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Consumption of animal source foods, especially fish, is associated with better nutritional status among women of reproductive age in rural Bangladesh

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Abstract

In rural Bangladesh, intake of nutrient-rich foods, such as animal source foods (ASFs), is generally suboptimal. Diets low in nutrients and lacking in diversity put women of reproductive age (WRA) at risk of malnutrition as well as adverse birth outcomes. The objective of this study was to assess the relationship between maternal dietary diversity, consumption of specific food groups and markers of nutritional status, including underweight [body mass index (BMI) < 18.5 kg/m^2], overweight (BMI ≥ 23 kg/m^2) and anaemia (haemoglobin < 120 g/dl) among WRA in Bangladesh. This analysis used data from the third round of a longitudinal observational study, collected from February through May of 2017. Dietary data were collected with a questionnaire, and Women's Dietary Diversity Score (WDDS) was calculated. Associations between WDDS, food group consumption and markers of nutritional status were assessed with separate adjusted logistic regression models. Among WRA, the prevalence of underweight, overweight and anaemia was 13.38%, 40.94% and 39.99%, respectively. Women who consumed dark green leafy vegetables (DGLV) or eggs were less likely to be anaemic or underweight, respectively, and women who consumed ASFs, particularly fish, were less likely to be underweight compared with women who did not consume these foods. WDDS did not show any consistent relationship with WRA outcomes. Interventions that focus on promoting optimal nutritional status among WRA in Bangladesh should emphasise increasing consumption of specific nutrient-rich foods, including ASFs, DGLV and eggs, rather than solely focusing on improving diet diversity in general.

KEYWORDS

anaemia, Bangladesh, diet, malnutrition, nutritional status, overweight, women of reproductive age

1 | INTRODUCTION

In rural Bangladesh, diets of women of reproductive age (WRA) are typically dominated by staple crops like rice, and the intakes of important nutrients, such as iron, calcium and vitamin A are inadequate (Arimond et al., 2011; Wable Grandner et al., 2020). Women in Bangladesh consume 84% of their daily energy from white rice, without diversity of non-staple foods to support their achievement of micronutrient-intake adequacy (Arsenault et al., 2013). Animal source foods (ASFs), which provide more bioavailable protein and micronutrients, comprise just 4% of the daily energy intake of women in Bangladesh (Arimond et al., 2011; Murphy & Allen, 2003). Fruits and vegetables also comprise only 4% of daily energy intake (Arimond et al., 2011). The prevalence of micronutrient-intake adequacy for 11 key micronutrients among women in Bangladesh is only 26%, with particularly low intakes of calcium, folate, riboflavin, vitamin B-12 and vitamin A (Arsenault et al., 2013).

WRA (15–49 years) are of special concern given the role of preconception and pregnancy nutrition on foetal outcomes. Malnutrition in the preconception period can increase the risk of adverse foetal outcomes and negatively affect placental development and function (King, 2016; Wu et al., 2012). Preconception folate status is of particular concern as deficiency can increase the risk of neural tube defects (King, 2016). On the other hand, nutrient deficiencies during pregnancy increase the risk of adverse birth outcomes, including neural tube defects, cretinism, intrauterine growth restriction (IUGR), low birthweight (LBW) and preterm birth (Wu et al., 2012). Similarly, nutrition plays an important role in maternal health during delivery, including survival from haemorrhage, hypertension disorders of pregnancy, anaemia and obstructed labour (Wu et al., 2012).

Adequate nutrition is especially important in childbearing adolescents (CBA) as they are in a critical period of growth themselves. In 2010, Bangladesh was the only country outside of sub-Saharan Africa that had an adolescent birth rate above 30%, with 40% of women aged 20–24 having given birth by the age of 18 years old (Loaiza & Liang, 2013). Among girls aged 15–19 years old, maternal mortality is the second leading cause of death and younger mothers experience higher rates of newborn mortality (World Health Organization, 2014). Adolescent mothers have significantly lower BMI's compared with mothers 20 years and older and infants of adolescent mothers have the lower height for age *z*-score (HAZ) and lower weight for age *z*-score (WAZ) compared with infants of adult mothers (Nguyen et al., 2017).

Poor nutritional status in WRA, including low pre-pregnancy body mass index (BMI) and haemoglobin levels, are widely linked to suboptimal maternal and infant birth outcomes. A recent large meta-analysis ($n = 1{,}025{,}794$) found that women with an underweight BMI had 1.29 and 1.64 times the risk of preterm birth and delivering a LBW infant, respectively. Interestingly, the association of maternal underweight and preterm birth was only significant in developed, but not developing, countries when sensitivity analyses were conducted (Han et al., 2011). Other studies have found similar associations between maternal underweight and the risk of delivering a LBW or small for gestational age (SGA) infant (Kader & Tripathi, 2013; Liu et al., 2019). Maternal overweight and obesity are also associated with adverse pregnancy and birth outcomes, including the risk of gestational diabetes, pregnancy-induced hypertension and preeclampsia, birth defects, large for gestational age (LGA) and caesarean sections (Brite et al., 2014; Gaillard et al., 2011; Kim et al., 2010; Lee et al., 2018; Persson et al., 2017; Yang et al., 2019). Maternal haemoglobin level is another important contributor to birth outcomes, as women with anaemia have higher risks of preterm birth, LBW and neonatal mortality compared with non-anaemic women (Rahman et al., 2016).

Key messages

- Women's nutrition remains poor in rural Bangladesh, with high rates of underweight, overweight and anaemia.
- Women's Dietary Diversity Score (WDDS) was not systematically associated with underweight, overweight, or anaemia. This has implications for the widespread use of WDDS as a proxy for the quality of women's diet and nutrition.
- Consumption of specific food groups, including dark green leafy vegetables (DGLV), eggs and animal source foods (ASFs), is positively associated with women's nutrition.
- Consumption of ASFs, particularly fish, is especially protective against underweight (fish vs. no fish: odds ratio: 0.8, 95% confidence interval: 0.65–0.99, $p < 0.05$).
- Policies seeking to improve women's nutrition should emphasise the importance of increasing the consumption of specific foods, including ASFs, eggs and DGLV.

The purpose of this study is to examine the associations between Women's Dietary Diversity Score (WDDS), consumption of specific food groups, and anthropometric indicators of nutritional status, including underweight, overweight and anaemia, among WRA in Bangladesh.

2 | METHODS

2.1 | Data source

The results presented here are derived from the Bangladesh Aquaculture and Horticulture for Nutrition Research study conducted from 2015 to 2017 by the Feed the Future Innovation Lab for Nutrition at Tufts University. That study used a longitudinal observational panel design to assess the impacts of agriculture, nutrition and health programs on maternal and child dietary diversity and nutritional status. The study collected three rounds of data from 3060 households in 102 unions (geographic areas), conducted at an interval of six months. The unions were selected from the Feed the

Future Zones of Influence (ZOIs) from three divisions in Bangladesh; Dhaka, Barisal and Khulna. In each round, data were collected on demographic, socioeconomic conditions, agriculture practices, markets and infrastructure, food security, health and nutritional status. This analysis uses data from the third round of the study, which was collected between February and May 2017.

2.2 | Access to diverse diets

Food consumption was assessed for the female household caregiver of the selected child through a questionnaire asking if the women had eaten food from forty-one food categories within 24 h before the survey.

These data were then used to calculate the WDDS, which is a count of the different food groups consumed by WRA in the previous 24 h (Kennedy et al., 2011). The WDDS is a continuous variable, with scores ranging from 0 to 9, based on the number of food groups consumed 24 h before the interview. The 41 food items were classified into nine food groups according to the Food and Agriculture Organization (FAO) guidelines for calculating the WDDS: (1) starchy staples; (2) DGLV; (3) other vitamin A-rich fruits and vegetables; (4) other fruits and vegetables; (5) organ meat; (6) meat and fish; (7) eggs; (8) legumes, nuts and seeds; and (9) milk and milk products (Kennedy et al., 2011). Consumption of each food was defined as 'yes' when at least one food item within the food group was consumed and 'no' when no food items within the food group were consumed. It is worth noticing that food items under legumes, nuts and seeds were grouped as one single food group at the time of data collection, as a result of which, the diet diversity score was calculated using nine food groups. As the data were available for nine food groups only, this analysis did not use the minimum dietary diversity for WRA (MDD-W) indicator, which is a dichotomous indicator of whether WRA have consumed at least five out of ten defined food groups the previous day or night.

ASF consumption was assessed as both a binary variable and a categorical variable. Four food groups counted towards the ASF score: organ meat and blood; meat and fish; eggs; and milk and milk products. For the binary variable, consumption of ASFs was defined as 'yes' when at least one food item from one of the four ASF groups was consumed and 'no' when no food items from any of the ASF groups were consumed. The count variable was created by counting the number of ASF groups consumed by the mother in the 24 h before the interview and ranged from 0 to 4. Furthermore, the individual food groups that comprised the meat and fish variable were assessed to explore the role of meat and fish separately. These four food groups comprised meat/poultry/offal, any fish, small fish and large fish.

2.3 | Nutritional status

Primary outcomes included underweight, overweight and anaemia of WRA. Underweight and overweight were defined as BMI < 18.5 kg/m^2 and ≥23 kg/m^2, respectively. Anaemia was defined as haemoglobin <120 g/L based on the World Health Organization (WHO) cut-off point (World Health Organization, 2011). Anaemia was further classified as mild, moderate, or severe if haemoglobin was 110–119 g/L, 800–109 g/L, or <800 g/L, respectively (World Health Organization, 2011). It is important to note that there are many limitations to using haemoglobin as a measure of nutrition-related anaemia as many factors influence haemoglobin levels.

All measurements were completed by a trained field team. Height was measured using standard height boards (stadiometers) and weight was measured using digital weighing scales. BMI was calculated by dividing the weight in kilograms (kg) by the height in metres squared (m^2). Haemoglobin levels were measured with a noninvasive finger prick test and readings were done using the HemoCue 201 system.

2.4 | Statistical analysis

Statistical analyses were performed using Stata Statistical Software Version 15.1 In all cases, the threshold of significance was defined as $p < 0.05$.

Nonpregnant women aged 15–49 were included in the analysis ($n = 2653$). Bi-variate associations were conducted to assess which covariates were associated with underweight, overweight and anaemia and needed to be adjusted for. Confounders included in all analyses were age, geographic location by division, educational status of the woman, educational status of the household head, household wealth status and gender of the household head.

Data on age, socioeconomic status, geographic location by division, educational status of the woman, educational status of the household head, household wealth status and gender of the household head were presented categorically. WRA age was divided into four categories: 15–19, 20–29, 30–39 and 40–49 years. Geographic locations were divided by division: Barisal, Dhaka and Khulna. The educational status of the WRA and of the household head included no education, primary incomplete, primary complete, secondary incomplete and secondary complete or higher. Wealth status was determined using the Demographic and Health Surveys wealth index method, which includes data on the household's ownership of specific assets, access to water and sanitation and the main materials used to construct the house. The wealth index was divided into quintiles and included poorest, poorer, middle, richer and richest. The gender of the household head included male or female.

Demographic characteristics of the WRA were calculated. Percent of WRA consuming each food group and mean WDDS were calculated for the total population and by demographic characteristics. Percent of WRA classified as underweight and overweight were also calculated for the total population and by demographic characteristics. Differences in food group consumption, WDDS and outcomes by demographic characteristics were assessed with Pearson's χ^2 tests.

Associations between WDDS and consumption of each of the nine food groups and underweight, overweight and anaemia were calculated using separate multivariate logistic regression models. Multivariate logistic regression analysis was also used to measure the associations between ASF consumption, consumption of the individual meat and fish food groups and underweight, overweight and anaemia.

3 | RESULTS

3.1 | Characteristics of the study population

The demographic characteristics of the study population are presented in Table 1. The mean age of the women was 26.6 years; 7% were aged 15–19 years, 62% were 20–29 years, 28% were 30–39 years and less than 3% were 40-49 years. Almost half of the women were from Khulna (47%), while 29% were from Barisal and 24% were from Dhaka. The proportion of women who received no education was 10%, while 15% began but did not complete primary school, 16% completed primary school, 44% began but did not complete secondary school, and 15% completed secondary school or higher. The proportion of household heads who received no education was 29%, 18% began but did not complete primary school, 14% completed primary school, 26% began but did not complete secondary school and 12% completed secondary school or higher. Household wealth was distributed equally among quintiles. Only about 15% of households had a female as the household head.

The anthropometric and biochemical measures of the WRA are also presented in Table 1. The mean BMI of the women was 22.5 kg/m^2; 46% had a normal BMI, 13% were underweight, 31% were overweight and 10% were obese. Forty percent of the women had any type of anaemia with 25% classified as having mild anaemia, 15% as moderate anaemia and less than 1% as severe anaemia.

3.2 | Underweight, overweight and anaemia

The prevalence of women's underweight, overweight and anaemia by demographic characteristics are presented in Table 2. The percentage of women who were underweight and overweight differed significantly by age group, women's education level, household head's education level and wealth quintile. The percentage of women with anaemia differed significantly by age group, geographic location, women's education level, wealth quintile and gender of the household head.

3.3 | WDDS and individual food group consumption

The associations between consumption of each of the nine food groups used to calculate WDDS, mean WDDS and demographic characteristics of the women are presented in Table 3. The mean WDDS score among all women was 4.14 (SD: 1.1). One hundred

TABLE 1 Descriptive characteristics of the participants

Characteristic	
Age (years) (mean ± SD)	26.59 ± 5.61
Age group	
15–19	184 (6.94)
20–29	1655 (62.38)
30–39	739 (27.86)
40–49	75 (2.83)
Geographic location	
Barisal	778 (29.33)
Dhaka	636 (23.97)
Khulna	1239 (46.70)
Women's education	
None	255 (9.61)
Primary incomplete	385 (14.51)
Primary complete	435 (16.40)
Secondary incomplete	1178 (44.40)
Secondary complete or higher	400 (15.08)
Household head's education	
No	771 (29.06)
Primary incomplete	487 (18.36)
Primary complete	370 (13.95)
Secondary incomplete	694 (26.16)
Secondary complete or higher	331 (12.48)
Gender of household head	
Female	392 (14.78)
Male	2261 (85.22)
BMI (kg/m^2) (mean ± SD)	22.45 ± 3.72
BMI categories	
Underweight (<18.5 kg/m^2)	355 (13.38)
Normal (18.5–22.9 kg/m^2)	1212 (45.68)
Overweight (23–27.4 kg/m^2)	833 (31.40)
Obese (≥27.5 kg/m^2)	253 (9.54)
Anaemia	
Non-anaemia (Hgb ≥ 120 g/L)	1592 (60.01)
Anaemia (Hgb < 120 g/L)	1061 (39.99)
Anaemia category	
Non-anaemia (Hgb ≥ 120 g/L)	1592 (60.01)
Mild (Hgb 110–119 g/L)	661 (24.92)
Moderate (Hgb 800–109 g/L)	392 (14.78)
Severe (Hgb < 800 g/L)	8 (0.30)

Note: *n* = 2653 for all results. Values are *n* (%) unless otherwise stated.
Abbreviations: BMI, body mass index; Hgb, haemoglobin; SD, standard deviation.

TABLE 2 Prevalence of underweight, overweight and anaemia by demographic characteristics

	Underweight BMI < 18.5 kg/m^2		Overweight BMI ≥ 23 kg/m^2		Anaemia Hgb < 120 g/L	
	n	%	*n*	%	*n*	%
Age group						
15–19	44	23.91	43	23.37	57	30.98
20–29	238	14.38	653	39.46	638	38.55
30–39	63	8.53	353	47.77	325	43.98
40–49	10	13.33	37	49.33	41	54.67
p-value		0.000**		0.000**		0.000**
Geographic location						
Barisal	116	14.91	314	40.36	393	50.51
Dhaka	89	13.99	241	37.89	273	42.92
Khulna	150	12.11	531	42.86	395	31.88
p-value		0.173		0.109		0.000**
Women's education						
None	38	14.90	93	36.47	119	46.67
Primary incomplete	56	14.55	139	36.10	173	44.94
Primary complete	72	16.55	170	39.08	174	40.00
Secondary incomplete	151	12.82	473	40.15	448	38.03
Secondary complete or higher	38	9.50	211	52.75	147	36.75
p-value		0.036*		0.000**		0.015*
Household education						
None	118	15.30	274	35.54	299	38.78
Primary incomplete	71	14.58	193	39.63	198	40.66
Primary complete	67	18.11	131	35.41	153	41.35
Secondary incomplete	82	11.82	295	42.51	274	39.48
Secondary complete or higher	17	5.14	193	58.31	137	41.39
p-value		0.000**		0.000**		0.880
Wealth Quintiles						
Poorest	99	18.86	159	30.29	247	47.05
Poorer	84	15.85	200	37.74	234	44.15
Middle	64	12.14	219	41.56	202	38.33
Richer	65	12.26	215	40.57	190	35.85
Richest	43	7.95	293	54.16	188	34.75
p-value		0.000**		0.000*		0.000*
Gender of household head						
Female	45	11.48	170	43.37	176	44.90
Male	310	13.71	916	40.51	885	39.14
p-value		0.231		0.289		0.032*

Note: $n = 2653$ for all results. Comparisons were done using Pearson's χ^2 test.
Abbreviations: BMI, body mass index; Hgb, haemoglobin.
*$p < 0.05$; **$p < 0.01$.

TABLE 3 Associations between consumption of each food group and WDDS versus demographic characteristics

	n	% of women who consumed each food group in the last 24 h								WDDS	
		DGLV	Vit A F&V	Other F&V	Organ meat	Meat/fish	Eggs	Legumes, nut, seed	Milk, milk products	Mean	SD
All women	2653	45.38	11.68	98.61	0.38	68.87	28.38	32.76	27.70	4.14	1.10
Age group											
15–19	184	42.93	16.30	96.20	0.00	71.20	30.43	28.80	20.11	4.06	1.14
20–29	1655	45.20	11.12	98.85	0.48	69.24	28.88	33.35	27.55	4.15	1.09
30–39	739	46.14	12.04	98.65	0.27	67.93	26.93	32.61	29.50	4.14	1.09
40–49	75	48.00	9.33	98.67	0.00	64.00	26.67	30.67	32.00	4.09	1.10
p-value		0.838	0.186	0.037*	0.637	0.635	0.691	0.631	0.066	0.759	
Geographic location											
Barisal		44.73	8.48	98.71	0.39	70.69	29.95	39.20	27.51	4.20	1.11
Dhaka		63.21	12.11	99.37	0.31	67.61	26.10	34.43	30.82	4.34	0.99
Khulna		36.64	13.48	98.14	0.40	68.36	28.57	27.85	26.23	4.00	1.12
p-value		0.000*	0.003*	0.095	0.956	0.401	0.274	0.000*	0.109	0.000*	
Women's education											
None	255	48.63	12.16	98.82	1.18	60.78	22.35	28.63	19.61	3.92	1.12
Primary incomplete	385	41.82	9.09	98.70	0.26	65.45	21.56	30.13	22.08	3.89	0.98
Primary complete	435	47.82	10.57	98.85	0.00	65.75	25.75	31.72	26.90	4.07	1.05
Secondary incomplete	1178	44.40	12.48	98.22	0.42	70.03	31.15	33.96	27.16	4.18	1.10
Secondary complete or higher	400	47.00	12.75	99.25	0.25	77.25	33.50	35.50	40.75	4.46	1.13
p-value		0.289	0.374	0.591	0.173	0.000*	0.000*	0.237	0.000*	0.000*	
Household head's education											
None	771	45.53	11.80	98.44	0.13	67.44	23.99	29.96	23.35	4.01	1.10
Primary incomplete	487	42.09	9.86	98.77	0.82	66.53	26.49	30.18	27.52	4.02	1.05
Primary complete	370	44.05	13.24	99.73	0.81	67.84	30.81	34.59	23.51	4.15	1.04
Secondary incomplete	694	46.97	11.10	98.13	0.14	70.89	28.53	34.73	29.25	4.20	1.07
Secondary complete or higher	331	48.04	13.60	98.49	0.30	72.51	38.37	36.86	39.58	4.48	1.18
p-value		0.400	0.425	0.305	0.151	0.237	0.000*	0.074	0.000*	0.000*	
Wealth quintiles											
Poorest	525	48.00	10.48	98.86	0.38	63.24	23.24	30.86	25.33	4.00	1.03
Poorer	530	49.43	11.51	99.25	0.19	67.17	27.17	33.02	23.96	4.12	1.04
Middle	527	44.21	11.20	97.91	0.57	69.07	28.08	33.40	26.19	4.11	1.10
Richer	530	43.02	10.94	98.30	0.57	69.06	30.75	36.23	29.06	4.18	1.12
Richest	541	42.33	14.23	98.71	0.18	75.60	32.53	30.31	33.83	4.28	1.16
p-value		0.075	0.335	0.399	0.725	0.001**	0.010**	0.254	0.003**	0.001*	
Gender of household head											
Female	392	44.90	7.40	99.23	0.51	68.88	31.89	32.14	29.08	4.14	1.07
Male	2261	45.47	12.43	98.50	0.35	68.86	27.78	32.86	27.47	4.14	1.10
p-value		0.835	0.004*	0.250	0.641	0.996	0.095	0.780	0.509	0.957	

Note: $n = 2653$ for all results. Comparisons were done using Pearson's χ^2 test.

Abbreviations: DGLV, dark green leafy vegetables; WDDS, Women's Dietary Diversity Score.

*$p < 0.05$; **$p < 0.01$.

percent of the women reported to have consumed starchy staples, 45% consumed DGLV, 12% consumed vitamin A-rich fruits and vegetables, 98% consumed other fruits and vegetables, less than 1% consumed organ meat, 69% consumed meat and fish, 28% consumed eggs, 33% consumed legumes, nuts and seeds and 28% consumed milk and milk products.

Women from Dhaka had the highest mean WDDS score, followed by women from Barisal, and Khulna ($p < 0.05$). WDDS differed significantly by women's level of education, household head's level of education and wealth quintile ($p < 0.01$).

Consumption of DGLV was highest among women in Dhaka, followed by Barisal, and then Khulna ($p < 0.01$). Consumption of vitamin A-rich fruits and vegetables was higher for women living in a household with a male household head ($p < 0.01$). Consumption of other fruits and vegetables differed significantly by age group ($p < 0.05$). Consumption of meat and fish differed significantly by level of women's education, level of household head's education (both $p < 0.01$) and wealth quintile ($p = 0.01$) Consumption of legumes, nuts and seeds was highest in women living in Barisal, followed by Dhaka, and then Khulna ($p < 0.01$). Milk and milk product consumption differed significantly by level of women's education, level of household head's education and wealth quintile (all $p < 0.01$).

3.4 | Food group consumption, WDDS and underweight, overweight and anaemia

The associations between consumption of each of the nine food groups used to calculate WDDS, mean WDDS and underweight, overweight and anaemia are presented in Table 4. Women who consumed eggs were less likely to be underweight [odds ratio (OR): 0.75, 95% confidence interval (CI): 0.56–1.00, $p < 0.05$] and women who consumed DGLV were less likely to be anaemic (OR: 0.81, 95% CI: 0.67–0.98, $p < 0.05$). WDDS was not significantly associated with underweight, overweight, or anaemia in fully adjusted models. Due to the possibility that education and wealth are on the causal pathway, influencing maternal diet, and therefore nutritional status, we analysed these associations without adjustment for women's level of education, household head's level of education and wealth quintile. In these analyses, women with higher WDDS were less likely to be underweight (OR: 0.84, 95% CI: 0.75–0.95, $p < 0.05$) and more likely to be overweight (OR: 1.08, 95% CI: 1.01–1.17, $p < 0.05$) (Table S1).

3.5 | ASFs

The associations between ASF consumption (as either a binary or count model) and underweight, overweight and anaemia are presented in Table 5. No women in the analyses reportedly consumed foods from all four ASF groups in the previous 24 h. Women who consumed food from at least one of these food groups were less likely to be underweight compared with women who consumed no ASFs (OR: 0.68, 95% CI: 0.50–0.93, $p < 0.05$). Compared with women who consumed no ASFs, those who consumed foods from one or two of the ASF groups were less likely to be underweight (OR: 0.71, 95% CI: 0.51–0.97, $p < 0.05$ and OR: 0.58, 95% CI: 0.38–0.89, $p < 0.05$, respectively), but there was no statistically significant difference between women who consumed foods from three of the ASF groups compared with women who consumed none. In other words, there was no additional benefit to each additional ASF food consumed over two per 24 h.

3.6 | ASFs—meat, poultry and offal versus fish (small/large)

ASF consumption was further analysed to assess the associations between meat/poultry/offal, total fish, small fish and large fish consumption and underweight, overweight and anaemia. The results are also presented in Table 5. Total fish was protective against underweight only (OR: 0.80, 95% CI: 0.65–0.99, $p < 0.05$), but there were no other significant associations found after separating out the type of ASF.

4 | DISCUSSION

In nonpregnant WRA in Bangladesh, there are multiple manifestations of malnutrition, with 13% classifying as underweight and 41% as overweight or obese. Our findings are similar to those of the 2014 Bangladesh Demographic and Health Survey which found that in women, the prevalence of underweight decreased from 34% to 19% while the prevalence of overweight and obesity increased from 9% to 24% since 2004 (National Institute of Population Research and Training—NIPORT/Bangladesh Mitra and Associates & ICF International, 2016). This shift towards lower rates of underweight and higher rates of overweight and obesity is important to consider as maternal obesity plays an equally critical role in maternal and child health (Van Lieshout et al., 2011).

We found higher rates of underweight among adolescent WRA compared with women in older age groups, with 24% of WRA classifying as underweight. Nguyen et al. (2017) found that in Bangladesh, adolescent mothers had significantly lower body weights and BMIs compared with adult mothers. The poorer baseline nutritional status of adolescent women puts them at greater risk during pregnancy when nutrient demands increase. Policies targeted to WRA should especially focus on those individuals in their adolescent years as promoting adequate growth in this at-risk population in preparation for pregnancy is imperative to both their own and their child's health.

Increased dietary diversity was not associated with a lower risk of underweight, overweight, or anaemia in fully adjusted models. In models without adjustment for education and wealth, increased dietary diversity was protective against underweight and increased odds of overweight. The true causal effect of diet on these outcomes

TABLE 4 Associations between consumption of specific food groups and mean WDDS with underweight, overweight and anaemia

Food group	Underweight BMI < 18.5 kg/m^2			Overweight BMI ≥ 23 kg/m^2			Anaemia Hgb < 120 g/L		
	Odds ratio	*p*-value	95% CI	Odds ratio	*p*-value	95% CI	Odds ratio	*p*-value	95% CI
Dark green leafy vegetables									
No	Reference			Reference			Reference		
Yes	0.92	0.509	0.72–1.18	1.01	0.888	0.84–1.22	0.81	0.027*	0.67–0.98
Vitamin A fruits and vegetables									
No	Reference			Reference			Reference		
Yes	0.74	0.084	0.52–1.04	0.99	0.951	0.78–1.26	0.91	0.455	0.70–1.17
Other fruits and vegetables									
No	Reference			Reference			Reference		
Yes	0.79	0.582	0.34–1.85	1.90	0.064	0.96–3.73	1.68	0.203	0.75–3.77
Organ meat									
No	Reference			Reference			Reference		
Yes	2.76	0.152	0.68–11.11	0.78	0.694	0.23–2.66	0.20	0.150	0.021–1.82
Meat and fish									
No	Reference			Reference			Reference		
Yes	0.84	0.172	0.66–1.08	1.03	0.730	0.86–1.24	1.01	0.920	0.85–1.20
Eggs									
No	Reference			Reference			Reference		
Yes	0.75	0.047*	0.56–1.00	1.08	0.386	0.90–1.29	0.92	0.347	0.77–1.10
Legumes, nuts and seeds									
No	Reference			Reference			Reference		
Yes	1.06	0.624	0.83–1.35	1.05	0.518	0.90–1.23	1.09	0.275	0.93–1.28
Milk and milk products									
No	Reference			Reference			Reference		
Yes	1.01	0.937	0.78–1.30	0.90	0.231	0.76–1.07	0.99	0.912	0.81–1.20
WDDS	0.89	0.075	0.79–1.01	1.02	0.578	0.95–1.10	0.95	0.233	0.88–1.03

Note: $n = 2653$. Associations between WDDS, consumption of specific food groups and underweight, overweight and anaemia were assessed with separate logistic regression models. Associations were adjusted for women's age, women's education level, division, education level of the household head, wealth quintile and gender of the household head. All regression models were adjusted for the survey round.

Abbreviations: BMI, body mass index; CI, confidence interval; Hgb, haemoglobin; WDDS, Women's Dietary Diversity Score.

*$p < 0.05$.

is likely somewhere between these two estimates. Consumption of specific food groups, including DGLV, eggs and ASFs were protective against underweight and anaemia.

In our study, 45% of women consumed DGLV. It is widely accepted that DGLV are a good source of iron, especially in diets limited in meat, and are an important food for the prevention of anaemia. However, DGLV contain the non-haem form of iron, which is less bioavailable to humans than the haem form of iron found in meat (Miret et al., 2003). Ahmed et al. (2018) found that in pregnant Bangladeshi women, less than 40% of anaemia could be defined by iron deficiency. In fact, in Bangladesh, the national prevalence of iron deficiency among nonpregnant non-lactating women was found to be 7.1%. This has been linked to the high iron concentration of the groundwater consumed (Ahmed et al., 2018).

Other vitamins also influence iron homoeostasis and anaemia and there are many non-nutritional contributors to anaemia, including worm infestation, malaria, infections and genetic disorders (Ahmed et al., 2018; Dreyfuss et al., 2000). Wirth et al. (2017) also found that in countries with a high infection burden, anaemia prevalence among WRA was ~40%, but the proportion of these anaemic women who were iron-deficient was only 35%. Vitamin A, folic acid, vitamin B_{12}, riboflavin and vitamin B_6 are all required for the normal production of red blood cells. Additionally, riboflavin,

TABLE 5 Associations between animal source food consumption and underweight, overweight and anaemia

ASF Consumption	Underweight BMI < 18.5 kg/m²			Overweight BMI ≥ 23 kg/m²			Anaemia Hgb < 120 g/L		
	Odds ratio	*p*-value	95% CI	Odds ratio	*p*-value	95% CI	Odds ratio	*p*-value	95% CI
Binary model									
No	Reference			Reference			Reference		
Yes	0.68	0.015*	0.50–0.93	1.03	0.795	0.81–1.32	0.99	0.910	0.78–1.25
Categorical model (number of ASF groups consumed)									
0	Reference			Reference			Reference		
1	0.71	0.031*	0.51–0.97	1.02	0.904	0.78–1.32	1.00	0.998	0.78–1.29
2	0.58	0.013*	0.38–0.89	1.12	0.401	0.86–1.32	1.00	0.983	0.75–1.32
3	0.83	0.484	0.50–1.39	0.87	0.481	0.60–1.27	0.84	0.339	0.59–1.20
4	–	–	–	–	–	–	–	–	–
Type of meat and fish consumed									
Meat/poultry/offal									
No	Reference			Reference			Reference		
Yes	1.12	0.427	0.84–1.49	0.94	0.607	0.73–1.20	1.04	0.705	0.83–1.31
Fish									
No	Reference			Reference			Reference		
Yes	0.80	0.046*	0.65–0.99	1.03	0.784	0.86–1.23	1.00	0.963	0.85–1.18
Small fish									
No	Reference			Reference			Reference		
Yes	0.79	0.118	0.59–1.06	1.01	0.930	0.80–1.27	0.98	0.887	0.77–1.25
Large fish									
No	Reference			Reference			Reference		
Yes	0.86	0.139	0.70–1.05	1.07	0.426	0.91–1.26	1.01	0.865	0.87–1.18

Note: $n = 2653$. All associations were assessed with separate logistic regression models adjusted for age, division, education of the woman, education of the household head, wealth quintile and gender of the household head. The ASF binary model depicts whether food from at least one of the four ASF categories (meat and fish, organ meat, eggs, dairy products) was consumed or not. The ASF categorical model counts the number of individual ASF categories (meat and fish, organ meat, eggs, dairy products) that were consumed. Meat and fish were further analysed by type of meat and fish, including meat/poultry/offal, fish, small fish and large fish.

Abbreviations: ASF, animal source food; BMI, body mass index; CI, confidence interval; Hgb, haemoglobin.

*$p < 0.05$.

vitamin A and vitamin C improve intestinal absorption of iron and facilitate iron mobilisation from body stores (Fishman et al., 2000). DGLV are a good source of vitamin A, folate and vitamin C, potentially contributing further to their protective role against anaemia in this population.

Twenty-eight percent of the women consumed eggs, which were protective against underweight. Eggs are rich in protein, providing seven grams of protein per one egg, and are a good source of essential fatty acids, choline and vitamins A, E, D and B_{12} (Iannotti et al., 2014; Lutter et al., 2018). Two large eggs provide a large share of the recommended dietary allowance or adequate intake of many micronutrients for pregnant and lactating women (Lutter et al., 2018). Choline may be especially important during pregnancy as increased intake has been associated with decreased risk of neural tube defects; however, other studies have found no association (Mills et al., 2014; Shaw et al., 2004). The potential of eggs to improve nutritional status among WRA is promising; however, barriers to consumption should be addressed. In Zambia, cost and physical accessibility were the main reported barriers to routine egg consumption (Hong et al., 2016). Policies and interventions with the goal of increasing egg consumption in resource-poor countries should not ignore these economic and physical barriers to egg consumption.

Overall, ASFs were protective against the underweight. ASFs are rich in digestible protein, fat and many micronutrients and are a nutrient-dense source of calories. When the ASF variable was disaggregated, total fish consumption was protective against underweight. Meat, poultry and offal, milk and milk products and organ meat were not independently protective against underweight or anaemia, indicating that composite ASF consumption is more protective than independent ASF group consumption—presumably, because different ASFs offer different combinations of nutrients. Among WRA in Vietnam, modest ASF supplementation improved micronutrient intakes of iron, vitamin A, vitamin B_{12} and zinc and improved iron status (Hall et al., 2017). Increasing consumption of ASFs in WRA in Bangladesh could improve micronutrient status in addition to underweight and anaemia, further protecting the health of WRA and their future offspring.

One limitation of our study was the absence of data on quantities of foods consumed, which were not collected as part of food frequency surveys. Having consumed a certain food group in the last 24 h does not necessarily indicate that adequate quantities were consumed, especially in resource-poor countries like Bangladesh. Arsenault et al. (2013) found that when the threshold of consumption of a food group for women in Bangladesh is increased from 1 to 15 g, the percent consumption decreased for all food groups, except for starchy staples. Future research should focus on quantifying the amounts of foods consumed to generate more translatable evidence that can better guide policies and recommendations. Another limitation of our study was determining the causal pathway and deciding which confounders to control for. We addressed this limitation by conducting our main regressions with and without adjustment for education and wealth variables and acknowledging that the true estimate likely falls somewhere between these estimates.

5 | CONCLUSION

This study found that consumption of specific food groups containing nutrient-rich foods, especially ASFs, rather than generic broadly-framed dietary diversity in the aggregate, is associated with improved nutritional status in WRA in southwestern Bangladesh. Our findings contribute to the growing evidence that policies and interventions focusing on improving women's nutritional status should encourage the consumption of specific sets of nutrient-dense foods, including ASFs, eggs and DGLVs. We also conclude that it is potentially misleading to rely solely on an index like the WDDS to assess the nutritional status of WRA.

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CONFLICT OF INTERESTS

The authors declare that there are no conflict of interests. The opinions expressed herein are solely those of the authors.

AUTHOR CONTRIBUTIONS

Overall design and planning of the study: Patrick Webb, Shibani Ghosh and Robin Shrestha. *Analysis and writing of the manuscript with feedback from Patrick Webb, Elizabeth Marino Costello, Sabi Gurung and Lynne M. Ausman, with primary responsibility for the final content*: Chloe Andrews, Robin Shrestha and Katherine Appel. All authors reviewed the manuscript for accuracy and read and approved the final manuscript.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

REFERENCES

Ahmed, F., Khan, M. R., Shaheen, N., Ahmed, K. M. U., Hasan, A., Chowdhury, I. A., & Chowdhury, R. (2018). Anemia and iron deficiency in rural Bangladeshi pregnant women living in areas of high and low iron in groundwater. *Nutrition*, *51–52*, 46–52. https://doi.org/10.1016/j.nut.2018.01.014

Arimond, M., Wiesmann, D., Becquey, E., Carriquiry, A., Daniels, M., Deitchler, M., Fanou, N., Ferguson, E., Joseph, M., Kennedy, G., Martin-Prével, Y., & Torheim, L. E. (2011). *Dietary diversity as a measure of the micronutrient adequacy of women's diets in resource-poor areas: Summary of results from five sites* (p. 360). FANTA-2 Bridge, FHI.

Arsenault, J. E., Yakes, E. A., Islam, M. M., Hossain, M. B., Ahmed, T., Hotz, C., Lewis, B., Rahman, A. S., Jamil, K. M., & Brown, K. H. (2013). Very low adequacy of micronutrient intakes by young children and women in rural Bangladesh is primarily explained by low food intake and limited diversity. *The Journal of Nutrition*, *143*(2), 197–203. https://doi.org/10.3945/jn.112.169524

Brite, J., Laughon, S. K., Troendle, J., & Mills, J. (2014). Maternal overweight and obesity and risk of congenital heart defects in offspring. *International Journal of Obesity (2005)*, *38*(6), 878–882. https://doi.org/10.1038/ijo.2013.244

Dreyfuss, M. L., Stoltzfus, R. J., Shrestha, J. B., Pradhan, E. K., LeClerq, S. C., Khatry, S. K., Shrestha, S. R., Katz, J., Albonico, M., & West, K. P. (2000). Hookworms, malaria and vitamin A deficiency contribute to anemia and iron deficiency among pregnant women in the plains of Nepal. *The Journal of Nutrition*, *130*(10), 2527–2536. https://doi.org/10.1093/jn/130.10.2527

Fishman, S. M., Christian, P., & West, K. P. (2000). The role of vitamins in the prevention and control of anaemia. *Public Health Nutrition*, *3*(2), 125–150. https://doi.org/10.1017/s1368980000000173

Gaillard, R., Steegers, E. A. P., Hofman, A., & Jaddoe, V. W. V. (2011). Associations of maternal obesity with blood pressure and the risks of gestational hypertensive disorders. The Generation R Study. *Journal of Hypertension*, *29*(5), 937–944. https://doi.org/10.1097/HJH.0b013e328345500c

Hall, A. G., Ngu, T., Nga, H. T., Quyen, P. N., Hong Anh, P. T., & King, J. C. (2017). An animal-source food supplement increases micronutrient intakes and iron status among reproductive-age women in rural Vietnam. *The Journal of Nutrition*, *147*(6), 1200–1207. https://doi.org/10.3945/jn.116.241968

Han, Z., Mulla, S., Beyene, J., Liao, G., McDonald, S. D., & Knowledge Synthesis Group. (2011). Maternal underweight and the risk of preterm birth and low birth weight: A systematic review and metaanalyses. *International Journal of Epidemiology*, *40*(1), 65–101. https://doi.org/10.1093/ije/dyq195

Hong, J. J., Martey, E. B., Dumas, S. E., Young, S. L., & Travis, A. J. (2016). Physical, economic, and social limitations to egg consumption in the Luangwa Valley, Zambia. *The FASEB Journal*, *30*(S1), 670.2. https://doi.org/10.1096/fasebj.30.1_supplement.670.2

Iannotti, L. L., Lutter, C. K., Bunn, D. A., & Stewart, C. P. (2014). Eggs: The uncracked potential for improving maternal and young child nutrition among the world's poor. *Nutrition Reviews*, *72*(6), 355–368. https://doi.org/10.1111/nure.12107

Kader, M., & Tripathi, N. (2013). Determinants of low birth weight in rural Bangladesh. *International Journal of Reproduction, Contraception, Obstetrics and Gynecology*, *2*(2), 130–134. https://doi.org/10.5455/2320-1770.ijrcog20130604

Kennedy, P. G., Ballard, T., & Dop, M. (2011). *Guidelines for measuring household and individual dietary diversity*. FAO.

Kim, S. Y., England, L., Wilson, H. G., Bish, C., Satten, G. A., & Dietz, P. (2010). Percentage of gestational diabetes mellitus attributable to overweight and obesity. *American Journal of Public Health*, *100*(6), 1047–1052. https://doi.org/10.2105/AJPH.2009.172890

King, J. C. (2016). A summary of pathways or mechanisms linking preconception maternal nutrition with birth outcomes. *The Journal of Nutrition*, *146*(7), 1437S–1444SS. https://doi.org/10.3945/jn.115.223479

Lee, K. W., Ching, S. M., Ramachandran, V., Yee, A., Hoo, F. K., Chia, Y. C., Wan Sulaiman, W. A., Suppiah, S., Mohamed, M. H., & Veettil, S. K. (2018). Prevalence and risk factors of gestational diabetes mellitus in Asia: A systematic review and meta-analysis. *BMC Pregnancy and Childbirth*, *18*(1), 494. https://doi.org/10.1186/s12884-018-2131-4

Liu, L., Ma, Y., Wang, N., Lin, W., Liu, Y., & Wen, D. (2019). Maternal body mass index and risk of neonatal adverse outcomes in China: A systematic review and meta-analysis. *BMC Pregnancy and Childbirth*, *19*(1), 105. https://doi.org/10.1186/s12884-019-2249-z

Loaiza, E., & Liang, M. (2013). *Adolescent pregnancy: A review of the evidence*. UNFPA.

Lutter, C. K., Iannotti, L. L., & Stewart, C. P. (2018). The potential of a simple egg to improve maternal and child nutrition. *Maternal & Child Nutrition*, *14*(Suppl. 3), e12678. https://doi.org/10.1111/mcn.12678

Mills, J. L., Fan, R., Brody, L. C., Liu, A., Ueland, P. M., Wang, Y., Kirke, P. N., Shane, B., & Molloy, A. M. (2014). Maternal choline concentrations during pregnancy and choline-related genetic variants as risk factors for neural tube defects. *The American Journal of Clinical Nutrition*, *100*(4), 1069–1074. https://doi.org/10.3945/ajcn.113.079319

Miret, S., Simpson, R. J., & McKie, A. T. (2003). Physiology and molecular biology of dietary iron absorption. *Annual Review of Nutrition*, *23*, 283–301. https://doi.org/10.1146/annurev.nutr.23.011702.073139

Murphy, S. P., & Allen, L. H. (2003). Nutritional importance of animal source foods. *The Journal of Nutrition*, *133*(11 Suppl. 2), 3932S–3935S. https://doi.org/10.1093/jn/133.11.3932S

National Institute of Population Research and Training—NIPORT/Bangladesh, Mitra and Associates, & ICF International. (2016). *Bangladesh Demographic and Health Survey 2014*. NIPORT, Mitra and Associates, and ICF International.

Nguyen, P. H., Sanghvi, T., Tran, L. M., Afsana, K., Mahmud, Z., Aktar, B., Haque, R., & Menon, P. (2017). The nutrition and health risks faced by pregnant adolescents: Insights from a cross-sectional study in Bangladesh. *PLoS One*, *12*(6), e0178878. https://doi.org/10.1371/journal.pone.0178878

Persson, M., Cnattingius, S., Villamor, E., Söderling, J., Pasternak, B., Stephansson, O., & Neovius, M. (2017). Risk of major congenital malformations in relation to maternal overweight and obesity severity: Cohort study of 1.2 million singletons. *BMJ (Clinical Research Ed.)*, *357*, j2563. https://doi.org/10.1136/bmj.j2563

Rahman, M. M., Abe, S. K., Rahman, M. S., Kanda, M., Narita, S., Bilano, V., Ota, E., Gilmour, S., & Shibuya, K. (2016). Maternal anemia and risk of adverse birth and health outcomes in low- and middle-income countries: Systematic review and meta-analysis1,2. *The American Journal of Clinical Nutrition*, *103*(2), 495–504. https://doi.org/10.3945/ajcn.115.107896

Shaw, G. M., Carmichael, S. L., Yang, W., Selvin, S., & Schaffer, D. M. (2004). Periconceptional dietary intake of choline and betaine and neural tube defects in offspring. *American Journal of Epidemiology*, *160*(2), 102–109. https://doi.org/10.1093/aje/kwh187

Van Lieshout, R. J., Taylor, V. H., & Boyle, M. H. (2011). Pre-pregnancy and pregnancy obesity and neurodevelopmental outcomes in offspring: A systematic review. *Obesity Reviews*, *12*(5), e548–e559. https://doi.org/10.1111/j.1467-789X.2010.00850.x

Wable Grandner, G., Dickin, K., Kanbur, R., Menon, P., Rasmussen, K. M., & Hoddinott, J. (2020). Assessing statistical similarity in dietary intakes of women of reproductive age in Bangladesh. *Maternal & Child Nutrition*, *17*(2), 13086. https://doi.org/10.1111/mcn.13086

Wirth, J. P., Woodruff, B. A., Engle-Stone, R., Namaste, S. M., Temple, V. J., Petry, N., Macdonald, B., Suchdev, P. S., Rohner, F., & Aaron, G. J. (2017). Predictors of anemia in women of reproductive age: Biomarkers Reflecting Inflammation and Nutritional Determinants of Anemia (BRINDA) project. *The American Journal of Clinical Nutrition*, *106*(Suppl. 1), 416S–427S. https://doi.org/10.3945/ajcn.116.143073

World Health Organization. (2011). *Haemoglobin concentrations for the diagnosis of anaemia and assessment of severity*.

World Health Organization. (2014). *Health for the world's adolescents: A second chance in the second decade*. WHO IRIS.

Wu, G., Imhoff-Kunsch, B., & Girard, A. W. (2012). Biological mechanisms for nutritional regulation of maternal health and fetal development. *Paediatric and Perinatal Epidemiology*, *26*(Suppl. 1), 4–26. https://doi.org/10.1111/j.1365-3016.2012.01291.x

Yang, Z., Phung, H., Freebairn, L., Sexton, R., Raulli, A., & Kelly, P. (2019). Contribution of maternal overweight and obesity to the occurrence of adverse pregnancy outcomes. *Australian and New Zealand Journal of Obstetrics and Gynaecology*, *59*(3), 367–374. https://doi.org/10.1111/ajo.12866

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