EVALUATION OF VITAMIN D STATUS AND ITS ASSOCIATION WITH DIETARY PATTERNS AND SOCIODEMOGRAPHIC FACTORS AMONG ADOLESCENTS ATTENDING THE OUTPATIENT DEPARTMENT OF SELECTED HOSPITALS IN DHAKA CITY, BANGLADESH

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ABSTRACT

Objectives: The current study aims to evaluate the vitamin D status of adolescents undergoing treatment at selected tertiary hospitals' outpatient departments (OPD) in Dhaka city and to look at the relationships between vitamin D levels and sociodemographic characteristics and dietary habits. **Methods:** The study followed a cross-sectional study design targeting adolescents (10–19 years old) who came to the OPD of selected tertiary hospitals. Following the convenience sampling procedure, a total of 384 adolescents were included in the study whose medical records were available with vitamin D status. Vitamin D status was evaluated based on medical reports. In addition, dietary habits were recorded using the Food Frequency Questionnaire (FFQ). To ascertain the factors influencing the individual's vitamin D status, a multinomial logistic regression model was constructed. **Results:** Approximately two-thirds of the respondents were female, and over 58% of the respondents were young adolescents (ages 10 to 14). It was discovered that 32% of the adolescents lacked enough vitamin D, while 36.7% of them had insufficient levels of this nutrient. The deficiency level was considerably higher in older adolescents (15–19 years old). Girls were inadequate by 36.2% as opposed to boys, who were lacking by 24.6%. Deficits in vitamin D were more prevalent in women with low-paying employment, mothers with primary/below or no institutional education, mothers from lower-income families, etc., in addition to other sociodemographic characteristics. In terms of eating patterns, the study suggested that participants who frequently ate foods strong in vitamin D, like dairy, meat, eggs, nuts, fatty fish, fruits, and vegetables, as well as Horlicks, showed a decreased incidence of vitamin D deficiency. The mother's occupation (service holder), the less frequent use of dairy, meat, fortified oil, and Horlicks were discovered to be highly predictive factors of vitamin D deficiency, according to a multinomial logistic regression study. **Conclusion:** According to the current study, eating foods high in vitamin D, such as dairy, beef, fortified oil, and Horlicks, may raise adolescents' vitamin D levels. Therefore, if any awareness programs or campaigns could be conducted for both parents and adolescents, it might be beneficial for reducing vitamin D deficiency.

KEYWORDS: Adolescents, Vitamin D, Blood 25(OH) D, Dietary habits, Bangladesh.

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Introduction

"The Sunshine Vitamin" is how people refer to vitamin D. Sunlight being exposed is the main way that most people get vitamin D. The photoisomerization of 7-dehydrocholesterol (7DHC) in human skin results in the creation of pre-vitamin D3 when exposed to ultraviolet (UV) radiation (Webb, 2006). After 24 hours, 20,000 IU of vitamin D is similar to the recommended quantity of sun exposure, resulting in a slight reddish tinge on the skin (1MED) (Holick, 2010). Among adults and children worldwide, vitamin D deficiency (VDD) is one of the most common micronutrient deficiencies. Foods that are rarely found to naturally contain vitamin D include milk, cereal, yoghurt, orange juice, margarine, shitake mushrooms, salmon, tuna, and hardboiled eggs. However, those don't provide enough vitamin D for both adults and children (Hilger *et al.*, 2014). Rickets is a potential side effect of low vitamin D levels in youngsters, but this is only the tip of the iceberg. In addition to osteoblasts, most human organs have vitamin D receptors, including the brain, heart, skin, gonads, prostate, and breast; other organs include the small intestine, colon, activated T and B lymphocytes, β islet cells, and mononuclear cells. (Holick and Chen, 2008).

With 163 million people living in its small, 147,570 km^ South Asian nation, Bangladesh is the eighth most densely populated country in the world. It is located in an area that encompasses latitudes 200°43´ to 260°36´N and longitudes 880°3´ to 920°40´E, with a tropical to subtropical climate and sufficient UV radiation (290–315 nm). For this reason, it has long been assumed that Bangladeshis consume enough vitamin D. However, despite Bangladesh's high level of sunshine, a small number of earlier studies have repeatedly demonstrated that vitamin D deficiency is a silent epidemic (Islam *et al.,* 2022). Twenty years ago, there was very little research on vitamin D deficiency in different Bangladeshi ethnic groups. A growing body of research and public health concern has been raised in the past several years regarding vitamin D inadequacy and insufficiency. Low levels of vitamin D are linked to various factors such as age, duration of sun exposure, exposed skin area, time of day, latitude, atmospheric pollution, season, clothing, melanin pigmentation, usage of sunscreen, use of supplements, food, and inheritance (Holick, 2007). Deficiency in vitamin D is a worldwide problem that has several detrimental impacts on health. In Bangladesh, vitamin D deficiency affects people of all ages, but it is more common in teenagers and young children of both sexes. It is believed that one billion people globally lack adequate amounts of vitamin D (Cutolo and Otsa, 2008).

These days, a hidden and often ignored global public health problem is vitamin D insufficiency. Over a billion people globally experience a shortfall or deficiency of vitamin D (Holick, 2007). Contrary to popular belief, vitamin D insufficiency does not exclusively affect individuals in western nations. Previous theories suggested that because sun exposure stimulates the skin's ability to produce vitamin D, hypovitaminosis D is less common in tropical nations. Interestingly, however, only 20% of the healthy population has a inadequate levels of vitamin D (<20 ng/mL), whereas up to 40% of people in South Asia have a severe deficiency (<10 ng/mL) (Arya *et al.*, 2004). A number of factors have been connected to insufficient levels of vitamin D, including living inside, not getting enough sunlight, air pollution, skin tone, mother's educational background, and the clothes that the mother and child wear. Another consequence of solely nursing a baby is low levels of vitamin D (Tolppanem *et al.,* 2012; *Mokhtar et al.*, 2017; Vith Streym *et al.*, 2017).

An important global frequency of inadequate vitamin D has been shown by numerous studies evaluating how frequently adolescents are insufficient or low in the vitamin ((Hilger *et al.,* 2014; Basatemur *et al.,* 2017). Since sunlight is necessary for the synthesis of endogenous vitamin D, this was true even in nations with lots of sunshine. Research looking at how common vitamin D insufficiency is in adolescents, for example, revealed that it ranged from 85% to 98% in India (Garg, 2013; Kapil, 2017) and roughly 96% in Saudi Arabia (Al Buhairan, 2015). Information regarding vitamin D levels in children and adolescents in the Arab states of the Gulf or the wider Middle East is scarce. There were serious methodological problems with the few studies that found that adolescents were very susceptible to vitamin D inadequacy (Al Buhairan, 2015; Kaddam *et al.*, 2017; Mansour *et al.*, 2012). All these data from other Asian nations suggest that Bangladesh is likely to be vulnerable to rickets and other health problems associated with a vitamin D deficiency. According to additional studies, ranging from 30 to 50% of children in Australia, Turkey, India, and Lebanon might not get enough vitamin D (Marwaha *et al.,* 2005; El-Hajj *et al.*, 2001; McGrath *et al.,* 2001). Since the skin can create vitamin D when exposed to sufficiently of sunshine, vitamin D insufficiency was typically ignored in Bangladesh. According to a recent study, children in Bangladesh have a considerable incidence of deficient vitamin D (80.0%), just as children in other places (Zaman *et al.,* 2017).

However, there isn't much published data about the measurement of vitamin D levels in Bangladeshi adolescents. The current study's objective was to evaluate the vitamin D status of adolescents visiting the outpatient department (OPD) of particular tertiary hospitals in Bangladesh and moreover, the connection between vitamin D and dietary practices and sociodemographic traits. This research focused on some specific objectives are to ascertain the sociodemographic characteristics of adolescents, to measure the serum vitamin D levels of adolescents who visited a certain tertiary hospital's outpatient department, to obtain the adolescents dietary history through the use of the Food Frequency Questionnaire (FFQ) and to find out how frequently adolescents who visited an OPD at particular tertiary institutions were vitamin D deficient.

Literature Review

Available Sources of Vitamin D

The skin produces vitamin D3 naturally, which is one significant source of vitamin D, which makes up around 90% of blood 25 (OH) D concentrations (Lehmann, 2010). Fortified meals and pills are two more significant ways to acquire vitamin D. Vitamin D has the ability to be found in a wide variety of naturally occurring foods. Natural sources include fatty fish like tuna, salmon, and sardines (Lehmann, 2010) and fresh or sun-dried shiitake mushrooms (Holick, 2007). Fortified foods include things like milk, orange juice, yoghurts, cheeses, butter, margarine, baby formulas, and cereals for breakfast (Holick, 2007).

Variables That Influences The Status About Vitamin D

Age, quantity of sun exposure, exposed skin region, time of day, latitude, geographic location, air pollution, season, gender, race, clothing, melanin pigmentation, use of sunscreen, use of supplements, dietary habits, genetic factors, outdoor activities lifestyle, obesity, and so on are some of the factors that are linked to low vitamin D levels (Holick, 2007). Some reasons for low vitamin D levels are covered in the section that follows: Since animal products like fish, egg yolks, and fish oil are crucial sources of the vitamin D, due to a lack of sun exposure, those who pass a lot of time indoors or wear clothes that hides a lot of skin have a greater likelihood of being vitamin D deficient. Additionally, people with darker skin tones and higher melanin levels are less able to produce pre-vitamin D3. As vitamin D is fat-soluble and fat cells can readily absorb it from the bloodstream, melanin competes with it by inhibiting the photolysis of provitamin D3 to generate pre-vitamin D3. Obesity is another significant factor contributing to vitamin D insufficiency, among other things (Clevel and Clinic Abu Dhabi, 2018).

Dietary Patterns

The skin produces fat-soluble vitamin D, which is also present in food, when exposed to UVB rays from the sun. In technical terms, vitamin D is not a genuine vitamin but rather a class of secosteroids with endocrine and paracrine functions. Pre-vitamin D3, which is produced by photoconverting 7-dehydrocholesterol to vitamin D3, isomerizes to become vitamin D3 when exposed to ultraviolet B (UVB) light from the sun (wavelength: 280 to 315 nm). Season, ozone, clouds, latitude, time of day, surface reflectivity, and individual characteristics such as age, skin type, clothing, and sunscreen cream use are the primary environmental factors that impact the body's capacity to synthesize vitamin D. Most regions on Earth that fall between latitudes 420N and 420S have an abundance of sunshine, according to the FAO/WHO expert panel. This is how subcutaneous fat, which contains 7-dehydrocholesterol, is converted by the skin to vitamin D.

Vitamin D differs from other vitamins in a number of ways. Basically, the key difference is that vitamin D in the blood does not originate mostly from food consumption. In actuality, only a select few foods—such as egg yolks, sun-dried mushrooms, and oily salmon—contain vitamin D. Trace levels of vitamin D can be found in fortified foods and drinks like breads, milk, cereals, and fruit drinks. In order to maintain appropriate blood levels of vitamin D, most people only receive very little of it naturally from their diet and must spend time in the sun.

An alternative approach, dietary pattern analysis, is becoming more and more popular as a means of avoiding these problems. In order to identify dietary patterns, this approach examines how food and nutrients are paired based on eating behaviors (Hu FB, 2002). Food patterns are not immediately measured; hence they are statistically inferred from data obtained from food intake assessments (Hu FB, 2002).

Using information gathered from food frequency questionnaires (FFQs) or dietary notebooks, factor or fundamental component analysis is a multidimensional analytical approach.

It looks for similarities (or patterns) in the foods that people eat and provides ratings so that users can rank one another based on how closely their food consumption matches the overall pattern (Hu FB, 2002).

Methods For Assessing Vitamin D Levels

It's probable that vitamin D deficiency is more common than previously thought and has become a global public health concern, according to a number of studies. Thus, there is a growing need for 25(OH)D detection as vitamin D deficiency becomes more common. Clinical laboratories are being forced to expand their precise techniques that are appropriate for routine readings due to the increasing demand for the 25-(OH)D test.

25-(OH)D is the only vitamin D metabolite that can be used to measure a patient's vitamin D status. With a half-life of about two to three weeks, 25(OH)D is the most common form of vitamin D in circulation.

Currently, the main 25-(OH) D detection methods employ a variety of approaches based on different measuring concepts.

Some of the commonly used alternative assays are liquid chromatography combined with enzyme-linked immunosorbent assay, radioimmunoassay (RIA), high-performance liquid chromatography (HPLC), mass spectrometry (LC-MS), automated assays using chemiluminescence immunoassay (CLIA) (Zhiliang *et al.*, 2020).

Suggestions and Vitamin D Level

The recommended vitamin D status level is still up for debate (Institute of Medicine, 2011). The Institute of Medicine (IOM) and the American Academy of Paediatrics report that blood 25-(OH)D concentrations of less than 11 ng/mL (≤27.5 nmol/L) have previously been linked to vitamin D insufficiency in neonates and early children (Huh and Gordon, 2008).

The general agreement is that the following thresholds should be met: >30 ng/mL (>75 nmol/L) for vitamin D sufficiency, ≤30 ng/mL (≤75 nmol/L) for insufficiency, and ≤20 ng/mL (≤50 nmol/L) for vitamin D deficiency (Holick, 2007; Bischoff-Ferrari *et al.*, 2006; Dawson-Hughes *et al.*, 2005; Vieth *et al.*, 2007).

According to the most recent standards supplied by the IOM, vitamin D inadequacy was classified as ≤12 ng/mL (≤30 nmol/L) and sufficiency as >20 ng/mL (>50 nmol/L) (Institute of Medicine, 2011). Vitamin D requirements for children and adolescents are 400 IU/d and 600 IU/d, respectively, according to the Estimated Average Requirement (EAR) and Recommended Daily Allowance (RDA) (Institute of Medicine, 2011). Additionally, the IOM committee noted that blood 25-(OH) D concentrations above 50 ng/mL (125 nmol/L) may be cause for concern and that levels above 30 ng/mL (>75 nmol/L) may not always be linked to greater advantages (Institute of Medicine, 2011). Subsequently, in July 2011, the Endocrine Society released guidelines indicating that infants under the age of one should get sufficient amounts of vitamin D—at least 600 IU and possibly as much as 1000 IU/d—to raise blood 25(OH) D levels around 30 ng/mL (Abrams, 2011).

Methodology

Design, Settings and Population of study

This study was conducted using a cross-sectional approach. The data was obtained from the outpatient departments of two chosen hospitals for the study, which was conducted at two chosen tertiary hospitals. Adolescents (10–19 years old) who visited hospitals for minor symptoms in the outpatient department made up the study population.

Sample size

The sample's composition was established using following n=z2pq/d2 is the formula.

Where,

n=the preferred sample size.

z=Standard normal distribution value as specified by the significance (confidence) level; typically, 1.96 at the 95% Confidence Interval

p= Prevalence value (50%) [Using Cochran's method (Equation 1), the necessary sample size was determined to be 305, taking into account Bangladesh's 28% point prevalence of stunting among children under five.]

q = 1-p = 1-0.5 = 0.5

d = Study's acceptable error of 5% (0.05)

Hence desired sample size,

n is equal to {(1.96)2 x (0.5) x (0.5)} / (0.05)2 = 384.6.

So desired sample size was 384.

Sampling technique

The study utilised a convenience sampling strategy to recruit participants from among the adolescents who visited the hospital in the study area.

Criteria for Inclusion and Exclusion

The adolescents (10–19 years old) who visited the outpatient department of two chosen hospitals with mild symptoms and whose blood levels of vitamin D were measured were involved in this investigation. Conversely, individuals who were using supplemental vitamin D, had a chronic ailment, or were severely ill as well as participants, parents, attendees, or those who did not complete the FFQ, were excluded.

Formulation of the Research Questionnaire

Formulation of socio-demographic questionnaire

A validated vitamin D questionnaire, together with a sociodemographic and food frequency questionnaire (FFQ), has been answered by participants. The demographic questions comprised fifteen categories, such as age, sex, height, weight, dwelling area, religion, and the educational and occupational backgrounds of the mother and father, as well as the family's total income. Closed-ended questions also made up a large portion of the questions. For instance, choices were provided based on factors including the purpose of medical visits, level of education, occupational position, etc.

Formulation of Food Frequency Questionnaire (FFQ)

The frequency of eating items that were naturally or artificially fortified with vitamin D was considered in the FFQ in order to evaluate adolescents' dietary habits. A questionnaire has been created, reviewed, and approved. A total of 71 food items, including both common and vitamin D-rich foods, were included in the food frequency questionnaire. Foods were categorised according to their vitamin D nutritional content or culinary use, and they were categorised in a manner similar to those used in earlier studies. A further 39 foods were highlighted because they were high in vitamin D. Following the guidelines provided by the Food Composition Table for Bangladesh, ten separate food categories were created from the food items: cereal, pulses, meat, fish, eggs, milk and milk products, oil, nuts, fruits and vegetables, and miscellaneous. However, **Table 1** only displays the eight food groups that are high in vitamin D.

When asked how often they ate meals, participants gave one of four answers: daily, weekly, monthly, or never. Once a week, once a month, twice a month, once a day, 2-3 times a day, 4-5 times a day, never, 2-4 times a week, 5–6 times a week, and 6+ times a day were the responses for consumption pattern. In addition, **Table 2** classified it into four labels based on the frequency of intake. The frequency with which each participant consumed each of these ten food groups allowed for the identification of major dietary trends.

Table 1. List of Vitamin D rich food items

Food Group	Food item	
Meat	Beef	
Fatty Fish	Hilsa Pangash Catla Puti Mola Mrigal Rohu Salmon	Tuna Nile tilapia Prawn Rupchada Koi mach Gura mach (Sagor Ponna)
Egg	Chicken egg with yolk Duck egg with yolk Koel egg with yolk	
Dairy	Milk (cows) Yoghurt Cheese Butter Pasteurized/UHT milk Dairy desert (custard, pudding, Firni/Payesh) Ice cream Milk shake	
Fortified oil	Teer Fortified (Vit D) Soyabean Oil Bashundhara Fortified (Vit D) Soyabean Oil Cod liver oil	
Nuts	Almonds Cashews	
Fruits and vegetables	Dates Raisins Fortified Orange Juice Ripe Banana	Spinach Brocoli Mushroom
Miscellaneous	Horlicks	

Table 2. Consumption frequency

Frequent consumption	Daily (at least one time)/ 5-7 times every week
Occasionally	two to four times every week or once a week
Rarely	Each month or as often as three times a month
Never	Never eaten

Data Collection Tools

Data were gathered using structured paper versions of the questionnaire, which were completed by participants, mothers, career, and attendees who were accompanied by adolescents. The questionnaire addressed dietary practices (including sources of vitamin D) by FFQ and sociodemographic traits. In order to get data on the sociodemographic traits and food habits of adolescents, participants were questioned in the out-patient departments (OPDs) of two chosen tertiary hospitals. Direct interviews were used to gather data, and reports on vitamin D blood samples were obtained from the chosen hospitals in order to assess vitamin D levels subsequently. During the research procedure, strict standards were implemented to safeguard participant privacy and data confidentiality. Additionally, formal all participants, parents, careers, or attendees gave their consent.

Evaluation of vitamin D levels

Measuring the blood level of 25-hydroxyvitamin D [25(OH) D] is the most precise and trustworthy method. In Bangladesh, it is measured using a variety of techniques include high-performance liquid chromatography (HPLC), chemiluminescent immunological test, and enzyme-linked immunosorbent assay (ELFA).

A report on blood 25(OH) D was acquired from the lab records. Venipuncture was performed on participants in the hospitals' sample collection rooms using standard procedures to draw blood samples. This instance involved taking a sample report from two distinct laboratories located in two different hospitals and utilising the automated chemiluminescence microparticle immuneassay (CMIA) method for analysis.

Thus, there are multiple approaches to categorise or define what constitutes sufficient or inadequate for circulation of 25 (OH) D. Vitamin D sufficiency was classified by the IOM as >20 ng/mL (>50 nmol/L) and vitamin D inadequacy as ≤12 ng/mL (≤30 nmol/L) **(Table 3)** (Institute of Medicine, 2011). It was used as a cutoff point for circulating 25(OH) D in this investigation. These guidelines state that the recommended daily allowance and estimated average requirement 600 IU/d and 400 IU/d of vitamin D, respectively, are recommended for children and adolescents (Institute of Medicine, 2011).

Table 3. Vitamin D Status

Segmenting Vitamin D Status Based on Blood 25-Hydroxyvitamin D		
ng/mL	**nmol/L**	**Classification**
Less than 12 ng/mL	Less than 30 nmol/L	Deficient
More than 20 ng/mL	More than 50 nmol/L	Sufficient

Evaluation of Statistics

Version 25 of IBM SPSS was used for data analysis. Depending on how the data were distributed, several descriptive and inferential statistics were applied. The categorical variables were presented with chi-square statistics. This non-parametric test was designed to find out how different sociodemographic characteristics related to eating habits and vitamin D status. The model for multinomial logistic regression was constructed in order to look at the connection between different dietary practices and sociodemographic traits and level of vitamin D. The dependent variable for vitamin D level was divided into three categories: normal, inadequate, and deficient. Dietary practices and sociodemographic characteristics were independent variables.

Results

Of the 384 responders, 58.3% belonged to the 10–14 age range, 41.7% to the 15–19 age groups, and 64.1% and 35.9%, respectively, were females and males (Table 4). By religion, there were 89.6% Muslims, 9.1% Hindus, and 1.3% Christians. Based on the living area, the non-slum area makes up 77.6% of the area, while the slum area makes up 22.4%. 50.5% of families had four children, 39.8% had five or more, and 9.6% had fewer than three, according to family size. By family income, the percentages were as follows: 15.1% of (Bangladesh Taka) BDT earned less than 25,000 BDT taka, 49.7% made more than 500001 BDT, and 35.2% earned between 250001 and 50,000 BDT.

Table 4. General characteristics of the study subjects (n = 384)

Variable	n (%)
Age category	
10-14	224 (58.3)
15-19	160 (41.7)
Sex	
Male	138 (35.9)
Female	246 (64.1)
Religion	
Muslim	344 (89.6)
Hindu	35 (9.1)
Christian	5 (1.3)
Living area	
Slum	86 (22.4)
Non-slum	298 (77.6)
Family size	
≤3	37 (9.6)
4	194 (50.5)
≥5	153 (39.8)

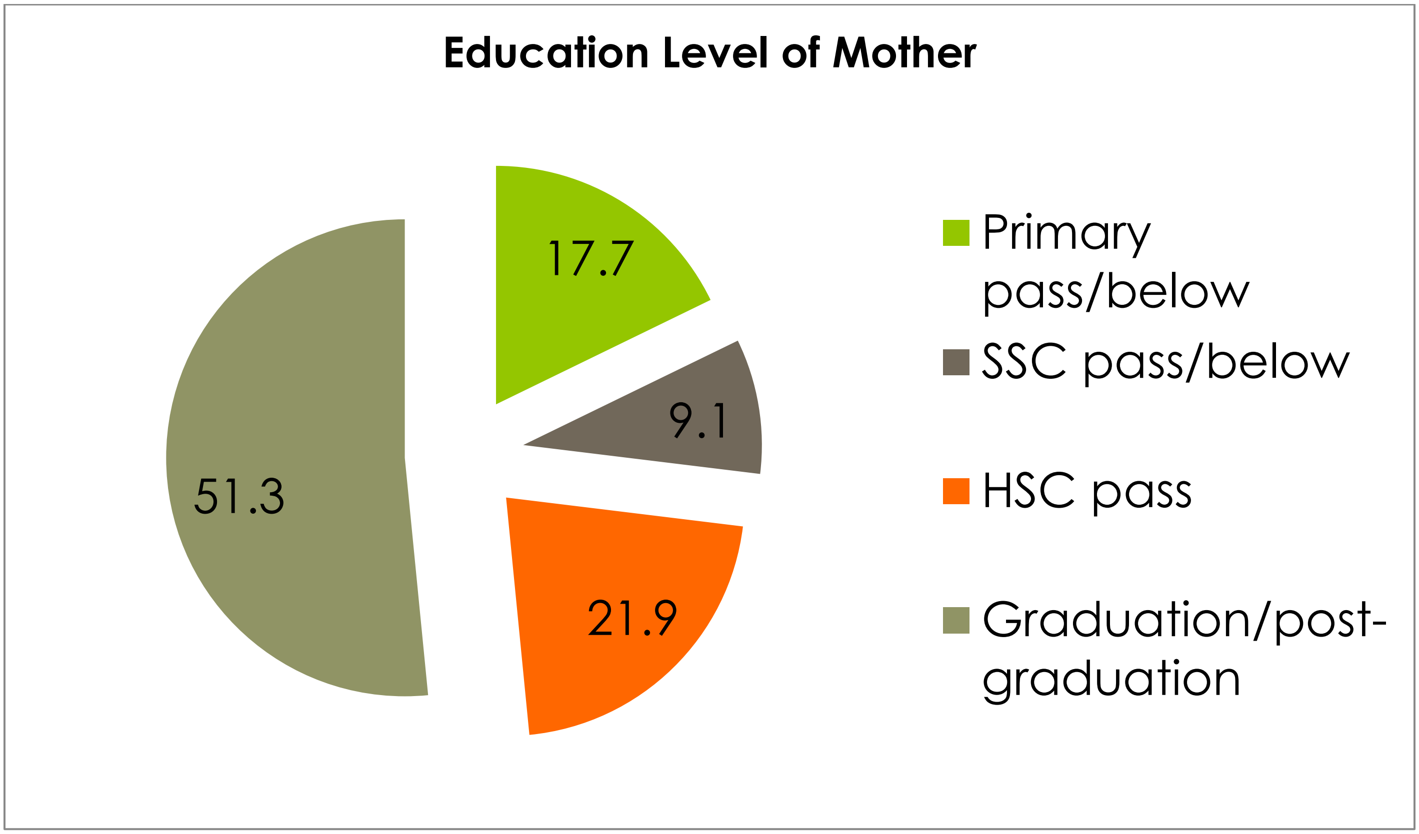
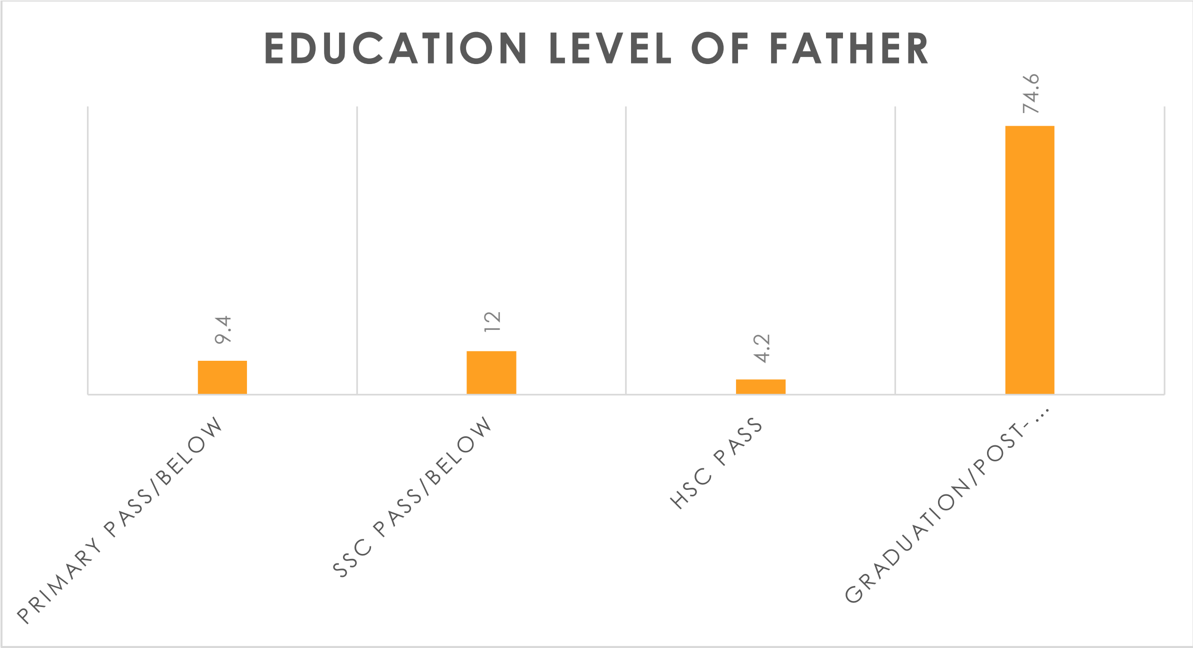


Figure 1. shows that, 51.3% of the mothers had graduated or been post-graduated, 21.9% had passed the HSC, 17.7% had passed or been below the primary level, and 9.1% had passed or been below the SSC.



According to **Figure 2**, father educational level was found to be 74.6% post-graduate or graduated, 12.0% SSC passed or below, 9.4% primary pass/lower, and 4.2% HSC passed.

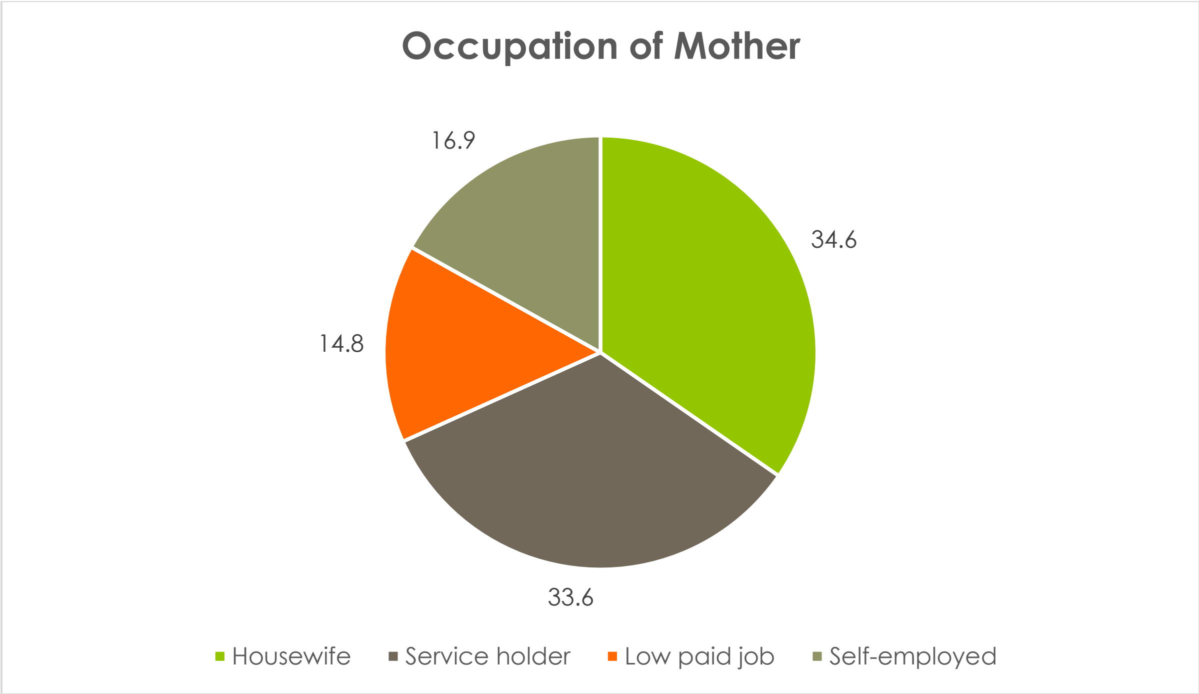
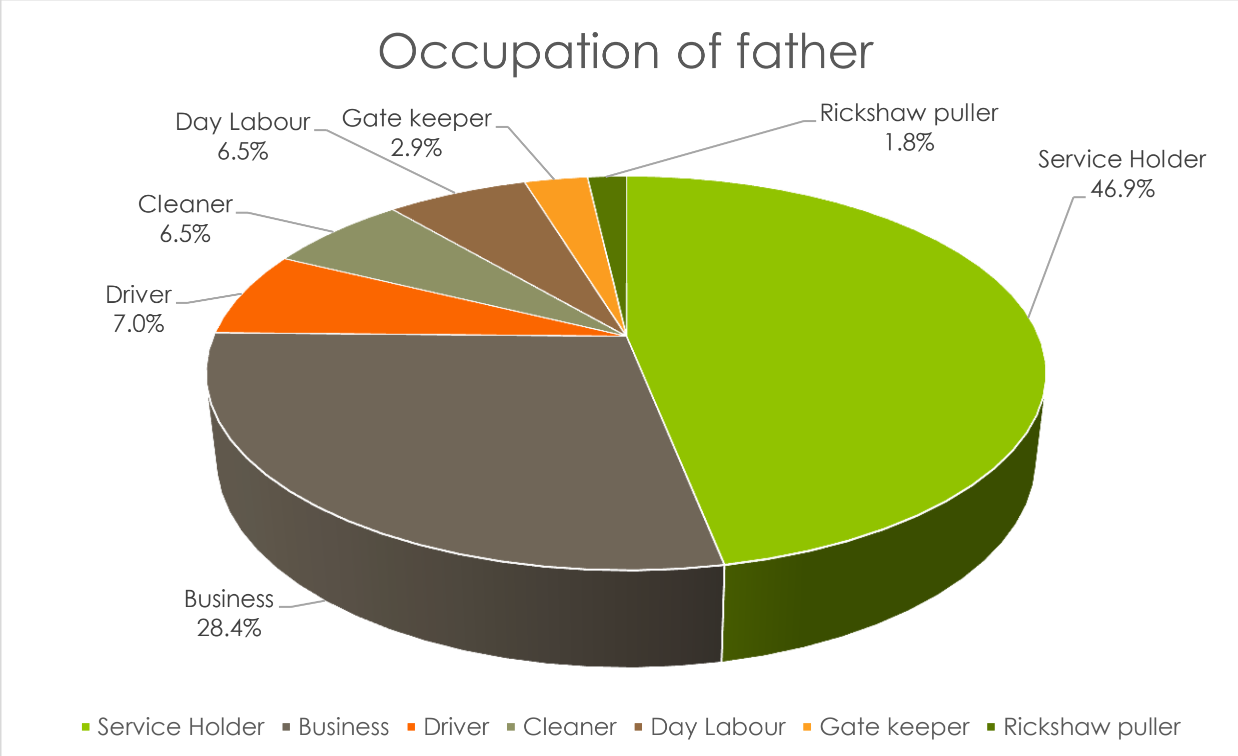


Figure 3. shows that, according to the mother's occupation, 34.6% were housewives, 33.6% were employed in services, 16.9% were self-employed, and 14.8% held low-paying jobs such as those in the garment, tailor, or maidservant industries.



Based on the father's occupation, the following occupations were reported: 1.8% was rickshaw puller; 2.9% was gatekeeper; 7.0% was driver; 6.5% was cleaner; 6.5% were day worker; and 46.9% were service holders (**Figure 4**).

Vitamin D status of the respondents

Regarding the amount of vitamin D, Figure 5 reveals that out of 384 respondents, 36.7% were insufficient, 32% were deficient, and 31.3% were sufficient.

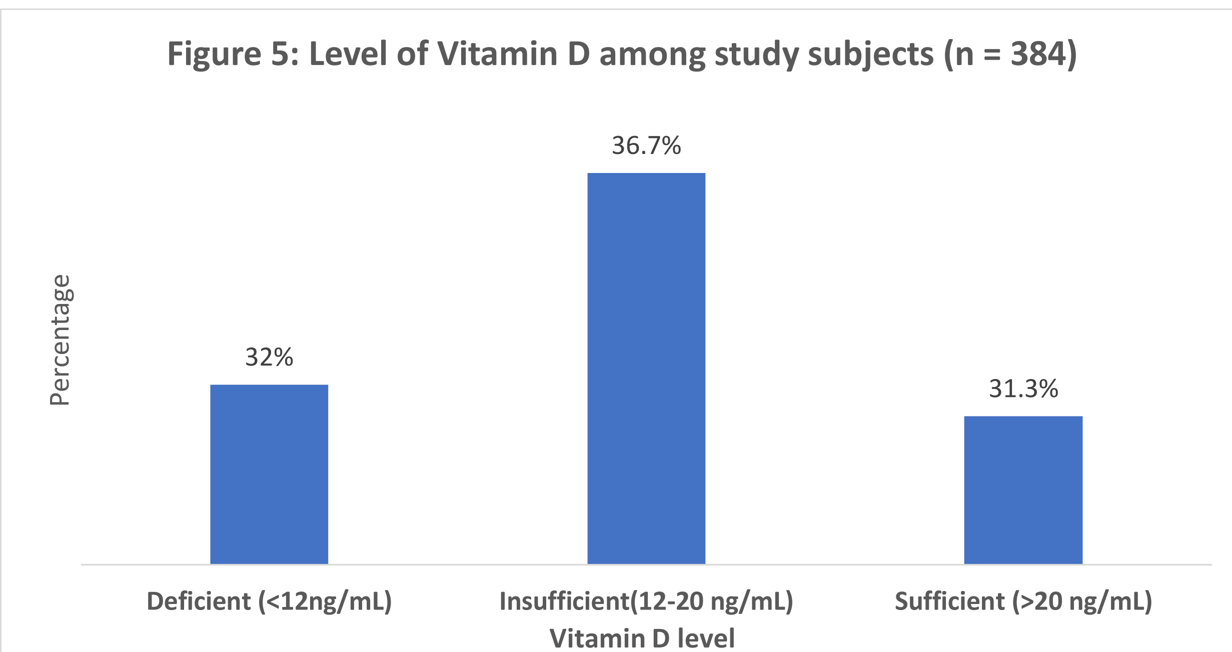


Figure 5: Level of Vitamin D among study subjects (n = 384)

Relationship between sociodemographic and vitamin D levels

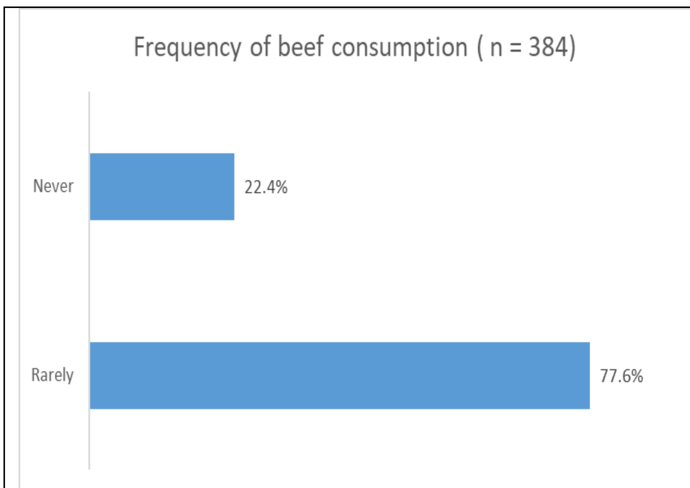
Vitamin D deficiency was observed in 35.6% of the 15–19 age group and 29.5% in the 10–14 age group. In contrast, vitamin D sufficiency was observed in 33.0% of the 10–14 age group and 28.7% in the 15–19 age group. Males were more vitamin D sufficient than females by 39.9% compared to 26.4%, while female were more deficient by 36.2% compared to male by 24.6%. Religion-wise, Muslims had a 33.7% higher vitamin D deficiency than Hindus (20.0%). Of the Muslim population, 31.1% lacked adequate vitamin D, while 34.3% of Hindus did. Slum dwellings were found to be more vitamin D deficient than non-slum dwellings by 87.2% and 16.1%, respectively, whereas non-slum dwellings were found to be more vitamin D sufficient than slum dwellings by 39.9% and 1.2%, respectively (Supplementary table 1).

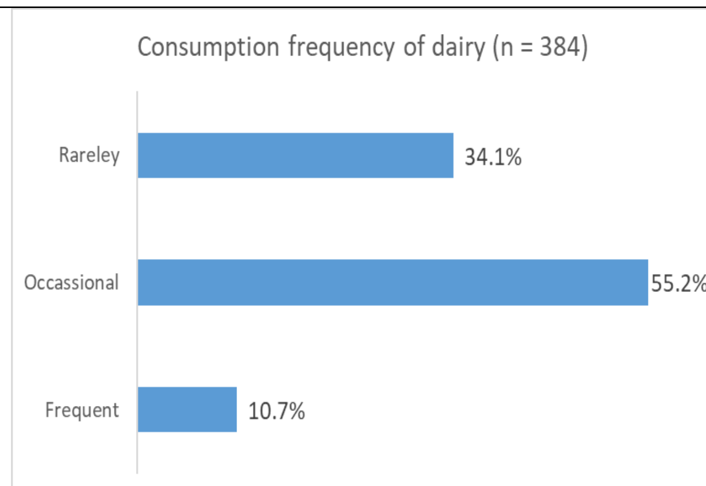
Mothers who were primary passed/below or who had no institutional education had higher levels of vitamin D deficiency by 92.6%, 62.9% in SSC passed/below mothers, 17.9% in HSC passed mothers, and 11.7% in graduated/post-graduated mothers. Conversely, 50.8% of mothers who were graduated/post-graduated, 20.2% in HSC passed mothers, and 8.6% in SSC passed/below mothers had sufficient vitamin D. When it came to father, it was found that 94.4% of fathers who were primary passed/below without any institutional education were more likely to be vitamin D deficient; 91.3% of these fathers were SSC passed or below, 31.3% were HSC passed, 14.7% were graduated or post-graduated, 41.6% had sufficient vitamin D in graduated or post-graduated fathers, and 6.3% in HSC passed fathers.

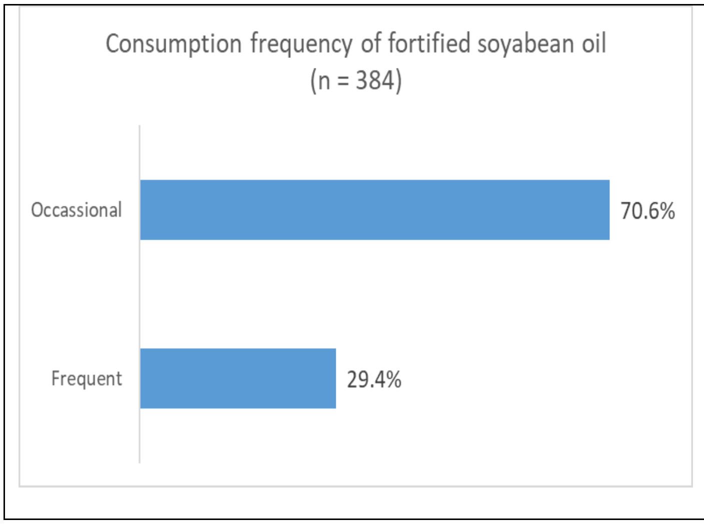
89.5% of low-paid work moms had vitamin D deficiencies according to their occupation; homemaker mothers had deficiencies in 34.6% of cases; self-employed mothers had deficiencies in 26.2% of cases; and service holder mothers had deficiencies in 7.0% of cases. 48.8% of mothers who were working as service providers, 40.0% of self-employed people, 22.6% of housewives, and 1.8% of people had adequate vitamin D. Vitamin D deficiency was found in 85.3% of fathers with low-paying jobs, 18.3% of fathers with service-holder jobs, and 8.3% of fathers in business jobs. 52.3% of fathers in business, 33.9% of fathers in service, and 2.1% of fathers in low-paying jobs had adequate vitamin D.

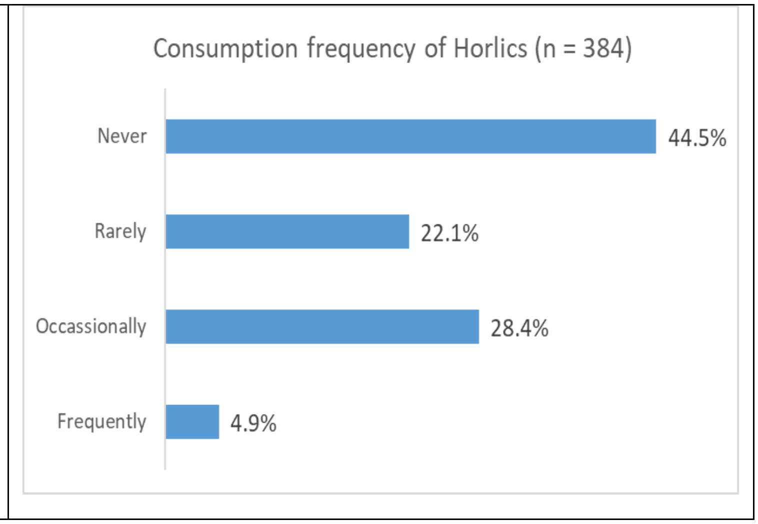
Vitamin D deficiency was found in 91.4% of families with monthly incomes under 25,000 taka, 34.8% with incomes between 25,001 and 50,000 taka, and 12% with incomes beyond 50,001 taka. 13.3% of those with adequate vitamin D and monthly incomes between 25,001 and 50,000 taka also had adequate vitamin D. 53.4% of those with sufficient vitamin D earned more than 50,001 taka.

Figure 6 Results show that, of 384 respondents, 77.6% had eaten beef occasionally and 22.4% had never done so. Of those surveyed, 54.7% indicated they ate fatty fish rarely, 45% said they did so occasionally, and only 0.3% said they never did. Of those who consumed eggs, 64.1% did only occasionally, 33.9% frequently, and 2.1% rarely. A little over 55.2% said they occasionally consumed dairy products, 34.1% said they did very rarely, and 10.7% said they did so frequently. Fortified soy oil users reported using it both occasionally 70.6% and frequently 29.4%. 67.4% of those who ate nuts did so very rarely, 27.9% never did, and only 4.7% did so occasionally. In terms of fruits and vegetables, 67.4% of participants reported eating them occasionally, 27.9% reported eating them rarely, and 4.7% reported eating them frequently. Of the Horlicks consumers, 44.5% never ate the product, 28.4% occasionally did, 22.1% rarely did, and 4.9% usually did.









Relationship between food habits and vitamin D levels

Compared to 19.9% of respondents who seldom consumed beef, 37.9% of respondents who rarely consumed beef had adequate vitamin D. Compared to 74.4% of respondents who had never consumed beef, 8.1% of respondents who had never consumed beef had adequate vitamin D. Those who never ate fatty fish reported a 100% vitamin D deficit, compared to 30.1% of those who did so infrequently and 23.7% of those who did so sometimes. Vitamin D deficiency was present in 46.2% of individuals who did so occasionally and 19.0% of those who did so infrequently (Supplementary table 2).

With respect to the frequency of egg consumption, 40.7% of individuals had inadequate vitamin D levels and occasionally ate eggs, whereas 100.0% had low vitamin D levels and seldom ate eggs. Additionally, 11.5% of people had inadequate vitamin D levels and frequently consumed eggs, 60.0% had appropriate levels and frequently consumed eggs, and 17.1% had sufficient vitamin D levels and occasionally consumed eggs.

When respondents consumed dairy products frequently, 85.4% of them had enough vitamin D in their bodies, occasionally, 36.5% had enough vitamin D in their bodies, and seldom, 6.1% had enough vitamin D in their bodies. Of the participants, 55.7% were lacking when they ate dairy products infrequently, 21.7% were lacking when they ate dairy products sometimes, and 9.8% were lacking when they ate dairy products regularly.

Those with inadequate vitamin D and infrequent oil consumption were 39.6% of the population; 14.2% had insufficient vitamin D and frequent oil consumption; 60.2% had sufficient vitamin D and frequent oil consumption; and 19.2% had sufficient vitamin D and occasional oil consumption.

Out of the people who consumed nuts, 68.2% had never eaten any, 19.3% had eaten some occasionally and were vitamin D deficient, 94.4% had enough vitamin D and occasionally ate nuts, 36.7% had enough vitamin D and seldom ate nuts, and 7.5% had enough vitamin D and never ate nuts.

Survey respondents stated that they were vitamin D deficient in four different scenarios: they were deficient when they ate fruits and vegetables infrequently (86.9%), deficient when they ate them occasionally (24.9%), deficient when they ate them frequently (13.8%), and sufficient (64.9%) when they ate them frequently (25.3%), sufficient when they ate them occasionally (1.6%), and sufficient when they ate them infrequently (13.8%).

Of the respondents who took Horlicks, 53.2% never took them, 23.5% took them seldom, 11% took them occasionally and was vitamin D deficient, and 100% of those who used Horlicks frequently had enough vitamin D in their bodies. 13.5% had adequate vitamin D when they did not consume it, compared to 40.4% who took it infrequently and 40.0% f percent who consumed it frequently.

Predictors of vitamin D

The variables related to the research participants' vitamin D status. The model for multinomial logistic regression was built, in which the frequency of consumption of different vitamin D-rich diet was paired with a set of demographic covariates. Significant vitamin D insufficiency risk factors included the mother's job status as a service provider, as well as her intake of dairy, beef, fortified oil, and Horlicks. It was discovered that mothers who worked as service providers had lower odds of deficit than mothers who worked for themselves (AOR: 0.17, $p = 0.012$). This study also discovered that eating foods high in vitamin D, such as dairy, meat, fortified oil, and Horlicks, had a beneficial effect on vitamin D levels. Adolescents who regularly ate these kinds of meals had a lower chance of vitamin D shortage than those who did so sometimes or never at all.

Table 5. Predictors of Vitamin D status

	Deficient		**Insufficient**	
Characteristics	**AOR (95 % CI)**	**p value**	**AOR (95 % CI)**	**p-value**
Sex				
Female	2.26 (0.973, 5.251)	0.058	2.226 (1.145, 4.327)	0.018
Male	1		1	
Religion				
Other	1.009 (0.229, 4.441)	0.9	2.479 (0.751, 8.183)	0.13
Muslim	1		1	
Living area				
Slum	6.15 (0.072, 28.127)	0.9	7.40 (4.56, 10.01)	0.99
Non-slum	1		1	
Education level of mother	0.257 (0.001, 23.12)	0.99	0.15 (0.04, 0.781)	0.99
Primary pass/below	1.781 (0.163, 19.437)	0.636	0.372 (0.036, 3.81)	0.4
SSC pass/below	0.608 (0.161, 2.301)	0.464	2.352 (0.775, 7.139)	0.13
HSC pass	1		1	
Graduation/post-graduation				
Education level of father	1.631 (1.01, 3.435)	0.98	4.37 (2.32, 6.17)	0.8
Primary pass/below	5.98 (3.435, 12.345)	0.9	1.55 (1.1, 3.44)	0.9
SSC pass/below	1.51 (0.45, 7.98)	0.35	1.622 (1.235, 5.672)	0.9
HSC pass	1		1	
Graduation/post-graduation				
Occupation of mother				
Housewife	1.372 (0.372, 5.013)	0.63	1.073 (0.321, 3.592)	0.9
Service holder	0.17 (0.043, 0.678)	**0.012**	2.527 (0.877, 7.279)	0.086
Low paid job	7.13 (6.28, 24.29)	0.98	1.76 (1.341, 4.879)	0.9
Self-employed	1		1	
Occupation of father				
Service Holder	0.118 (0.001, 11.17)	0.36	2.259 (1.04, 4.875)	<0.001
Business	0.049 (0.001, 5.752)	0.19	-	
Low paid job	1		1	

Discussion

Even though vitamin D insufficiency in children, adults, or any other group in Bangladesh has been the subject of multiple research, there is a lack of documentation regarding its incidence among teenagers.

In this research, of the 384 respondents, 58.3% belonged to the 10–14 age range. Based on the living area, the non-slum area makes up 77.6% of the area. 51.3% of the mothers had graduated or been post-graduated; 21.9% had passed the HSC; 17.7% had passed or been below the primary level; and 9.1% had passed or been below the SSC. Regarding the father's educational level, it was found to be 74.6% post-graduate or graduated, 12.0% SSC passed or below, 9.4% primary pass or lower, and 4.2% HSC passed. By mother's profession, 34.6% were housewives, 33.6% were employed in services, 16.9% were self-employed, and 14.8% held low-paying jobs such as those in the garment, tailor, or maidservant industries. According to the father's occupation, the following occupations were reported: 1.8% was rickshaw pullers; 2.9% were gatekeepers; 7.0% were drivers; 6.5% were cleaners; 6.5% were day workers; and 46.9% were service holders. ≤3 members made up 9.6% of the family, 4 members made up 50.5%, and ≥5 members made up 39.8%.

Of the 274 children surveyed, 26.3% were between the ages of 10 and 14. Urban dwellers made up 51.8% of the sample. 2.6% had graduated, 4.7% of the mothers had completed the HSC, 31.4% had finished high school (up to SSC), 44.9% had completed primary school, and 16.4% of the mothers had no formal education. Among the fathers, 14.2% had no formal education, 38.0% had completed elementary school, 37.6% had completed high school (up to SSC), 5.5% had completed the HSC, and 4.7% had made it to graduation. Of the mothers of their subjects, 76.3% were housewives, 8.8% held jobs, and 5.1% were employed in the garment industry. The remaining 9.9% of mothers worked in a variety of professions. Fathers made up 26.3% of the service holders; 16.8% operated their businesses; 13.1% were drivers; 10.2% were cleaners; and 8.4% were daily labourers. Of them, 25.3% worked in a variety of professions. 54.0% of them had a family of up to four members, 41.6% had a family of five to six members, and 4.4% had a family of six or more (Ahmed *et al.*, 2019).

According to this study analysis, the vitamin D levels of 384 respondents, 36.7% were insufficient, 32% were deficient, and 31.3% were sufficient. There was a 29.5% increased risk of vitamin D deficiency in age groups 10 to 14. Women were more deficient than men were, at 36.2% as opposed to 24.6%.

A total of 40 percent of those surveyed had 25-OHD levels below 20 ng/mL, of which 110 (or 25%) had deficiencies and 66 (15%) had insufficiencies. They found a particularly high frequency of low vitamin D status in the 10–16 age groups. In the 10–16 age groups, older children had a lower mean level of 25 (OH) D (18.7±11.5 ng/mL) when vitamin D levels were compared between age groups. On the other hand, 64.8% of teenage girls had blood vitamin D levels below 20 ng/mL. Girls were more likely than boys to be vitamin D deficient (Andıran *et al.*, 2012).

It was found that girls were more likely than boys in the adolescent age range to be vitamin D deficient. It is noteworthy that vitamin D insufficiency may become more common as one age.

According to the Oren *et al.*, 2010 study, girls are more prone than boys to have inadequate vitamin D levels. Vitamin D levels below 20 ng/mL were seen in 64.8% of teenage girls between the ages of 10 and 16 (Oren *et al.*, 2010). Vitamin D deficiency was shown to be prevalent in a group of Turkish girls aged 14–18 years, with a range of 15.6% to 59.4% depending on the season and socioeconomic position (Olmez *et al.*, 2006).

This study found that the prevalence of vitamin D insufficiency was higher in females when accounting for the age groups included in the sample.

Zaman et al. (2017) looked into the prevalence of hypovitaminosis D in children in Dhaka between the ages of 0 and 16. They showed a relatively high frequency of hypovitaminosis D and an increasing tendency of vitamin D deficiency and insufficiency with ageing. Vitamin D deficiency and insufficiency (S-25OHD <75 nmoL/L) were reported to be prevalent in the 6–11 year old group at 41.02% and 52.56%, respectively, and in the 12–16 year old group at 46.75% and 51.95%, respectively. Their findings indicate that as children become older, the prevalence of vitamin D deficiency increases because children' serum 25-hydroxyvitamin D levels gradually drop as they get older.

According to the National Micronutrients Survey (NMS, 2011–2012), for children in preschool and school age groups, the prevalence of vitamin D deficiency was 45.5% and 39.6%, respectively. It was found that children living in impoverished areas were more vulnerable to vitamin D insufficiency (ICDDR, 2011-2012). According to the NMS conducted in 2019–2020, the overall percentage of children with vitamin D deficiency was 21.9%. Compared to boys (21.0%), girls had a marginally higher chance of deficit (23.0%). 8.3% of urban areas have greater inadequacies than rural ones. When comparing the vitamin D deficiency levels for NMS 2011–12 and NMS 2019–20, NMS 2019–20 has an 18% lower level, at 39.6% and 21.9%, respectively (ICDDR, 2019-2020).

Significant risk variables for vitamin D deficiency included dairy, meat, enriched oil, and Horlicks consumption, as well as the mother's employment status as a service holder. It was found that women who were self-employed had higher odds of deficit than mothers who worked as service holders (AoR: 0.17, p = 0.012). This study found that consuming vitamin D-rich foods, like dairy, beef, fortified oil, and Horlicks, improved vitamin D levels. Adolescents who regularly ate these items were less likely to suffer from a vitamin D deficit than those who either sometimes or never did.

The relationship between DP and food intake and serum vitamin D levels has not been thoroughly studied in previous studies (Denova-Gutierrez *et al.*, 2016; Grigoriou *et al.*, 2020; Ganji *et al.*, 2018). A positive relationship between vitamin D intake and "dairy and fish DP," which is high in fish and dairy products, was found in a cross-sectional study (Denova-Gutierrez *et al.*, 2016).

Regarding the consumption of fatty fish, 54.7% of participants reported doing so very rarely, 45% said they did it occasionally, and only 0.3% claimed they did so never. A little over 55.2% reported consuming dairy products occasionally, 34.1% reported doing it rarely, and 10.7% reported doing so frequently. Regular dairy product use by adolescents has been linked to a decreased risk of vitamin D insufficiency through dietary intake.

In sample 742 Greek, Three kinds of unhealthy DPs—"sweets DP," "fast food DP," and "western DP"—were distinguished by Grigoriou et al., 2020 from three categories of healthier DPs—"healthy DP," "vegetables fruit DP," and "traditional DP." It was demonstrated that there was a favourable correlation between serum 25(OH) D and "healthy DP," which includes a variety of non-refined breads, low-fat dairy products, low-fat cheese, and low-fat yoghurt. But there was no correlation found between 25(OH) D levels and "traditional DP," which was characterized by a high positive loading factor of full-fat yoghurt and milk, and "vegetables fruit DP," which was rich in fruits, vegetables, refined rice, and fish. The bulk of vitamin D was obtained from dairy products, however "traditional DP," with its high loading factor of full-fat milk and full-fat yoghurt, did not correlate with 25(OH) D levels (Grigoriou *et al.*, 2020).

According to Sharifan *et al.*, 2021, throughout the winter, there is a favourable relationship between healthy DP and 25(OH) D. This implies that during this time of year, when sun exposure is less efficient, food may have a substantial impact on serum vitamin D levels in humans in addition to other factors. The "Western DP" and "fast food DP" of the study population were also determined. While "fast food DP" refers to people who consume a lot of low-fat cheese, low-fat milk, and low-fat yoghurt, and a low amount of low- and full-fat milk, yoghurt, and fish, "Western DP" refers to a group of people who consume a lot of processed and red meat, pasta, potatoes, chicken, and full-fat cheese, full-fat milk, and full-fat yoghurt and fish. Adherence to these two unhealthy eating patterns did not connect with serum vitamin D levels, even though dairy products are a substantial source of dietary vitamin D. Therefore, the positive benefits of nutritious diets on serum vitamin D levels may be offset by a high intake of bad foods (Sharifan *et al.,* 2021).

The study conducted by Ganji *et al.,* 2018, there is a positive relationship between participants' serum 25(OH)D levels and "prudent DP," which is high in fruits, vegetables, tomatoes, meat and seafood. The participants ranged in age from 2 to 19 years old. Few studies show that there is a negative or nonexistent correlation between unhealthy DPs and serum 25-(OH) D.

Serum 25-(OH) D levels and "high-fat low-vegetable DP" (HFLVD) demonstrate a negative connection, as reported by Ganji *et al.,* 2018. Foods had high loading factors in HFLVD included fast food, energy drinks, sauces, snacks, sweets, and seafood; low-fat dairy products, on the other hand, had negatively charged loading factors. Moreover, people on an HFLVD diet usually had greater rates of overweight and obesity; as a result, their vitamin D absorption was lower (Ganji *et al.,* 2018).

According to the study's findings, 67.4% of participants said they occasionally ate fruits and vegetables, 27.9% said they did rarely, and 4.7% said they did so often. Despite the fact that vegetables are a poor source of vitamin D, 86.9% of them were found to be vitamin D deficient. Vegetables have a low concentration of vitamin D because strict vegetarians—those who refrain from eating animal-based meals like eggs and dairy products—often experience vitamin D deficiency (Kim *et al.,* 2018).

Male Mediterranean diet scores, healthy DP, and higher Healthy Eating Index (HEI) were favorably connected with higher education levels, according Mullie *et al.,* 2010 study. Individuals with lower levels of education ingested a higher grade "western DP" in a different trial with a large Iranian population (Asadi *et al.,* 2019). In a systematic review, high educational attainment was considered as a predictor of a healthy DP (Kant, 2004). This finding would suggest that, based on their understanding of dietary requirements and overall health, educated persons are more worried about their health (Wakimoto and Block, 2001).

The educational attainment of the mothers in this study also showed that, in contrast to 92.6% of moms with primary passed, below, or no institutional education, 50.8% of women who graduated or post-graduated had adequate vitamin D. 94.4% of fathers who had only completed their primary schools or had no formal education had inadequate vitamin D, compared to 41.6% of fathers who had graduated or were post-graduated.

Limitations of the Study

Because the study was cross-sectional, it was not possible to demonstrate a causal relationship between the level of vitamin D and other variables. The results of the study could not be applied to all adolescent patients because it only included two specific hospitals in Dhaka city. Moreover, recall bias could not be totally ruled out when assessing dietary practices. We were also unable to take into account other significant variables that could affect the subject's vitamin D levels, including sun exposure, latitude of residence, use of sunscreen creams, clothing selections, etc.

Conclusions and Recommendation

We might conclude that adolescents in Bangladesh may be susceptible to a vitamin D shortage as a result of the dietary and lifestyle choices they make. This study emphasizes how widespread and adolescent populations are affected by vitamin D insufficiency. It's concerning that vitamin D inadequacy and insufficiencies are extremely common among adolescents in Bangladesh. Reaching adolescents and communities—including people from the tribe who reside in hilly regions—is a challenge for public health programes addressing this issue. Additional research is needed to examine among the national representative populations. Furthermore, because prevention of these inadequacies is essential to the nation needs to create an extensive action plan to address the growth and development of adolescents.

The current investigation discovered a beneficial correlation between regular intake of foods high in vitamin D (either naturally occurring or fortified with vitamin D). Therefore, more investigation can be done to see whether it would be possible and feasible to fortify other foods with vitamin D. The study discovered that some foods high in vitamin D were rarely consumed. Thus, (narrative of the awareness program is reheated).

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