Is attained height associated with overnutrition measures in adolescents?

A cross-sectional analysis of 15 years’ follow-up data in the Maternal and Infant Nutrition Interventions in Matlab (MINIMat) study in rural Bangladesh

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Abstract
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**Background:** As overnutrition rises along with nutrition transition in low- and middle-income settings such as Bangladesh, evaluating metabolic risk factors using overnutrition measures in adolescents is important. Before doing such evaluation, a preliminary step should be taken to attest the independence of overnutrition measures from total height. Moreover, sitting height measures are recognized as important metabolic risk indicators. This study aims to understand the association of attained height –total and sitting– with overnutrition measures including body mass index (BMI), percent body fat (PBF), fat mass index (FMI) and fat free mass index (FFMI) and to assess modification by sex.

**Methods:** Cross-sectional analysis of the MINIMat study’s 15-year follow-up data from October 2017 to December 2018 was undertaken. The associations of attained height –total and sitting– with each of the overnutrition measures were analysed using multiple linear regressions.

**Results:** Overnutrition measures were non-independent of total height among male adolescents. The taller they were, the higher their BMI would be. This increase of BMI along with the height would have been contributed relatively more by the increase of fat free mass (FFM) than that of fat mass (FM). When total heights of both sexes were kept equal at the median, female adolescents had lower lean mass (FFMI) and higher fat mass (FMI) than the males although there was no difference in BMI on average between them. Sitting height was associated with all overnutrition measures with varying extents depending on the sex.

**Conclusion:** When assessing overnutrition measures, it is important to examine beyond BMI and into FMI and FFMI. Again, when assessing the metabolic risks using overnutrition measures among adolescents, normalizing those indices for height is important to be considered to avoid inferring the implication from growth as risks.
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<td>BMI-for-Age Z-score</td>
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<td>BIHS</td>
<td>Bangladesh Integrated Household Survey</td>
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<td>BMI</td>
<td>Body Mass Index</td>
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<td>DHS</td>
<td>Demographic and Health Survey</td>
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<td>FFMI</td>
<td>Fat Free Mass Index</td>
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1. Introduction

1.1 Malnutrition and its forms

Malnutrition can be defined as simply as a condition of nutritional imbalances (1). According to the World Health Organization (WHO), malnutrition is defined as “the cellular imbalance between the supply of nutrients and energy and the body’s demand for them to ensure growth, maintenance, and specific functions.”(2) A scrutinized and expanded quest in some scholarly works (2–13) for a universal definition of malnutrition had led to a fact that the definition has been still evolving along with enduring global efforts. In a consensus statement endorsed by ESPEN (8), a set of diagnostic criteria for malnutrition applicable independently of aetiology and clinical setting in order to unify international terminology was presented. As this idea of dissociating the ways of diagnosing malnutrition from its definition had received reasonable critiques for not being unambiguous and comprehensive (10), other approaches of defining malnutrition that embraced the aetiological and outcomes-related perspectives were appraised as being more rational (3–5,9). Mehta et al (5) summarized five domains to be considered in defining malnutrition which were (a) anthropometric variables, (b) growth, (c) chronicity of malnutrition, (d) aetiology and pathogenesis and (e) developmental or functional outcomes. Certain things to be addressed in each of the domains were also recommended. In the domain of anthropometric variables, for instance, the questions about which type of anthropometric variables to be used, what reference to have the individual measurement plotted against, which statistical method to classify the nutritional status have to be attended. Again, regarding the aetiology it can be either related to illnesses such as diseases or trauma or not related to illnesses in cases such as starvation, poor socioeconomic situations and behavioural factors.

A joint statement by WHO and UNICEF articulated that the term malnutrition encompasses both undernutrition and overnutrition (14). The term ‘overnutrition’ was in deed ‘unbalanced’ nutrition indicated by overweight and obesity (15). As elaborated by Saskia et al (15), malnutrition can occur at different levels—individual, household or population level— and in a spectrum. At the individual level, it can be undernutrition—as measured anthropometrically as stunting, wasting or underweight—, overweight or obese—as measured by anthropometric indicators such as Body Mass Index (BMI), weight-for-height z-score, et cetera— and micronutrient deficiency—as in deficiency of vitamins and minerals. At the household level, food insecurity is a measure of malnutrition characterized
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by the decreased or lack of availability, access, stability and utilization of food by the households. At the population level, an instance of malnutrition is undernourishment—indicating the proportion of population who are not meeting energy requirement. Additionally, double burden of malnutrition can exist at individual, household and population levels. An individual who is stunted which is an outcome of uncorrected long-term undernutrition might at the same time be overweight/obese which is a result of recently unbalanced nutrition. A household might have one or more of its members with different problems and so be in the population.

1.2 Nutrition transition and the rise of overweight and obesity

The shift in dietary pattern and physical activity, along with consumption of energy dense food and adopting sedentary life style is described as nutrition transition (16). Accelerated increase in overweight and obesity in low-income countries is a result of such continued changes in lifestyle patterns (17). The rise in overweight and obesity is again related to the rapid shifts in adult-onset diabetes and several other non-communicable diseases (18). In many low-income countries, adult-onset diabetes and other comorbidities such as hypertension, dyslipidaemia and atherosclerosis have been increasing (19,20). These findings were revealed in the studies which focused on the population over 18 years of age.

1.3 Measures of overnutrition and body compositions

Body mass index (BMI) has been well ingrained for a long time in both clinical and public health practices for determining health risks and mortality. It is an anthropometric index in which body weight in kilograms is divided by height in meters squared. In children and adolescents, BMI is age and sex specific since body fatness varies with age and sex in them (21,22). The reference of the BMI-for-age in school-aged children and adolescents (6 to 19 years) to determine overweight and obesity was developed by WHO in 2007 and has been used widely (23,24).

The most known reasons of choosing BMI over other relative weight indices were its independence from height (25) and its proven association with body fatness albeit indirectly (25–28). The use of BMI per se was commonly rationalized by (a) its strong correlation with body weight while being independent of height and (b) its quality to correctly capture the relationship between weight and height (29,30). These might not always be true, especially in the earlier years of the life time. BMI had been increasing
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more in the taller 3 year-old children than their shorter peers (31). There were some other studies that showed that BMI was non-independent of height among 7 to 12 years old children (32).

BMI has limitation to distinguish between fat mass and fat free mass (lean mass) of the body (33–35). In any given population, a substantial variability of the fat mass exists with a relatively less variable fat free mass. BMI cannot then be a reliable index for any specific component of body composition (36,37). A person with a higher BMI, in any population, can simply be because they have a higher proportion of fat free mass and thus such healthy persons with high BMI can be miscategorised as though they had metabolic risk (38,39). And vice versa, those who have metabolic risk might fall within the normal BMI cut-offs. Lastly, there can also be systematic differences, between populations, in the average level of body fatness at a given value of BMI (40,41). For instance, Indians whether or not they were residing within Asia, had higher body fatness for a given value of BMI than other groups of ethnicity (42,43). The variation is not only in the body fatness but also in the metabolic risks such as insulin resistance. For example, South Asians have a greater proportion of body fat and they were found to be insulin resistant, compared to white Europeans of the same BMI values (42,44,45).

Detailed body composition measures such as percent body fat (PBF), fat mass (FM) and fat free mass (FFM) can serve the interest of understanding the differentiated components of body mass followed by understanding the role of them in malnutrition – both under- and overnutrition –, growth and ultimately the health outcomes. Fat mass and fat free mass are usually adjusted for height, the concept of which again based on the relationship of weight and height as in the case of BMI (46). As Barker presented in his paper (47), increased proportion of fat mass and decreased proportion of fat free mass were found to be associated with increased risk of cardiovascular diseases. In addition to the association with elevated risk, mortality in certain chronic diseases was found to be related to FM or FFM losses (48). Again in the clinical setting, overweight or obese patients with higher FMI to FFMI ratio was positively associated with longer length of stay in hospital (49). Wells et al summarized the available techniques of measuring body compositions into groups: (a) simple measures or indices such as skinfold thickness measurements, BMI and waist circumference, (b) predictive techniques using skinfold thickness measurements and bioelectrical impedance measurements, (c) two-component techniques and models and (d) multicomponent models (50).

A few highlights on some of the body composition measures which are simple measures
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or indices and predictive techniques were presented briefly in the following part of this section. Among the simple measures, skinfold thickness measurements have been useful to rank the relative fatness of a person and to assess the amount of subcutaneous fat storage (51). The limitation of BMI in differentiating the components of body composition was presented above. Waist circumference is a simple measure that can provide the information of central fatness. Waist-hip ratio is found independently associated with morbidity of metabolic and cardiovascular diseases after adjusting for relative weights in adults (52,53) and similar evidence have been emerging in children (54). Measuring body compositions, particularly percent body fat and body density, with the predictive technique using skinfold thickness measurements are facilitated by several equations which are usually applicable only to the population from which they were derived (50). Bioelectrical impedance analysis (BIA) assesses the impedance of the body to a small current of electricity. Assuming the body as comprised of a cylinder of length equivalent to height, BIA first estimates total body water (TBW) from height^2/impedance after adjusting for height. TBW is then converted to FFM (55,56). Various machines available for conducting BIA use in-built equations to predict the bioelectrical data (height^2/impedance) to TBW (57). The relationship between bioelectrical data and TBW may vary significantly between populations (58–60). Therefore, such relationship should be firstly established using validation studies which assessed impedance and TBW in a sample representative of the populations. This ideal is not always possible for every user usually because of time and cost constraints which render them the only option to use the equation derived from other population (37).

1.4 Adolescent malnutrition in the world and in Bangladesh

According to the UNICEF in April 2016 (61), the world’s adolescent population (age 10-19 years) was approximately 1.2 billion, making up to one fifth of the world’s population. A notable point was that South Asian region was home to the largest population of adolescents—around 340 million—in compared to the other regions. The classification of the regions was mentioned elsewhere (62). Segregated with income levels, the World bank estimated that nearly 90% of just over 1.2 billion adolescents in the world were living in low- and middle-income countries as at 2017 (63).

Taken a glance at some anthropometric indicators, malnutrition problems were seen in different patterns between male and female adolescents at the population level. While
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Overweight\(^1\) was a larger problem than thinness\(^2\) among the females, the male adolescents had thinness as a larger problem than overweight. The 2018 DHS comparative report summarized the most recent DHS surveys from low- and middle-income countries from 2001 to 2016 (64). In nearly half of 62 reporting countries, more than 10% of female adolescents (age 15 to 19 years) were overweight. Meanwhile, the prevalence of thinness among them was less than 2% in almost half of the reporting countries and between 2 to 10% in another near-half. An almost opposite pattern was seen in male adolescents (age 15 to 19 years). More than 10% of the male adolescents were found to be thin in nearly half of 17 reporting countries while the prevalence of overweight among them was 2 to 10% in over half of the reporting countries. The same report revealed that more than 10% of the adolescent females were stunted\(^3\) in half of the 62 reporting countries. All these facts provide a glimpse at the multi-faceted presentations of malnutrition in the non-affluent countries.

Leroy et al (65) analysed the 2011-2012 BIHS which was a nationally representative study of rural Bangladesh. It was found that almost 20% of both adolescent males and females aged 10-20 years (n=4093) were thin. Thinness was obviously a larger problem than the overweight, which was prevalent merely over 3% in both sexes. This pattern was no different between the males and the females. The adolescents of both sexes had a low height-for-age z-score (-1.62) on average. In a birth cohort (n=1930) of the MINIMat study in rural Bangladesh, the stunting prevalence by 14 years of age was 25% in both sexes (66).

1.5 Adolescence: windows of opportunity

The commencement of adolescence is characterized by the onset of physiologically normal puberty and the end of it by the acquirement of adult identity and behaviour. The chronological age of 10 to 19 years’ period in a person roughly denotes this particular stage of development. This age period is in consistency with the WHO’s definition of adolescence (67).

Prentice et al (68) underpinned an argument that adolescence, second to the first 1000 days of life, is the window of opportunity to rectify the sequelae of early-life nutritional deficiencies. Their summary highlighted a significant catch-up in height which happened

\(^1\) BMI-for-age z-score above +1 SD of the WHO child and adolescent growth reference median  
\(^2\) BMI-for-age z-score below -2 SD of the WHO child and adolescent growth reference median  
\(^3\) Height-for-age z-score below -2 SD of WHO child and adolescent growth reference median
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between 24 months and mid-childhood (referred as 48 months in the source studies) and again between mid-childhood and adulthood. Spear in his paper about adolescence growth (69) described that weight gain during the pubertal process in adolescence accounted for 50% of the ideal adult weight and that 15% of the adult final height was attained during such process. Rah et al (70) mentioned that many adolescents continued growing in their stature, even in the events of adolescent pregnancies (71,72).

In addition to the nutritional improvement window, adolescence has a unique window of opportunity as many changes are evolving in the body and mind (73). Adolescence period is densely packed with transitions in physiological, psychological and social environments of a person (70). It is a critical lifetime for a person to have prepared for a successful transition into adulthood. Transitions, being said, are not immune to a variety of risks and can be perilous in one way or the other for all the adolescents. Adolescent girls in particular are having higher risks and more vulnerable especially in the context of prevalent norms for unequal gender roles and in the situations where child marriage and adolescent pregnancy are common (74,75).

1.6 ‘Short and fat’ or ‘tall and fat’?

Exposures to deprived environment and nutritional restrictions in foetal life and infancy can lead to stunting in adolescence and short stature in adult life (76,77). In addition, there was ample evidence that long-term unbalanced nutrition in utero and infancy increases the risk of obesity and development of non-communicable diseases in later life (78,79). Unsurprisingly, stunting which is the outcome of chronic undernutrition, was positively associated with adult overweight and obesity (80–82). Although the evidence of such relationships among children and adolescent age groups was relatively scanty, a study on Latin American and Caribbean preschool children had found out the association between stunting and overweight (83).

A study of 303 children (age 6-16 years) with simple obesity (84) observed the difference of their height in compared to the children with normal weight. It was found that younger children (age 6 to 9 years) with simple obesity were taller than their normal-weight peers by around 1 SD. However, as their ages transited into adolescence (age 10 to 16 years), their height for the age became close to or lower than the average. This was also supported in some earlier longitudinal studies (85). Another study in younger children (31) had shown that taller children were having much higher increase in BMI than their shorter peers. These previous findings signalled the need for more understanding of the dynamic
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of the relationship between height and overnutrition measures particularly among children and adolescents.

1.7 Sitting height measures: useful biomarkers for assessing metabolic risks

An anthropometric indicator which is useful in evaluating metabolic risks is the measure of sitting height (SH). SH has been recognized as important in the evaluation of children with growth and pubertal disorders. Moreover, it has been viewed as a useful biomarker of cardiovascular risk, which is increased in adults with relatively short legs (86,87). Burton et al proved the statistical privilege of using sitting height in predicting body mass status better than BMI (88). Assessing the relationships between sitting height attained during adolescence and overnutrition measures including BMI and other body composition measures would be an asset in understanding the potential application of it in accessing the risks.

1.8 Rationale of the current study

In evaluating health risks of overnutrition using body composition measures especially in adolescents, there is an emerging need to elucidate the relationship between BMI and body composition mainly because overweight can be a result of increase in body mass, either fat or lean (section 1.3). Many more children who were at risk of overnutrition related conditions cannot be apparent if the BMI and its reference percentiles or standard deviation scores were of sole reliance in screening. This is especially applicable as in the case of studying South Asian population because of the so-called South Asian body phenotype which is comprised of low lean mass, high percent body fat and tendency to central adiposity in compared to other populations (89,90). Moreover, Asians in general not only have higher PBF at a lower BMI but higher body fat percentiles was also found to be related to insulin resistance (91).

Preliminary to addressing this emerging need, a crucial step to be taken carefully is to elicit the association between height and overnutrition measures. One of the rationales of using BMI or even FMI and FFMI for being independent of height should rather be attested than assumed. Thus, whether or not there are any associations between total attained height and overnutrition measures such as BMI, PBF, FMI and FFMI should be assessed. As mentioned in section 1.7, assessing the association between sitting height and these overnutrition measures would also contribute to the foundation of further analyses involving sitting height measures. If any associations were found out, additional
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knowledge would be generated for how overnutrition measures would change along with the attained height –both total and sitting– and whether those changes were specific to the sex of the adolescents or not.

1.9 Aim and objectives

Aim
To understand the associations between attained height and overnutrition measures

Objective
To assess whether attained height –total and sitting– is associated with overnutrition measures such as BMI and body compositions (PBF, FMI & FFMI) and whether there are stratifications by adolescent sex

2. Methods
2.1 Study setting

With the collaboration among the International Centre for Diarrheal Disease Research, Bangladesh (icddr,b), Uppsala University and other international partners, MINIMat study was carried out in Matlab, Bangladesh. Matlab is a rural sub-district, 57 km south of the capital Dhaka. It is an area where icddr,b has been implementing a Health and Demographic Surveillance System (HDSS) with a population coverage of 220,000 since 1966. MINIMat study enrolled pregnant women in the Matlab area over 2 years’ period from 2001 to 2003. Since then, repeated follow-ups of the cohort of mothers and their offspring were made. The details of the profile of the cohort was mentioned elsewhere (92). The most recent follow-up was the 15-year follow-up started in the last quarter of 2017. The brief overview of the timeline since the outset of the MINIMat study till the 15-year follow-up was summarized in the annex-1.

2.2 Study design and population

Cross-sectional analysis of the 15-year follow-up data of the MINIMat study was undertaken. Adolescents who were followed-up in this study were born between May 2002 and September 2003. The follow-up was initiated by household visits from October 2017 to September 2018. Adolescents were then invited to four health centres where
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measurements of their anthropometry and body compositions were taken. Those health-centre visits took place from October 2017 to December 2018. Study participants in this cross-sectional analysis were the adolescents with the information of anthropometry, body compositions and their households. The flow of participants in particular to the 15-year follow-up is presented in figure-2 in the result section.

2.3 Collection of data

During household visits, the information including of maternal education, adolescent’s education, household food insecurity and household wealth were assessed by interviewing mothers or caregivers of the adolescents with the use of structured questionnaire. The interviewers were community health research workers who had completed at least ten years of education.

During visits to health centres, anthropometry and body compositions of the adolescents were measured by a team of nurses, a medical doctor, and a laboratory technician, assisted by trained field staff. Attained height – total height (Ht) and sitting height (SH) were measured in centimetre (cm) to the nearest first decimal place of one, using a freestanding stadiometer which was complimented by a horizontal sitting plane in measuring the latter. Body compositions including of fat mass (FM), fat free mass (FFM) and percent body fat (PBF) were assessed by bioelectrical impedance analysis (BIA) machine; Tanita TBF-300A. The machine assessed leg-to-leg bioelectrical impedance and applied it in an in-built prediction equation to estimate FM, FFM and PBF (93). Body weight (Wt) was measured using Tanita TBF-300A. While doing all these measurements, the adolescents were barefoot and in light clothes. Wt was recorded with automatic adjustment for weight of clothes.

2.4 Variables

2.4.1 Outcome variables

BMI-for-age z-score (BAZ), as a continuous variable, indicates the number of standard deviations by which a BMI-for-age value is above or below the WHO school-aged children and adolescent growth reference median. For instance, a random z-score of +1.3 tells us that the adolescent’s BMI-for-age is 1.3 standard deviation above the reference median.

Each of the SD scores of FMI, FFMI and PBF informs the number of standard deviations by which a value of the respective indicator is above or below their means in
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the study sample. The indices of FM and FFM were obtained by dividing the respective masses in kg by height in m².

2.4.2 Exposure variables

Attained total height in term of height-for-age z-score (HAZ) is a continuous variable which indicates the number of standard deviations by which a certain value of height-for-age is above or below the WHO school-aged children and adolescent growth reference median. Attained sitting height (SH) in term of sitting height standard deviation score (SH SDS) tells us the relative distance in standard deviation of any given value of SH from its mean in the study sample.

2.4.3 Covariables

In this study, the adolescents’ sex was treated as the effect modifying variable in whichever associations between the exposure and outcome variables. Maternal as well as the adolescents’ education levels were co-variables categorized based on the completed years of formal education. Household wealth index was the standardized household wealth index score which included multiple items such as source of drinking water, land ownership, construction materials of house walls, household assets ownership, etc (94). The index scores of the sample of the 15-year follow-up (n=1360) was sliced into quintiles of household wealth orderly as; ‘poorest’, ‘poorer’, ‘middle’, ‘richer’ and ‘richest’.

Another covariable was household food insecurity category variable. Firstly, the original data from MINIMat was recoded in accordance with the Household Food Insecurity Access Scale (HFIAS) (95). The HFIAS assessed 9 items, each of which were the past 4-weeks’ period recall questions with 4 possible frequency responses (9I4F) as ‘never’, ‘rarely’ (1-2 times), ‘sometimes’ (3-10 times) and ‘often’ (>10 times). The original household questionnaire of the MINIMat study assessed the same 9 items as HFIAS did, albeit with 5 possible frequency responses (9I5F): (a) never, (b) 1-3 times in last 30 days, (c) once in 7 days, (d) 2-3 times in 7 days and (e) at least 4-5 times in 7 days. Those five frequencies were recoded into four as follow: ‘a’ into ‘never’ (recoded as 0), ‘b’ into ‘rarely’ (recoded as 1), ‘c’ and ‘d’ into ‘sometimes’ (recoded as 2) and ‘e’ into ‘often’ (recoded as 3). Secondly and using the criteria as in HFIAS indicator guide (95), the newly recoded 9 items with 4 frequencies (9I4F) were categorized orderly as ‘food secure’, ‘mildly food insecure access’, ‘moderately food insecure access’ and ‘severely
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food insecure access’.

2.4.4 Management of variables

Statistical software R version 3.5.3 (96) on macOS Mojave 10.14.4 was used to manage the variables as necessary. Age in completed months with reference to the date of health-center visit since the date of birth were calculated using ‘age_calc’ function from R package ‘eeptools’ (97). BMI, HAZ and BAZ were calculated using R package ‘WHO 2007’ (98) which took account of these compulsory parameters such as age in completed months and not rounded, sex, height in cm and weight in kg. The resulted BMI, HAZ and BAZ were thus age and sex specific. Among the resulted BAZ values, those below -5 SD or above +5 SD were flagged automatically as biologically implausible. Those values of HAZ below -6 SD or above +6 SD were also flagged. To calculate the quintiles of household wealth, ‘quantcut’ function from R package ‘gtools’ was used (99).

2.4.5 Missing values

All the missing values in anthropometric measurements were excluded. Observations with missing values in covariables were included in univariate analyses. They were nevertheless dropped throughout the bivariate and multivariate analyses.

2.5 Statistical analyses

2.5.1 Frame of analysis

Statistical software R version 3.5.3 (96) on macOS Mojave 10.14.4 was used for the statistical analyses in this study. The statistical analyses in this study were framed in a simplified mapping (figure-1) of the associations among the variables which were explicated in the section above.
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- adolescent’s education
- maternal education
- household wealth
- household food insecurity

Attained height (total & sitting height) \[\rightarrow\] Overnutrition measures \(^a\)

adolescent’s sex

\(^a\)Body Mass Index (BMI), Percent Body Fat (PBF), Fat Mass Index (FMI) & Fat Free Mass Index (FFMI)

**Figure 1.** Simplified map of variables and their associations under research

2.5.2 Steps of analysis and applied statistical tests

Univariate analyses of the key variables were performed to describe the characteristics of the study participants as pertinent to the theme of the study, and to explore the summary statistics visualizing the nature of the spread of their data at the entire population level using R package ‘packHV’ (100) as well as by sex groups using R packages ‘easyGgplot2’ (101) and ‘gridExtra’ (102). The univariate analyses were followed by primary bivariate analyses with the purpose of answering the following research questions, the refinement of which were governed by the map in figure-1.

1.1 Is HAZ associated with BAZ?
1.2 Is HAZ associated with PBF SDS?
1.3 Is HAZ associated with FMI SDS?
1.4 Is HAZ associated with FFMI SDS?
1.5 Is SH SDS associated with BAZ?
1.6 Is SH SDS associated with PBF SDS?
1.7 Is SH SDS associated with FMI SDS?
1.8 Is SH SDS associated with FFMI SDS?

The significance level of all the test statistics were set at 0.05. Pearson’s correlation coefficients were calculated in assessing the relationship between continuous variables. A line of best fit that used the linear model of regressing the outcome variables onto the
Is attained height associated with overnutrition measures?

exposure variables was overlaid on the scatter plots calculating the coefficients of
determinations. This was accomplished by using the R packages ‘ggplot2’ (103) and
‘ggpubr’ (104).

Secondary bivariate analyses were performed to examine whether the key exposure
and outcome variables were associated with the covariables. When comparing the means
of different groups, the homoscedasticity assumption was preliminarily checked by
Levene’s test, using an R package ‘car’ (105). If homoscedasticity assumption was
fulfilled for the two independent groups, ‘two-sample t test’ was performed. Otherwise,
non-parametric equivalent Welch’s test was performed. When comparing the means of
more than two groups, analysis of variance (ANOVA) was undertaken and in cases of
heteroscedasticity, Welch’s ANOVA for unequal variances was chosen.

Multivariate analyses were undertaken based on the preceding findings in bivariate
analyses. Multiple linear regression models were developed for each of the four outcome
measures considering the exposure and covariables which presented an association during
bivariate analyses. When the association between the main exposure and outcome was still
significant in multiple linear regressions, a follow-up multiple linear regression was
developed by adding a statistical interaction term between the main exposure and sex.

2.5.3 Interpreting the effect of the interaction

The example for a simple equation of multiple regression would be as follow;

\[ Y = a + b_1 X_1 + b_2 X_2 + b_3 X_1 \times X_2 \]

where \( Y \) = outcome variable, \( a \) = intercept,

\( X_1 \) = exposure, \( X_2 \) = sex,

\( X_1 \times X_2 \) = interaction between exposure and sex,

\( b_1 \) or \( b_2 \) or \( b_3 \) = respective coefficients of regression.

When \( b_3 \) (the coefficient of interaction term) was significant, it meant that the effect of \( X_1 \)
on \( Y \) is conditional on \( X_2 \). As suggested in these discussions (106,107), the extent of the
effect of \( X_1 \) on \( Y \) would be;

\[ (b_1 + b_3 X_2) \times X_1 \]

When \( X_2 = 0 \) (i.e., male), the extent of the effect of \( X_1 \) on \( Y \) would be \( b_1 \times X_1 \) and the
confidence interval of the coefficient was taken directly from \( b_1 \).
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When $X_2 = 1$ (i.e., female), the extent of the effect of $X_1$ on $Y$ would be $(b_1+b_3) * X_1$ and the confidence interval of the coefficient can be calculated as suggested elsewhere (106). However, since the statistical method in dealing with covariance matrix was complicated and advanced for the author to handle, corresponding stratified analyses for the female stratum was undertaken. Although the complete results of those stratified analyses were not presented, the parameter estimates (confidence interval in this case) were extracted from those models and were reported at relevant points.

2.6 Ethical consideration

The MINIMat trial and the subsequent follow-ups of the children, including the most recent follow-ups at 15 years of age (PR# 17029 date 2017/05/23), have been reviewed and approved by the icddr,b Ethical Review Committee in Dhaka, Bangladesh. All studies have been conducted in accordance with the Helsinki Declaration. Informed consent was sought from the parents of the participating mothers and assent was obtained from the adolescents. The parents or guardians of the subjects were informed about the procedures at each visit and the freedom to decline participation at any time. Once consent from parents and assent from adolescents was obtained, they were interviewed in person by a trained interviewer. Refusal to participate did not affect any of the routine health care they receive through icddr,b.

3. Results

3.1 Flow of participants

Figure 2. Flow of participants

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The 15-year follow up started with household visits from October 2017 to December 2018 and assessed 1,424 participants. In the following health-centre visits, 1,360 adolescents were assessed. There were 64 absentees between household and health-centre visits, mainly due to the reasons such as family problems, refusal or unavailability. Height was missing in 2 participants and those observations were excluded. There were no participants with biologically implausible SDs in HAZ and BAZ, flagged by the function WHO 2007. Arbitrary cut-offs of ‘below -6 SD’ or ‘above +6 SD’ were set also in SDS of FMI, FFMI and PBF. Thus, 2 additional participants were excluded because their FFMI SDS were outside the cut-offs. Of the remaining, missingness in all the variables mentioned in section 2.4 were checked and subsequently excluded.

3.2 Main characteristics of participants

**Table 1. Characteristics of study participants**

<table>
<thead>
<tr>
<th></th>
<th>n/n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Adolescent Sex</strong></td>
<td></td>
</tr>
<tr>
<td>female</td>
<td>689/1356 (51%)</td>
</tr>
<tr>
<td>male</td>
<td>667/1356 (49%)</td>
</tr>
<tr>
<td><strong>BAZ in category</strong></td>
<td></td>
</tr>
<tr>
<td>obese (BAZ &gt; 2 SD)</td>
<td>17/1356 (1%)</td>
</tr>
<tr>
<td>overweight (1 &lt; BAZ ≤ 2 SD)</td>
<td>66/1356 (5%)</td>
</tr>
<tr>
<td>normal (-2 ≤ BAZ ≤ 1)</td>
<td>994/1356 (73%)</td>
</tr>
<tr>
<td>thin (BAZ &lt; -2)</td>
<td>279/1356 (21%)</td>
</tr>
<tr>
<td><strong>Stunting</strong></td>
<td></td>
</tr>
<tr>
<td>Stunted (HAZ &lt; -2 SD)</td>
<td>270/1356 (20%)</td>
</tr>
<tr>
<td>Non-stunted (HAZ ≥ -2 SD)</td>
<td>1,086/1356 (80%)</td>
</tr>
<tr>
<td><strong>Adolescents’ education level</strong></td>
<td></td>
</tr>
<tr>
<td>no education</td>
<td>106/1,348 (8%)</td>
</tr>
<tr>
<td>Enrolled in primary (1 to 5 years)</td>
<td>43/1,348 (3%)</td>
</tr>
<tr>
<td>Completed primary (&gt;5 years)</td>
<td>1,199/1,348 (89%)</td>
</tr>
<tr>
<td><strong>Maternal education level</strong></td>
<td></td>
</tr>
<tr>
<td>no education</td>
<td>280/1,310 (21%)</td>
</tr>
<tr>
<td>Enrolled in primary (1 to 5 years)</td>
<td>475/1,310 (36%)</td>
</tr>
<tr>
<td>Completed primary (&gt;5 years)</td>
<td>555/1,310 (42%)</td>
</tr>
<tr>
<td><strong>Household food insecurity in categories</strong></td>
<td></td>
</tr>
<tr>
<td>Severely food insecure</td>
<td>44/1,355 (3%)</td>
</tr>
<tr>
<td>Moderately food insecure</td>
<td>81/1,355 (6%)</td>
</tr>
<tr>
<td>Mildly food insecure</td>
<td>550/1,355 (41%)</td>
</tr>
<tr>
<td>Food secure</td>
<td>680/1,355 (50%)</td>
</tr>
</tbody>
</table>

BAZ = BMI-for-age z-score, HAZ = Height-for-age z-score
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The mean age of the adolescents in this study was 15 years (SD 0.16). In compared to the reference population, the adolescents in MINIMat study were on average thinner with a mean BAZ of -0.99 (SD 1.22) and shorter with a mean HAZ of -1.25 (SD 0.9). The mean PBF was 17.62 % (SD 9.61). The mean FMI was 3.44 kg/m² (SD 2.41) and the mean FFMI was 14.86 kg/m² (SD 1.47). The mean SH was 118.5 cm (SD 3.98). Basic characteristics of the study population were described in table-1. The distribution of wealth characteristics in the study population was presented in the annex-2. Further exploratory univariate analyses contributed to understanding of distributions of anthropometric and body composition measurements. Basic histograms with the boxplots for the key variables were presented in the annex-3 to portray the distribution of data in the entire sample population. Figure-3 provided a visualization to the distributions of those variables by sex groups of the adolescents. In compared to the male adolescents (BAZ mean -1.25, SD 1.25), female peers were less thin (BAZ mean -0.73, SD 1.14). Adolescent males were less short (HAZ mean -1.18, SD 0.98) than the adolescent females (HAZ mean -1.32, SD 0.80). The males had taller sitting height (SH SDS mean 0.3, SD 1.11) than the females (SH SDS mean -0.31, SD 0.76). Apparently, female adolescents were less lean than their male peers because they had an apparently higher mean SD scores of PBF and FMI while their mean SD score of FFMI was lower (figure-3D, 3E & 3F).
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3.3 Main results of primary bivariate analyses

Both total and sitting height had positive correlations with BMI-for-age z-score and fat free mass index (FFMI) SD score. Whilst total height had no significant correlation with percent body fat (PBF) SD score, sitting height had a significant and negative correlation.

Figure 3. Histograms (with mean lines) stacked by sex groups (n=1,356)
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with PBF SDS. None of the height measures were correlated with fat mass index (FMI) SD score.

3.3.1 Associations of attained total height (HAZ) with the outcome variables

![Scatter plots](image)

**Figure 4.** Scatter plots for association between HAZ and outcome variables (n=1,303)

Attained height had positive correlations with BAZ (Pearson correlation coefficient $R=0.17$ & 95%CI: 0.11, 0.22) and FFMI ($R=0.21$ & 95%CI: 0.15, 0.26). In figure-4, the lines of best fit were laid over the scatter plots using the method linear model in which the outcomes variables were fitted against the exposure variable of HAZ. The coefficients of determination ($R^2$) were calculated in each assessment using the respective lines of best fit. Nearly 3% of variations in BAZ ($R^2=0.027$) and 4% in FFMI SDS ($R^2 = 0.042$) could
Is attained height associated with overnutrition measures?

be explained when HAZ was taken into account. Attained height had no correlation with either percent body fat (PBF) or fat mass index (FMI).

3.3.2 Association of attained sitting height (SH SDS) with the outcome variables

![Graphs showing correlations between SH SDS and outcome variables](image)

**Figure 5.** Scatter plots for association between SH SDS and outcome variables (n=1,303)

Sitting height had a positive correlation with BAZ ($R = 0.25$, $p < 2.2e-16$, $R^2 = 0.083$) whereas it had a negative correlation with PBF SDS ($R = -0.1$, $p = 0.00025$, $R^2 = 0.01$). About 6% of variations in BAZ and 1% of variations in PBF SDS could be explained when sitting height SDS was taken into account. Sitting height had a positive correlation with FFMI SDS ($R = 0.47$, $p = 0.29$, $R^2 = 0.00085$). When FFMI SDS was regressed on SH SDS and a line of best fit was overlaid over the scatterplot (figure-5D), it was found that approximately 22% of variations in FFMI SDS could be explained when taking SH SDS into account ($R^2=0.22$). Sitting height and fat mass index were not correlated.

3.4 Main results of secondary bivariate analyses

3.4.1 Associations of attained height with covariables

**Total height** (HAZ) was associated with all covariables except household food insecurity. HAZ was associated with adolescent education (ANOVA $F$-statistic 11.16, $P$-value < 0.001), maternal education levels (ANOVA $F$-statistic 14.21, $P$-value <0.001) and
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Household wealth (ANOVA F-statistic 12.34, P-value < 0.001). HAZ was not associated with household food insecurity. Although there was borderline significance in the F-statistic of ANOVA (P-value = 0.0497), post-hoc pair-wise Tukey test proved that none of the pairs of household food insecurity categories had a significant difference in means of HAZ.

**Sitting height** (SH SDS) was associated with all covariates except household food insecurity. SH SDS was associated with adolescents’ education level (ANOVA F-statistic 7.26, P-value <0.001), maternal education level (ANOVA F-statistic 11.75, P-value < 0.001) and household wealth (ANOVA F-statistic 10.04, P-value < 0.001). There was no association found between sitting height and household food insecurity access categories (ANOVA F-statistic 2.08, P-value=0.102).

### 3.4.2 Association of overnutrition measures with covariates

**BMI-for-age z-score** was associated with all four covariates. BAZ was associated with adolescents’ education level (ANOVA F-statistic 7.71, P-value <0.001), maternal education level (ANOVA F-statistic 3.81, P-value=0.022), household wealth (Welch’s ANOVA for unequal variances F-statistic 14.65, P-value < 0.001) and household food insecurity (ANOVA F-statistic 4.55, P-value=0.004).

**Percent body fat** (PBF) was associated with adolescents’ education level (Welch’s ANOVA for unequal variances F-statistic 4.55, P-value=0.004) and household wealth (Welch’s ANOVA for unequal variances F-statistic 4.92, P-value=0.001). It had no association with either maternal education level (ANOVA F-statistic 0.86, P-value=0.424) or household food insecurity. Although there was borderline significance in ANOVA (F-statistic 2.63, P-value=0.0489) between PBF and household food insecurity, the post-hoc Tukey test could not find any difference in means of PBF across the different groups of household food insecurity with non-significant P-values in each possible pairs.

**Fat mass index** (FMI) was associated with two of the covariates. FMI SDS was associated with adolescent’s education level (Welch’s ANOVA for unequal variances F-statistic 22.64, P-value < 0.001), household wealth (Welch’s ANOVA for unequal variances F-statistic 7.17, P-value < 0.001) and household food insecurity (Welch’s ANOVA for unequal variances F-statistic 3.09, P-value=0.029). FMI SDS was not associated with maternal education level.

**Fat free mass index** (FFMI) was associated with all four covariates. FFMI SDS was associated with adolescent’s education level (ANOVA F-statistic 9.42, P-value < 0.001),
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maternal education level (ANOVA $F$-statistic 4.26, $P$-value=0.014), household wealth (Welch’s ANOVA for unequal variances $F$-statistic 14.66, $P$-value < 0.001) and household food insecurity (ANOVA $F$-statistic 6.19, $P$-value < 0.001).

3.5 Main results of multivariate analyses

3.5.1 Multiple linear regressions of the outcome variables on total height

The effect of total height on BMI was found conditional to the sex of the adolescent (significant coefficient of interaction term with $P$-value < 0.001). While one $z$-score

Table 2. Multiple linear regression of BAZ on total height and other covariables (n=1,303)

<table>
<thead>
<tr>
<th>Variables</th>
<th>model without interaction</th>
<th>model with interaction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Adjusted $b$ (95% CI) a</td>
<td>$P$-value b</td>
</tr>
<tr>
<td>HAZ</td>
<td>0.2 (0.13, 0.27)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Adolescent education</td>
<td></td>
<td></td>
</tr>
<tr>
<td>no education d</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>enrolled in primary (1 to 5 y)</td>
<td>-0.68 (-1.09, -0.26)</td>
<td>0.001</td>
</tr>
<tr>
<td>completed primary (&gt;5 y)</td>
<td>-0.33 (-0.56, -0.09)</td>
<td>0.007</td>
</tr>
<tr>
<td>Maternal education</td>
<td></td>
<td></td>
</tr>
<tr>
<td>no education d</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>enrolled in primary (1 to 5 y)</td>
<td>-0.14 (-0.32, 0.03)</td>
<td>0.105</td>
</tr>
<tr>
<td>completed primary (&gt;5 y)</td>
<td>-0.12 (-0.3, 0.06)</td>
<td>0.201</td>
</tr>
<tr>
<td>Wealth quintile</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poorest d</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Poorer</td>
<td>0.1 (-0.1, 0.3)</td>
<td>0.328</td>
</tr>
<tr>
<td>Middle</td>
<td>0.41 (0.2, 0.61)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Richer</td>
<td>0.31 (0.11, 0.52)</td>
<td>0.003</td>
</tr>
<tr>
<td>Richest</td>
<td>0.79 (0.57, 1.01)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male d</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Female</td>
<td>0.60 (0.48, 0.73)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>HAZ*Sex</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HAZ*female</td>
<td>-0.33(-0.47, -0.19) f</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

HAZ = height-for-age z-score

a Adjusted regression coefficients, b Multiple Linear Regression ($R^2=0.07$), c Multiple Linear Regression with interaction term ($R^2=0.14$), d Base categories: coded as 0

e the effect of HAZ when sex = 0, i.e., male,
f the effect of HAZ when sex = 1, i.e., female
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Increase of total height in the male adolescents would increase their BMI by 0.33 z-score (95%CI: 0.24, 0.43) on average, such increase in the female adolescents would not have any change in BMI (95%CI: -0.1, 0.11) on average (table-2).

When the total heights of the male and female adolescents were kept equal at the median value (i.e., HAZ = 0), there would be no difference in their BMI (P-value=0.099, 95%CI: -0.03, 0.4). Since the adolescents’ education level, maternal education level and household wealth were found to be associated with both the exposure (HAZ) and outcome (BAZ), the effect of those variables were controlled in the model (table-2).

**Total height** had significant and positive associations with **PBF SDS** (regression coefficient=0.08) and **FMI SDS** (regression coefficient=0.07) in separate multivariate analyses in the male adolescents (data not reported). However, total height of the female adolescents was not associated with either FMI or PBF. When the total heights of the male and female adolescents were kept equal at their median value (i.e., HAZ = 0), the females would have on average a higher PBF by 1.23 SDS as well as a higher FMI by 1.5 SDS than the male peers.

**Total height** was associated with **fat free mass index** (table-3). And the effect of total height on FFMI varied depending on the sex of the adolescents (coefficient of interaction term P-value<0.001). While a unit increase in HAZ of the male adolescents would have an increase of FFMI by 0.26 SDS on average (95%CI: 0.2, 0.32), such increase in the female adolescents would not have any change in FFMI on average (95%CI: -0.1, 0.03). Nevertheless, the female adolescents would have a lower FFMI by 1.39 SD score (P-value < 0.001, 95%CI: 1.54, 1.25) than the males when the total height values of both sexes were kept equal at the median value (i.e., HAZ = 0). Since HAZ and FFMI were found associated with adolescents’ education level, maternal education level and household wealth during bivariate analyses, the effect of them was controlled in the model (table-3).
Is attained height associated with overnutrition measures?

Table 3. Multiple linear regression of FFMI SDS on total height and other co-variables (n=1,303)

<table>
<thead>
<tr>
<th>Variables</th>
<th>model without interaction</th>
<th>model with interaction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Adjusted b (95% CI)</td>
<td>P-value</td>
</tr>
<tr>
<td>HAZ</td>
<td>0.14 (0.09, 0.19)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Adolescent education</td>
<td></td>
<td></td>
</tr>
<tr>
<td>no education</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>enrolled in primary (1 to 5 y)</td>
<td>-0.37 (-0.64, -0.09)</td>
<td>0.009</td>
</tr>
<tr>
<td>completed primary (&gt;5 y)</td>
<td>-0.21 (-0.37, -0.05)</td>
<td>0.009</td>
</tr>
<tr>
<td>Maternal education</td>
<td></td>
<td></td>
</tr>
<tr>
<td>no education</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>enrolled in primary (1 to 5 y)</td>
<td>-0.1 (-0.22, 0.01)</td>
<td>0.087</td>
</tr>
<tr>
<td>completed primary (&gt;5 y)</td>
<td>-0.09 (-0.21, 0.04)</td>
<td>0.164</td>
</tr>
<tr>
<td>Wealth quintile</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poorest</td>
<td>0.04 (-0.1, 0.17)</td>
<td>0.587</td>
</tr>
<tr>
<td>Poorer</td>
<td>0.23 (0.1, 0.37)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Middle</td>
<td>0.19 (0.05, 0.33)</td>
<td>0.007</td>
</tr>
<tr>
<td>Richer</td>
<td>0.42 (0.28, 0.57)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Richest</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Female</td>
<td>-1 (-1.1, -0.93)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>HAZ*Sex</td>
<td>-0.3 (-0.39, -0.21)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

HAZ = Height-for-age z-score

a Adjusted regression coefficients, b Multiple Linear Regression ($R^2=0.36$), c Multiple Linear Regression with interaction ($R^2=0.38$), d Base categories: coded as 0

Effect of HAZ when sex = 0, i.e., male
e Effect of HAZ when sex = 1, i.e., female
f Effect of HAZ when sex = 1, i.e., female

3.5.2 Multiple linear regressions of the outcome variables on sitting height

Sitting height had a positive association with BMI (table-4). A unit increase in sitting height SD score would increase BMI by 0.4 z-score ($P$-value < 0.001, 95%CI: 0.34, 0.46) on average. On average, the female adolescents would have a higher BMI by 0.84 z-score ($P$-value < 0.001, 95%CI: 0.71, 0.97) than the male peers when sitting height values of both sexes were kept equal at the mean value (i.e., SH SDS = 0). As the coefficient of interaction term was not significant ($P$-value=0.55), the association of sitting height with BMI was not conditional upon sex. Since the adolescents’ education level, maternal education level and household wealth were found to be associated with both the exposure
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(SH SDS) and the outcome (BAZ), the effect of those variables were controlled in the model (table-4).

### Table 4. Multiple linear regression of BAZ on sitting height and other co-variables (n=1,303)

<table>
<thead>
<tr>
<th>Variables</th>
<th>model without interaction</th>
<th>model with interaction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Adjusted $b$ (95% CI) $^a$</td>
<td>$P$-value $^b$</td>
</tr>
<tr>
<td>SH SDS</td>
<td>0.4 (0.34, 0.46)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Adolescent education</td>
<td></td>
<td></td>
</tr>
<tr>
<td>no education $^d$</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>enrolled in primary (1 to 5 y)</td>
<td>-0.53 (-0.93, -0.14)</td>
<td>0.009</td>
</tr>
<tr>
<td>completed primary (&gt;5 y)</td>
<td>-0.34 (-0.57, -0.11)</td>
<td>0.004</td>
</tr>
<tr>
<td>Maternal education</td>
<td></td>
<td></td>
</tr>
<tr>
<td>no education $^d$</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>enrolled in primary (1 to 5 y)</td>
<td>-0.13 (-0.29, 0.04)</td>
<td>0.13</td>
</tr>
<tr>
<td>completed primary (&gt;5 y)</td>
<td>-0.14 (-0.31, 0.04)</td>
<td>0.13</td>
</tr>
<tr>
<td>Wealth quintile</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poorest $^d$</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Poorer</td>
<td>0.12 (-0.07, 0.31)</td>
<td>0.22</td>
</tr>
<tr>
<td>Middle</td>
<td>0.39 (0.2, 0.59)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Richer</td>
<td>0.3 (0.1, 0.5)</td>
<td>0.004</td>
</tr>
<tr>
<td>Richest</td>
<td>0.75 (0.54, 0.96)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male $^d$</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Female</td>
<td>0.84 (0.71, 0.97)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>SH SDS*Sex</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SH SDS*female</td>
<td>-0.13 (-0.27, 0.002) $^f$</td>
<td>0.055</td>
</tr>
</tbody>
</table>

SH SDS = sitting height standard deviation score  
$^a$ Adjusted regression coefficients, $^b$ Multiple Linear Regression ($R^2$=0.20),  
$^c$ Multiple Linear Regression with interaction term ($R^2$=0.20),  
$^d$ Base categories: coded as 0  
$^e$ the effect of SH SDS when sex = 0, i.e., male  
$^f$ the effect of SH SDS when sex = 1, i.e., female

As shown in table-5, the effect of sitting height on PBF was conditional upon adolescent sex (coefficient of interaction term $P$-value=0.013). While a unit increase of sitting height SD score in the male adolescents would have an increase in their PBF by 0.1 SDS on average (95%CI: 0.05, 0.15), such increase in the female adolescents would have an increase in PBF by 0.2 SDS on average (95%CI: 0.13, 0.27). Additionally, the female adolescents would have a higher PBF on average by 1.6 SD score ($P$-value < 0.001,
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95%CI: 1.52, 1.67) than the males when the sitting height values of both sexes were kept equal at the mean (SH SDS=0). Since both SH SDS and PBF were associated with adolescent education and household wealth, the effect of those covariables were controlled in the model (table-5).

Table 5. Multiple linear regression of PBF SDS on sitting height and other co-variables (n=1,303)

<table>
<thead>
<tr>
<th>Variables</th>
<th>model without interaction</th>
<th>model with interaction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Adjusted b (95% CI) a</td>
<td>P-value b</td>
</tr>
<tr>
<td>SH SDS</td>
<td>0.13 (0.09, 0.17)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Adolescent education</td>
<td></td>
<td></td>
</tr>
<tr>
<td>no education d</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>enrolled in primary (1 to 5 y)</td>
<td>-0.25 (-0.49, -0.02)</td>
<td>0.031</td>
</tr>
<tr>
<td>completed primary (&gt;5 y)</td>
<td>-0.12 (-0.26, 0.01)</td>
<td>0.071</td>
</tr>
<tr>
<td>Wealth quintile</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poorest d</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Poorer</td>
<td>0.05 (-0.06, 0.16)</td>
<td>0.363</td>
</tr>
<tr>
<td>Middle</td>
<td>0.2 (0.09, 0.31)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Richer</td>
<td>0.1 (-0.01, 0.22)</td>
<td>0.073</td>
</tr>
<tr>
<td>Richest</td>
<td>0.43 (0.32, 0.55)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male d</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Female</td>
<td>1.58 (1.51, 1.66)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>SH SDS*Sex</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SH SDS*female</td>
<td>0.1 (0.02, 0.17) f</td>
<td>0.013</td>
</tr>
</tbody>
</table>

SH SDS = sitting height standard deviation score  
\* Adjusted regression coefficients, b Multiple Linear Regression ($R^2=0.59$),  
c Multiple Linear Regression with interaction ($R^2=0.59$), d Base categories: coded as 0  
e Effect of SH SDS when sex = 0, i.e., male  
f Effect of SH SDS when sex = 1, i.e., female

Significant and positive association was found when fat mass index was regressed on the sitting height while controlling the effect of the covariables, adolescents’ education level and household wealth. The regression coefficients of sitting height were 0.12 and 0.24 in the male and female adolescents respectively. The association was thus conditional to the sex of the adolescents (data not reported). When their sitting heights were kept equal at the mean value (i.e., SH SDS = 0), the female adolescents would have a higher FMI by 1.34 SD score on average than the male peers.

Sitting height had a positive association with fat free mass index (table-6). And, this
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effect of sitting height on fat free mass index was conditional upon the adolescent’s sex (coefficient of interaction term \( P\)-value < 0.001). While a unit increase of sitting height SD score in the male adolescents would increase FFMI by 0.35 SDS on average (95%CI: 0.3, 0.4), such increase in the female adolescents would increase FFMI only by 0.14 SDS on average (95%CI: 0.08, 0.21). Moreover, the female adolescents would have on average a lower FFMI by 0.87 SDS than their male peers when the sitting height of both sexes were kept equal at the mean value (i.e., SH SDS = 0). Since both SH SDS and FFMI SDS were associated with adolescent education, maternal education and household wealth, the effect of those covariables were controlled in the model (table-6).

<p>| Table 6. Multiple linear regression of FFMI SDS on sitting height and other co-variables (n=1,303) |</p>
<table>
<thead>
<tr>
<th>Variables</th>
<th>model without interaction</th>
<th>model with interaction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Adjusted ( b ) (95% CI)</td>
<td>( P)-value</td>
</tr>
<tr>
<td>SH SDS</td>
<td>0.28 (0.24, 0.32)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Adolescent education</td>
<td></td>
<td></td>
</tr>
<tr>
<td>no education (^d)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>enrolled in primary (1 to 5 y)</td>
<td>-0.27 (-0.53, -0.003)</td>
<td>0.047</td>
</tr>
<tr>
<td>completed primary (&gt;5 y)</td>
<td>-0.22 (-0.37, -0.07)</td>
<td>0.005</td>
</tr>
<tr>
<td>Maternal education</td>
<td></td>
<td></td>
</tr>
<tr>
<td>no education (^d)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>enrolled in primary (1 to 5 y)</td>
<td>-0.09 (-0.2, 0.02)</td>
<td>0.110</td>
</tr>
<tr>
<td>completed primary (&gt;5 y)</td>
<td>-0.1 (-0.21, 0.02)</td>
<td>0.095</td>
</tr>
<tr>
<td>Wealth quintile</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poorest (^d)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Poorer</td>
<td>0.05 (-0.08, 0.18)</td>
<td>0.435</td>
</tr>
<tr>
<td>Middle</td>
<td>0.22 (0.09, 0.35)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Richer</td>
<td>0.18 (0.05, 0.31)</td>
<td>0.008</td>
</tr>
<tr>
<td>Richest</td>
<td>0.39 (0.25, 0.53)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male (^d)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Female</td>
<td>-0.85 (-0.93, -0.76)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>SH SDS*Sex</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SH SDS*female</td>
<td>-0.21 (-0.3, -0.13)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

\( SH\) SDS = sitting height standard deviation score  
\(^a\) Adjusted regression coefficients, \(^b\) Multiple Linear Regression (\( R^2\)=0.42),  
\(^c\) Multiple Linear Regression with interaction (\( R^2\)=0.43), \(^d\) Base categories: coded as 0  
\(^e\) Effect of SH SDS when sex = 0, i.e., male  
\(^f\) Effect of SH SDS when sex = 1, i.e., female
4 Discussion
4.1 Brief summary of the main results

This study aimed at understanding the associations of the attained height—total and sitting—with overnutrition measures among the 15 years old adolescents in Matlab area of Bangladesh. The first rationale behind the aim of this study was to attest the commonly assumed independence of the overnutrition measures from height. It was revealed that those indices were non-independent from total height, except for the females whose overnutrition measures were found independent of their total height. The other rationales were to understand how those measures would change along with the attained height—total and sitting—if they were found associated and to assess the sex-specific differences in any of the associations.

In the male adolescents unlike the female peers, overnutrition measures were non-independent of the attained total height. Total attained height (HAZ) had significant and positive associations with BMI-for-age z-score (regression coefficient=0.33), FMI SD score (regression coefficient=0.08) and FFMI SD score (regression coefficient=0.26) in separate multivariate analyses. The taller the male adolescents were, their BMI would increase on average. This increase in BMI along with the height would have been contributed relatively more by the increase of fat free mass (FFM) than that of fat mass (FM). This comment was however drawn out of the indirect observation at their separate associations with total height. Among the female adolescents, all the overnutrition measures (BMI, PBF, FMI and FFMI) were independent of the attained total height.

When the effect of total height was controlled, there would be no difference in the average BMI between the male and female adolescents. Not unexpectedly, BMI could not have differentiated the specific components of body compositions. The female adolescents were found less lean than the male peers even after the effect of height was controlled. The females would have a higher PBF by 1.5 SD score, a higher FMI by 1.23 SD score but a lower FFMI by 1.39 SD score than the male peers.

In both the male and female adolescents, attained sitting height was associated with all the overnutrition measures in a varying pattern. Sitting height (SH SDS) was found positively associated with BMI-for-age z-score (regression coefficient=0.4) independently of the adolescent sex. Sitting height also had significant and positive associations with PBF, FMI and FFMI in separate multivariate analyses. Those associations were dependent on the sex of the adolescents. When their sitting heights increase, the corresponding increase of PBF SD score in the female adolescents (regression coefficient=0.2) would be on
average twice as much as that in the male adolescents (regression coefficient=0.1). Similarly, the increase of FMI SD score in the female adolescents (regression coefficient=0.24) would be on average twice as much of that in the male adolescents (regression coefficient=0.12). On the contrary, the increase in FFMI SD score in the female adolescents (regression coefficient=0.14) would be on average at least half of that in the male adolescents (regression coefficient=0.35) when their sitting height SD scores increase by one unit.

4.2 Strengths and weaknesses of the study

MINIMat study has been implemented in an excellent research infrastructure that fulfilled many pre-requisites for obtaining high quality longitudinal data. Data collection at several stages of the study was accomplished by experienced field workers, study nurses and medical doctors. Frequent refresher trainings including anthropometry standardization exercises were provided to the data collectors in order to mitigate measurement errors.

There were 57 participants excluded in analyses because of missing values in anthropometry, maternal and adolescents’ education or having implausible FFMI SD score. 24 (42%) of them were male whereas 33 (58%) were female. Almost half of them (45%) are from the poorest household wealth quintile and the rest were 10% to 15% in each quintile. There were apparently no striking differences in their means of HAZ and BAZ in compared to those of the adolescents included in the analyses.

As this is a cross-sectional analysis, temporal relationship of the associated variables cannot be inferred, and it was not a part of the aim of the study. Adjusting for potential confounders could have been made in the multivariate analyses. Potential confounders controlled in this study were socio-economic factors such as adolescents’ and maternal education level, household wealth index.

4.3 Internal validity

Measurements of body compositions using one of the predictive techniques, bioelectrical impedance analysis (BIA) involved two steps of predictions. The first prediction was the total body water (TBW) applying the raw data (height²/impedance) in an empirical regression equation. The relationship between bioelectrical data and TBW may vary significantly between populations (58–60). Therefore, such relationship should be firstly established using validation studies which assessed impedance and TBW in a
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Sample representative of the populations. The second prediction was the conversion of TBW to FFM. Tanita TBF-300A BIA machine was used to assess body compositions in this study. It uses in-built equations derived from the Caucasian populations and the application of it in other ethnic population was not recommended. A prediction equation derived from a validation study in this population of 15 years old adolescent would help improving the validity of the measures such as PBF, FMI and FFMI.

The applicability of PBF in measuring metabolic risks was questioned as it is including fat mass in both numerator and denominator (46,108). Another critique that is more relevant to the aim of the current study is the inherent flaw in PBF for not adjusting for height (109).

4.4 External validity

This study was conducted in Matlab area of rural Bangladesh which is a low socio-economic setting where undernutrition in early life are common and the prevalence of metabolic diseases such as hypertension and diabetes have been increasing. The results of this study would be applicable to other South Asian countries which are undergoing nutrition transition and have contextual similarities such as socioeconomic conditions. However, it is note-worthy that body composition measures especially fat mass varies much between any given populations.

4.5 Interpreting the results of study in a wider academic context

This increase of BMI along with the increase in attained total height among the male adolescents was found in this study. Such pattern in children and adolescents was not unprecedented (31,32). There was however no association found between BMI and total height among the female adolescents. One possible explanation for this would be that the female adolescents were already adopting adult characteristics particularly in a way of having BMI which is independent of attained total height (29). Nevertheless, it would be modest to consider careful steps for checking the non-independence of body composition indices for height and considering normalizing it as relevant to objectives of further studies.

It would not be a new thing to report that BMI is age and sex specific in children and adolescents. Since body fatness varies from one population to another even at a given value of BMI, it is important to look beyond BMI and into differentiated body composition measures such as FMI and FFMI. Even in the same population, there can be differences of body compositions depending on the sex. This study found that the adolescent males and
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females had significant differences in their fat masses and fat free masses even when their BMI were no different on average. If BMI-for-age z-score was the only index that was relied to look into body composition, such findings would not be possible to get revealed.

Sitting height measures used in the previous studies for assessing metabolic risks were as in the form of ratio such as sitting-height-to-stature ratio or as an index such as sitting height index of build (87,110,111). More analyses using such measures would improve the understanding of sitting height in relation to variations in body compositions.

4.6 Conclusion

Among the male adolescents in this study, the increase in BMI-for-age z-score (regression coefficient=0.33) along with the increase in height would have been contributed relatively more by the increase in FFMI SDS (regression coefficient=0.26) than that of FMI SDS (regression coefficient=0.08). Even though there was no difference in their BMI on average between the male and female adolescents, female adolescents had lower lean mass (FFMI) and higher fat mass (FMI). Overnutrition measures such as FMI and FFMI should be examined when metabolic risks are assessed in relations to body compositions. This study proved that overnutrition measures were non-independent of total attained height among the 15 years old male adolescents. Again, when assessing the metabolic risks in relation to the variations in overnutrition measures such as BMI, FMI and FFMI, normalizing those indices for height should be considered especially if the study population is still undergoing growth. Without taking such cautious step, the assessed risk using those indices might be implicated from the effect of growth trajectory and nutritional status. More analyses using sitting height measures such as sitting-height-to-stature ratio and sitting height index of build is necessary to improve the understanding of their relations to overnutrition measures.
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5. References


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26. Zimmermann MB, Gübeli C, Püntener C, Molinari L. Detection of overweight and obesity in a national sample of 6–12-y-old Swiss children: accuracy and validity of reference values for body mass index from the US Centers for Disease Control and
Is attained height associated with overnutrition measures?


Is attained height associated with overnutrition measures?


44. Deurenberg P, Deurenberg-Yap M, Guricci S. Asians are different from Caucasians and from each other in their body mass index/body fat per cent relationship. Obes Rev. 2002 Aug;3(3):141–6.


Is attained height associated with overnutrition measures?


Is attained height associated with overnutrition measures?


74. UNFPA Global Open Database 2015.

75. Motherhood in childhood, state of the world’s population. UNFPA; 2013.


Is attained height associated with overnutrition measures?


88. Burton R. The Sitting-Height Index of Build, (Body Mass)/(Sitting Height)3, as an Improvement on the Body Mass Index for Children, Adolescents and Young Adults. Children. 2018 Feb 22;5(2):30.


Is attained height associated with overnutrition measures?


Is attained height associated with overnutrition measures?


111. Burton RF. Sitting height as a better predictor of body mass than total height and (body mass)/(sitting height)\(^3\) as an index of build. Annals of Human Biology. 2015 May 4;42(3):212–6.

6. Annexes

6.1. Annex-1 Timeline overview of the MINIMat cohort study

[Diagram showing the timeline of the MINIMat cohort study]

- 4436 Randomized
- 3625 Total live births followed up to five years
- 10-year follow-up at 2013
- 11.5-14.5 years’ follow-up at 2016-17
- 15-year follow-up at 2017-18
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6.2. Annex-2 Table. Distribution of wealth characteristics in the study population

<table>
<thead>
<tr>
<th>wealth-related variables</th>
<th>Wealth Quintiles</th>
<th>Average (n=1,356)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>poorest (n=272)</td>
<td>poorer (n=271)</td>
</tr>
<tr>
<td></td>
<td>Percentage of population</td>
<td></td>
</tr>
<tr>
<td>Source of drinking water</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Piped water</td>
<td>3%</td>
<td>4%</td>
</tr>
<tr>
<td>Rain water</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Tube-well water</td>
<td>95%</td>
<td>94%</td>
</tr>
<tr>
<td>River/Pond water</td>
<td>2%</td>
<td>2%</td>
</tr>
<tr>
<td>Toilet facilities</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sanitary latrine</td>
<td>4%</td>
<td>8%</td>
</tr>
<tr>
<td>Ring/Slab Latrine</td>
<td>93%</td>
<td>90%</td>
</tr>
<tr>
<td>Concrete latrine</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Earth latrine (open)</td>
<td>0%</td>
<td>1%</td>
</tr>
<tr>
<td>Open/Open/Bush</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Shared with other</td>
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<td>1%</td>
</tr>
<tr>
<td>Type of cooking fuel</td>
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<td></td>
</tr>
<tr>
<td>Electricity</td>
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<td>0%</td>
</tr>
<tr>
<td>Wood</td>
<td>74%</td>
<td>75%</td>
</tr>
<tr>
<td>Gas</td>
<td>2%</td>
<td>5%</td>
</tr>
<tr>
<td>Crop/Animal dung</td>
<td>1%</td>
<td>2%</td>
</tr>
<tr>
<td>Straw/Dry leaves</td>
<td>23%</td>
<td>18%</td>
</tr>
<tr>
<td>Land ownership</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Own land</td>
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<td>28%</td>
</tr>
<tr>
<td>Type of house floors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mud floor</td>
<td>97%</td>
<td>93%</td>
</tr>
<tr>
<td>Cement floor</td>
<td>3%</td>
<td>7%</td>
</tr>
<tr>
<td>incomplete floor</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Type of house walls</td>
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<td></td>
</tr>
<tr>
<td>Mud wall</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Cement wall</td>
<td>2%</td>
<td>4%</td>
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<tr>
<td>Tin wall</td>
<td>96%</td>
<td>95%</td>
</tr>
<tr>
<td>Incomplete wall</td>
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<td>0%</td>
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<tr>
<td>Others</td>
<td>1%</td>
<td>1%</td>
</tr>
<tr>
<td>Type of house roof</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Straw roof</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Tin roof</td>
<td>99%</td>
<td>98%</td>
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</tbody>
</table>
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<table>
<thead>
<tr>
<th>Asset ownership</th>
<th>1%</th>
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<th>1%</th>
<th>8%</th>
<th>24%</th>
<th>7%</th>
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<tbody>
<tr>
<td>Cement roof</td>
<td>1%</td>
<td>2%</td>
<td>1%</td>
<td>8%</td>
<td>24%</td>
<td>7%</td>
</tr>
<tr>
<td>Others</td>
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<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Electricity</td>
<td>47%</td>
<td>86%</td>
<td>97%</td>
<td>99%</td>
<td>100%</td>
<td>86%</td>
</tr>
<tr>
<td>Television</td>
<td>5%</td>
<td>14%</td>
<td>25%</td>
<td>61%</td>
<td>88%</td>
<td>38%</td>
</tr>
<tr>
<td>VCR/DVD player</td>
<td>0%</td>
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<td>2%</td>
<td>6%</td>
<td>25%</td>
<td>7%</td>
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<tr>
<td>Mobile phone</td>
<td>88%</td>
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<td>100%</td>
<td>99%</td>
<td>99%</td>
<td>97%</td>
</tr>
<tr>
<td>Radio</td>
<td>1%</td>
<td>1%</td>
<td>2%</td>
<td>4%</td>
<td>13%</td>
<td>4%</td>
</tr>
<tr>
<td>Watch clock</td>
<td>12%</td>
<td>20%</td>
<td>37%</td>
<td>52%</td>
<td>86%</td>
<td>42%</td>
</tr>
<tr>
<td>Clock</td>
<td>3%</td>
<td>7%</td>
<td>15%</td>
<td>38%</td>
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<tr>
<td>Sewing machine</td>
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<td>6%</td>
<td>9%</td>
<td>12%</td>
<td>32%</td>
<td>12%</td>
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</table>
Is attained height associated with overnutrition measures?

6.3. Annex-3 Histograms with boxplots of the continuous variables of the anthropometric and body compositions measurements