Exploring rural adolescents’ dietary diversity, ultra-processed food consumption, and relevant socio-economic correlates: a cross-sectional study from Matlab, Bangladesh

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Abstract

Background

Bangladesh is home to 36 million adolescents with the majority living in rural areas. Adolescence presents an additional window of opportunity to correct nutritional deficits among rural Bangladeshi adolescents. A high-quality, diverse diet is pivotal in this regard. Ultra-processed food (UPF) consumption is an emergent threat to public health. This study aimed to explore dietary diversity (DD) and UPF consumption in terms of gender and socio-economic stratification among rural adolescents in Matlab, Bangladesh.

Methods

Adopting cross-sectional design 1441 adolescents were surveyed. Dietary diversity score and ultra-processed food consumption score (UFCS) were constructed through 24-hour recalls. Means and consumption proportions were compared across gender and socio-economic strata. Binary and ordinal logistic regression models were fitted to isolate socio-demographic variables associated with inadequate DD and higher UFCS respectively.

Results

43% of the adolescents had inadequate DD. Pro-boy gap in DD was evident, so was heavy reliance on rice and scant consumption of nutrient-rich foods. UPF consumption was low. Belonging to the richest and to food secure households were associated with lower odds of inadequate DD. Girls were more likely to have inadequate DD but less likely to have higher UFCS. Gender modified the effect of socio-economic status on UPF consumption.

Conclusions

The diet of adolescents in Matlab lacked diversity, putting them at significant risk of nutritional deficiencies. Improving their DD requires pragmatic policies and tailored programs to tackle affordability and food insecurity issues, address social norms and intra-household dynamics that favor boys, and sensitize the adolescents to importance of consuming diverse diet.
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Exploring rural adolescents’ dietary diversity, ultra-processed food consumption, and relevant socio-economic correlates: a cross-sectional study from Matlab, Bangladesh
List of Abbreviations and Acronyms

ASF  Animal-source food
BMI  Body mass index
CHRW Community Health Research Worker
DD  Dietary diversity
DDS  Dietary diversity score
DOHaD Developmental Origins of Health and Disease
FAO Food and Agriculture Organization of the United Nations
HIC  High-income country
icddr,b  International Centre for Diarrhoeal Disease Research, Bangladesh
LMICs  Low- and middle-income countries
NCD  Non-communicable disease
OR  Odds ratio
PCA  Principal component analysis
PAHO  Pan American Health Organization
SD  Standard deviation
SDG  Sustainable Development Goal
SSB  Sugar-sweetened beverage
UPF  Ultra-processed food
UFCS  Ultra-processed food consumption score
WHO  World Health Organization
Exploring rural adolescents’ dietary diversity, ultra-processed food consumption, and relevant socio-economic correlates: a cross-sectional study from Matlab, Bangladesh
1. Introduction:
Countries across the world have committed to the attainment of Sustainable Development Goals (SDGs) (1). Nutrition is a key determinant of individual and population health status; thereby playing an important role in strengthening various development mechanisms. Although nutrition appears to be the domain addressed by SDG 2, which spells out the goals of ending hunger, achieving food security and improved nutrition, and promoting sustainable agriculture, actually nutrition is interwoven with all 17 SDGs. This necessitates explicit attention to nutrition as an input for fulfilment of SDGs as well as an outcome of accomplishment of SDGs (2).

The State of Food Security and Nutrition in the World 2018 puts the number of undernourished people at an estimated 821 million, which translates roughly into one in every nine individuals being unable to meet dietary energy needs with habitual food consumption (3). Malnutrition is a universal predicament and countries are riddled with multiple forms of it (4). While low-income countries continue to suffer from food insecurity and nutrient deficiencies in the backdrop of rising overnutrition, most high- and middle-income countries are dealing with overweight, obesity and diet-related chronic diseases to a greater extent (4,5). Body mass index (BMI) is a common anthropometric indicator (6) and population-based data suggest that the upward trends of mean BMI among children and adolescents have plateaued at high levels in high-income countries (HICs); but soared in parts of Asia. At the same time, undernutrition has concentrated in South Asia and Africa. As a consequence, the contribution of malnutrition contingent on suboptimal or poor-quality diet to the global burden of morbidity and mortality remains substantial (7).

Measures to improve this challenging landscape of global nutrition need to coherently address two distinct, equally daunting aspects- eliminating the large remaining undernutrition and curbing the escalation of overweight and obesity (4,7). Promoting accessibility to and consumption of a sufficient amount of high-quality, diversified diet on a global scale is pivotal in this regard. Epidemiological studies show that the quality and diversity of diets are influenced by a wide range of socio-economic, demographic, and cultural factors (8–10); that often establish a socio-economic gradient characterized by inadequate consumption of nutrient-rich foods and excessive consumption of energy-dense foods by those belonging to lower socioeconomic status (11). Interventions to enhance the quality and diversity of diet at individual, community and population levels, therefore, depend not only on economic development and political commitment, but also
on context-specific understanding of socio-economic, demographic, and cultural determinants of dietary patterns and practices.

1.1 Adolescent nutrition in the SDG era

The World Health Organization (WHO) defines adolescence as the period from 10-19 years of age (12). Global adolescent population is estimated to be 1.2 billion, with Asia and Africa hosting more than three quarters of them (13). This staggering number alone signals the critical role of adolescent nutrition in sustaining and scaling up of global health gains in the SDG era. A growing consensus on the importance of investing in adolescent health and nutrition for achieving the global goals is reflected by two recent calls to action urging nutrition community to prioritize adolescent nutrition from the standpoint of a life course approach: one launched in the Global Nutrition Summit 2017 and another published in 2018 following a stakeholder consultation co-hosted by the United States Agency for International Development (USAID) and the Pan American Health Organization (PAHO) (4).

Adolescence is a critical phase in the life course that presents an additional window of opportunity to correct the nutritional deficits and growth faltering initiated during the first decade of life and to promote healthy dietary practices and lifestyle (12,14,15). This is of great importance for developing countries, like Bangladesh, where still unacceptably high proportion of children enter adolescence being stunted or underweight (16,17). Without tackling such deficits during adolescence, by means of balanced and diversified diet rich in essential nutrients, developing countries are likely to fail to capitalize on their demographic dividend (4,18). Considering that adolescent girls often get married in many low- and lower-middle-income countries (19), this window of opportunity is also vital for breaking the vicious intergenerational propagation of malnutrition (14,20).

Adolescence is characterized by remarkable physical growth, physiological and cognitive development, and sexual maturation. During this phase there occurs attainment of 40-60% of the peak bone mass and up to 50% of adult body weight along with a 15-20% increase in height (21); leading to a significantly higher nutritional requirement (22). Physiological demand for both macro- and micronutrients is high during adolescence. This underlies the nutritional vulnerability of adolescents; which is more profound in low- and middle-income countries (LMICs), and yet, they received less attention over the past decades (17). Such LMICs as Uganda, Bangladesh,
Sudan, Maldives, Cambodia, and Vietnam have a prevalence of thinness greater than 10% among younger adolescent girls aged 13-15 years (17). Additionally, the Global Burden of Diseases, Injuries, and Risk Factors Study 2017 reveals micronutrient deficiencies to be responsible for a major share of ill-health among younger adolescents- iron deficiency with associated anemia, and iodine deficiency contributing to 50-600 disability-adjusted life years (DALYs) per 100,000 adolescents (23). As suboptimal diet exposes adolescents to these deficiencies, a diversified diet mounted on healthy eating habits and food security can resolve their nutritional vulnerability.

The uniqueness of adolescence in the life course also relates to the cognitive, emotional, and social transformation that the adolescents undergo, enabling them to engage broadly with familial, socio-cultural and economic environment. Adolescents are open to new ideas and it is during this life phase that values, attitudes, and habits are established, including those that determine lifelong dietary practices, food choices, and other health-related behaviors (24,25). This has important implications for adolescent nutrition. Adolescence provides an ideal opportunity to improve dietary practices and quality of diet; on the other hand, adolescents are more vulnerable to the pervasive nature of food marketing exposing them heavily to empty-calorie, obesogenic foods (25,26). Nevertheless, evidence shows that adolescents globally are consuming an excess of refined carbohydrates and empty-calorie foods with limited amounts of fruits and vegetables (4,27,28). Such health-compromising dietary practices as less consumption of fruits and vegetables (29), snacking (30), frequent consumption of “fast food” and sugar-sweetened beverage (SSB) (28,31), and tendency to skip breakfast (28,32,33) characterize the current adolescent population worldwide. Additionally, dietary pattern of adolescents is also influenced by peer pressure, awareness of peer norms, exposure to media, parenting style and parental dietary choices (34,35).

Nutrition impacts adolescents’ present health status and future health trajectories. Presence of cardiometabolic risk factors during adolescence, including overweight or obesity, high blood glucose level, and increased BMI, have been linked to early onset of hypertension, type 2 diabetes, coronary artery disease, and premature mortality as well (36,37). Furthermore, the Developmental Origin of Health and Disease (DOHaD) hypothesis puts into perspective how exposure to energy and nutrient restrictions in early life increases the risk of non-communicable diseases (NCDs) later in life (38,39). One inference applicable for LMICs is that children who enter adolescence being stunted or with history of intra-uterine growth retardation, and continue as stunted or thin.
adolescents into adulthood, carry a higher biological susceptibility to develop NCDs (40–42). Adolescent obesity has been reported to lower educational attainment also (43). Between 1975 and 2016 the global prevalence of adolescent obesity rose annually without any exception; reaching 6.5% among adolescent boys and 4.7% among adolescent girls in 2016 (7). Apart from Africa, the burden of adolescent obesity apparently falls more on adolescent boys than adolescent girls (4). Moreover, one recent study from India reported pro-boy gender disparity in dietary diversity among adolescents (44).

To sum it up, in spite of steadily increasing prevalence of overnutrition; at present, more adolescents are underweight and stunted in the world than obese. Adding another layer of complexity to this is the socio-demographic, economic, and urban-rural variation in the distribution of the determinants of different forms of malnutrition among adolescents. Overweight or obesity has been increasing in settings traditionally exposed to food insecurity and undernutrition (5). The different forms of malnutrition also point to the fundamental role of consumption of inadequate or excessive amounts of energy, protein, fat, vitamins and minerals due to poor dietary diversity and low intake of nutrient-dense foods (45). Interventions and policies aiming to address the complex paradigm of adolescent malnutrition in developing countries must take into account existing dietary patterns and practices, associated determinants, and how these associations vary among different socio-economic and gender strata in a particular context.

1.2 Dietary diversity: conceptual and operational aspects

The concept of diet quality gained ample attention in nutritional epidemiology over the last couple of decades; as it has been employed to evaluate dietary patterns at population level, to evaluate efficacy of dietary interventions, and also to formulate dietary guidelines (46,47). Dietary diversity (DD) relates to the nutrient adequacy dimension of diet quality, reflecting the adequacy of intake of essential nutrients at the household or individual level. It entails the consumption of diverse foods across and within the food groups over a given reference period, ensuring an adequate dietary provision of essential nutrients for promoting health, growth and development (48). From a conceptual perspective, the proposition is that a diversified diet reduces the likelihood of developing deficiency or excess of any particular nutrient (49).

DD is usually operationalized through a score, created by summing the number of foods or food groups consumed over a reference period varying from the preceding 24-hours or 7 days, 15 days,
to up to 30 days. The score is called dietary diversity score (DDS) when derived from a food group count or food variety score (FVS) when calculated from single food item counts. Questionnaire-based instruments for assessing DD have been extensively used at household and individual level, owing to their simplicity and cost-effectiveness. The calculation process varies slightly depending on whether it is intended to gauge household dietary diversity score (HDDS) or individual dietary diversity score (IDDS). While the former acts as a proxy indicator for household food security, or more specifically, economic ability of households to access a variety of foods; the latter aims to reflect nutrient adequacy, particularly of the diets consumed by nutritionally vulnerable populations: young children, adolescents, and women of reproductive age (48,50). The Food and Agriculture Organization of the United Nations (FAO) published guidelines for measuring household and women’s DDS in 2011, without any cut-off to determine adequate or high DD (50). Later on, in 2016, the FAO and Food and Nutrition Technical Assistance (FANTA) III Project published guidance on measurement of Minimum Dietary Diversity for Women of Reproductive Age (MDD-W), with a proposed cut-off (i.e. consumption of 5 out of 10 described food groups) to indicate minimum DD that would represent nutrient adequacy (51).

Studies validating DD against nutrient adequacy in LMICs countries capture a positive association between higher DD and nutrient adequacy (measured by nutrient adequacy ratio and mean adequacy ratio) among non-breastfed children, adolescents, and adults (52–56). Socio-economic status or relative wealth, education and sex of the household head, maternal education, schooling, knowledge of nutrition, food security, residence (urban versus rural), household size, seasonality, ownership of livestock and vegetable garden, etcetera have been reported as significant determinants of DD (57–64). On the other hand, existing body of research demonstrates that greater dietary diversity is related to such health outcomes as improvements in birth weight and anthropometric indices (65–67), higher hemoglobin concentration (68), lower risk of hypertension and type 2 diabetes, and reduced mortality from cancer, cardiovascular and other chronic diseases (69–71).

However, there are some methodological issues to consider critically. As studies employed different measures to elicit DDS involving different, contextualized food groupings and various reference periods, it is difficult to draw comparative interpretation from these studies. Other critical aspects include whether or not to consider portion sizes, which cut-off values distinguish high from
low DD, what could be an optimal recall period when administering the questionnaires, and ideal time of the year to assess DD in rural, agriculture-dependent settings versus in non-agriculture-dependent settings (48).

1.3 Role of industrial food processing in shaping dietary patterns

Foods consumed now-a-days are invariably processed in one way or the other. Some form of food processing can be traced back to the time of hunter-gatherer societies (72). Pre-industrial food processing evolved slowly along with the societal transition from hunter-gatherer to pastoral-migrant to peasant-agricultural arrangements (73). Following the Industrial Revolution in eighteenth century, food processing gradually emerged as a global industry, that underwent rapid technological transformation in the second half of the last century. Thereafter, mass-produced food products such as loaves, buns, cakes, cookies, candies, breakfast cereals, jam, condensed milk, soft drinks, processed meat and cheese, etcetera started dominating the food supplies of HICs, then of wealthier, urban settings of LMICs, and recently of rural areas in many LMICs. Thus, industrial food processing has become an essential determinant of dietary patterns, diet quality, and impact of diet on health and well-being (73,74).

1.3.1 Food classification without focus on industrial food processing

Conventional food classification systems (75), which actually form the basis of dietary assessments at population-level, food-based dietary guidelines and nutrition-related public health policies, do not take into account food processing, and thus, end up classifying foods with significantly different nutritional profiles into the same category (73,76). Industrial food processing received no systematic attention for a long period. Conceptual framework of traditional food classifications places emphasis on the botanical or animal origin of the ingredients or the chemical composition of foods (73). For instance, often, fresh meat and fish are grouped with processed products like ‘nuggets’ and ‘fish fingers’ under the heading of ‘meat and meat products’; whole, fresh fruits are put together with canned fruits and reconstituted sugary fruit drinks in the group of ‘fruits’ (77). Nevertheless, robust evidence-base pinpoints the role of ever-increasing production and consumption of industrially processed foods and beverages as one of the drivers of obesity and diet-related chronic diseases (78–80).
Therefore, Monteiro and colleagues argue that, it is imperative to focus on industrial food processing to better understand the link between population dietary patterns and its public health impact (77,81). They put forward the NOVA system (NOVA not an acronym) of classifying foods according to the nature, extent and purpose of industrial food processing that could serve as a tool to capture how food processing interplay with biological, sociocultural and environmental factors to affect health and modify disease risk (81). NOVA defines industrial food processing as those physical, chemical and biological processes employed by manufacturers and associated industries after separation of foods from nature to make them less perishable, easier to consume, or to transform them into food products (73). Nonetheless, Monteiro et al. acknowledged that healthy diets are not necessarily composed of unprocessed or minimally processed foods only, rather it is the proportion of processed and UPFs in the diets that relates to the risk of different forms of malnutrition (77,81).

1.3.2 The NOVA classification

NOVA has established itself as a valid tool in nutrition-oriented public health research, policy and action (73,77). It categorizes foods and drinks into the following four groups (76,82):

*Group 1. Unprocessed or minimally processed foods:* These are natural foods available as edible parts of plants (e.g. seeds, fruits, leaves, stems, roots, etcetera) or originating from animal (meat, milk, egg, etcetera); and also include fungi, algae, water. The group 1 foods are commonly prepared or cooked along with processed culinary ingredients.

*Group 2. Processed culinary ingredients:* This group includes substances extracted and purified industrially from group 1 foods or from nature, including oil, butter, sugar, salt, spices, etcetera. Items which belong to this group are not usually consumed by themselves, rather used in combination with group 1 foods to make diverse, palatable, handmade dishes and meals.

*Group 3. Processed foods:* The foods that are manufactured by adding oil, sugar, salt, or any other substances from group 2 to group 1 foods for the purpose of increasing the durability or enhancing the sensory qualities of the latter constitute this group. Examples include simple breads, cheese, canned fish, cured meat, and fruits, legumes and vegetables preserved in syrup or brine.

*Group 4. Ultra-processed foods (UPF):* These are not modified foods like those of group 3; rather industrial formulations composed of substances derived from foods (e.g. starches, fats, oils, sugar,
etcetera) or synthesized through further processing, like hydrogenation or hydrolysis, of food constituents (e.g. whey, gluten, soya protein isolate, maltodextrin, corn syrup, etcetera). Consequently, UPFs contain little to no intact group 1 food. UPFs are distinguished by their higher content of colors, emulsifiers, flavors, preservatives, stabilizers, bulking agents, sensory enhancers, and sweeteners. Some UPFs are loaded with synthetic micronutrients. Common examples of UPFs are chips (crisps), chocolate, ice cream, biscuit (cookies), SSBs, cake, pastry, “instant” noodles and soup, energy bar, pre-prepared pizza, poultry and fish ‘nuggets’, burger, hot dog, etcetera.

Of note, UPFs are “ready-to-heat” or “ready-to-eat” formulations, requiring no actual culinary preparation. The word ultra-processed signifies the multitude of industrial processes needed to create the final group 4 food. The ultimate purpose of ultra-processing is to produce branded, convenient, hyper-palatable and low-cost food products. Hence, these products are inherently unbalanced in nutrient profile and tend to trigger excessive consumption (81,82).

1.3.3 Relevance of studying ultra-processed food consumption

Application of NOVA classification is unmasking the universal threat to public health posed by the UPFs. The displacement of dietary patterns mostly based on handmade meals and dishes by diets dominated by ultraprocessed food and drink products has become a global phenomenon spanning both HICs and LMICs (83–87). Epidemiological studies consistently demonstrate diets with higher share of UPFs to be associated with greater energy intake, greater consumption of refined sugar, added salt and trans-fat, and lower consumption of fruits and vegetables. Simply put, increasing dietary share of UPFs diminishes the overall diet quality (85,87–91). Studies have also linked higher consumption of UPFs to overweight and obesity (92–94), metabolic syndrome in adolescents (95), hypertension (96), and certain cancers (97).

Furthermore, food environment in LMICs has undergone drastic change, characterized by an increased access to cheaper UPFs; sold in the convenience stores, grocery stores and supermarkets (98–100). With the growth in sales of UPFs in high-income countries slowing down, albeit level of sales still being high, low- and middle-income countries of the Global South- Asia, Africa, Latin America- have emerged as the most attractive market for UPFs. Rural food environments have also been infiltrated by UPFs (98,101,102). This has serious implications for rural adolescents in LMICs. Firstly, the overwhelming access to inexpensive calories would expose adolescents from
rural households lacking food security, many of whom are already stunted (103), to a disproportionately high risk of overweight or obesity (104). Secondly, energy intake among adolescents in LMICs has spiralled, whereas DD remained limited (105); leading to unhealthy dietary patterns, which in turn confer risk of NCDs in the ensuing adulthood. Thirdly, the aggressive marketing of UPFs (76) affects adolescents the most, as they are particularly susceptible to food marketing (26). Accordingly, it is important to explore the pattern of UPF consumption among rural adolescents with an aim to identify associated factors.

1.4 Bangladesh perspective

Bangladesh is a lower-middle-income country with a per capita GDP of 1517 USD as of 2017. Between the years of 2000 and 2018, Bangladesh enjoyed annual GDP growth of 5.8-7.8%, combined with a reduction in poverty (proportion of population living on less than 1.90 USD per day) from 34.8% in 2000 to 14.1% in 2018 (106). Nonetheless, the 2018 Global Hunger Index puts Bangladesh in 86th position out of 119 countries with an estimated 15.2% of the total population being undernourished (107).

Bangladesh achieved one of the most sustained reductions in childhood undernutrition in the world (108), as evidenced by a decline in the proportion of under-5 children stunted from 54.6% in 1997 to 36.1% in 2016 (109,110). However, Bangladeshi diet is still dominated by rice (111). While the per capita dietary energy supply (DES) increased, the contribution of cereals to the DES declined minimally, from 79.6% in the mid-1990s to 76.3% in 2013; whereas the FAO recommends no more than 60% of the DES to come from cereals (109). Such heavy reliance on the staple is reflected by the slim mean DDS of 4.1 at national level estimated in 2015 (112). One study estimated that Bangladesh produces only 22% of the fruits and vegetables required for meeting current dietary guidelines (113). Another quantifiable aspect of this stagnation in DD is the persistently low average supply of proteins of animal origin; which increased from 6 gram/capita/day in 2011 to a meagre 9 gram/capita/day in 2013 (114). Corroborating these numbers, recent studies capture widespread micronutrient deficiencies secondary to low DD (115,116).

Bangladesh is home to 36 million adolescents, forming 21% of its total population (117). Healthy diet and optimum nutrition for adolescents merit highest priority, if Bangladesh is to benefit from this huge potential workforce. Limited published estimates reveal high prevalence of underweight
and stunting among Bangladeshi adolescents with adolescent girls suffering more (103,118). Another emerging concern is the higher proportion of adolescents at household level that adopts coping strategies (e.g. skipping meal, eating only rice, etcetera) in response to food insecurity. National Nutrition Surveillance data from 2015 show that when facing food shortage women and adolescents were far more likely to reduce consumption than were under-5 children or men (119). On the other hand, prevalence of overweight and obesity among adolescents has started to increase in Bangladesh (120). Hence, improving quality and diversity of the diet, especially among adolescents and women of reproductive age, is crucial for Bangladesh to accelerate its progress toward the global goals. UPF consumption by adolescents also needs to be assessed and confronted seriously in order to halt any upward trend of overweight or obesity in the near future. These cannot be pursued without context-specific understanding of the associated determinants and their socio-economic stratification.

1.5 Conceptual framework:

The conceptual framework guiding this study drew upon the UNICEF malnutrition framework (121) that identifies an array of interlinked factors in a hierarchical arrangement - basic, underlying and immediate causes- and the model proposed by Herman et al. (122) that elucidates how nutrition impacts health trajectories from a “Life Course Perspective”. Rural adolescents’ dietary diversity is conceptualized as an outcome of three interacting dimensions (represented by the three intersecting circles in figure 1 below): i. recognition of adolescence as an additional window of opportunity, especially for those who enter this life phase with malnutrition uncorrected from childhood, and also, as a period in life course with higher nutritional demand; ii. household food security and inequitable population-level distribution of food insecurity based on socioeconomic and demographic strata; and iii. biological and behavioral responses by adolescents to immediate social and physical environment, factoring in influence of family members, peers, culture and norms, as well as effect of school settings, neighborhoods, food outlets, built environment, etcetera (122). Factors pertinent to these three dimensions act as underlying causes, fortified from the root by the basic causes traditionally outlined in the UNICEF framework; culminating in inadequate dietary diversity that leads to different forms of malnutrition, which could potentially drive intergenerational transmission of malnutrition and increase disease risk during adulthood.
Figure 1. Conceptual framework adapted from the UNICEF framework of the determinants of malnutrition and the work of Herman et al.

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1.6 Rationale for the study

Optimum nutrition is vital during adolescence. Poor-quality, undiversified diet increases vulnerability of adolescents to different forms of malnutrition that could resonate throughout generations as well (45). Macro- and micro-nutrient deficiencies are prevalent among Bangladeshi adolescents (17,103,118,123). As UPFs have become readily available, energy intake is increasing while overall diet continues to be suboptimal among rural segments of the adolescent population (119); heightening their risk for negative health consequences. However, little is known about rural adolescents’ DD in Bangladesh. Extent and pattern of their UPF consumption also remained unexplored. Therefore, examination of rural adolescents’ DD would delineate the associated socio-economic and demographic factors and capture the role of UPFs in their dietary pattern. Identification of these correlates would better inform policies on adolescent health and help authorities to develop targeted intervention from a public health viewpoint.

1.7 Aims of the study

This study aims to explore dietary diversity and pattern of UPF consumption in a cohort of rural adolescents from Matlab, Bangladesh; with a systematic focus on the underlying socio-economic correlates. Drawing on the evidence presented above, it is hypothesized that adolescents’ diet in Matlab is inadequate in diversity and that UPF consumption is becoming increasingly common among them. The specific objectives are:

I. To describe and analyze rural adolescents’ dietary diversity in Matlab and its social and economic stratification.

II. To evaluate the pattern of UPF consumption among the rural adolescents in terms of social and economic stratification.

III. To identify the predictors of inadequate dietary diversity and higher UPF consumption among the rural adolescents.
2. Methodology:

2.1 Study design

This cross-sectional study availed the opportunity provided by the 15-year follow-up of the MINIMat (Maternal and Infant Nutrition Interventions in Matlab) trial (ClinicalTrials.gov identifier ISRCTN16581394). The follow-up began in September 2017 and is expected to be completed by August 2019. MINIMat was a factorial randomized trial with 6 arms that primarily examined the effects of early prenatal food and micronutrient supplementation for pregnant women on hemoglobin level at 30 weeks’ gestation, birth weight and infant mortality. The trial was conducted in the rural area of Matlab, Bangladesh with recruitment of pregnant women taking place from November 2001 to October 2003 (124).

2.2 Study setting

![Figure 2. The location of Matlab study area in the map of Bangladesh. Source: icddr,b.](image)

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The MINIMat trial, and accordingly, the present study was carried out in Matlab; which is a rural sub-district located about 55 kilometers to the southeast of Dhaka, the capital of Bangladesh. Matlab is part of Chandpur district within the administrative division of Chittagong. The International Center for Diarrheal Disease Research, Bangladesh (icddr,b), formerly the South-East Asia Treaty Organization (SEATO) Cholera Research Laboratory (CRL) has been operating a Health and Demographic Surveillance System (HDSS) in Matlab since 1966, which now covers a population of about 237,000 living in 142 villages. The HDSS data are collected by trained Community Health Research Workers (CHRWs) on a monthly basis through household visits and unique identification system allows longitudinal monitoring and tracking of health and demographic events and trends (125,126).

Matlab is a low-lying, deltaic plain; having a sub-tropical climate with three seasons: monsoon, cool-dry and hot-dry. The area is crisscrossed by the river Gumti and its numerous branches. Rice farming is the main occupation of people in Matlab, except few of the villages which depend on fishing as the source of livelihood. A three-month long agricultural lean period usually occurs between September and November. The literacy rate is around 60% (national data portal, data.gov.bd). Table 1 below lists some of the demographic attributes of the population in Matlab.

Table 1. Key demographic attributes of the study setting in Matlab. Corresponding national estimates for Bangladesh presented alongside (125,127,128).

<table>
<thead>
<tr>
<th>Demographic Characteristics</th>
<th>Matlab</th>
<th>Bangladesh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude birth rate (per 1000)</td>
<td>22.3</td>
<td>18.7</td>
</tr>
<tr>
<td>Total fertility rate (per woman)</td>
<td>2.7</td>
<td>2.1</td>
</tr>
<tr>
<td>Neonatal mortality rate (per 1000 live births)</td>
<td>21.8</td>
<td>18.4</td>
</tr>
<tr>
<td>Under-5 mortality rate (per 1000 live births)</td>
<td>35.8</td>
<td>32.4</td>
</tr>
<tr>
<td>Life expectancy at birth (years):</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>71.0</td>
<td>71.2</td>
</tr>
<tr>
<td>Female</td>
<td>74.2</td>
<td>74.6</td>
</tr>
</tbody>
</table>
2.3 Study population, sampling and sample size

The MINIMat trial originally recruited and randomized 4436 pregnant women from Matlab study area, resulting in 3625 live births, of which 3560 were singletons. These children born to the participating mothers constituted the MINIMat cohort and have been repeatedly followed up: monthly from birth to one year of age, then once in every three months up to two years of age; thereafter, once at 4.5 and 10 years, twice between the ages of 12.3-14.5 years. During this last follow-up round 2307 children were assessed, with outmigration, unavailability due to involvement in other activities, refusal to participate and deaths being the reasons behind loss to follow-up (129). The repeated follow-ups yielded a rich database. The present study was based on the 15-year follow-up of adolescents belonging to this cohort. Those who completed 15 years of age during the period from October 2017 to September 2018, representing the first half of the 15-year follow-up, were eligible to participate (n = 1441). Figure 3 in the Results section clarifies the participant flow to this study.

Any woman of reproductive age in the Matlab study area who reported cessation of menstruation to a CHRW between November 2001 to October 2003 was assessed for recruitment in the MINIMat trial. After assessment of 5880 such reporting women, 4436 were randomized to the different intervention arms in the trial (129). Therefore, the MINIMat cohort, formed by children born to these mothers, is assumed to be representative of the adolescents in the rural area of Matlab. Although the study sample is not nationally representative, it is reasonable to acknowledge that the rural adolescents from Matlab are not remarkably dissimilar to rural adolescent population in Bangladesh with regard to broader socio-economic and demographic aspects. However, generalization of the findings for entire Bangladesh would be erroneous.

2.4 Data collection

Data were collected from October 2017 to September 2018 totaling a period of 12 months that allowed examination of dietary practices round the year, accommodating any seasonal variation. Trained interviewers with at least 12 years of formal education identified adolescents who completed 15 years of age during this period using unique identification (ID) numbers and interviewed mother-adolescent dyads at their residences administering a pre-tested, structured questionnaire that contained pre-coded questions, arranged in 6 sections: A-F, with sections E and F not giving inputs to this study. Section A dealt with particulars of the participants and
interviewers, and sections B-D elicited information regarding socio-economic status, demographic attributes, relative wealth, household food security, and dietary practices and consumption patterns of the adolescents. The questionnaire, constructed in English, was translated into Bengali and administered with the help of Samsung tablet computer device.

2.5 Variables of interest

2.5.1 Outcome variables

a. Dietary diversity (DD): One of the two primary outcomes of this study was DD. It can be defined as the consumption of a variety of foods across and within a number of specified food groups over a given reference period (130). DD was assessed at individual level by constructing dietary diversity score (DDS) based on a 24-hour recall of consumed foods prompted by locally adapted version of a standard tool (embedded in section D of the questionnaire); that has been suggested by the FAO and FANTA (51), applied widely (131,132), and validated for adolescents too (58,133). The tool consisted of 10 food groups: i. grains, white roots and tubers, and plantains; ii. vitamin A-rich vegetables, tubers and fruits; iii. green, leafy vegetables; iv. other vegetables; v. other fruits; vi. flesh and organ meat; vii. egg; viii. fishes; ix. legumes, nuts and seeds; and x. milk products. Context-specific list of the food items in each of these 10 groups is presented in the following table.
Table 2. Food items belonging to the 10 food groups used for constructing DDS (Bengali names are italicized).

<table>
<thead>
<tr>
<th>Food group</th>
<th>Individual food items</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vitamin A-rich vegetables, tubers and fruits**</td>
<td>Carrot, pumpkin, sweet potato, mango (ripe), papaya (ripe), hog plum, watermelon.</td>
</tr>
<tr>
<td>Dark green leafy vegetables</td>
<td>Red amaranth, taro leaves, spinach, bottle guard leaves, mustard leaves, other locally available <em>shaak</em>.</td>
</tr>
<tr>
<td>Other vegetables</td>
<td>Tomato, gourd, brinjal, <em>zinga</em>, long bean, cucumber, teasle gourd, wax gourd, green papaya, cabbage, cauliflower, radish.</td>
</tr>
<tr>
<td>Other fruits</td>
<td>Guava, banana, orange, apple, bori, grapes, jackfruit, any other fruits that are yellow/orange/red inside.</td>
</tr>
<tr>
<td>Flesh and organ meat</td>
<td>Chicken, duck, beef, sheep, goat, pigeon, and liver, kidney or any other organ meat.</td>
</tr>
<tr>
<td>Egg</td>
<td>Chicken, duck, or quail eggs.</td>
</tr>
<tr>
<td>Legumes, nuts and seeds</td>
<td>Beans, peas, lentils, hyacinth beans, pea seeds, groundnuts, peanuts.</td>
</tr>
<tr>
<td>Milk products</td>
<td>Milk, yoghurt, <em>shemai</em>, <em>shuji</em>, <em>payesh</em>, <em>khir</em>, paneer, or other foods made with milk.</td>
</tr>
</tbody>
</table>

** Definition of Vitamin A-rich vegetables and fruits was based on the FAO guideline (50).

An adolescent consuming a food item belonging to one of the 10 food groups, in an amount of one tablespoonful (roughly 15 gram) at least, on the day preceding the survey received a score of 1 for that food group, otherwise received 0. It has been advocated that a minimum of 15 gram of a food item is needed be consumed to avoid foods eaten in trivial amounts from contributing to the score (52). Of note, the questionnaire ensured that the recall period coincided with one usual weekday, not weekend, holiday, or any day of fasting. As open-ended 24-hour recall may lead to some food items mistakenly not being reported, interviewers initially requested a qualitative recall; after which, they carefully probed for any unreported consumption using the list of food groups and accompanying pictures of the food items. This two-pronged approach is supported by some researchers (134).
The DDS was then calculated by summing up the score for each of the 10 food groups. Hence, possible values of DDS ranged from 0-10. In accordance with the cut-off proposed by the FAO and FANTA (51), individual DDS was dichotomized; so that adolescents with DDS of 4 or less were categorized as having inadequate DD (coded “1”) and those with DDS of 5 and more were deemed as having adequate DD (coded “0”).

b. **UPF consumption:** It was ascertained by ultra-processed food consumption score (UFCS), a simple summary measure constructed in a way similar to the DDS with a 24-hour recall of ultra-processed food items consumed by the adolescents that belonged to the 4 UPF groups (see Table 3). The contextualized grouping of UPF items was based on the definition and classification of UPF proposed by Monteiro and colleagues (76) that has been employed in many epidemiological studies for examining population dietary patterns (83–85,88,89,91,94). Consumption of approximately one tablespoonful amount or more of an UPF item earned the participant a score of 1 for that specific UPF group, otherwise the participant scored 0 for that group. Summation of the scores for the 4 UPF groups yielded individual UFCS with possible values ranging from 0-4. Therefore, UFCS was a discrete, numerical variable.

**Table 3.** Food items belonging to the 4 UPF groups used for constructing UFCS.

<table>
<thead>
<tr>
<th>UPF group</th>
<th>Individual UPF item</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ready-to-eat or “instant” foods</td>
<td>Instant noodles (Maggi noodles), burgers, industrially mass-produced loaves and buns.</td>
</tr>
<tr>
<td>Ultra-processed sweets, confectioneries and similar packaged products</td>
<td>Biscuits or cookies, chocolates, candies; industrially mass-produced, packaged muffins and cakes, ice cream</td>
</tr>
<tr>
<td>Savory snacks</td>
<td>Potato chips, crisps, <em>chanachur</em>, other salty/spicy packaged snacks, such as roasted peanuts, <em>jhalu muri</em> etcetera.</td>
</tr>
<tr>
<td>Sugar-sweetened beverage (SSB)</td>
<td>Soft drinks (Coca-Cola, Pepsi, Mirinda, Fanta etcetera), <em>Jeera Pani</em> (bottled cumin water), energy drinks (Tiger, Shark, Speed, Power etcetera), mix-and-drink sachet (such as Tang).</td>
</tr>
</tbody>
</table>
2.5.2 Explanatory variables

a. Socio-economic status (SES): Acknowledging the numerous existing ways of assessing and describing socio-economic condition in epidemiological studies (135), this project conceived SES as a constellation of socially derived material and economic characteristics that largely determine what position the household and its members enjoy in the context of that specific community (136). It is a relative indicator that cannot be compared across different research settings. SES was derived from household asset score. Data on family income were collected, but not used for constructing asset score.

This asset-based approach to ascertain SES relied on information regarding ownership of a range of durable household assets (20 in total, such as mobile phone, radio, television, refrigerator, bicycle, sewing machine, etcetera), access to basic utility (electricity and drinking water), and housing construction characteristics (material of the roof, walls and floor of the largest room). Principal Component Analysis (PCA) was employed to assign weights to each of these components. PCA represents a “data reduction” procedure that yields a number of “principal components”- clusters of combinations of the component variables- which explain the variance in asset ownership. The weights derived from the first “principal component” was used to compute the household asset score (137,138). This continuous, numerical variable was converted to tertiles: the lowest representing the poorest, the middle representing the middle-status, and the highest representing the richest households. Accordingly, SES was a categorical variable with three categories: the poorest, middle-status, and the richest.

b. Sex of the adolescent: A number of studies observe difference in dietary practices and preferences, eating habits, and intrahousehold allocation of food between adolescent boys and girls (44,60,139,140). This study incorporated sex of the adolescent as an explanatory variable as well, which had two categories- boy and girl. However, biological sex was not formally examined; instead the questionnaire practically collected information on the gender.

c. Household food security: Food security is a sophisticated, multi-dimensional phenomenon; conceptualized to be existing when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life (141). There are four dimensions of food security, namely food

Exploring rural adolescents’ dietary diversity, ultra-processed food consumption, and relevant socio-economic correlates: a cross-sectional study from Matlab, Bangladesh
availability, food access, food utilization, and stability (of the former three over time) (142). It was hypothesized that food security, or its absence, at household level affects the dietary diversity of adolescents. This study assessed household food security by applying an adapted version of the Household Food Insecurity Access Scale (HFIAS); which is a 9-item, experience-based scale (143). HFIAS has been validated for use in LMICs (144,145). It evaluates the access dimension of food security based on the assumption that food insecurity induces predictable reactions and responses that can be captured and quantified through a survey (143). These reactions and responses broadly fall into three domains: feeling of anxiety and uncertainty over household food supply, perception of food being insufficient in quantity, and perception of food being insufficient in quality. Mothers (or guardians) of the adolescents were asked nine questions relating to these three domains- for example, how frequently, in the past 4 weeks, did the respondent worry that the household would not have enough food. If the answer was “never happened”, it was coded 0; if it was reported to occur 1-3 times, it was coded 1 (rarely); if occurred once in a week to 2-3 times in a week, it was coded 2 (sometimes); and if happened 4-5 times a week or more frequently, it was coded 3 (often). The final HFIAS score was calculated by adding up such graded responses to all nine questions, with minimum and maximum possible scores being 0 and 27 respectively. The higher the score, the more food insecure was the household.

Food secure households were those with a total score of 0 or 1, only if that 1 point comes from the first question, that asks about worrying over food running out (cited as example above); implying that a food secure household experiences none of the nine food insecurity situations asked about, or just experiences worry, but rarely (143). Thus, household food security was operationalized as a categorical variable having 2 categories: food secure and food insecure.

d. Maternal education: It was hypothesized that maternal educational attainment influences dietary diversity of the adolescents in a number of pathways; for instance, through empowerment, nutrition literacy, and so forth (146). Three categories were constructed for this variable according to the number of completed years of formal education: no education, primary education (1-5 years), and secondary education and above (6 years or more). Home schooling and education in unregistered madrasa were not considered as formal education.
e. **Ownership of farming land**: This was a categorical variable thought to reflect the likelihood of involvement of the household in agricultural production activities, and subsequently, of accessing a diversified diet. The variable was assessed at household level. The two categories were those owning farming land (coded “1”) and those not owning farming land (coded “0”).

f. **Ownership of livestock**: It was assumed that livestock ownership improves access of the adolescents to such animal source foods (ASF) as milk, egg, and meat. Besides, any income generated through livestock ownership might affect the outcome variables (147,148). Two categories were created- households owning livestock (coded “1”) and those not owning any (coded “0”).

g. **Household size**: It refers to the total number of family members (regardless of age) who share the food from the same pot. It was postulated to affect the intra-household allocation of foods, and thereby, the dietary pattern of the adolescents; particularly at times of scarcity (119,149). Created initially as a discrete, numerical variable, household size was later converted into a categorical variable based on the reported mean household size in Bangladesh of 4.5, with this mean expected to be slightly higher in rural Bangladesh (150). Consequently, households with a total number of 2-5 members were categorized as smaller households and those with six or more as larger households.

### 2.6 Addressing potential biases

The MINIMat trial and the subsequent follow-up studies have been carried out in an area with a well-developed research infrastructure. This facilitated obtainment of high-quality data. The initial recruitment of mothers in the trial ensured that the sample was representative of the rural population in Matlab. Additionally, the MINIMat cohort is well-characterized due to rigorous, repeated follow-ups (129).

Nevertheless, over a period of 15 years some loss to follow-ups were inevitable. Out of 3625 live births in the trial, 2307 (63.6%) participated in the follow-ups between 12.3-14.5 years (129); and 2800 (77.2%) are expected to be covered in the ongoing 15-year follow-up, of which 1441 (who completed 15 years of age between October 2017 to September 2018) were included in this study.
Children with more educated mothers and children belonging to wealthier households were found to be less likely to take part in these follow-ups. These differences, however, were small and highly unlikely to distort the findings.

Rigorous attempts were made to ensure high internal validity of this study. Insights from the previous follow-ups and qualitative assessment based on focus group discussions (involving mothers and adolescents) guided the preparation of the structured questionnaire and the context-specific adaptation of standard tools. No survey enumerator had less than 12 years of formal education. They received comprehensive training on questionnaire survey techniques and data collection procedures; which was followed by a pre-testing phase where they used Samsung tablet computer devices to collect data. Feedback sessions were conducted after pre-testing to address any challenge faced by them and to incorporate any suggested change or correction in the final version of the questionnaire. Qualitative recall followed by list-based probing supplemented with pictorial aid (flip chart) was adopted during collection of dietary data to minimize recall bias. Periodic field supervisions were undertaken to evaluate data collection procedure in real-time and to ensure uniformity of the procedure for avoiding ascertainment bias. A web portal also allowed off-site monitoring of progress in data collection and quality of collected data.

Potential confounders were identified through literature search and mapping exercise to construct a concept map outlining exposure, outcome, and plausible factors that are associated with both (see Additional Figure 1 in Appendices). Data on these potential confounders were collected. Although multivariable statistical modelling accounted for these confounders, residual confounding could not be entirely ruled out. Some social desirability bias might also be present in self-reporting consumption.

2.7 Statistical analysis

2.7.1 Data management: Data from 1441 participants were compiled in a standard Microsoft Excel workbook and analyzed using the R statistical software [version 3.5.3], supported by the packages R commander [version 2.5-2] and R studio [1.2.1335] (151). Data were checked for missing values and disturbing outliers. In order to construct DDS, UFCS, and HFIAS score recoding of related questionnaire variables was done, complete process of which can be found in the Appendices. Categorical variables were visualized with Histograms and numerical variables with Histograms and Box Plots. Less than 1% of the
total number of observations for DDS and UFCS fell beyond 2 standard deviations (SD) from the respective means.

2.7.2 **Statistical methods:** The study adopted descriptive and inferential statistics to present results. Sample characteristics were expressed as frequency (percentage) for categorical variables and as mean with SD for numerical variables. Bivariate analyses were carried out to test differences in proportion of adolescents with inadequate DD (DDS≤4) and differences in mean UFCS by adolescent sex, SES, maternal education, household food security status, household size, and ownership of farming land and livestock. Pearson’s Chi-squared test was employed to determine statistical significance of differences in proportion between groups. For mean UFCS, difference between two groups was analyzed with independent sample t-test, whereas difference between more than two groups was analyzed with one-way analysis of variance (ANOVA). All tests were two-tailed and p-value of less than 0.05 at 95% confidence interval (CI) was considered statistically significant. Explanatory variables with p-value <0.1 in the bivariate analysis were candidates for inclusion in the multivariate analysis.

A multi-variable binomial logistic regression model was fitted with DD as the binary outcome variable (inadequate versus adequate DD) for identifying predictors of inadequate DD (DDS≤4). Crude and adjusted odds ratios (OR) with 95% CI were reported to reflect the strength of association. In the crude analysis, predictors were tested against the outcome one-by-one. Adjusted analysis followed a hierarchical approach with the final model accounting for all the variables. Nagelkerke’s pseudo-$R^2$ (152) value was retrieved to assess model fit.

Additionally, proportional odds ordinal logistic regression model (153) was fitted to explore association between higher UFCS and explanatory variables selected from the bivariate analysis. UFCS was treated as an ordinal outcome variable with higher score reflecting greater UPF consumption. Crude and adjusted OR with 95% CI were computed. Adjusted model accounted for three explanatory variables (adolescent sex, SES and household food security) simultaneously.

Collinearity between categorical explanatory variables was evaluated by cross tabulation and application of Chi-squared test; and if found dependent (p-value < 0.05), the strength of collinearity was estimated by computing Goodman and Kruskal’s gamma (154) value,
which could range from -1 (denoting 100% negative association) to +1 (denoting 100% positive association). A gamma value greater than +0.5 was considered to indicate high collinearity. Although the variable ownership of farming land was found to be significantly associated with inadequate DD in the bivariate analysis, a high collinearity between this variable and SES (G-K gamma value of +0.59) rendered it ineligible for inclusion in multivariate analysis. Variance inflation factors (VIF) were also checked after modelling to detect multicollinearity. The lowest possible value of VIF is 1 and VIF greater than 5 is usually considered to signify high collinearity. VIF for no given predictor was found to exceed 1.3.

2.8 Ethical considerations
The 15-year follow-up of the MINIMat trial was approved by the Ethical Review Committee (ERC) at icddr,b in Dhaka, Bangladesh on 23rd of May 2017. This study as a part of the 15-year follow-up was entitled to the same ethical considerations and was conducted in complete accordance with the principles outlined in the Declaration of Helsinki (155). Participation was entirely voluntary and participants, throughout the study, retained the right to withdraw without any consequences. Written informed consent and assent were obtained from the participating mothers and adolescents respectively, after full disclosure and detail explaining of the purpose, methods, risks and benefits of the study, and confidential, anonymous handling of personal information and collected data. Ensuring proper understanding by the participants of what they are giving consent to received utmost attention. Questionnaires were administered only after obtainment of consent and assent. No invasive procedure or biological sample collection was required for this study.
3 Results:

A total of 1441 adolescents completed 15 years of age between October 2017 to September 2018 and were surveyed. Concerning the variables used in this study, no missing data were found. The flowchart below depicts the participant flow starting from the original trial up to the ongoing follow-up.

**Figure 3.** Flowchart illustrating participant flow starting from the MINIMat trial up to 15-year follow-up.

Exploring rural adolescents’ dietary diversity, ultra-processed food consumption, and relevant socio-economic correlates: a cross-sectional study from Matlab, Bangladesh
3.1 Socio-demographic characteristics of the study participants

Descriptive statistics related to the individual and household characteristics of socio-demographic relevance, adolescents’ DDS and UFCS are summarized in Table 4. Out of 1441 participants, there were 732 boys and 709 girls. More than 40% of the mothers received secondary education and above, while more than one-fifth did not have any formal education. As SES was categorized according to tertiles of asset score, roughly 33% households belonged to each category. Almost half of the adolescents were from food insecure households. More than 70% of the households were smaller in size with the number of total family members ranging from 2-5. A vast majority (92.99%) of the households met their need for drinking water from tube-wells and only about 6% of the families could access piped water supply. Electricity coverage was considerably high (86.47%). Tin was the predominant roofing material in Matlab area, with more than 90% of the houses having a tin roof. Almost half of the households had ownership of farming land; whereas more than 70% of the families owned livestock of some type. Mean DDS among the adolescents was 4.83 and mean UFCS was found to be 1.14.
Table 4. Socio-demographic characteristics, DDS and UFCS of the 1441 adolescents participating in the study.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>n (%) or mean (± SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex:</td>
<td></td>
</tr>
<tr>
<td>Boys</td>
<td>732 (50.8%)</td>
</tr>
<tr>
<td>Girls</td>
<td>709 (49.2%)</td>
</tr>
<tr>
<td>Socio-economic status (SES):</td>
<td></td>
</tr>
<tr>
<td>Poorest</td>
<td>482 (33.45%)</td>
</tr>
<tr>
<td>Middle</td>
<td>478 (33.17%)</td>
</tr>
<tr>
<td>Richest</td>
<td>481 (33.38%)</td>
</tr>
<tr>
<td>Maternal education (completed years of formal education):</td>
<td></td>
</tr>
<tr>
<td>No education</td>
<td>335 (23.25%)</td>
</tr>
<tr>
<td>Primary (1-5 y)</td>
<td>512 (35.53%)</td>
</tr>
<tr>
<td>Secondary and above (≥ 6 y)</td>
<td>594 (41.22%)</td>
</tr>
<tr>
<td>Household food security:</td>
<td></td>
</tr>
<tr>
<td>Food insecure</td>
<td>713 (49.48%)</td>
</tr>
<tr>
<td>Food secure</td>
<td>728 (50.52%)</td>
</tr>
<tr>
<td>Household size:</td>
<td></td>
</tr>
<tr>
<td>Smaller (2-5 members)</td>
<td>1018 (70.65%)</td>
</tr>
<tr>
<td>Larger (≥ 6 members)</td>
<td>423 (29.35%)</td>
</tr>
<tr>
<td>Household source of drinking water:</td>
<td></td>
</tr>
<tr>
<td>Piped water</td>
<td>84 (5.83%)</td>
</tr>
<tr>
<td>Tube-well water</td>
<td>1340 (92.99%)</td>
</tr>
<tr>
<td>Others (rain water or surface water from river/pond)</td>
<td>17 (1.18%)</td>
</tr>
<tr>
<td>Household electricity coverage:</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>195 (13.53%)</td>
</tr>
<tr>
<td>Yes</td>
<td>1246 (86.47%)</td>
</tr>
<tr>
<td>Roof material of the largest room in the house:</td>
<td></td>
</tr>
<tr>
<td>Tin</td>
<td>1324 (91.88%)</td>
</tr>
<tr>
<td>Cement</td>
<td>113 (7.84%)</td>
</tr>
<tr>
<td>Others (straw, slate, talli, etcetera)</td>
<td>4 (0.28%)</td>
</tr>
<tr>
<td>Family ownership of farming land:</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>710 (49.27%)</td>
</tr>
<tr>
<td>Yes</td>
<td>731 (50.73%)</td>
</tr>
<tr>
<td>Family ownership of livestock:</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>410 (28.45%)</td>
</tr>
<tr>
<td>Yes</td>
<td>1031 (71.55%)</td>
</tr>
<tr>
<td>Dietary diversity score (DDS)</td>
<td>4.83 (±1.57)</td>
</tr>
<tr>
<td>Ultra-processed Food Consumption Score (UFCS)</td>
<td>1.14 (±0.92)</td>
</tr>
</tbody>
</table>
3.2 Mean DDS and UFCS across sex and SES categories

Table 5. Mean DDS and UFCS among the participants (n=1441) by sex and SES.

<table>
<thead>
<tr>
<th>Categories</th>
<th>Mean DDS (±SD)</th>
<th>p-value*</th>
<th>Mean UFCS (±SD)</th>
<th>p-value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boys</td>
<td>4.93 (±1.61)</td>
<td>0.011*</td>
<td>1.27 (±0.95)</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Girls</td>
<td>4.72 (±1.52)</td>
<td></td>
<td>1.00 (±0.86)</td>
<td></td>
</tr>
<tr>
<td>SES:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poorest</td>
<td>4.48 (±1.56)</td>
<td>&lt;0.001*</td>
<td>1.06 (±0.89)</td>
<td>0.012*</td>
</tr>
<tr>
<td>Middle-status</td>
<td>4.82 (±1.47)</td>
<td></td>
<td>1.12 (±0.88)</td>
<td></td>
</tr>
<tr>
<td>Richest</td>
<td>5.19 (±1.59)</td>
<td></td>
<td>1.23 (±0.97)</td>
<td></td>
</tr>
</tbody>
</table>

*Means between two groups were tested by independent sample t-test and between three groups by one-way ANOVA.

Table 5 above demonstrates how the mean DDS and UFCS differed across sex and SES categories. While both boys and girls recorded mean DDS below five, the small pro-boy difference appeared to be statistically significant (p=0.011). Adolescents from the richest households had significantly higher mean DDS than those from the poorest (5.19 versus 4.48, p<0.001). On the other hand, mean UFCS was higher among boys than girls (1.27 versus 1.00, p<0.001) and among adolescents from the richest households than their counterparts from the poorest households (1.23 versus 1.06, p=0.012).

3.3 Dietary diversity and consumption patterns among the adolescents and its socio-economic and gender stratification

Figure 4 illustrates consumption pattern across the 10 food groups among the participants. Consumption of rice (belonging to the group of grains) was universal as all of the interviewees were found to have eaten rice, at least once, during the reference period. Consumption of fish was also considerably high among this cohort of adolescents, with more than 70% consuming some type of fish. Dark green leafy vegetables were the least consumed, with only 25.82% responding to have consumed any item from this group. Vitamin A-rich vegetables, tubers and fruits were
Figure 4. Vertical stacked bar chart showing the proportion of adolescents who consumed item/s from the 10 food groups during the 24-hour recall period. Each bar represents 100% participants (i.e. 1441 adolescents).

consumed by only about a third of the participants (34.76%), whereas more than half of them (56%) consumed other vegetables. Food items from the groups legumes, nuts and seeds, and other fruits were consumed by 45.11% and 46.29% of the adolescents respectively. Excluding fish, the consumption of animal-source foods (ASF) was noticeably low: milk products consumed by a meagre 30%, meat by about 35%, and egg by about 37% of the participants.
The proportion of adolescents who consumed various food items from the 10 food groups is presented by categories of SES in Figure 5 and by sex in Figure 6. On stratification by SES, significant difference in reported consumption was observed for five food groups: flesh and organ meat; egg; other fruits; vitamin A-rich vegetables, tubers and fruits; and milk products. In comparison to adolescents from the richest households, those from the poorest households were consuming less meat (by about 16.48%, \( p<0.001 \)), egg (by about 13.37%, \( p<0.001 \)), other fruits (by about 11.73%, \( p=0.001 \)), vitamin A-rich vegetables, tubers and fruits (by about 10.25%, \( p=0.002 \)), and milk products (by about 9.20%, \( p=0.007 \)). For these five food groups, a socio-economic gradient of consumption proportion was observed- the richest adolescents consuming the most, middle-status adolescents consuming at intermediate levels, and the poorest adolescents consuming the least. Interestingly, proportions of adolescents from the richest households and from the poorest households who consumed fish were almost equal (74.64% and 74.90 % respectively).

On gender stratification (Figure 6), small but statistically significant difference was observed between the proportions of boys and girls who consumed milk products (34.43% of the boys and 25.53% of the girls, \( p<0.001 \)) and egg (41.26% of the boys and 32.58% of the girls, \( p<0.001 \)). Although not statistically significant, percentage consumption of fishes, vitamin A-rich vegetables, tubers and fruits, and leafy vegetables was higher among girls than among boys.
**Figure 5.** Horizontal grouped bar chart showing proportion of adolescents consuming item/s from the 10 food groups by socio-economic status. Pearson’s Chi-squared test was applied to test the difference in proportion between groups and $p$-values were retrieved with level of statistical significance fixed at $p<0.05$. Non-significant $p$-values not shown.
Figure 6. Horizontal grouped bar chart showing proportion of adolescents consuming item/s from the 10 food groups by sex (boy/girl). Pearson’s Chi-squared test was applied to test the difference in proportion between groups and $p$-values were retrieved with level of statistical significance fixed at $p<0.05$. Non-significant $p$-values not shown.
3.4 UPF consumption among the adolescents and its socio-economic and gender stratification

Table 6 and Table 7 present the proportion of adolescents who reportedly consumed food items belonging to the four groups of UPF. Ready-to-eat or “instant” foods were the least consumed with 12.77% of the adolescents responding to have consumed items from that group, whereas ultra-processed sweets, confectioneries and similar packaged products were the most consumed as 52.60% of the adolescents consumed those. Savory snacks and SSB were consumed by 35.80% and 13.46% of the participants respectively. While adolescents from the richest households consumed each of the four UPF groups more than their peers from the poorest households, the difference in consumption proportion reached statistical significance only for SSB. 16.22% of the adolescents from the highest SES category consumed SSB compared with 13.46% of those from the lowest SES category who consumed SSB (Table 6).

Table 6. Proportion of adolescents who consumed UPF during the 24-hour recall period by socio-economic status.

<table>
<thead>
<tr>
<th>Ultra-processed food groups</th>
<th>Adolescents consuming item/s from the 4 UPF groups n (% of total in that SES category)</th>
<th>Total n (% of total adolescents)</th>
<th>p-valuea</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Poorest</td>
<td>Middle-status</td>
<td>Richest</td>
</tr>
<tr>
<td>Ultra-processed ready-to-eat or “instant” foods</td>
<td>52 (10.79%)</td>
<td>59 (12.34%)</td>
<td>73 (15.18%)</td>
</tr>
<tr>
<td>Ultra-processed sweets, confectioneries and similar packaged products</td>
<td>241 (50%)</td>
<td>259 (54.18%)</td>
<td>258 (53.64%)</td>
</tr>
<tr>
<td>Ultra-processed savory snacks</td>
<td>173 (35.89%)</td>
<td>154 (32.22%)</td>
<td>189 (39.29%)</td>
</tr>
<tr>
<td>Sugar-sweetened beverage (SSB)</td>
<td>47 (9.75%)</td>
<td>69 (14.44%)</td>
<td>78 (16.22%)</td>
</tr>
</tbody>
</table>

a Pearson’s Chi-squared test was employed to calculate the p-values.

* Asterisk indicates statistical significance at p<0.05.
Analysis by gender stratification revealed that the consumption proportion of adolescent boys was significantly higher than that of girls for three out of the four UPF groups: ready-to-eat or “instant” foods (boys 15.57% versus girls 9.87%, \( p=0.001 \)); sweets, confectionaries and similar packaged products (boys 56.01% versus girls 49.08%, \( p=0.008 \)); and SSBs (boys 18.58% versus girls 8.18%, \( p<0.001 \)). Among these three groups of UPF, the widest boy-girl difference in consumption was captured for SSB (10.4%). The only UPF group without statistically significant gender-based difference in consumption was that of savory snacks (Table 7).

Table 7. Proportion of adolescents who consumed UPF during the 24-hour recall period by sex (boy/girl).

<table>
<thead>
<tr>
<th>Ultra-processed (UPF) Groups</th>
<th>Adolescent boys n (% of total boys)</th>
<th>Adolescent girls n (% of total girls)</th>
<th>Total n (% of total adolescents)</th>
<th>( p )-value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultra-processed ready-to-eat or “instant” foods</td>
<td>114 (15.57%)</td>
<td>70 (9.87%)</td>
<td>184 (12.77%)</td>
<td>0.001*</td>
</tr>
<tr>
<td>Ultra-processed sweets, confectionaries and similar packaged products</td>
<td>410 (56.01%)</td>
<td>348 (49.08%)</td>
<td>758 (52.60%)</td>
<td>0.008*</td>
</tr>
<tr>
<td>Ultra-processed savory snacks</td>
<td>279 (38.11%)</td>
<td>237 (33.43%)</td>
<td>516 (35.80%)</td>
<td>0.064</td>
</tr>
<tr>
<td>Sugar-sweetened beverage (SSB)</td>
<td>136 (18.58%)</td>
<td>58 (8.18%)</td>
<td>194 (13.46%)</td>
<td>&lt; 0.001*</td>
</tr>
</tbody>
</table>

* Pearson’s Chi-squared test was employed to calculate the \( p \)-values. The significance level was 0.05.

* Asterisk indicates statistical significance at \( p<0.05 \).

3.5 Factors associated cross-sectionally with DD and UPF consumption among the adolescents

For the purpose of further analysis, DDS was dichotomized, as mentioned in the Methodology section, to yield two categories of DD- inadequate DD (DDS\( \leq \)4) and adequate DD (DDS\( \geq \)5). Besides, mean UFCS for different categories were computed. Table 8 shows bivariate analysis of DD and mean UFCS by socio-demographic variables including household food security status. Adolescent sex (\( p=0.01 \)), SES (\( p<0.001 \)), maternal education (\( p=0.001 \)), household food security (\( p<0.001 \)), and ownership of farming land (\( p<0.001 \)) were associated with adolescents’ DD. On
the other hand, UFCS was associated with adolescent sex ($p<0.001$), SES ($p=0.011$), and household food security ($p=0.003$). 46.95% of the boys and 53.05% of the girls had inadequate DD. 42.28% of adolescents from the poorest households were observed to have inadequate DD, while 26.21% of their peers from the richest households had inadequate DD (Table 8).

Logistic regression analyses were carried out to estimate the odds of having inadequate dietary diversity in this cohort of adolescents (Table 9). The crude analysis revealed that the girls had higher odds of having inadequate DD than boys (cOR 1.31, 95% CI: 1.06-1.62); whereas adolescents from the richest (cOR 0.43, 95% CI: 0.33-0.55) and middle-status (cOR 0.58, 95% CI: 0.45-0.75) households, from the food secure (cOR 0.53, 95% CI: 0.43-0.65) households, and adolescents whose mothers had primary education (cOR 0.87, 95% CI: 0.66-1.14), and secondary or higher education (cOR 0.62, 95% CI: 0.47-0.81) had lower odds of having inadequate DD compared with those from the poorest households, food insecure households, and adolescents whose mothers had no education respectively. When adolescent sex and SES were included together in a model (Model I), both remained significantly associated with the outcome with small changes (<5%) in the adjusted odds ratios. Thereafter, household food security was put into the model (Model II) and all three variables emerged as significantly associated with the outcome. However, adjusted odds ratio for adolescents from food secure households increased by about 20% to become 0.64 from the crude odds ratio of 0.53, implying that adolescents in this category had 36% lower odds of having inadequate DD compared to their peers from food insecure households.

The adjusted odds ratios for the richest and middle-status SES categories in Model II also showed an increase by about 20% and 10% respectively, from the crude odds ratios. In the final adjusted model (Model III), which accounted for sex, SES, food security, and maternal education simultaneously, association between maternal education and inadequate DD lost statistical significance. When other variables held adjusted, on average, the odds of having inadequate DD was 25% higher among girls than boys; adolescents from the richest and middle-status households had 45% and 35% lower odds of having inadequate DD respectively than their peers from the poorest households; and adolescents from food secure households had 36% lower odds of having inadequate DD (see aOR$^3$ and CI in Table 9).
Table 8. Bivariate analysis with DD and mean UFCS as outcome among 1441 adolescents by relevant sociodemographic variables.

<table>
<thead>
<tr>
<th>Socio-demographic variables</th>
<th>Adolescents’ DD</th>
<th>Adolescents’ UFCS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Inadequate DD (DDS≤4) n (% of total adolescents in that category)</td>
<td>Adequate DD (DDS≥5) n (% of total adolescents in that category)</td>
</tr>
<tr>
<td>Sex: Boy</td>
<td>292 (46.95%)</td>
<td>440 (53.72%)</td>
</tr>
<tr>
<td>Girl</td>
<td>330 (53.05%)</td>
<td>379 (46.28%)</td>
</tr>
<tr>
<td>SES: Poorest</td>
<td>263 (42.28%)</td>
<td>219 (26.74%)</td>
</tr>
<tr>
<td>Middle-status</td>
<td>196 (31.51%)</td>
<td>282 (34.43%)</td>
</tr>
<tr>
<td>Richest</td>
<td>163 (26.21%)</td>
<td>318 (38.83%)</td>
</tr>
<tr>
<td>Maternal education:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No education</td>
<td>165 (26.53%)</td>
<td>170 (20.78%)</td>
</tr>
<tr>
<td>Primary</td>
<td>234 (37.62%)</td>
<td>278 (33.94%)</td>
</tr>
<tr>
<td>Secondary and above</td>
<td>223 (35.85%)</td>
<td>371 (45.28%)</td>
</tr>
<tr>
<td>HH food security:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Food insecure</td>
<td>363 (58.36%)</td>
<td>350 (42.74%)</td>
</tr>
<tr>
<td>Food secure</td>
<td>259 (41.64%)</td>
<td>469 (57.26%)</td>
</tr>
<tr>
<td>HH size:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Larger</td>
<td>180 (28.94%)</td>
<td>243 (29.67%)</td>
</tr>
<tr>
<td>Smaller</td>
<td>442 (71.06)</td>
<td>576 (70.33%)</td>
</tr>
<tr>
<td>Ownership of farming land:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>339 (54.50%)</td>
<td>371 (45.30%)</td>
</tr>
<tr>
<td>Yes</td>
<td>283 (45.50%)</td>
<td>448 (54.70%)</td>
</tr>
<tr>
<td>Ownership of livestock:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>172 (27.65%)</td>
<td>238 (29.06%)</td>
</tr>
<tr>
<td>Yes</td>
<td>450 (72.35%)</td>
<td>581 (70.94%)</td>
</tr>
</tbody>
</table>

<sup>a</sup> Pearson’s Chi-squared test was employed to compare proportions between groups.

<sup>b</sup> Independent sample t-test was employed to compare means between two groups and one way ANOVA was employed to compare means between more than two groups.
Table 9. Multivariable logistic regression model predicting the likelihood of inadequate DD among 1441 adolescents in Matlab, Bangladesh.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Inadequate DD (DDS ≤ 4)</th>
<th>Crude analysis¹</th>
<th>Adjusted analysis² (Model I)</th>
<th>Adjusted analysis² (Model II)</th>
<th>Adjusted analysis² (Model III)³</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>cOR 95% CI</td>
<td>aOR1 95% CI</td>
<td>aOR2 95% CI</td>
<td>aOR3 95% CI</td>
</tr>
<tr>
<td>Sex:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boy (Ref)</td>
<td></td>
<td>1.31 1.06-1.62*</td>
<td>1.25 1.009-1.544*</td>
<td>1.25 1.007-1.544*</td>
<td>1.25 1.008-1.547*</td>
</tr>
<tr>
<td>Girl</td>
<td></td>
<td>1.59 1.25-2.05</td>
<td>1.45 1.18-1.78</td>
<td>1.45 1.21-1.71</td>
<td>1.45 1.21-1.71</td>
</tr>
<tr>
<td>SES:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poorest (Ref)</td>
<td></td>
<td>0.58 0.45-0.75*</td>
<td>0.59 0.45-0.76*</td>
<td>0.64 0.49-0.83*</td>
<td>0.65 0.50-0.85*</td>
</tr>
<tr>
<td>Middle-status</td>
<td></td>
<td>0.43 0.33-0.55*</td>
<td>0.44 0.33-0.56*</td>
<td>0.52 0.40-0.69*</td>
<td>0.55 0.41-0.74*</td>
</tr>
<tr>
<td>Richest</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HH food security:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Food insecure (Ref)</td>
<td></td>
<td>0.53 0.43-0.65*</td>
<td>0.64 0.51-0.80*</td>
<td>0.64 0.51-0.81*</td>
<td></td>
</tr>
<tr>
<td>Food secure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maternal education:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No education (Ref)</td>
<td></td>
<td>0.87 0.66-1.14*</td>
<td></td>
<td>0.96 0.72-1.27</td>
<td></td>
</tr>
<tr>
<td>Primary</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Secondary and above</td>
<td></td>
<td>0.62 0.47-0.81*</td>
<td></td>
<td>0.85 0.64-1.15</td>
<td></td>
</tr>
</tbody>
</table>

¹Bivariate analysis of each row characteristic against inadequate DD separately. cOR and aOR stand for crude odds ratio and adjusted odds ratio respectively.
²Model I adjusted for sex and SES; Model II for sex, SES, and household food security; and Model III for sex, SES, food security, and maternal education simultaneously.
³Nagelkerke’s pseudo-R² for Model III was 0.06.
* Asterisk indicates statistical significance as CI did not include 1.

Table 10 below presents the odds ratios derived from ordinal logistic regression analysis with higher UFCS as the ordinal outcome. In the crude analysis, being girl was found to be negatively associated with higher UFCS (cOR 0.59, 95% CI: 0.49-0.71), while belonging to the richest households (cOR 1.38, 95% CI: 1.09-1.75) and to the food secure households (cOR 1.31, 95% CI: 1.08-1.58) appeared to be positively associated with higher UFCS. Nevertheless, when adjusted simultaneously, only the association between being girl and higher UFCS remained statistically significant.
significant (aOR 0.59, 95% CI: 0.49-0.73); implying that, on average, the odds of attaining higher UFCS was 41% lower among the girls than the boys.

Table 10. Ordinal logistic regression model predicting cross-sectional association of higher UFCS with socio-demographic variables and household food security among 1441 adolescents in Matlab, Bangladesh.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Crude analysis</th>
<th>Adjusted analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>cOR 95% CI</td>
<td>aOR 95% CI</td>
</tr>
<tr>
<td>Sex:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boy (Ref)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Girl</td>
<td>0.59 0.49-0.71*</td>
<td>0.59 0.49-0.73*</td>
</tr>
<tr>
<td>SES:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poorest (Ref)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Middle-status</td>
<td>1.12 0.89-1.40</td>
<td>1.04 0.83-1.31</td>
</tr>
<tr>
<td>Richest</td>
<td>1.38 1.09-1.75*</td>
<td>1.22 0.96-1.57</td>
</tr>
<tr>
<td>HH food security:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Food insecure (Ref)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Food secure</td>
<td>1.31 1.08-1.58*</td>
<td>1.22 0.99-1.49</td>
</tr>
<tr>
<td>Stratified analysis by gender:</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Boys (n=732)</td>
<td>Girls (n=709)</td>
</tr>
<tr>
<td>SES:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poorest (Ref)</td>
<td>0.77 0.55-1.07</td>
<td>0.36 0.43-0.91*</td>
</tr>
<tr>
<td>Middle-status</td>
<td>0.99 0.70-1.37</td>
<td>0.43 0.34-0.80*</td>
</tr>
<tr>
<td>Richest</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HH food security:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Food insecure (Ref)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Food secure</td>
<td>1.30 1.00-1.73</td>
<td>1.07 0.81-1.44</td>
</tr>
</tbody>
</table>

1 Bivariable analysis of each row characteristic against higher UFCS separately. cOR and aOR stand for crude odds ratio and adjusted odds ratio respectively.
2 Adjusted for sex, SES, and household food security simultaneously.
* Asterisk indicates statistical significance as CI did not include 1.
Stratified analyses did not reveal any significant difference between crude and stratum-specific odds ratios by strata of gender or SES for the outcome of inadequate DD (see Appendices). No effect modification by SES was observed for the outcome of higher UFCS too. However, gender appeared to be modifying the association between SES and higher UFCS, as girls from the richest households had 57% lower odds of having higher UFCS in comparison to girls from the poorest households (stratum-specific OR 0.43, 95% CI: 0.34-0.80) and girls from the middle-status households had 64% lower odds having higher UFCS compared with girls from the poorest households (stratum-specific OR 0.36, 95% CI: 0.43-0.91). The stratum-specific odds ratios for boys from the richest and middle-status households were 0.99 and 0.77 respectively, but the CIs included one.

4 Discussion:

Adopting a cross-sectional design this study explored DD and UPF consumption in a cohort of rural Bangladeshi adolescents from Matlab. The findings paint a less-than-ideal picture; characterized by a limited DD driven by remarkably high reliance on rice, the staple food, and low consumption of leafy vegetables, vitamin A-rich vegetables, tubers and fruits, and animal-source foods (ASF). Small but statistically significant differences in mean DDS and mean UFCS were observed by gender and SES; with boys having higher means than girls and adolescents from the richest households scoring higher means than their peers from the from the poorest households. On applying literature-supported cut-off for determining inadequate and adequate DD, more than half of the boys were found to have adequate DD, whereas 46.28% of the girls had adequate DD. While nearly 39% of the adolescents from the richest households reportedly consumed items from five or more food groups, only about one-fourth of their fellow participants from the poorest households consumed foods from five or more groups.

Further segregation of the data revealed that the pro-boy gap in DD stemmed from moderate yet significant differences in consumption proportion for egg and milk products in favor of the boys. Segregation by SES demonstrated statistically significant differences in consumption of five food groups: i. vitamin A-rich vegetables, tubers and fruits, ii. other fruits, iii. flesh and organ meat, iv. egg, and v. milk products; for each of which, participants from the poorest households consumed less than their counterparts from the richest households.
After adjusting for confounders in a multi-variable logistic regression model; gender, SES and household food security emerged as factors significantly associated with inadequate DD. Adolescent girls were significantly more likely than boys to have inadequately diversified diet. In comparison to adolescents from the poorest households, those from the richest and those from the middle-status households were significantly less likely to have inadequate DD. The odds of inadequate DD were also significantly lower among adolescents from food secure households. Stratified analyses undertaken after modelling were unremarkable.

Overall, the consumption of UPF was low among the participants. Ultra-processed sweets, confectioneries and similar packaged products was the most consumed group with more than 50% of the participants consuming items belonging to this group. Out of the four UPF groups, three showed significant gender-based difference in consumption; namely ready-to-eat or “instant” foods; sweets, confectioneries and similar packaged products; and SSB; with boys consuming these more than girls. SSB was also consumed more by adolescents from the richest households. Ordinal logistic regression model that accounted for gender, SES and household food security showed that the odds of having higher UFCS were significantly lower among girls than among boys. Stratified analysis yielded evidence of gender modifying the association between SES and UPF consumption with girls from the richest and middle-status households being significantly less likely to have higher UFCS than their peers from the poorest households.

4.1 Interpretative appraisal of the findings

Limited DD with low consumption of non-staple foods: This study showed that diets of the rural adolescents in Matlab are suboptimal in diversity and dominated by rice, lending support to similar studies previously conducted in Bangladesh (64,123,156). In line with the universal consumption of rice by the adolescents found in this study, Harris-Fry and colleagues also found that 100% of their study participants consumed rice during the 24-hour recall period (64) and Leroy et al. reported a remarkable energy contribution by rice (75% of the total energy intake) among rural Bangladeshi adolescents (123). While the fact that Matlab is an agriculture-dependent locality with rice being the main produce explains such a dietary reliance on the staple, the research and policy bias at national level promoting rice production (157) contributes to such over-reliance too. Besides, dependence on rice could make adolescents’ dietary diversity unduly sensitive to changes in the price of rice (158). Rice-farming families might opt to sell much of the cultivated rice and
use the money for buying various foods across the food groups, whereas families that do not cultivate rice might be compelled to divert limited available money to buy rice, and thus, having even less DD. Consequent to the suboptimal DD, these adolescents are at risk of multiple micronutrient deficiencies, as diversified diet is necessary to ensure intake of such micronutrients as iron, zinc, calcium, vitamin A, folate, etcetera (52). Other than fish the consumption of ASF was low, exposing the adolescents to risk of different forms of malnutrition and of deficiency of essential amino acids (159).

Consumption of fish was considerably high among this cohort. Matlab being a low-lying, rural area traversed by tributaries, this was not surprising. In their study based on a sample representative of rural Bangladesh, Bogard et al. showed a significantly lower consumption of fish in poor households (160). Differing from that finding, fish consumption in this study did not vary significantly by gender or SES. This probably reflects the greater access of rural families in Matlab to different fishes. Rural adolescents are found to be more likely to consume fish than their urban peers in previous research as well (161). As nutritional profile of non-farmed fishes differs from that of fishes produced by aquaculture in Bangladesh (162), whether such higher fish consumption among these adolescents translate into nutritional and health benefits remains to be studied in future.

Consumption of vitamin A-rich and dark green leafy vegetables as well as fruits was low among the participants. Not only such a dietary pattern with low fruit and vegetable intake increases the risk of nutritional deficits, but also it deprives these adolescents of the benefit of lowered cardiovascular disease risk offered by diets rich in fruits and vegetables (163). Adolescents’ fruit and vegetable consumption is influenced by a number of determinants, of which availability and accessibility are powerful predictors (164,165). Whether the low consumption in this cohort resulted from limited availability of fruits and vegetables or from lack of nutritional knowledge could not be explored. The prevalence of subclinical vitamin A deficiency among school-age children in Bangladesh is about 20% and consumption of leafy vegetables in this group is not positively associated with serum retinol level (166). This indicates that despite Bangladesh increasing the production of spinach and red amaranth (major plant sources of vitamin A) and traditional rural diets usually incorporating a fair amount of leafy vegetables, vitamin A deficiency
persists at a burdensome level (166). Therefore, diversifying diet through ASF needs to be prioritized for improving vitamin A status among rural adolescents.

Less than a third of the adolescents responded to have consumed milk products, which was unanticipated considering that more than 70% of the households owned livestock with milk-producing cow and goat being common possession. The low intake is likely to preclude these adolescents from benefits like lower adiposity and higher cardiorespiratory fitness associated with consumption of milk products (167). It is shown that intake of dairy products decreases drastically during adolescence; primarily, because of reduction in milk consumption (168) and qualitative exploration linked this to such subjective factors as misconceptions regarding dairy foods and their health benefits, dislike of the taste, parental and peer influence, and so forth (169). However, the scope of this study did not allow examination of such hypotheses.

**Pro-boy disparity in DD and significant variation in consumption by SES:** This study documented a pro-boy disparity in DD with more boys than girls achieving adequate DD. Milk products and egg were consumed significantly more by boys than girls. Literature on such gender-based gap in adolescents’ DD is relatively sparse and inconclusive as well. The longitudinal study from India by Aurino finds a significant pro-boy gap in DD with boys having higher mean DDS at ages 5, 8 and 15; driven by a significantly lower consumption of ASF, legumes, root vegetables and fruits by the girls (44). Interestingly, she observes the pro-boy disparity to widen to the maximum at 15 years of age, which is the age at which participants in this study were surveyed. Such pro-boy disparity is also reported in rural Ethiopia where odds of consuming ASF was 73% higher among boys than among girls (61). Nonetheless, another study drawing on data from Ethiopia, India, Peru and Vietnam does not find marked gender disparity in DD (170).

This pro-boy disparity might result from intra-household inequalities in food allocation favoring the adolescents that spend more time outdoors or spend more time playing, engage in vigorous activities to help fathers during cultivation and harvesting periods, or are considered to be the future breadwinner for the family; which in most cases are the boys (171). Additionally, existing cultural norms that favor males might provide adolescent boys with differential access to foods (e.g. egg, meat or milk) that are perceived as having higher quality or capable of delivering more energy (172). Deep-rooted belief of difference in nutritional needs of adolescent boys and girls could also nurture a pro-boy gap. On top of that, during mid-adolescence the gender norms might
become more influential in determining intra-household food allocation dynamics leading to girls being disfavored (149). One counter-argument to this relates to the greater prevalence of body image dissatisfaction and restrictive dietary practices among adolescent girls than boys, found to be existing even in LMIC setting (173,174). Therefore, the lower DD among girls could result from their intentional avoidance of some foods; particularly the unitary, high-quality foods, such as egg, milk, meat, etcetera; that they perceive to be linked with weight gain.

A major effect of SES on consumption was observed- foods from five out of the ten groups (dairy, egg, meat, vitamin A-rich vegetables, tubers and fruits, and other fruits) were consumed more by adolescents belonging to the richest households. This aligns with a body of literature from Bangladesh and elsewhere that reports similar pro-rich variation in consumption and in DD (62,66,123,156,175). Adolescents from households with higher SES are usually found to consume more ASF, fruits and vegetables; and have access to diverse diets. This largely indicates the effect of purchasing power of families that can ensure household access to a variety of foods. The almost equally high consumption of fish across SES strata in Matlab hints that there are contextual factors which when acknowledged and capitalized on could form the basis for successful dietary diversification interventions in low-income settings.

**Factors influencing adolescents’ DD in Matlab:** Gender, SES and household food security were associated with DD of the adolescents in Matlab. The stark influence of SES on both household- and individual-level DD is demonstrated across different settings (60–62,64,156,176). Findings from this study pinpointed the socio-economic gradient in DD of adolescents in a rural context of a lower-middle-income country.

Scientific literature persistently shows that high-quality, diverse diets cost more than diets dominated by grains and starchy staples (177,178). It is also recognized that poorer households spend a greater proportion of income on food purchase than richer households (179). Weighing this against the fact that the cost of nutrient-rich foods (such as ASF or fruits) is significantly higher than that of grains or starchy staples (178) gives insights into how the DD could remain inadequate for those who are socio-economically disadvantaged. Besides, studies repeatedly show that respondents with lower SES stress the role of high perceived cost of meat, fruits and vegetables in narrowing their options for accessing a varied diet (180,181). Although level of education, knowledge of nutrition, taste preference, cultural acceptability of certain foods play a role, the
dimension of cost poses the strongest obstacle to accessing and consuming diversified diets (178). In Matlab, it is not uncommon for households to have some means of homestead production of fruits, milk and egg as families commonly own livestock and trees of seasonal fruits like mango, jackfruit, guava, jujube, papaya, etcetera around their house yards. Although sensitive to seasonality, what role such homestead production plays in shaping adolescents’ DD could not be examined using data collected for this study.

As expected in a rural setting where nearly half of the total participants come from food insecure households, this study captured a significant association between food security and DD; adding to similar findings reported by previous studies from LMICs (60,64,182–186). Previous studies reveal that food insecurity results in decreased individual-level consumption of meat, egg, milk products, fruits and vegetables (60,186) suggesting how lack of food security imparts its negative effect on DD. One alarming aspect to consider is that Bangladeshi adolescents are shown to be more likely than other family members (i.e. men and under-5 children) to adopt coping strategies and restrict consumption in response to food insecurity (119), which might partly explain the negative association between food insecurity and DD in this cohort. The findings underscore the importance of broader poverty alleviation measures in achieving household food security, without which efforts to improve rural adolescents’ DD are likely to be futile.

The non-association that merits attention is related to maternal education. This study did not find maternal education to be associated with adolescents’ DD, and thus, departed from previous research carried out in Bangladesh (57,158,187) which show that maternal education improves DD. In addition to empowerment ensuing from educational attainment and greater bargaining power entitled to empowerment, maternal education is assumed to equip mothers with nutrition literacy and capability to understand and act upon nutrition-related information and messages (146); thereby, contributing to better DD of their family members. However, Sraboni and Quisumbing demonstrate from Bangladesh that the association between maternal education and better diet quality of family members varies across the life course and cannot modify the pro-boy disparity in DD that emerges during adolescence (187). Moreover, in a recent study from India, Aurino notes that gender disparity evident in early- and mid-adolescence does not vary by maternal education (44). No influence of maternal education on nutrient intakes of rural Bangladeshi adolescents is found by Leroy et al. too (123).
One plausible explanation for this lack of association could be that limited affordability due to resource constraints is preventing mothers with considerable formal education from trying and diversifying the diets of the adolescents. In an impoverished setting where food insecurity prevails to a substantial extent, diversification of adolescents’ diet is likely to receive minimum attention. The absence of significant effect of maternal education on adolescents’ DD questions the assumption operating at policy-making level that educating and empowering women will invariably translate into equitable improvement in dietary and nutritional outcomes. It needs to be acknowledged that directing resources to women for improving nutrition might be unsuccessful without concurrent socio-economic development and without addressing existing gender norms.

**Low overall UPF consumption with a gendered pattern:** Consumption of UPF among the participants was low, implying that the proportion of daily energy intake in these adolescents that come from UPF is likely to be much lower than those reported from elsewhere. For instance, studies from Brazil (188), Mexico (86), Chile (87) and Canada (91) report that UPF contributes to 21.5%, 29.8%, 28.6% and 48% of the total caloric intake respectively. Scarce literature from South Asia on UPF consumption did not allow comparison with settings that are more comparable with Matlab. The low UPF consumption in this cohort can be partly explained by three attributes of the study setting: firstly, the rural food environment in Matlab does not provide access to retail food outlets like super- or hyper-markets, or fast food chains, which are major drivers of UPF intake (74); secondly, in contrast to busy, urban settings the consumer-side demand for ready-to-eat or convenience foods in Matlab is expectedly low; and thirdly, the cost of UPF items in Matlab might be excessive when considered against low purchasing ability of rural consumers.

Nevertheless, gendered pattern of consumption was observed for three UPF groups- ready-to-eat or “instant” foods; sweets, confectioneries and similar packaged products; SSB- with boys consuming more than girls. The strongest gendered consumption (in terms of difference in consumption proportion) was observed for SSB. SSB was also significantly more consumed by adolescents from the richest households. Existing literature suggests that boys are more likely to drink SSB than girls (189–191) and this study found the same. The fact that boys consumed more SSB is worrisome as research shows that once established earlier in life, SSB consumption tends to increase in early adulthood (192). Boys might have a taste preference toward SSB (193) and more access to SSB as they stay outdoors more and frequent the village markets. Besides, boys
might have perceptions that link consumption of energy drinks (included in the SSB group) with increased bodily strength or masculine features (193,194) which drive the gendered pattern of consumption. In addition, gender appeared to modify the effect of SES on UPF consumption as girls from the better off households were found to be less likely to consume UPF than girls from the poorest households. This could point toward a greater availability of fresh and home-cooked foods in households with higher SES that does not allow those adolescent girls to snack on packaged products or other UPF. However, why such an effect was obscured among boys could not be determined.

4.2 Strengths and limitations

A number of strengths and limitations needs to be considered while interpreting the findings from this study. Availing community-based, high-quality data collected from a well-characterized cohort in a rural setting with long-established research infrastructure this study explored pattern and diversity of adolescents’ diets, contributing to the existing literature on this topic from rural Bangladesh which focused on pregnant adolescent girls and women (57,133,156). To the best of the author’s knowledge, this study was also the first from Bangladesh to investigate UPF consumption among rural adolescents. Besides, strength of this study lies in its application of simple, cost-effective, validated tools, and rigorous attempts to ensure high internal validity.

Cross-sectional design of the study did not allow analysis of temporal association and no inference on causality could be drawn from the findings. Since changes in dietary diversity might reciprocally affect determinants of SES and food security, reverse causality could not be totally ruled out. Dietary patterns and practices are influenced by a wide range of critically interplaying factors and this study could not quantify all of those; for example, data on mothers’ and adolescents’ nutrition-related knowledge or media exposure were not collected. This compromised the comprehensiveness of analysis, and perhaps, is reflected by the low Nagelkerke’s pseudo-$R^2$ value (0.06) for the final model (Model III) predicting inadequate DD.

DD and UPF consumption were ascertained using synthetic, qualitative scores derived from a single 24-hour recall, which may not have captured habitual consumption and may have incorporated consumption of items that are not typically consumed (195). Although one tablespoonful amount of consumption of an item was required for obtaining one point, quantitative assessment of intake is extremely difficult in settings like that of Matlab where people share food
from a common bowl (196). Furthermore, DDS is a population-level indicator in spite of being constructed from individual participants, and hence, must not be interpreted as a proxy for diet quality of an individual adolescent (50). Moreover, the cut-off determining adequacy of DD (i.e. consumption of items from 5 or more food groups) might not be uniformly applicable across settings and age groups (133).

4.3 Recommendations

Future research avenues in relation to rural adolescents’ DD: Findings from this study provide a starting point for further exploration of the gender bias found in DD and intake of high-quality foods among rural adolescents. How intra-household food allocation dynamics drive and maintain such a disparity merits intensive research focus. Examination of the apparent lack of effect of maternal education on adolescents’ DD in a rural context is also necessary, as it has policy implications. Adolescence is a transitional phase in life course (12) and correlates of their dietary practices and preferences are diverse (27). Mixed-method investigation into knowledge and perceptions of Matlab adolescents regarding importance of consuming a diverse diet might form the basis for targeted interventions. Additional research is needed to delineate what underlies the gendered consumption of UPF, particularly SSB, with attention to factors existing in the built environment or adolescents’ social network that might be influencing boys more than girls to drink SSB.

Potential intervention strategies: In general, the number of studies on intervention designed for improving DD of young children and mothers is growing (197–200). However, there is a striking paucity of studies on intervention that specifically targeted adolescents’ DD. Periodic food rations for food insecure households in Malawi (198), cash transfer to poor households during lean season in Burkina Faso (199), and provision of food voucher for households in Ecuador (200) reported improvement in DD of children aged 12-72 months. Similar social transfer programs in Bangladesh have been shown to increase calorie intake and per capita food expenditure (201). Nevertheless, whether such strategies could translate into better DD among rural adolescents remain to be studied. Although adolescents enjoy autonomy to a certain extent regarding their dietary choices, they are not the only decision-maker when it comes to food purchase, food expenditure and intra-household allocation of foods. This might affect success of rationing or transfer interventions.

Exploring rural adolescents’ dietary diversity, ultra-processed food consumption, and relevant socio-economic correlates: a cross-sectional study from Matlab, Bangladesh
Evidence from rural Ethiopia shows an improvement in DD, again, of children aged 6-24 months, following community-based, participatory nutrition promotion program that consisted of women-led, interactive group sessions focusing on preparation of dishes with recipes that utilize locally available ingredients followed by discussion on nutrition-related messages and know-how (197). Although designed for mother-children dyads, tailoring this for mother-adolescent dyads would not be unrealistic. Perhaps, most relevant for rural adolescents in Matlab is the example from Jimma, Ethiopia where school-based, peer-led behavior change communication (BCC) coupled with provision of various seeds for home gardening resulted in significant improvement in DD of 10-19 year old adolescents (202). Such BCC strategy can be contextualized with a community-based setup to reach adolescents who are out of school and to address gender-biased practices as well. As Bangladesh is considerably successful in retaining girls in school by employing transfer programs (123), interventions incorporating school-based distribution of food basket combined with nutrition education for sensitizing rural adolescents to the importance of adequate DD could bring promising results. Promoting homestead production by facilitating rural families to undertake vegetable gardening could be another rational intervention as home gardening is found to improve DDS in rural settings (203).

**Policy imperatives:** Adolescents constitute about 21% of the total population in Bangladesh (117). Their health and nutrition have immense implications for Bangladesh to continue on its impressive trajectory of development. Findings from this study underscores the urgent need to invest in formulating and implementing targeted measures to diversify the diets of rural adolescents. Inadequate DD and heavy reliance on rice found among Matlab adolescents calls for a shift in policy focus from increasing rice production toward a focus on crop diversification and increased fruit and vegetable production. More importantly, lack of affordability and food insecurity in rural Bangladesh need to be tackled with sustainable socio-economic development and poverty alleviation for any of the interventions suggested above to create an impact in improving adolescents’ DD. Moreover, policymakers need to acknowledge that educating women may not automatically result in an equitable improvement in individual-level nutrition and dietary outcomes.

*Exploring rural adolescents’ dietary diversity, ultra-processed food consumption, and relevant socio-economic correlates: a cross-sectional study from Matlab, Bangladesh*
5 Concluding remarks:

DD is a pivotal dimension of high-quality, healthy diet. Findings from this study indicate that the diet of rural adolescents in Matlab, Bangladesh is suboptimal with considerably low DD, heavy reliance on staple, and scant consumption of vegetables, fruits and ASF other than fish. In general, a pro-boy disparity in DD was observed. A socio-economic gradient, in favor of adolescents from the richest households, was also found regarding consumption nutrient-rich foods. Gender, SES and household food security were associated with DD. Consumption of UPF was low and gender emerged as the only significant correlate. Drawing on the findings, it can be concluded that Matlab adolescents are at significant risk of nutritional deficiencies. Owing to the limitations inherent to cross-sectional design and the pitfalls in operationalizing exposure and outcome through recall-based survey and synthetic scores respectively, the findings need to be interpreted with caution. Improving the DD of these rural adolescents requires pragmatic policies and tailored programs that enhance access to diverse diets by tackling affordability and food insecurity issues, address social norms and intra-household dynamics that favor boys over girls, and sensitize the adolescents to importance of diversity in diet.

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7 References:


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Exploring rural adolescents’ dietary diversity, ultra-processed food consumption, and relevant socio-economic correlates: a cross-sectional study from Matlab, Bangladesh


68. Bhargava A, Bouis HE, Scrimshaw NS. Dietary Intakes and Socioeconomic Factors Are Associated with the Hemoglobin Concentration of Bangladeshi Women. :7.


Exploring rural adolescents’ dietary diversity, ultra-processed food consumption, and relevant socio-economic correlates: a cross-sectional study from Matlab, Bangladesh


Exploring rural adolescents’ dietary diversity, ultra-processed food consumption, and relevant socio-economic correlates: a cross-sectional study from Matlab, Bangladesh
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Exploring rural adolescents’ dietary diversity, ultra-processed food consumption, and relevant socio-economic correlates: a cross-sectional study from Matlab, Bangladesh


134. Martin-Prevel Y, Becquey E, Arimond M. Food Group Diversity Indicators Derived from Qualitative List-Based Questionnaire Misreported Some Foods Compared to Same Indicators Derived from Quantitative 24-Hour Recall in Urban Burkina Faso. J Nutr. 2010 Nov 1;140(11):2086S-2093S.


144. Frongillo EA. Development and Validation of an Experience-Based Measure of Household Food Insecurity within and across Seasons in Northern Burkina Faso1,2. .11.
Exploring rural adolescents’ dietary diversity, ultra-processed food consumption, and relevant socio-economic correlates: a cross-sectional study from Matlab, Bangladesh


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8 Appendices:

Exposure dimension:
- Gender
- Socio-economic status (SES)

Outcome dimension:
1. Dietary diversity (DD)
2. Ultra-processed food consumption

Potential confounding factors:
1. Household food security
2. Maternal education
3. Ownership of land
4. Ownership of livestock
5. Household size

Additional Figure 1. Simple concept map guiding the data analysis.
### Additional Table 1. Data management and specification for major constructed variables.

<table>
<thead>
<tr>
<th>Variable name</th>
<th>Short name</th>
<th>Variable construction</th>
<th>Codes for components</th>
<th>Specification</th>
<th>Type of variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dietary diversity score</td>
<td>DDS</td>
<td>DDS = DAFG'[(1A+1B+2)+(3+6)+4+5+7+8+9+(10A+10B)+11+12]</td>
<td>0 = Didn’t consume more than one tablespoonful, 1 = Consumed, but less than one tablespoonful</td>
<td>If DAFG 1A = 0 or 2, then DAFG’ 1A = 0, If DAFG 1A = 1, then DAFG’ 1A = 1, Likewise for all food groups.</td>
<td>Numerical, discrete</td>
</tr>
<tr>
<td>Dietary diversity</td>
<td>DD</td>
<td>DD = 1 if DDS ≤ 4, DD = 0 if DDS ≥ 5</td>
<td>1 = Inadequate dietary diversity, 2 = Adequate dietary diversity</td>
<td>N/A</td>
<td>Categorical, dichotomous</td>
</tr>
<tr>
<td>Household food insecurity access scale score</td>
<td>HFIAS</td>
<td>HFIAS = HFS’[1+2+3+4+5+6+7+8+9]</td>
<td>1 = Never happened, 2 = 1-3 times in the last 30 days, 3 = Once in 7 days, 4 = 2-3 times in 7 days, 5 = At least 4-5 times in 7 days</td>
<td>If HFS1 = 1, then HFS’1 = 0, If HFS1 = 2, then HFS’1 = 1 (Rarely), If HFS1 = 3 or 4, then HFS’1 = 2 (Sometimes), If HFS1 = 5, then HFS’1 = 3 (Often)</td>
<td>Numerical, discrete</td>
</tr>
<tr>
<td>Household food security</td>
<td>FS</td>
<td>FS = 1, if HFIAS = 0 or 1 (only if that 1 point was derived from HFS’1). FS = 0, if HFIAS = 1-27 (in case of HFIAS being 1 that must be derived from HFS’ 2 to 9).</td>
<td>1 = Food secure, 0 = Food insecure</td>
<td>N/A</td>
<td>Categorical, dichotomous</td>
</tr>
</tbody>
</table>
**Additional Table 2.** Analysis of factors associated with inadequate DD stratified by gender and SES (Odds ratios derived from multi-variable logistic regression).

<table>
<thead>
<tr>
<th>Stratification by gender</th>
<th>Variables</th>
<th>Inadequate DD (DDS≤4)</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Boys (n=732)</td>
<td>Girls (n=709)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>OR</td>
<td>95% CI</td>
<td>OR</td>
<td>95% CI</td>
</tr>
<tr>
<td>SES:</td>
<td>Poorest (Ref)</td>
<td>0.67</td>
<td>0.46-0.99*</td>
<td>0.62</td>
<td>0.43-0.91*</td>
</tr>
<tr>
<td></td>
<td>Middle-status</td>
<td>0.57</td>
<td>0.37-0.86*</td>
<td>0.53</td>
<td>0.34-0.80*</td>
</tr>
<tr>
<td></td>
<td>Richest</td>
<td>0.67</td>
<td>0.46-0.87*</td>
<td>0.67</td>
<td>0.46-0.89*</td>
</tr>
<tr>
<td>Household food security:</td>
<td>Food insecure (Ref)</td>
<td>0.67</td>
<td>0.46-0.99*</td>
<td>0.62</td>
<td>0.43-0.91*</td>
</tr>
<tr>
<td></td>
<td>Food secure</td>
<td>0.57</td>
<td>0.37-0.86*</td>
<td>0.53</td>
<td>0.34-0.80*</td>
</tr>
<tr>
<td>Maternal education:</td>
<td>No education (Ref)</td>
<td>1.04</td>
<td>0.69-1.56</td>
<td>0.87</td>
<td>0.58-1.31</td>
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<tr>
<td></td>
<td>Primary education</td>
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<td>0.55-1.26</td>
<td>0.87</td>
<td>0.57-1.33</td>
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<td></td>
<td>Secondary education and above</td>
<td>0.67</td>
<td>0.46-0.87*</td>
<td>0.67</td>
<td>0.46-0.89*</td>
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</table>

<table>
<thead>
<tr>
<th>Stratification by SES</th>
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<th>Inadequate DD (DDS≤4)</th>
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<th></th>
<th></th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Poorest (n=482)</td>
<td>Middle-status (n=478)</td>
<td>Richest (n=481)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>OR</td>
<td>95% CI</td>
<td>OR</td>
<td>95% CI</td>
</tr>
<tr>
<td>Adolescent sex:</td>
<td>Boy (Ref)</td>
<td>1.32</td>
<td>0.92-1.90</td>
<td>1.21</td>
<td>0.83-1.75</td>
</tr>
<tr>
<td></td>
<td>Girl</td>
<td>1.01</td>
<td>0.62-1.39</td>
<td>0.52*</td>
<td>0.35-0.75</td>
</tr>
<tr>
<td>Household food security:</td>
<td>Food insecure (Ref)</td>
<td>0.93</td>
<td>0.62-1.39</td>
<td>0.52*</td>
<td>0.35-0.75</td>
</tr>
<tr>
<td></td>
<td>Food secure</td>
<td>0.84</td>
<td>0.56-1.27</td>
<td>1.01</td>
<td>0.62-1.67</td>
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<td></td>
<td></td>
<td>0.62</td>
<td>0.38-1.01</td>
<td>0.92</td>
<td>0.56-1.52</td>
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