC-for-age. Children who do not have toilet facility were in higher risk of stunting, thinness, wasting and underweight. Children who do not have electricity in their houses were in higher risk of thinness ($p<0.01$) and wasting. Children having kaccha house were in higher risk of stunting and underweight. These results of the present study were in concordance with several ther studies done in this research field (Ramachandran 2014; Tigga et al. 2015a,b; Debnath et al. 2018). It is further evident from the results that children belonging to poor socio-economic and adverse environments, including low income, were more affected by undernutrition, thereby agreeing with the results of other existing studies (Choudhury et al. 2000; Mahgoub et al. 2006). Some household hygienic practices such as access to safe water, hand washing using soap, and other sanitation practices have major role on morbidity related risks, which have a considerable effect on child growth (Checkley et al. 2004; Fink et al. 2011; García et al. 2017; Tigga et al. 2015a,b; Debnath et al. 2018). Children with lower number of rooms one or two were in higher risk of stunting, underweight and low HdC-for-age. Children with low birth weight (<2.5 kg) were in higher risk of thinness, wasting, underweight and low HdC-for-age than the children with higher birth weight. Therefore, it implies to the fact that birth weight has significant impact on a child's growth in later ages. Children with lesser number of years of breast feeding were observed to be in higher risk of stunting, thinness, underweight and low HdC-for-age. Therefore, breast feeding duration is an important factor among Bengali Muslim childrens in the present study. Children whose mothers were without education were in higher risk of stunting, wasting, underweight and low HdC-for-age than the educated mothers and Children of uneducated fathers were in higher risk of stunting, wasting, underweight and low HdC-for-age. Therefore, parent's educational status is significantly impacting the nutritional status of the children. This has also been observed by other research studies (e.g., Tigga et al. 2015a,b; Debnath et al. 2018). Mainly low educational status of mothers is a major determinant of child undernutrition (Tigga et al. 2015a,b; Debnath et al. 2018). Children whose mothers were working outside were in higher risk of stunting, thinness and wasting than the children of housewife mothers may be due to the fact that children of working mothers are left with their higher coborn and therefore not getting proper care in terms of food and nutrition. Father's occupation has been observed to be severely impacting the nutritional and health condition of children as observed in several studies. The present study also have observed similar trend and children of labourer and farmers were in higher risk of stunting, thinness ($p<0.01$), wasting and underweight as observed in other studies.

The various determinants of the maternal malnutrition are per capita income among families, family size, socio-economic disparities, gender inequality, poor feeding practices, healthcare facilities and lack of adequate care during childhood (Manu and Paul 2006; Bharati et al. 2008; Mondal and Sen 2010a; Subramaniyam et al. 2010; Cowling et al. 2014; Tigga et al. 2015; Mondal et al. 2016; Debnath et al. 2018). Age at menarche, age at marriage, place of residence, education levels, household wealth, womens occupational status, husbands occupation, awareness regarding infectious diseases, source of drinking water facilities are other strong predictors of maternal malnutrition in India (Mittal et al. 2007; Bharati et al. 2008; Subramanian et al. 2009; Tigga et al. 2015; Chowdhury et al. 2017; Chowdhury et al. 2018; Mkuu et al. 2018).

Studies have proven the fact that different ethnic groups show variation with respect to the nutritional status of populations in India. However, it is not clear if there is a casual relationship between them. Several studies have attributed to the fact that socio-economic status and economic development has little or no impact on reducing/controlling child undernutrition in developing countries as in India (Varadharajan et al. 2013; Ramachandran 2014; Subramanian and Subramaniyam 2015; Vollmer et al. 2017; Ruia et al. 2018). There is significant occurrence of gender bias among the Indian populations mainly among the marginalized sections of the society which is leading to the poor health/nutritional status of women and young girls in India (Bose et al. 2007; Mondal and Sen 2010a; Tigga et al. 2015; Kshatriya and Acharya 2016; Chowdhury et al. 2018).

Maternal nutritional status among the Bengali Muslim mothers are observed to be also associated with their socio-economic, demographic and lifestyle profile as observed in several other studies among other groups of Indian and non-Indian women. Association of socio-economic, demographic and life style related variables with the indicator of undernutrition, overweight and obesity has been analysed using multinomial logistic regression analysis and is depicted in Table 3.24. Bengali Muslim mothers of higher age group (28-34 years) were in higher risk of undernutrition, lower age groups (20-27 years) were in higher risk of overweight and obesity. Risk of prevalence of undernutrition and obesity were observed to be higher among the mothers who had a lower age at menarche. Studies have observed that prevalence of overweight and obesity among women tends to increase with age and several studies from low-income countries showed that older women are at a greater risk of overweight and obesity (Subramanian et al. 2009; Chowdhury et al. 2018). Studies also have observed that there is an increasing rate of overweight and obesity in rural areas whereas a declining rate of undernutrition in urban areas (Chowdhury et al. 2018).

This disparity between rural and urban areas may be the influence of multiple factors e.g., reduction in poverty and increase in per capita income. Risk of being overweight was higher among the mothers with higher age at menarche. Mothers with lower age at marriage were in higher risk of undernutrition and obesity and mothers with higher age at marriage were in higher risk of overweight. Mothers with higher age at first pregnancy were in higher risk of undernutrition and overweight and mothers with lower age at first pregnancy were in higher risk of obesity. Mothers with higher education level were in higher risk of undernutrition and overweight. Mothers in the category of no education were in higher risk of obesity. Mothers with earning head two or more were observed to be in higher risk of undernutrition and overweight. Mothers of the families with higher family income were in higher risk of overweight. Mothers of the families with higher family expenditure were in higher risk of overweight than the mothers with lower family expenditure. Mothers with lesser number of living children were in higher risk of undernutrition and overweight and mothers with higher number of living children were in higher risk obesity. Mothers of extended, joint and broken families were in higher risk of undernutrition ($p<0.01$) and overweight and mothers of nuclear families were in higher risk of obesity. Mothers using well water were in higher risk of undernutrition ($p>0.05$) and mothers using tube-well and supply water were in higher risk of overweight and obesity. Mothers using toilets were in higher risk of undernutrition and mothers without toilet facility were in higher risk of overweight ($p<0.01$) and obesity. Mothers of the house type category semi pucca and pucca were in higher risk of undernutrition and overweight. Mothers having higher number of rooms were in higher risk of overweight and mothers having lesser number of rooms were in higher risk of obesity. Women whose husbands were in the category of no education and with education upto class V were in higher risk of undernutrition. Women whose husbands were in the categories of education level class I to class V and class VI and above were in higher risk of overweight. Women whose husbands were in the category of no education were also in higher risk of obesity. Women whose husbands were farmers were in higher risk of undernutrition and whose husbands were businessmen were in higher risk of overweight. Mothers having higher number of children were in higher risk of undernutrition and mothers having lower number of children were in higher risk of overweight. Mothers with number of living children 2 were in higher risk of obesity. Mothers with duration of breast feeding upto 2 years 11 months i.e., lesser duration of breast feeding were in higher risk of obesity. Mothers with longer duration of breast feeding were in higher risk of undernutrition and overweight.

Studies have observed that women's marital status, women's educational status as well as their husband's educational status, employment status and employment status of their husbands also have significant impact on the nutritional status of women as observed in the present study (Subramanian et al. 2009; Chowdhury et al. 2017; Chowdhury et al. 2018; Mkuu et al. 2018) . present study also have found out that wealthier women are more likely to be overweight or obese which is consistent with studies done in other low and middle income countries (Dinsa Et al. 2012; Mkuu et al. 2018). This is may be due to the fact that increasing wealth in low and middle income countries are resulting in greater access to food and an escape from physical activity (Chowdhury et al. 2018).

CHAPTER- V:

SUMMARY AND CONCLUSION

5.1. SUMMARY AND CONCLUSION

The present study has been conducted among the Bengali Muslim children and their mothers to assess the body composition and nutritional status. Also, present study assessed the relationship between the socio-economic, demographic and lifestyle variables and nutritional status among the Bengali Muslim children and mothers in West Bengal, India. The relationship between child and maternal body composition and nutritional status is considered to be a complex phenomenon. The assessment of body composition and nutritional status is one of the major areas of interest of Biological and Physiological Anthropology. The biological anthropologists intend to explore the possible mechanisms, identify, explain and understand such complex biological processes in human population. The proper evaluation, identification, explanation and understanding of body composition and nutritional status will definitely help the researchers to tackle or answer several unwanted nutritional and health situations (e.g., undernourishment, over nourishment, growth retardation, delayed and poor cognitive development and mortality or morbidity). With the presence of overweight-obesity, India is also a home for undernutrition which is a major cause of child and maternal mortality and morbidity in its populations. Insufficient intake and poor absorption of food, poor biological use of nutrients are the causes of undernutrition which can result in impaired growth, underweight and impaired body functions among children. The presence of undernutrition in terms of stunting, wasting, underweight and thinness among children have detrimental effects on their life and these are the reasons behind slow brain development and lower cognitive development. Obesity is one type of disease that is associated with impaired functions related to alterations in the metabolism of steroid hormones, metabolic alterations including lipid and glucose levels and also increases in the turnover of free fatty acids that lead to insulin resistance syndrome. Due to the nutrition transition in India high rate of urbanization, sedentary life style and economic development have happened and these have caused the rise lifestyle disorders, non-communicable diseases, reduced physical activity and sedentary lifestyle mainly in urban populations but rural populations are also not out of the scenario. Now, energy-dense diets have replaced traditional diet patterns of individuals which have given rise to the deposition of excess body fat which gives rise to overweigh-obesity. Improper resource distribution, huge gap in per-capita income, and gap in socio-economic status in population are the major causes of the problem of both undernutrition and overnutrition in India. The undernourished children and overnourished mothers are not the results of different effects but have originated from the same cause i.e., inappropriate resources availability/allocation in the population. The undernourished (mainly stunted) children tend to become overweight and obese adults in most of the cases. Obesity is associated with increased risks of the metabolic diseases, hypertension, coronary heart disease, insulin resistance, type-2 diabetes mellitus, dyslipidemia, polycystic ovary syndrome and atherosclerosis among individuals. Maternal nutritional status and body composition impacts the intrauterine foetal growth and immediate postnatal development. The intrauterine environment is crudely assessed by birthweight of the infant. Epidemiological data indicates that intrauterine life is a crucial period because a suboptimal intrauterine environment can affect the future development of chronic diseases among children and adults. Mother's with poor nutritional condition tends to give birth to the low birth weight babies which can lead to the development of disease in adulthood as several research studies suggest a relationship between birth weight and development of disease in adulthood. Poor nutritional and body composition of mothers can cause growth retardation and poor nutritional status in children.

Anthropometry plays a pivotal role in assessment of body composition and nutritional status in population (e.g., children and mothers). In the present cross-sectional study the body composition and nutritional status of children and their mothers have been assessed using standard anthropometric procedures and measures. The results of the present study established a high prevalence of undernutrition in terms of stunting (low height-for-age), underweight (low weight-for-age), thinness (low BMI-for-age) and wasting (low weight-for-height) and low HdC-for-age among the Bengali Muslim children of Darjeeling district, West Bengal. Moreover, the present study has observed double burden of malnutrition (DBM) (i.e., undernutrition and overweight-obesity) among the mothers of these Bengali Muslim children. Chronic undernutrition in childhood gives rise to several developmental disorders among children (e.g., slow cognitive development due to undernutrition and lower performance level in schools due to high adiposity level) and hampers overall growth of children which continues and affects their future life. Poor growth and development of children when continues in higher age groups, it affects the overall economic growth of the country and becomes a persistent problem of the country as a whole. The problem of DBM among mothers is observed to be significant in the results of present study. The DBM contributes to the poor working capacity and poor physical activity in population. The problem of economic growth and DBM rotates in a cyclic process and one contributes to another. Body compositions of both children and mothers have also been assessed in the present study. Excess body fat in individuals is also linked with impaired immune function as a result of the secretion of increased cortisol which is a steroid hormone and released as the responsive action to psychological and environmental stress. Associations and effect of several socio-economic and demographic correlates have been observed among the Bengali Muslim children and their mothers. Therefore, present study has proved that the Bengali Muslim children and their mothers are in a critical junction nutritionally. Importance should be given to improve the overall nutritional status of the children and mothers. This is a very well-known scenario in Indian society where the poor nutrition conditions which perpetuates for generation after generation among Indian populations and gives rise to severe condition of ill health, mortality and poor reproductive outcomes (e.g., LBW) and working capacity in a large scale in the population. The increasing intake of whole gram, vegetables, fruits and dairy products and increasing physical activity could improve nutrient intakes and BMI status of the children and mothers. The proper assessment of health status is necessary among all the children and mothers in the population so that the risk of overweight obesity can also be minimised. It can be concluded that to reduce or control the problem of undernutrition and overweight-obesity among the children and mothers both the Government and Non-Government Organizations should adopt initiatives to improve nutritional status with proper planning and application of policies in the population. Globally the prevalence of DBM in populations is viewed as a severe public health challenge especially in countries with high burden of overnutrition and difficulties are occurring in combating the situation. Therefore, for India being a developing nation the prevalence of the same will cause expensive if it is not dealt with proper strategy and care.

There is an urgent need for attention to improve nutritional status by appropriate health and nutritional intervention programmes to ameliorate the problem of undernutrition among children and DBM among the mothers. Factors associated with malnutrition need closer investigation and prevention of dual burden should be targeted at the high-risk groups simultaneously. Dissemination of necessary nutritional knowledge, health related educations and child care practices will be very much helpful to control the problem of undernutrition among the Bengali Muslim children. Finally the conclusion of the present body composition and nutritional status of the Bengali Muslim children is summarized as follows:

1. The descriptive statistics (mean± SD) of anthropometric measures indicated that there are no statistically significant differences in the age-sex-specific mean of height, weight, MUAC, FM, FFM, FFMI, TUA, BMI. But statistically significant differences were observed in case of HdC, TSF, SSF, PBF, FMI, UMA, UFA, AFI, UME, UFE and PBF-BMI Ratio($p<0.05$).

2. The sex-specific adiposity pattern and skinfold thicknesses (e.g., TSF, SSF, FMI, AFI, UFA and UFE) and PBF were found to be significantly higher among girls than the boys ($p<0.01$).

3. The sex-specific overall muscularity pattern (e.g., UMA and UME) was observed to be significantly higher among boys than girls ($p<0.05$). Therefore, results showed that there is existence of sexual dimorphism in muscularity and adiposity pattern among Bengali Muslim children.

4. The age-sec specific mean anthropometric variables (e.g., height, weight, HdC, FM, FFM, TUA, UMA, UFA, UME AND UFE) were observed to increase with age with few exceptions among Bengali Muslim children. Hence, the results of the present study indicate the attainment of physical growth in anthropometric variables is an age-related effect among Bengali Muslim boys and girls.

5. Age-specific mean differences in anthropometric variables of physical growth pattern were found to be statistically significant in case of almost all the anthropometric and body composition variables for boys and girls ($p<0.01$ and $p<0.05$).

6. High magnitude of stunting, thinness, wasting, underweight and low HdC-for-age was observed among the Bengali Muslim children (aged 1-5 years). Statistically significant sex-differences was observed in the prevalence thinness (Low BMI-for-age), wasting (low weight-for-height), low HdC-for-age between boys and girls ($p<0.01$).

7. The high magnitude of undernourishment indicates the high nutritional demand among the children.

8. In case of the mothers of the Bengali Muslim children all the anthropometric and body composition variables were observed to show an age specific increasing trend.
9. Prevalence of a double burden of malnutrition (undernutrition, overweight and obesity) has been observed among the Bengali Muslim mothers.
10. Several socioeconomic and demographic correlates were observed to have statistically significant effect on the nutritional status of the Bengali Muslim children and mothers.
11. The findings of the present study propose a good opportunity to do more invasive study in the studied population. Moreover, present study indicates the need for proper dissemination of knowledge on nutritional requirement and awareness, on the improvement of socio-economic conditions, type of food for intake, on child care and feeding practices to reduce such prevalence.

5.2. LIMITATIONS OF THE PRESENT

The limitations of the present study on the body composition and nutritional status of Bengali Muslim children and mothers are summarized as follows:

1. The present study lacks the information related to food habits and dietary pattern or intra-household food or resource allocation and gender related pattern if any among the children and mothers which might have significant effect on the nutritional status of the children and their mothers.
2. The present study did not assess the physical growth pattern of the children because it was a cross-sectional study which did have an opportunity to assess the growth patterns of the children.

3. Further, the present study did not assess the physical development issues (i.e., timing any cognitive or motor development) among children due to cultural issues and limited resources and time framework.
4. The information on the inter-personal resource allocation, cultural practices related to gender among children which may have important effect on their nutritional status are could not include in the present study.
5. Present study includes the data on age at menarche and age at marriage which is dependent on the memory or recalling ability of the mothers therefore, can lack accuracy.
6. The present study focuses on the Bengali Muslim population residing in particular areas of Darjeeling district, West Bengal. Therefore, the findings may not represent the overall situation of the district and the state.

5.3. RECOMENDATIONS

The results of the present study revealed the high prevalence of malnutrition(undernutrition among children and both under and overnutrition among mothers) that is the unsatisfactory nutritional condition of the Bengali Muslim children and mothers. Therefore, following recommendations/suggestive measures may be proposed for overall improvements of the nutritional and body composition condition of the Bengali Muslim children and their mothers:

1. The nutritional status should be improved by introducing improved quality of nutrient rich foods in diet of the children and mothers. The supplementations in terms of protective foods and trace elements especially zinc, selenium should be provided.

2. The Government should play a major role to reduce the problem of undernutrition among children and DBM and overnutrition among mothers in the study and to the overall population in order to improve the health and nutritional status of the community/population.

3. The appropriate target oriented nutritional intervention programmes are necessary to be implemented for the overall improvement of nutritional status among the studied population.

4. The Government policies for improving the overall socio-economic and demographic situation of the poor children and mothers are necessary in order to reduce the menaces of undernutrition and overnutrition in population. There is a severe need for women empowerment, women education and employment to improve the nutritional situation in the studied population. Public/private partnerships are necessary for proper implementation of the public health policies.5. The healthcare facilities must be made more easily available for the children and women. The relevant healthcare knowledge must be disseminated in order to reach or access the benefits of the target population. Proper utilization of health care facilities should be ensured by Government.

5. Health check-up camps should be on more regular basis which is very necessary for the monitoring of the nutritional situation of the children and mothers. The Non-Governmental Organizations (NGOs) should also be involved in popularizing the utilization of existing health care facilities in order to combat ill-health and malnutrition condition in the population.

6. Rapid treatment and proper healthcare managements of nutritional diseases should be done to minimize the disease burden on the physical growth attainments and undernutrition of the children and double burden of nutrition among the Bengali Muslim mothers/women. Regular health check-ups, monitoring of physical growth attainment of children, clinical evaluation of nutritional deficiencies and morbidities among children should be done to prevent the energy loss and ensure adequate physical growth and development and nutritional status.

7. The health and nutrition related knowledge is necessary and should be imparted in the population for a better understanding of the problems at individual/ population level. Proper community intervention programmes and policy implementation is very necessary to resolve the problem of DBM.

8. Evidence based interventions are necessary which can be accurate/suitable, successful and sustainable in case of India. Moreover, routine monitoring and assessment of physical growth, development and nutritional status may introduced in individual/population level in order to identify or prevent the relative risk of unattained growth, development delay or related consequences of undernutrition among vulnerable segments of the population.

9. Finally, the prevalence of malnutrition manifests several physical consequences such as poor reproductive outcomes, reduced physical activity and productivity among adults and poor and slow cognitive development among children. Therefore, introduction of physical training could substantially improve the work capacity and health situation in the population.

10. Women empowerment will definitely lead to proper socio-economic conditions which will in turn improve the nutritional conditions in the studied population.

5.4. GENERAL CONCLUDING REMARKS

Finally, the present study emphasise to the fact that more importance should be given to improve the nutritional situation among the Bengali Muslim children and mothers of West Bengal. Present study establishes the fact that there is the prevalence of undernutrition among the Bengali Muslim children and DBM among Bengali Muslim mothers in the studied population. The conventional anthropometric indicators of stunting (low height-for-age), wasting (low weight-for-height), underweight (low weight-for-age), thinness (low BMI-for-age) and low HdC-for-age have been extensively used to assess the current situation of nutritional status among the Bengali Muslim children. BMI has been used as an indicator of nutritional status of Bengali Muslim mothers and prevalence of undernutrition and overnutrition has been observed. Present study indicates that the prevalence of undernutrition does not have an age specific trend. Therefore, it is very necessary to give equal importance in improving nutritional condition of the children of all groups. The mothers of Bengali Muslim community should be taken care of for improvement of the condition of malnutrition (undernutrition and overnutrition) so that it does not perpetuate to their future generation. The child and maternal nutritional status should be systematically included in all nutrition surveys. More extensive population specific studies among the Bengali Muslim children and women should be performed to get more insights in the nutrition situation in the population. Moreover, data on diet and food habit should be incorporated in research studies in the studied population which the present study lacks. Both government and non-governmental intervention is very necessary to combat and improve the present poor nutritional situation among the Bengali Muslim children and mothers. There is an urgent need to look into the problem and proper nutritional intervention programmes should be incorporate to ameliorate the nutrition situation among the Bengali Muslims.

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Percent of body fat, fat-mass, fat-free mass and assessment of body composition among rural school-going children of Eastern-India

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Abstract: Percent of body fat (PBF), fat mass (FM) and fat free mass (FFM) are useful indicators for the assessment of body composition. The present study was conducted among 1351 children (boys: 660; girls: 691) aged 5–12 years residing in West Bengal, Eastern-India. The children were selected using a stratified random sampling method. Anthropometric measurements of height, weight, triceps skinfold (TSF) and sub-scapular skinfold (SSF) were recorded using standard procedures. The PBF, PBF-for-age z-score (PBFZ) and body mass index (BMI) were subsequently calculated. Body composition was assessed using FM, FFM, fat mass index (FMI) and fat free mass index (FFMI). Age-specific mean values of FM ranged from 2.12–4.00 kg (boys) and 2.16–4.40 kg (girls). Age-specific mean values of FFM ranged from 14.45–23.93 kg (boys) and 14.01–23.03 kg (girls). Sex-specific mean differences between sexes were statistically significant in weight, height, TSF, SSF, PBF, PBFAZ, FM, FFM, FMI and FFMI ($p<0.05$), except in BMI ($p>0.05$). These results are important for future investigations in clinical and epidemiological settings so as to accurately identify the risk of lower or higher adiposity and body composition using PBF, FM and FFM.

Key words: Adiposity, anthropometry, body composition, fat mass, fat free mass, percent of body fat

Introduction

Body fat is a normal component of human body that accumulates in adipose tissue. It serves as a useful marker for assessing adiposity of individuals (Hu 2008; Sen and Mondal 2013; Colley et al. 2015; Griffiths et al. 2016; Xue et al. 2016). The predictions of body fatness and body composition are based mostly upon anthropometric measures such as height, weight, percentage body fat (PBF), body mass index (BMI), waist-hip ratio and skinfold thickness (Rolland-Cachera 1993; Hall et al. 2007). Although, several sophisticated techniques such as bioelectrical impedance analysis, dual-X-ray absorptiometry, computerized tomography, underwater weighing have also been developed to determine

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body composition (Lee and Gallagher 2008; Duren et al. 2008; Jensen et al. 2016; Andreoli et al. 2016; Gibby et al. 2017; Louer et al. 2017) anthropometric measurements are still widely used to assess the same in many field and epidemiological investigations. As body adiposity proportions vary with age, sex and environmental conditions, it serves as a good indicator of health and nutritional status of children (Rolland-Cachera 1993; Hall et al. 2007; Wells 2007; Sen and Mondal 2013; Reddon et al. 2016; De Onis 2017).

Body composition is most commonly assessed using surrogate anthropometric measures such as BMI, which measures excess adiposity in relation to greater body weight relative to height rather than excess adiposity (Cole et al. 2005; Freedman et al. 2005; Ablove et al. 2015; Hung et al. 2017). However, BMI is unable to differentiate between excess body-weight associated with muscle-mass and/or fat mass (Wells 2010; Thibault et al. 2012; Thibault and Pichard 2012). Moreover, the BMI is a discrete anthropometric measure and can be adjusted according to the body size and body composition (VanItallie et al. 1990; Wells 2010; Griffiths et al. 2016; Alpizar et al. 2017). BMI can be better expressed in terms of fat mass (FM) and fat free mass (FFM) [BMI = FFM (kg)/height^2 (m^2) + FM (kg)/height^2 (m^2)] (Wells 2010) and it also includes the FM index (FMI) and FFM index (FFMI). The disintegration of BMI into FM and FFM needs the help of anthropometric measurements and body composition assessment (VanItallie et al. 1990; Wells 2010; Sen and Mondal 2013; Xue et al. 2016; Sharma and Mondal 2018). Body composition status reflects nutritional intakes, losses and needs over time (i.e., FFM and FFMI) along with the prevalence of undernutrition. According to some researchers, FM and FFM have the advantage of providing discrete measures for these two components of weight, each adjusted for an independent component of size, although in some cases a more complex approach is required (Wells 2007; Wells 2010; Sen and Mondal 2013). A few research studies have used FM, FFM, FMI and FFMI to assess body composition and adiposity level of children and adults (Musaiger and Gregory 2000; Freedman et al. 2005; Gültekin et al. 2005; Mukhopadhyay et al. 2005; Chowdhury et al. 2007; Ghosh et al. 2009; Sen and Mondal 2013; Sharma and Mondal 2018).

Percent of body fat (PBF) is considered to be a relatively better measure of excess adiposity or obesity. The overall adiposity level is estimated by PBF mainly in epidemiological settings and studies have reported a significant relationship between PBF and BMI when sex and age are taken into account (Slaughter et al. 1988; Gallagher et al. 1996; Ablove et al. 2015; Ho-Pham et al. 2015; González-Agüero et al. 2017). The skinfold thickness (e.g. triceps and/or sub-scapular) are also now widely used to determine body adiposity (e.g., PBF and FM) using the standard equations (Slaughter et al. 1988; VanItallie et al. 1990; Rolland-Cachera 1993; Wells 2007; González-Agüero et al. 2017). Excess body adiposity have significant relationship with the occurrence of several preventable non-communicable diseases (e.g., cardiovascular disease, insulin resistance, diabetes mellitus, dyslipidaemia and certain types of cancer) and related mortality and morbidities. Several researchers have subsequently reported the widespread use and importance of using PBF, FM, FFM, FMI and FFMI as indicators of body adiposity (Slaughter et al. 1988; VanItallie et al. 1990; Rolland-Cachera 1993; Musaiger and Gregory 2000; Freedman et al. 2005; Gültekin et al. 2005; Freedman et al. 2005; Mukhopadhyay et al. 2005; Chowdhury et al. 2007; Wells 2007; Ghosh et al. 2009; Sen and Mondal 2013; Sharma and Mondal 2018). Several studies have also highlighted the important relationship between undernutrition and body composition among various vulnerable segments of the population in India (Bose et al. 2007; Kshatriya and Ghosh 2008; Datta Banik 2011; Sen and Mondal 2013; Singh and Mondal 2014; Datta Banik and Das 2015; Debnath et al. 2017; Sharma and Mondal, 2018). Hence, assessment of body composition is becoming imperative among the large sized, poverty stricken and nutritionally vulnerable segments of the Indian populations. Given the above, the present study aims to assess age-sex specific adiposity levels and body composition of rural school-going children using PBF, FM, FFM, FMI and FFMI so as to assess their nutritional status.

Materials and methods

The present school based cross-sectional study was conducted among 1351 school going children (boys: 660; girls: 691) aged 5-12 years residing in Phansidewa Block of the Darjeeling district of West Bengal, India. This block (Latitude 26° 34´59´´N, Longitude 88° 22´00´´E) covers an area of 308.65 km^2 and has a total population of 171,508 individuals (males: 87,945; females: 83,563) with a literacy rate of 41.59% (males: 51.85%; females: 30.80%) (Census of India 2011). The region is situated near the Indo Bangladesh border region and ~35–40 km from the sub-divisional town of Siliguri. The residents of the block have access to all the basic amenities, such as hospitals, schools, post office, markets and government offices (Mondal and Sen 2010; Sen and Mondal 2013; Debnath et al. 2018).

The children were residing in and around the block-level town of Phansidewa, located in the above-mentioned block. They were the students of 12 primary schools covered under the block. The schools were selected on the basis of identical student strengths and road accessibility. The children were selected using a stratified random sampling method. Initially 1477 children (boys: 746; girls: 731) in the age group of 5-12 years were identified and approached to participate in the study. Their dates of birth were checked from the school record and the birth certificates issued by the Government. Socio-economic status (SES) of the children was evaluated using a modified version of the scale of Kuppuswamy's (Mishra and Singh 2003; Kumar et al. 2007). This scale allows determination of SES based on a score calculated from education, occupation and monthly income. Of these 1477 children, 126 of them (boys: 86; girls: 40) were excluded from the study as their dates of birth were either not available or they were not in the age group of 5-12 years or they did not belong to the same SES. So the final sample consisted of 1351 (boy: 660; girls: 691) aged 5-12 years belonging to the same SES (in this case: lower SES) based on the modified scale of Kuppuswamy. All the children were free from any previous histories related to medical and surgical episodes, physical deformity and were not suffering from any diseases at the time of collecting the data. The parents of the children were informed about the objectives of the study prior to data collection. An informed consent was obtained from them and participation in the study was purely voluntary. The study was conducted in accordance with the ethical guidelines for human experiments, as laid down the Helsinki Declaration of 2000 (Touitou et al. 2004). The data were collected during the period from September 2015 to March 2016.

Anthropometric measurements collected

Anthropometric measurements of height, weight, triceps (TSF) and sub-scapular (SSF) skin-folds were recorded using standard anthropometric procedures. Height of the children was recorded to the nearest 0.1 cm using an anthropometer rod with the head held in the Frankfort horizontal plane. Weight of the children, wearing minimum clothing and with bare feet, was taken using a portable weighing scale to the nearest 100 gm. The skinfold measurements of TSF and SSF were measured using a Holtain skinfold calliper on the right side of each child to the nearest to 0.2 mm. The skinfold calliper was calibrated to exert a constant pressure of 10 gm/mm^2. The children were measured with ample care and precision to avoid any possible human error in the process of data collection.

The intra-observer and inter-observer technical errors of measurements (TEM) were calculated to determine the accuracy of the measurements using the standard procedure of Ulijaszek and Kerr (1999). The TEM was calculated using the following equation:

$TEM=\sqrt{(\Sigma D^2/2N)}$, [D=difference between the measurements, N=number of individuals].

The co-efficient of reliability (R) was subsequently calculated from TEM using the following equation:

$R=\{1-(TEM)^2/SD^2\}$, SD= standard deviation of the measurements.

For calculating TEM, height, weight, TSF and SSF were recorded by two of the authors (SD and NM) from 50 children aged 5-12 years other than those selected for the study. Very high values of R (>0.975) were obtained for height and weight. The values were observed to be within the acceptable limits of 0.95 as recommended by Ulijaszek and Kerr (1999). Hence, the measurements recorded by SD and NM were considered to be reliable and reproducible. All the measurements in the course of the present study were subsequently recorded by one of the authors (SD). Care was taken to avoid any possible systematic errors (instrumental or definition of landmarks) in the course of recording the anthropometric measurements as outlined by Harris and Smith (2009).

Assessment of body composition

The following equations of Slaughter et al. (1988) were used to estimate PBF:

$$\text{Boys} = 1.21\,(TSF + SSF) - 0.008\,(TSF + SSF)^2 - 1.7$$

$$\text{Girls} = 1.33\,(TSF + SSF) - 0.013\,(TSF + SSF)^2 - 2.5$$

The following equations of VanItallie et al. (1990) were utilized to assess the proportion of Fat mass (FM), Fat-free mass (FFM), Fat mass index (FMI) and Fat-free mass index (FFMI):

$$FM\ (kg) = (PBF/100) \times weight\ (kg)$$

$$FFM\ (kg) = Weight\ (kg) - FM\ (kg)$$

$$FMI\ (kg/m^2) = FM/Height^2\ (m^2)$$

$$FFMI\ (kg/m^2) = FFM/Height^2\ (m^2).$$

The BMI was calculated to assess the body composition characteristics of the children using the following standard equation:

BMI (kg/m^2) = Weight (kg)/$Height^2$ (m^2).

The age and sex-specific PBF-for-age z-score (PBFAZ) was calculated using the following equation:

Z-score = {(X/M)*L –1}/(L*S)

where X=PBF, L, M and S are the age-sex specific values of the appropriate table corresponding reference populations.

The recently proposed L, M, and S age-sex specific reference values using the National Health and Nutrition Examination Survey (NHANES) conducted by the National Centre for Health Statistics data were used to calculate the age and sex-specific z-scores among children (Laurson et al. 2011).

Statistical Analysis

The data were statistically analyzed using the Statistical Package for Social Sciences (SPSS, Inc., Chicago, IL; version 17.0). A p-value of less than 0.05 and 0.01 was considered to be statistically significant. Independent sample t-test was done to assess sex-specific mean differences in the anthropometric variables. One-way analysis of variance (ANOVA) using the Scheffe procedure was done to assess age-specific mean differences in the anthropometric and body composition variables. Two-way ANOVA was used to control the influence of age and sex on the body composition variables (e.g., BMI, PBF, FM, FFM, FMI and FFMI). The LMS model approach was utilized to convert the measurements for a child of known age and sex to evaluate the centile and standard deviation score or z-score, as proposed by Cole and Green (1992) and Cole et al. (1998). This method was used to derive the age- and sex-specific percentile reference curves of BMI, FM and FFM. The LMS Chart Maker software program (The Institute of Child Health, London) was used to obtain the smooth centile curves that fitted smooth centile curves to the reference data. The method summarizes percentiles at each age based on the power of age-specific Box-Cox power transformations used to normalize data. The centile curves (3rd, 10th, 25th, 50th, 75th, 90th and 97th) were derived as reference data for further evaluation of body composition.

Results

The age-sex specific subject distribution and the means (±standard deviations) of the anthropometric and body composition variables among rural school going children are presented in Table 1.

Age-specific mean values of weight, height and FFM were observed to progressively increase with age among both boys and girls. Boys were observed to be heavier than girls with exceptions in the ages of 7 years. The skinfold measurements of TSF, SSF, BMI, PBF, FMI and FFMI did not exhibit any noteworthy age and sex-specific trend among the children. The age-specific mean skinfold thickness (e.g., TSF and SSF) values were observed to be significantly higher among girls compared to boys ($p<0.01$). The age-specific mean value of TSF was higher at the age of 10 years (8.72 mm) and 10 years (9.61 mm) and lowest in 8 years (7.17 mm) and 12 years (8.68 mm) among boys and girls, respectively.

Table 1. Age-specific descriptive statistics: means and standard deviation (in parenthesis) of the anthropometric variables in children

Age (years)	Sample size		Height (cm)		Weight (kg)		TSF (mm)		SSF (mm)	
	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
5	61	62	108.28	108.26	16.58	16.17	8.03	8.74	4.93	5.07
			(6.47)	(5.30)	(2.69)	(1.86)	(2.21)	(1.80)	(1.82)	(1.01)
6	72	91	111.77	111.05	17.71	16.70	7.64	8.31	4.82	5.29
			(6.00)	(6.00)	(2.54)	(2.31)	(1.81)	(1.78)	(0.83)	(1.24)
7	98	104	115.72	117.15	19.11	19.19	7.40	8.36	4.88	5.53
			(6.59)	(4.87)	(2.82)	(2.17)	(1.68)	(2.03)	(0.97)	(1.30)
8	92	105	122.09	120.87	20.95	20.55	7.17	8.22	5.02	5.91
			(6.77)	(5.30)	(2.99)	(2.75)	(2.00)	(2.11)	(1.13)	(1.71)
9	117	122	127.09	126.01	23.04	22.83	7.50	9.02	5.42	6.36
			(5.54)	(5.90)	(3.08)	(3.91)	(2.86)	(2.98)	(1.86)	(2.27)
10	93	100	130.45	130.56	26.13	26.08	8.72	9.61	6.40	7.01
			(6.09)	(6.89)	(5.29)	(9.91)	(3.95)	(2.44)	(4.27)	(1.97)
11	83	75	134.49	134.00	27.66	27.43	7.76	9.51	5.73	7.02
			(6.24)	(6.08)	(5.03)	(4.79)	(2.79)	(2.97)	(2.55)	(2.68)
12	44	32	135.41	131.95	27.05	25.89	7.68	8.68	5.51	6.24
			(6.86)	(10.01)	(4.08)	(5.23)	(1.83)	(2.00)	(1.15)	(2.02)
Total	660	691	123.25	122.13	22.27	21.65	7.72	8.81	5.36	6.07
			(10.88)	(10.32)	(5.29)	(6.15)	(2.61)	(2.41)	(2.24)	(1.96)
F-value			190.30	188.50	98.83	60.78	3.07	4.79	5.33	13.23
p-value			<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Age (years)	Sample size		BMI (kg/m²)		PBF (%)		PBFZ		FM (kg)	
	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
5	61	62	14.12	13.80	12.52	13.07	-0.56	-0.64	2.12	2.16
			(1.67)	(1.15)	(3.36)	(2.43)	(0.81)	(0.73)	(1.04)	(0.51)
6	72	91	14.14	13.56	12.09	13.10	-0.61	-0.81	2.17	2.21
			(1.31)	(1.38)	(2.40)	(2.52)	(0.63)	(0.72)	(0.71)	(0.61)
7	98	104	14.23	13.97	11.91	13.36	-0.69	-0.89	2.30	2.58
			(1.44)	(1.33)	(2.33)	(2.85)	(0.60)	(0.79)	(0.66)	(0.69)
8	92	105	14.02	14.03	11.79	13.55	-0.89	-1.04	2.50	2.83
			(1.22)	(1.30)	(2.90)	(3.12)	(0.72)	(0.80)	(0.86)	(0.97)
9	117	122	14.24	14.30	12.45	14.57	-0.91	-1.04	2.94	3.43
			(1.56)	(1.61)	(3.86)	(3.96)	(0.70)	(0.82)	(1.35)	(1.56)
10	93	100	15.26	15.35	14.27	15.80	-0.78	-0.95	4.00	4.16
			(2.20)	(6.94)	(6.30)	(3.55)	(0.81)	(0.75)	(3.07)	(1.77)
11	83	75	15.21	15.20	12.96	15.56	-0.29	-1.19	3.73	4.40
			(1.76)	(1.83)	(4.37)	(4.22)	(0.55)	(0.80)	(2.31)	(1.96)
12	44	32	14.67	14.73	12.81	14.28	-0.88	-1.56	3.50	3.77
			(1.16)	(1.61)	(2.59)	(3.11)	(0.47)	(0.63)	(1.03)	(1.43)
Total	660	691	14.48	14.32	12. 59	14.20	-0.64	-0.98	2.91	3.16
			(1.66)	(3.06)	(3.90)	(3.45)	(0.77)	(0.79)	(1.78)	(1.51)
F-value			8.46	4.41	3.90	8.94	28.47	6.14	16.38	36.42
p-value			<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Abbreviations: TSF – triceps skinfold; SSF - sub-scapular skinfold; BMI – body mass index; PBF – percent of body fat; PBFZ – percent of body fat for-age z-score; FMI - fat mass index; FFMI - fat free mass index

Table 1. Age-specific descriptive statistics: means and standard deviation (in parenthesis) of the anthropometric variables in children

Age (years)	Sample size		FFM (kg)		FMI (kg/m²)		FFMI (kg/m²)	
	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
5	61	62	14.45 (1.96)	14.01 (1.61)	1.81 (0.76)	1.84 (0.43)	12.31 (1.14)	11.94 (0.86)
6	72	91	15.54 (2.03)	14.54 (1.92)	1.72 (0.45)	1.79 (0.47)	12.42 (1.07)	11.77 (1.10)
7	98	104	16.81 (2.37)	16.61 (1.80)	1.71 (0.44)	1.88 (0.49)	12.52 (1.18)	12.10 (1.08)
8	92	105	18.44 (2.43)	17.72 (2.08)	1.67 (0.50)	1.93 (0.60)	12.35 (0.96)	12.10 (0.88)
9	117	122	20.10 (2.24)	19.40 (2.67)	1.81 (0.77)	2.13 (0.84)	12.44 (1.14)	12.17 (1.01)
10	93	100	22.13 (2.83)	21.92 (8.49)	2.30 (1.56)	2.44 (1.11)	12.97 (1.00)	12.91 (6.00)
11	83	75	23.93 (3.30)	23.03 (3.28)	2.03 (1.04)	2.42 (0.97)	13.18 (1.06)	12.78 (1.13)
12	44	32	23.54 (3.36)	22.12 (4.16)	1.89 (0.46)	2.12 (0.64)	12.78 (0.97)	12.61 (1.25)
Total	660	691	19.36 (4.05)	18.49 (4.95)	1.87 (0.88)	2.07 (0.78)	12.61 (1.11)	12.27 (2.50)
F-value			141.10	58.32	5.33	10.04	7.30	2.33
p-value			<0.001	<0.001	<0.001	<0.001	<0.001	<0.05

Abbreviations: TSF – triceps skinfold; SSF - sub-scapular skinfold; BMI – body mass index; PBF – percent of body fat; PBFZ – percent of body fat for-age z-score; FMI - fat mass index; FFMI - fat free mass index

The age-specific mean value of SSF was ranged 4.82 mm (in 6 years) to 6.40 mm (in 10 years) and 5.07 mm (in 5 years) to 7.02 (in 11 years) among boys and girls, respectively. Age-specific mean BMI values were observed to be slightly higher among boys than girls, especially in the early ages (e.g., 5–7 years), but observed to be markedly higher among girls in the older age groups (e.g., 9, 10 and 12 years). The age-specific mean BMI values ranged from 14.12 kg/m² (in 5 years) to 15.26 kg/m² (in 10 years) and 13.56 kg/m² (in 6 years) to 15.35 kg/m² (in 10 years) among boys and girls, respectively. The age-specific means PBF and PBFAZ values did not show any uniform increase in age among the children. Mean PBF was observed to be higher in 10 years (14.27%) and lowest in 8 years (11.79%) among boys and highest in 10 years (15.80%) and lowest in 5 years (13.07%) among girls. The age-specific mean value of PBFAZ was ranged 0.29 (in 11 years) to −0.89 (in 8 years) and −0.64 (in 5 years) to −1.56 (in 12 years) among boys and girls, respectively.

The mean values in fat pattern indices of FM and FFM gradually increased with advancement of age among the children but exceptions were observed in 11-12 years (in boys) and 12 years (in girls). Age-specific mean FM and FMI were observed to be higher among girls than boys ($p<0.05$), but a reverse trend was observed in FFM and FFMI ($p<0.05$). Age-specific mean values of FM and FFM ranged from 2.12–4.00 kg (in boys) and from 2.16–4.16 kg (in girls) and from 14.45–23.92 kg (in boys) and from 14.01–23.03 kg (in girls), respectively (Table 1). Age-specific mean values of FMI and FFMI did not exhibit any age-specific trend among boys and girls. The age-sex specific mean FMI values were ranged 1.67 -2.30 kg/m^2 (in boys) and 1.79 -2.44 kg/m^2 (in girls). Similarly, the age-sex specific mean FFMI values were ranged 12.31 kg/m^2 (in 5 years) to 13.18 kg/m^2 (in 11 years) and 11.77 kg/m^2 (in 6 years) to 12.91 kg/m^2 (in 10 years) among boys and girls, respectively. The existence of significant sex differences indicates that these body composition indicators reflecting the sexual dimorphism in PBF, FM, FFM, FMI and FFMI ($p<0.05$). Age- and sex-specific smooth percentile curves for PBF, FM and FFM derived from further evaluation of body composition using L, M and S parameters

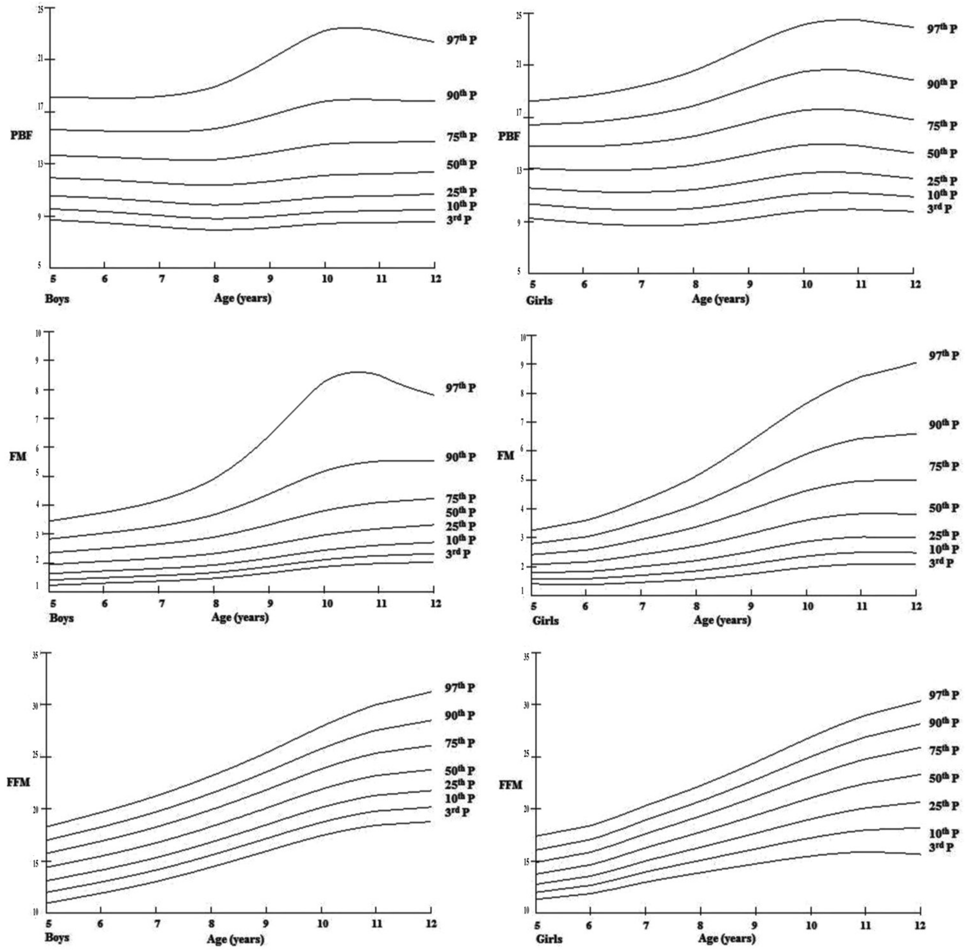

Figure 1: Age-sex specific smooth percentile curves of PBF, FM and FFM using LMS model.

in the model approach statistical procedures among the rural school-going children are presented in Figure 1. Age- and sex-specific selected percentile of 5th, 10th, 25th, 50th, 75th, 90th and 95th values for PBF, UMA and UFA were derived separately among rural school-going boys and girls and shown in Figure 1.

Using independent sample t-test, there were statistically significant sex differences ($p<0.05$) in anthropometric and body composition indicators of weight (t-value= 2.03), height (t-value= 2.02), TSF (t-value= −7.91), SSF (t-value= −6.24), PBF (t-value= −7.98), FM (t-value= −2.80), FFM (t-value= 3.59), FMI (t-value= −4.42) and FFMI (t-value= 3.27) except in BMI (t-value= 1.25) (not significant). Using ANOVA, differences in anthropometric and body composition variables were also observed to be statistically significant ($p<0.05$) with respect to age and weight, height, TSF, SSF, BMI, PBF, PBFAZ, FM. FFM, FMI and FFMI among boys and girls (Table 1). The results of two way ANOVA showed statistically insignificant association for the anthropometric and body composition variables of height, weight, BMI, PBF, TSF, SSF, FM, FFM, FMI and FFMI except in PBFZ ($p<0.001$) with respect to age and sex (Table 2).

Discussion

The amount and distribution of body adiposity (e.g., FM) and composition of muscularity (e.g., lean mass or FFM) are now understood to be important health outcomes in body composition assessment in infants and children (Wells and Fewtrell 2006; Thibault and Pichard 2012; Aguirre et al. 2015; Boone-Heinonen et al. 2015; Simmonds et al. 2015; Santos et al. 2016; González-Agüero et al. 2017; Sharma and Mondal 2018). Studies have reported marked sexual dimorphism in the relationship of visceral and peripheral adiposity (Wells 2007; Shen et al. 2009; Nedungadi and Clegg 2009; Pausova et al. 2012; Sen and Mondal 2013; Crocker et al. 2014; Singh and Mondal, 2014; Whitaker et al. 2016; Debnath et al. 2017). But the differences in adiposity distributions are evident during early childhood with differences in total body adiposity onset before puberty

Table 2. Two-way analysis of variance (ANOVA) of the age and sex specific anthropometric variables

Age* Sex specific effect	F-value	d.f.	*p*-value
Height	1.59	1,1350	0.13
Weight	0.33	1,1350	0.94
BMI	0.41	1,1350	0.89
PBF	1.17	1,1350	0.32
TSF	0.78	1,1350	0.60
SSF	1.07	1,1350	0.38
FM	0.93	1,1350	0.48
FFM	0.51	1,1350	0.83
FMI	1.01	1,1350	0.42
FFMI	0.35	1,1350	0.93
PBFZ	17.08	1,1350	0.00

(He et al. 2002; Staiano et al. 2013). The term 'mini puberty of early infancy' has been used for the sex-related divergence in adipose tissue distribution observed may be mediated by the hormonal fluctuations (Leung et al. 2004). Studies have attributed to such adiposity differences caused due to major hormonal (i.e., sex steroid) changes during puberty (Wells 2007; Correia-Costa et al. 2015).

Several studies have already validated different skinfold equations with alternate methods of estimation and recommended the use of the equations of Slaughter et al. (1988) for the evaluation of body fat among pre-pubertal children (Goran et al. 1996; Boot et al. 1997; Laurson et al. 2011; Sen and Mondal 2013; Almeida et al. 2016; González-Agüero et al. 2017). The present study evaluated PBF content in order to evaluate the body composition characteristics of rural school-going children using the equation of Slaughter et al. (1988). Furthermore, several studies have assessed body composition characteristics in children utilizing these equations for estimation of PBF among children from both non-Indian (Musaiger and Gregory 2000; Gültekin et al. 2005; Ghosh et al. 2009; Laurson et al. 2011; Aguirre et al. 2015; Noradilah et al. 2016; González-Agüero et al. 2017) and Indian ethnic populations (Mukhopadhyay et al. 2005; Chowdhury et al. 2007; Sen and Mondal 2013; Sharma and Mondal 2018). The results indicated pronounced sexual differences in adiposity and body composition measures (e.g., PBF, FM, FM, FMI and FFMI) between boys and girls ($p<0.01$). Similar trends of body composition and adiposity indicators were reported among Indian (Gerver et al. 2000; Sen and Mondal 2013) and rural Chinese (Wang et al. 2007) children. The differences in adiposity measures (PBF, FM and FFM) were also observed to be more prominent with the advancement of age (Table 1). The sex-specific mean values were greater in girls than boys but were distinctly higher in older age groups (e.g. 9–12 years) ($p<0.05$). The changes in body composition characteristics among girls have been observed in the present study, especially when they approached the stage of puberty. Wells (Wells 2007) advocated that sexual dimorphism of body composition is evident from fetal life, but emerges primarily during puberty and such differences in body composition are primarily attributed to the action of steroidal hormones. Sex steroid hormones (e.g., testosterone and oestrogen) play an important role in the distribution and accumulation of adipose tissue in abdomen and gluteofemoral regions, respectively (Norgan 1997; Lee and Fried 2017), which contributes critically to the sex differences in adiposity fat distribution during puberty (Gültekin et al. 2005; Wells 2010; Guo et al. 2016; Lee and Fried 2017). Moreover, testosterone is an important factor for the increase in lean mass or FFM (in boys) and oestrogen strongly influence the increased fatness or FM (in girls) which leads to the sex differences in body fatness (Wells 2007, 2010; Glass et al. 2016; Lee and Fried 2017). Several studies have reported that fatness showed stability between early infancy and childhood and sex differences appear in body composition prior to the onset of sexual maturation (Gerver et al. 2000; Wells 2010; Sen and Mondal 2013; Crocker et al. 2014; Breij et al. 2017; Halfon et al. 2018). Genetic effects on sex-specific differences on body fat deposition and distribution have been observed from fetal life and become more prominent from puberty and this difference decrease steadily with age and become almost similar in adulthood (Wells 2007, 2010; Sen and Mondal 2013; Crocker et al. 2014). In case of males lesser amount of deposited body adiposity and it remains allocated primarily in the abdomen but in females adipose tissue accumulation is observed to be almost double and mostly found in the lower body and breasts (Blouin et al. 2008; Wells 2010; Guo et al. 2016; Lee and Fried 2017). The present study also showed that girls were observed to have higher body fat levels than their male counterparts in connection with adiposity indicators (e.g., TSF, SSF, PBF, FM and FMI). Several studies have already used these equations to assess the PBF, FM, FFM, FMI and FFMI among children (Chowdhury et al. 2007; Ghosh et al. 2009; Sen and Mondal 2013; Almeida et al. 2016; González-Agüero et al. 2017; Sharma and Mondal 2018). It has been reported that the Tanner stages had a significant relationship with body composition in both sexes and were significantly positively related to lean tissue mass and bone mineral content among boys and girls and to PBF and FM in girls in the higher age groups (Boot et al. 1997). Differences in adiposity patterns have also been reported among Santhal (Chowdhury et al. 2007), Nepalese (Ghosh et al. 2009), Indian (Gerver et al. 2000), Chinese (Wang et al. 2007) and Dutch children (Weststrate et al. 1989). Age-specific FM values observed in the present study were higher than those obtained from Nepalese children (Ghosh et al. 2009). FFM-for-age values were lower than those reported for Bahraini (Musaiger and Gregory 2000), Turkish (Gültekin et al. 2005), Santhal (Chowdhury et al. 2007) and Nepalese children (Ghosh et al. 2009). The age-specific percentile values were almost similar in the 95th percentile, 75th percentile and 50th percentile to Turkish (Gültekin et al. 2005), Santhal (Chowdhury et al. 2007) and Nepalese children (Ghosh et al. 2009), respectively. Similar results have been reported by some other studies (Chowdhury et al. 2007; Ghosh et al. 2009; Guo et al. 2016). It has now been suggested that, due to the limitation of expressing body composition data as kilograms (e.g. kg of FM and FFM) and as percentages (e.g. PBF), the FMI (kg of FM/ height^2) and FFM (kg of FFM/ height^2) appear to be better indicators of body composition (Freedman et al. 2005). While the FMI relates fat mass to height, the FFMI estimates muscle mass related to height. The age-specific mean values of FMI and FFMI among the rural school going children were lower than the reported values of Eckhardt et al. (2003). The indices of FFMI and FMI therefore offer a powerful framework for evaluating within and between-population variability in body composition and address physique (FFMI) as well as relative adiposity (FMI). The ethnic variation might be attributed to genetic adaptations to ancestral environment and exposure to more contemporary ecological stresses, as it has been reported that variations in PBF, FM, FFM, FMI and FFMI between populations could be to their ethnic elements (Musaiger and Gregory 2000; Wells 2010; Sen and Mondal 2013).

Conclusion

The present study recommends the evaluation of body composition to improve screening for undernutrition in hospitalized patients and in field and clinical settings in order to reduce chronic undernutrition related mortality and morbidity. The findings of the present study are important in providing more insight for future investigations in the field and large epidemiological settings so as to accurately identify risk of lower or higher adiposity status and propose a major opportunity to improve through proper intervention programmes.

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Authors' contributions

SD, NM and JS have equally contributed to the conception and design of the study, acquisition of data, analysis and interpretation of data, drafting the manuscript and revising it critically for important intellectual content and the final approval of the version to being submitted.

Conflict of interest

There is no conflict of interests regarding publication of this paper.

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Subcutaneous Adiposity and Nutritional Status Among Children of Eastern-India

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Abstract

Introduction: Skinfold thickness is now considered to be an important indicator of body composition and nutritional status. Assessment of subcutaneous adiposity is becoming very important due to increasing trend of overweight and obesity. The objectives of the present study were to determine age-sex specific subcutaneous adiposity using skinfold thicknesses and its use in assessment of nutritional status among children of Eastern-India. **Material and Methods:** The investigation was carried out among 1262 children (619 boys; 643 girls) aged 5–12 years of Darjeeling district, West Bengal. Anthropometric measurements of skinfold thickness were recorded using standard procedures. Age-sex specific smooth percentile curves of skinfold thickness were derived using the L, M and S model. **Results:** Sexual dimorphism was observed in TSF, SSF, SISF, PBF, ∑2SKF and ∑4SKF measurements between sexes in children ($p<0.05$). Age-sex specific mean values of skinfold thicknesses of TSF, SSF, SISF and PBF of girls were observed to be significantly higher than boys ($p<0.05$). The age-sex specific mean values of BSF, TSF, SSF, SISF, ∑4SKF and PBF did not show any age-specific trend in children. Comparison with the NHANES-III data showed poor attainment of subcutaneous adiposity and nutritional status. **Conclusion:** Results of the present study showed the age-sex specific variations in subcutaneous adiposity pattern in children. The comparisons of skinfold thicknesses with references showed unsatisfactory nutritional status among children. These findings are important for future investigations in field, epidemiological and clinical settings.

Key words: Anthropometry, Body Composition, Nutritional Assessment, Skinfold thickness, Sexual Dimorphism, Subcutaneous Adiposity

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Introduction

Anthropometric measures are still considered to be reliable, non-invasive, and inexpensive and widely used technique to assess physical growth and nutritional status. The measures mostly comprise of height, weight and skinfold thickness measurements[1]. Body mass index (BMI, kg/m^2) is also widely used as an index of body fatness and is a measure of weight relative to height rather than of adiposity. It is used as a global proxy of nutritional status and highly correlated with different components of weight (e.g., lean mass or fat free mass, fat mass, skeletal muscle mass and bone mass), however, it is unable to provide differentiation between them[2]. The increase in BMI levels during puberty seems to be largely the result of increase in fat-free mass (e.g., muscle mass) rather than body fatness (e.g., adiposity) which further complicates the interpretation of physical growth among children and adolescents[3,4,5,6,7]. Variations in relative distribution of adipose tissue in the human body is an important area of research and it can be related with several preventable non-communicable diseases (e.g. cardiovascular diseases, metabolic disorders and gastrointestinal abnormalities, hyperlipidaemia, sleep apnoea, hepatic steatosis, polycystic ovary disease, and glucose intolerance)[2,6]. The distribution of adipose tissue is also associated with physical growth and maturation[8,9,10,11]. Epidemiologic evidence supports the theory that relation between excess adiposity (e.g., obesity) and relative risk of disease burden begins early in life[8,11]. Accumulation of higher adiposity levels tend to advance bone ages and early physical growth attainment and maturation in children[12,13].

Skinfold measurements of subcutaneous adiposity have a long history in human nutrition and body composition assessment related research[9,14] and have been widely used to determine the population specific body composition and relative subcutaneous adiposity distribution[3,15,16]. Amount of subcutaneous body adiposity is very specific to adipose tissue and can be determined using non-invasive techniques (e.g., anthropometry)[1,3,5]. Therefore, skinfold thickness is an important, useful and valid anthropometric measure of regional and total body adiposity in clinical or epidemiological research settings[1,11,15,16,17]. Skinfold thickness has been used extensively for estimating the changes in subcutaneous adiposity and body composition, and observed to be very useful technique due to its easy-to-use and non-invasive nature in research studies[3,9,14,15,18,19]. Adipose tissue accumulation is mostly dependent on nutritional status, age-sex specific and ethnic variation, and skinfold thicknesses are widely used as a practical tool for assessment of nutritional status in field, epidemiological or clinical settings[2,3,5,8,17]. Several researchers have reported age-sex variations in subcutaneous adiposity pattern, nutritional status and body composition using skinfold thicknesses among children[3,9,17,19,20]. The objectives of the present study were to determine the age-sex specific subcutaneous adiposity and assessment of nutritional status using skinfold thickness among rural children of Eastern-India.

Material and Methods

The present cross-sectional investigation was carried out among 1262 school-going children (boys: 619; girls: 643) aged 5-12 years residing in rural areas of Phansidewa Block, Darjeeling district, West Bengal, India. This community block (Latitude 26º 34´59´´ N, Longitude 88º 22´00´´ E) is situated near the Indo-Bangladesh border region and ~35– 40 km from the sub-divisional town of Siliguri and covers an area of 308.65 km^2. The community block has availability of all the basic amenities, such as hospitals, schools, markets, post office and government offices[3].The minimum number of participants required for the present investigation was estimated following the standard sample size estimation method[21]. In this method, the expected population proportion of 50%, absolute precision of 3% (≤5%; i.e., the lower margin of error) and confidence interval of 95% were taken into consideration. The minimum number of sample size estimated for the present investigation was 1068 individuals. Finally, 1262 children (619 boys; 643 girls) aged 5–12 years were selected to take part in the investigation. The socio-economic data on age, sex, parents' occupation and nature of occupation, parents' education, monthly family income, family size, family types, house-conditions, electricity facility, and drinking water and toilet facilities were collected using a structured schedule. A modified version Kuppuswamy's socio-economic scale was used to evaluate the socio-economic status (SES) of the children[22]. The determination of SES showed that all the children belonged to lower-middle SES. The data of the present investigation was collected during the period from September 2014 to November 2015.

Anthropometric measurements recorded: Anthropometric measurements were recorded using standard anthropometric procedures[1]. The skinfold measurements of biceps (BSF), triceps (TSF), sub-scapular (SSF) and supra-iliac (SISF) were measured using a Holtain skinfold calliper (London University Institute of Child Health, UK) on the left side of each child to the nearest to 0.2 mm. For calculating intra-observer and inter-observer technical errors of the measurements (TEM)[23], BSF, TSF, SSF and SISF were recorded from different data set of 50 children other than those selected for the investigation by SD and JS. Very high values of coefficient of reliability (R >0.975) were obtained for BSF, TSF, SSF and SISF and these values were observed to be within the recommended cut-off of 0.95[23]. Hence, the measurements recorded by SD and JS were considered to be reliable and reproducible. All the measurements in course of the present investigation were recorded by SD. The sum of two skinfolds (∑2SKF) and sum of four skinfolds (∑4SKF) were calculated using the following standard equations:

∑2SKF (mm)= TSF+SSF

∑4SKF (mm)= BSF+TSF+SSF+SISF

The body density (D) was calculated for the evaluation of peripheral adiposity or percent of body fat (PBF) using the standard equations of Deurenberg et al.[24]:

D_{Boys}= 1.1133−0.0561(log ∑4SKF) + 1.7(age*10^{-3})

D_{Girls}= 1.1187−0.0630 (log ∑4SKF) + 1.9(age*10^{-3})

The assessment of peripheral adiposity or PBF of the children was calculated using the standard equation of Westrate and Deurenberg[25]:

PBF=[562−4.2(age−2)]/D− [525−4.7(age−2)]

The data were statistically analysed using the Statistical Package for Social Sciences (SPSS, Inc., Chicago, IL; version 17.0). Descriptive statistical analysis of the data obtained was depicted in terms of mean and standard deviation (±SD). One-way analysis of variance (ANOVA) was performed to assess age-specific mean differences in anthropometric variables of the groups using Scheffe procedure. Independent sample t-test was done to assess sex-specific mean differences in anthropometric variables. The LMS model was utilized to convert the measurements for children of known age-sex to evaluate the centiles[26,27]. The LMS Chart Maker software program (The Institute of Child Health, London) was used to obtain the smooth centile curves. The method summarizes percentiles at each age based on the power of age-specific Box-Cox power transformations used to normalize data. The centile curves (3^{rd}, 10^{th}, 25^{th}, 50^{th}, 75^{th}, 90^{th} and 97^{th}) were derived as reference data for further evaluation of body composition. A p-value of <0.05 was considered to be statistically significant.

Results

Age and sex-specific subject distribution, means and standard deviations of BSF, TSF, SSF, SISF, ∑2SKF and ∑4SKF among the boys and girls are depicted in Table 1. Age-specific mean skinfold value was observed to be slightly higher among girls than boys, especially in TSF and SSF in older age groups (e.g. 10-12 years). Age-specific mean BSF and SISF were observed to be higher in younger age groups (e.g., 5-8 years). The mean values of ∑4SKF were observed to be higher among boys than girls of younger age groups (e.g. 5-8 years) and higher among girls than boys in older age groups (9-12 years). The age-specific PBF ranged from 13.24% (in 11 years) to 15.29% (in 5 years) (in boys) and 14.91% (in 8 years) to 17.22% (in 10 years) (in girls). The age-specific mean differences were observed to be statistically significant using ANOVA for all the variables of boys and girls ($p<0.05$) except in case of boys in TSF, SSF, ∑2SKF and ∑4SKF ($p>0.05$). The results of the independent sample t-test showed statistically significant ($p<0.05$) sex-specific differences in overall mean values of TSF (F-value= 48.81, d.f.,1,1261), SSF (F-value= 73.58, d.f.,1,1261), SISF (F-value= 32.15, d.f.,1,1261), PBF (F-value= 53.91, d.f.,1,1261), S2SKF (F-value = 65.46, d.f.,1,1261) and ∑4SKF (F-value= 28.06, d.f.,1,1261) ($p<0.05$). Age-specific LMS percentile curves of BSF, TSF, SSF and SISF for girls showed an ascending trend which is absent in boys. Sexual dimorphism appeared to be in TSF, SSF, SISF, PBF, ∑2SKF and ∑4SKF measurements between sexes ($p<0.05$). Age-sex specific percentile curves of BSF, TSF, SSF and SISF using LMS for assessment of nutritional status is depicted in Figure 1.

Assessment of nutritional status: The assessment of nutritional status was done by comparing the age and sex specific mean values of TSF, SSF and ∑TSF+SSF using the reference values of NHANES-III reference[28] (Figure 2). The comparison of the present investigation with reference population showed that the age-sex specific mean TSF values of the boys and girls were<25^{th} percentile which were below normal mean values of TSF. The mean SSF values were found to be <50^{th} percentile among boys and girls, respectively. The age-sex specific mean values of SISF of majority of boys and girls were <50^{th} percentile of the reference. The mean values of sum of ∑2SKF of boys and girls were <50^{th} percentile. Therefore, poor nutritional status of the children was observed with reference to the NHANES-III reference population[28]. Age-specific mean values were observed to be <50^{th} percentile (e.g., TSF, SSF, SISF and ∑2SKF) in age groups of 5-7 years in both sexes, but the mean values were observed to be almost on <25^{th} percentile values of reference in 10-11 years in TSF, SSF, SISF and ∑2SKF. Exceptions were observed in 12 years where TSF and SSF values of girls were in <25^{th} percentile, TSF and SSF values on 25^{th} percentile, SISF values were on 25^{th} percentile (in boys) and on 5^{th} percentile (in girls) and ∑2SKF values were on 25^{th} percentile for boys and in <25^{th} percentile in girls (Figure 2).

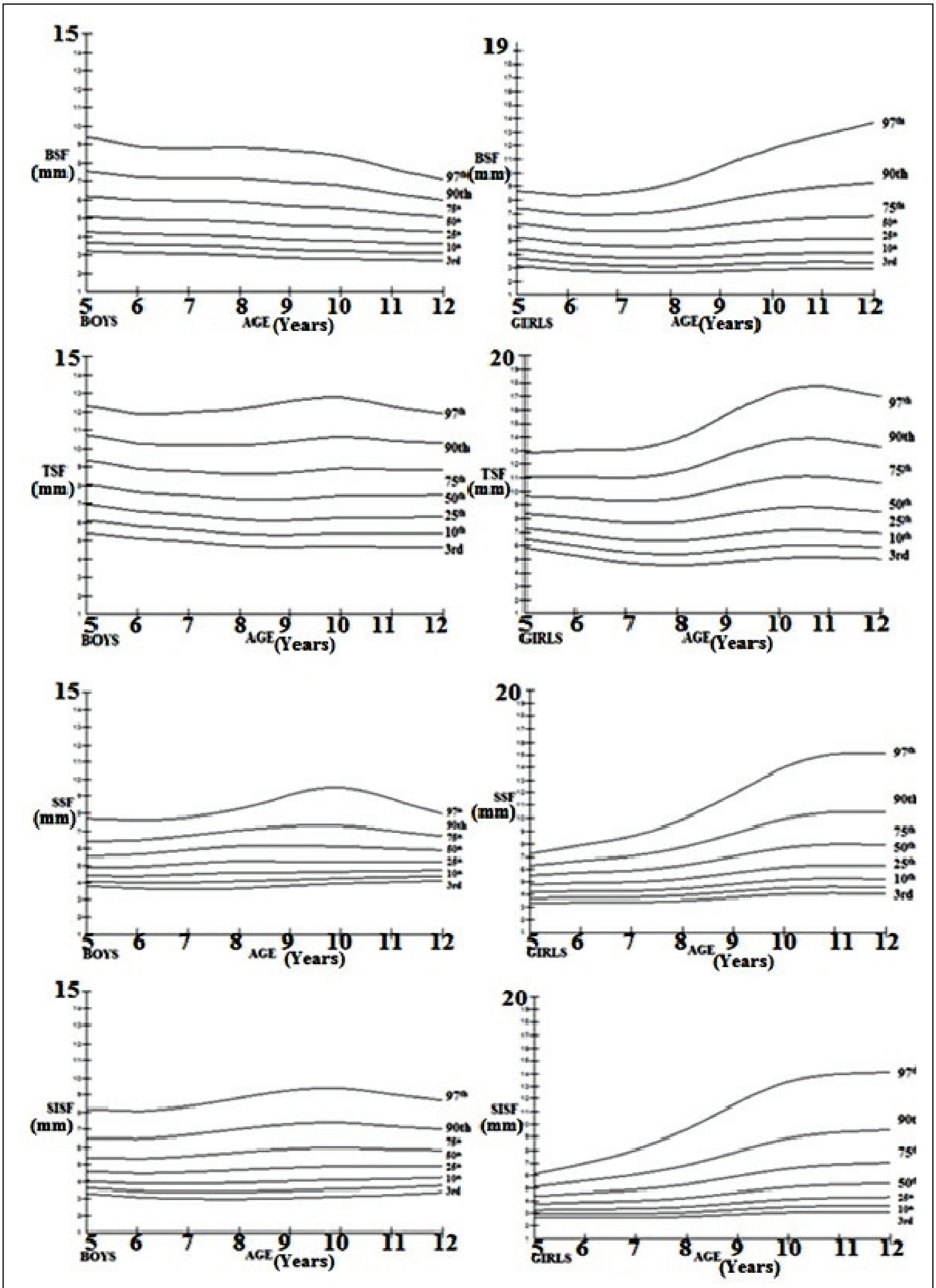

Fig. 1: Age-sex specific LMS graphs of BSF, TSF, SSF and SISF among the children

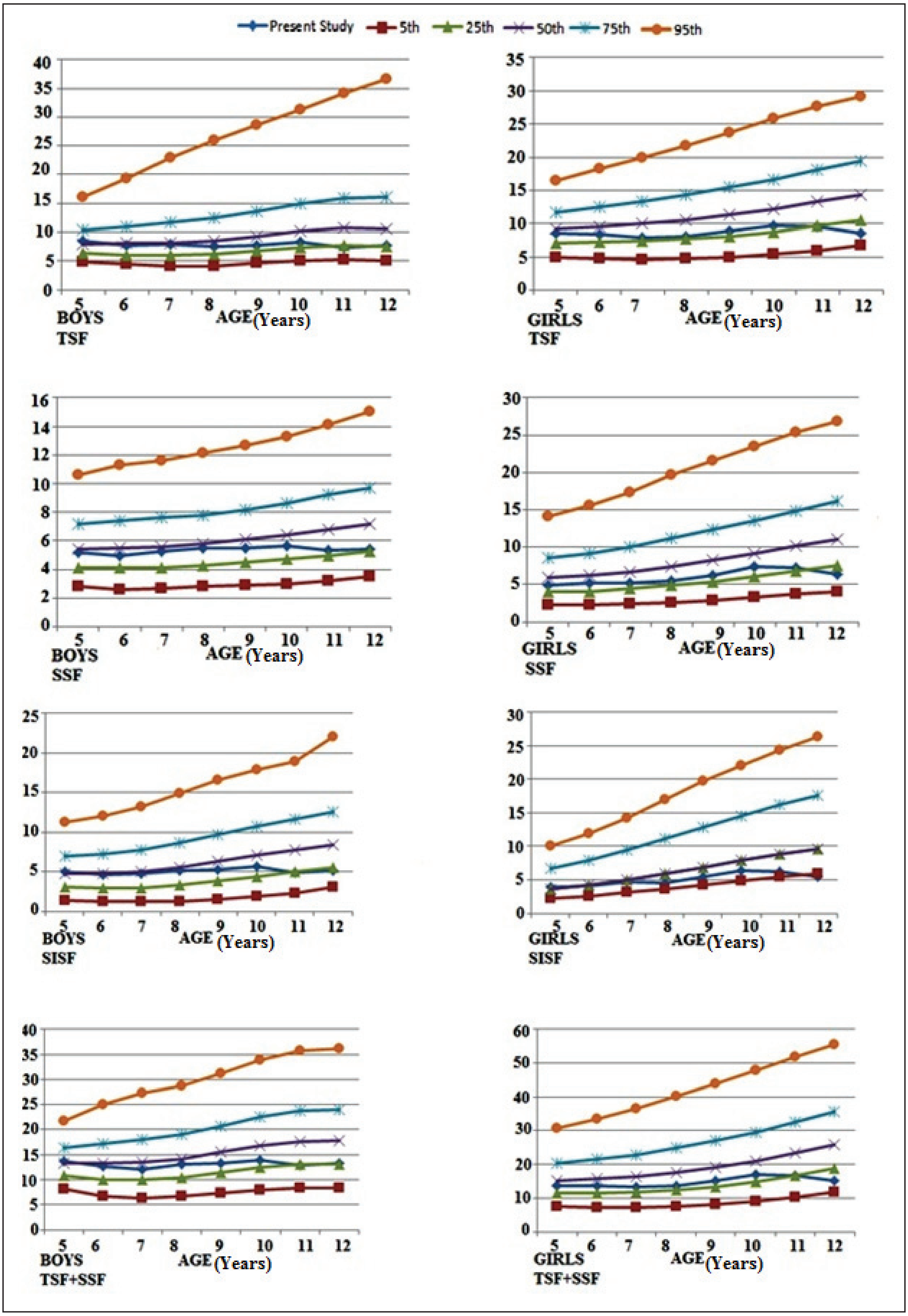

Fig. 2: Comparison of TSF, SSF and ∑TSF+SSF with NHANES-III reference[28] population among the children

Table 1: Age-sex specific mean and standard deviation of anthropometric variables among the children

Age Group	BSF (mm)		TSF (mm)		SSF (mm)		SISF (mm)		∑2SKF (mm)		∑4SKF (mm)		PBF	
	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
5 Years	7.36 ±1.74	5.54 ±1.58	8.46 ±2.22	8.59 ±1.90	5.23 ±1.83	4.89 ±1.07	5.07 ±2.00	3.93 ±1.00	13.69 ±3.76	13.53 ±2.69	26.12 ±16.37	22.98 ±4.41	15.29 ±4.10	15.89 ±2.63
6 years	5.03 ±1.21	4.88 ±1.30	7.67 ±1.51	8.47 ±2.07	5.00 ±0.95	5.21 ±1.26	4.69 ±1.19	4.07 ±1.00	12.67 ±2.13	13.68 ±3.08	22.39 ±3.90	22.63 ±4.50	13.98 ±2.06	15.41 ±2.61
7 years	5.17 ±1.41	4.97 ±1.56	7.85 ±1.75	7.98 ±2.19	5.29 ±1.02	5.16 ±1.41	4.82 ±1.32	4.67 ±3.33	12.13 ±2.40	13.22 ±3.42	23.13 ±4.45	22.80 ±5.97	14.19 ±2.25	15.10 ±3.25
8 years	5.20 ±1.46	4.85 ±1.62	7.53 ±2.00	8.00 ±2.30	5.50 ±1.40	5.52 ±1.72	5.11 ±1.66	4.50 ±1.51	13.02 ±3.07	13.57 ±3.74	23.33 ±5.39	22.86 ±5.84	14.07 ±2.68	14.91 ±3.20
9 years	4.98 ±2.30	5.48 ±2.54	7.73 ±2.89	8.88 ±3.21	5.52 ±1.90	6.29 ±2.36	5.26 ±2.10	5.41 ±2.76	13.25 ±4.32	15.21 ±5.31	23.48 ±8.18	26.06 ±9.16	13.85 ±3.18	16.17 ±4.01
10 years	5.09 ±1.45	5.54 ±2.30	8.27 ±2.44	9.75 ±3.59	5.65 ±1.25	7.38 ±3.83	5.66 ±2.04	6.34 ±3.95	13.92 ±3.27	17.13 ±7.10	24.67 ±6.04	29.01 ±11.48	14.47 ±2.76	17.22 ±4.40
11 years	4.45 ±1.23	5.95 ±2.77	7.42 ±1.75	9.56 ±3.52	5.38 ±1.15	7.27 ±3.24	4.92 ±1.16	6.17 ±2.82	12.80 ±2.62	16.80 ±6.53	22.17 ±4.57	28.94 ±10.18	13.24 ±2.31	17.06 ±4.16
12 years	4.44 ±1.08	5.82 ±2.97	7.78 ±1.81	8.55 ±2.13	5.43 ±0.95	6.41 ±2.08	5.19 ±1.37	5.53 ±2.15	13.21 ±2.42	15.03 ±3.80	22.85 ±4.12	26.31 ±7.11	13.57 ±2.00	15.91 ±3.11
Total	5.22 ±4.52	5.36 ±2.18	7.80 ±2.12	8.82 ±2.93	5.36 ±1.38	6.17 ±2.68	5.06 ±1.67	5.22 ±2.88	13.17 ±3.12	15.01 ±5.31	23.45 ±7.36	25.57 ±8.72	14.10 ±2.76	16.07 ±3.73
F-value*	2.36	2.90	1.83	4.88	1.73	12.49	2.39	9.12	1.19	8.29	1.92	9.66	2.81	5.08
p-value	0.02	0.00	0.08	0.00	0.09	0.00	0.02	0.00	0.31	0.00	0.06	0.00	0.007	0.00

*Age-specific mean differences, ± SD= standard deviations

Discussion

Human adiposity in body composition assessment is a resource for the energy cost required for growth, reproduction, immune function, heritability and hormonal secretions of adipose tissue which play a key regulatory role in these functions[2]. Population/ ethnic variations in adiposity and nutritional status can be attributed to several associated factors (e.g. sex, ethnicity, diet, physical exercise patterns, socio-economic status, environment and burden of infectious disease)[3,5,16,19,29,30,31,32,33,34]. Age-specific body adiposity increase has significant influence on the variation of subcutaneous adipose tissue[3,16,19,20,33,34,35]. However, the pronounced sex-specific difference was absent in the subcutaneous adipose tissue before puberty. Studies conducted among children of US[8,36], Netherlands[37] and Japan[38] showed insignificant sex-difference in abdominal and subcutaneous adipose tissue measured by skinfold thicknesses. Studies also showed that the attainment of puberty in girls tend to accumulate significantly higher adipose tissue than boys[3,16,19,29,35]. Several studies have reported sexual dimorphism in subcutaneous adiposity patter among children[3,9,16,19,18,33,35]. There were significant age-sex specific differences in subcutaneous adiposity pattern and PBF in children (Table 1). Several researchers have reported that the absolute skinfold thicknesses were higher in girls[3,16,18,19,29,35] but the demarcation in relative skinfold thickness were observed during puberty due to the increase in peripheral adipose tissue deposition in girls[5,9,29]. Such variation in subcutaneous adiposity can be attributed to sex-specific and genetic variations, sex-steroid hormones and environmental factors and it also serves as a good indicator of nutritional status of children[5,3,19,32].

Sexual dimorphism in adiposity levels primarily attributed to the action of sex steroid hormones[3,5]. Estrogen increases the fat storage, resulting in higher adipose tissue storage in females than in males. Moreover, the skinfold thicknesses directly measure subcutaneous adiposity and contributes to PBF[17,36]. Therefore, lower levels of adipose tissue gives rise to low levels of PBF or body composition indicating the poor nutritional conditions in children (Figure 2). However, several studies have provided the usefulness and validity of skinfold thickness in assessing body composition and nutritional status[10,16-20,29,35]. Population/ ethnic differences are observed in the accumulation of adipose tissue among children[8,10,33]. The results of the present investigation showed significantly higher adiposity among girls than boys (Table 1). The higher age-groups reaching puberty showed higher differences and higher values of skinfold thicknesses than the lower age groups. Comparison with NHANES-III reference population[28] showed very unsatisfactory nutritional status and also sex-specific differences in mean values were observed in children (Figure 2). Undernutrition is a major cause of concern in children and there is a scarcity of growth reference values for skinfold thickness (e.g. TSF, SSF, SISF and ∑TSF+SSF) except the reference values published by Frisancho[28] using NHANES-III data. This was why the results of the present investigation were compared to assess nutritional status and body composition. Several studies have reported that the children residing in rural areas were observed to be more vulnerable to unsatisfactory nutritional status than their urban counterparts where prevalence of overweight-obesity has become a cause of concern[3,30,32]. The lower adiposity levels among children could be the major indicator of undernutrition, which is actually being more frequent than overweight-obesity among Indian children[3,19,20,30,32]. The results of the present investigation will be useful for nutritionist, paediatrician and policy makers in their endeavour to formulate nutrition sensitive developmental and/or intervention strategies related to nutritional status and subcutaneous adiposity (i.e., body composition). Further studies should be conducted to formulate new ethnic specific standards and to identify the population specific undernutrition and body composition using skinfold among vulnerable segments of population.

Conclusion

Results of the present investigation showed the age-sex specific variations in subcutaneous adiposity pattern and subcutaneous adiposity was significantly greater among girls than boys. The comparisons of skinfold thicknesses with references showed unsatisfactory nutritional status among children. Hence, appropriate nutrition sensitive intervention programmes are necessary to ameliorate the nutritional situation. These findings are also important for future investigations in field, epidemiological and clinical settings.

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PUBLICATION LIST

	Publication Type	Title of the Paper	Journal Name	Year	Vol. No.	Page No.	ISSN No./ ISBN No.	Authorship
1.	International journal	Use of upper arm anthropometry, upper arm muscle area by height (UAMAH) and mid upper arm circumference (MUAC)-for height as indicators of body composition and nutritional status among children.	**Anthropological Review**	**2017**	80	85-102	20834594	First author
2.	International journal	Prevalence of thinness among rural children of West Bengal, India.	**Human Biology Review**	**2018**	7	362-385	22774424	First author
3.	International journal	Percent of body fat, fat mass, fat-free mass and assessment of body composition among rural school-going children of eastern-India.	**Anthropological Review**	**2018**	81	158-173	20834594	First author
4.	International journal	Subcutaneous adiposity and nutritional status among children of Eastern-India.	**Journal of Nepal Paediatric Society**	**2018**	38	38-45	1990-7974	First author
5.	International journal	Socioeconomic and demographic correlates of stunting and thinness among rural school going children (aged 5-12 years) of North Bengal, Eastern India.	**Journal of Life Sciences**	**2018**	10	29-46	2456-6306	First author

6.	International journal	Double burden of malnutrition among adolescents in India: A Review.	**Human Biology Review**	**2019**	8	155-178	22774424	First author
7.	International journal	Prevalence of Undernutrition and Overweight or Obesity Among the Bengali Muslim Population of West Bengal, India.	**Anthropology Open Journal**	**2018**	3	1-10	2473-4772	Second author
8.	International journal	Double burden of malnutrition among Bengalee Kayastha women of Siliguri town, Darjeeling district, West Bengal, India.	**Human Biology Review**	**2019**	8	367-380	22774424	First author
9.	Chapter in book	Prevalence of Double Burden of Malnutrition among Indian Children.	**Malnutrition: A Double Burden. Delhi: B.R. Publishing Corporation.**	**2018**	-	327-347	9789387587427	First author
10.	Chapter in book	Metabolic Disorder and Type-2 Diabetes Associations with Anthropometric Measures among Adult Asian Indians.	**Nova Science Publishers, New York.**	**2019**	-	167-199	9781536146707	First author
11.	National Journal	The WHO Multicentre Growth Reference Study (MGRS).	**North Bengal Anthropologist**	**2016**	4	208-213	2320-8376	First author
12.	National Journal	Forensic Anthropology.	**North Bengal Anthropologist**	**2017**	5	81-85	2320-8376	First author

13.	National Journal	Development of Dermatoglyphics in India	**South Asian Anthropologist**	**2020**	20	77-86	0257-7348	First author
14.	International Journal	Socio-economic and demographic correlates of composite index of anthropometric failure among rural children in West Bengal, India	**Man In India**	**2020**	100	73-90	0025-1569	Second author