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Epidemiology of iron deficiency among adolescents aged 10–19 years old in Qatar: a cross-sectional study

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ABSTRACT

Objective To estimate the magnitude and the determinants of iron deficiency among adolescents aged 10–19 years in the State of Qatar.

Design A cross-sectional study design was used to conduct the study.

Setting Primary healthcare centres covering the three main geographical areas. One health centre was selected randomly from each region catchment areas: Northern, Central and Western.

Participants Four hundred and fifty adolescents aged 10–19 years of all nationalities were enrolled in the study.

Outcome measures Serum ferritin cut-off level used to diagnose iron deficiency (<15 µg/L), with normal C reactive protein.

Results The mean age of the participants was 14.00±2.920, and more than half of the participating adolescents were among 10–14 years old age group (56.9%). Fifty-five per cent of the study participants were Non-Qatari, and females consisted of 70.0% of the participants. The prevalence of iron deficiency was 26.4%. Iron deficiency was significantly associated with gender, nationality, attaining menarche and consumption of iron absorption enhancers (citrus fruits and juice).

Conclusion Iron deficiency among adolescents is of moderate public health concern in the country, according to the classification of the WHO. The estimated prevalence of iron deficiency was close to what was found in other low-income and middle-income countries; however, it is still behind the developed countries. Gender, attaining menarche and dietary habits are among the important factors that are associated with iron deficiency. Thus, there is a need to coordinate efforts and resources to address this issue by implementing effective strategies at the community and primary healthcare levels.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ This is the first study to assess iron deficiency among adolescents age group 10-19 years old in Qatar.
⇒ The study setting, primary healthcare centres are among the main healthcare services provider for the adolescent population in the country.
⇒ A cross-sectional design was used to conduct this study; thus, temporality cannot be demonstrated, in addition to the potential for recall bias.
⇒ There is little comparison between this study's findings and other studies because of the differences in diagnostic criteria and laboratory cut-offs used in assessing iron deficiency.

INTRODUCTION

Adolescents are usually considered a healthy group who do not need priority action. Consequently, less attention is paid to them than other age groups, with less consideration for their needs.[1] Iron deficiency is the most common and the most widespread nutritional disorder around the world, and in addition to its high prevalence in low-income and middle-income countries, it is the only nutrient deficiency that is also significantly prevalent in industrialised countries.[2] The physical and physiological changes that occur in adolescents place a high demand on their nutritional requirements and put adolescents at high risk of iron deficiency and anaemia.[3 4] Adolescents with iron deficiency can suffer from different consequences, including impairment of mental and physical growth, which may be presented as a drop in their school performance and a decrease in physical fitness. Moreover, iron deficiency can impact the immune system, decreasing the body resistance to infection.[4–6]

WHO also stated that iron-deficiency anaemia is among the important causes of disability-adjusted life-years for 10–14 years old for both males and females. It ranks first among males and females in the South-East Asia Region, for males in the Americas Region, and among the top three in the European and Eastern Mediterranean Regions. Moreover, it is the fifth ranking for 15–19 years old females, the third in South-East Asia, and among the top four in Europe and Eastern Mediterranean Regions.[7] It was stated by the Eastern Mediterranean Region Office that iron deficiency is among the common micronutrient deficiencies in the region alongside iodine, zinc, calcium, vitamin A, vitamin D and folate.[8] In a comprehensive study that used data from the Global Burden of Disease Study 2015 concluded that during the period between 1990 and 2015, iron-deficiency anaemia was the principal cause of disability for females aged 10–19 years, and for males aged 10–14 years.[9]

Many factors contribute to the development of iron deficiency, including nutritional and non-nutritional factors. Among nutritional factors are low meat, poultry and fish; insufficient vitamin C intake from fruits and vegetables; and reduced iron absorption from diets high in phenolics, such as tea and coffee.[10] The non-nutritional factors include increased body requirements of iron such as growth, pregnancy and heavy menstruation.[11 12]

The State of Qatar, as part of the Gulf Cooperation Council (GCC), along with many Arab countries, has experienced a nutrition transition following the global trend, in which there is a substitution of healthy diet patterns, including food rich in vitamins, minerals and micronutrients such as fruits, vegetables and whole grains with unhealthy and fast food pattern including food rich in sugar, saturated fat and sodium.[13]

Attention to adolescent health has been increasing, as adolescence is when lifelong habits can become established, and lifestyle interventions during this period may significantly influence lifelong health. Healthy children and adolescents are among the priorities of the National Health Strategy 2018–2022 under the leadership of the Ministry of Public Health. The priority aims to improve nutrition and healthy lifestyles and improve provided services for children and adolescents.[14]

Despite the importance of measuring the prevalence and determinants of iron deficiency, local studies assessing this issue included different at-risk groups, including children, elderly and pregnant women, but not adolescents.[15–17] Therefore, baseline epidemiological studies are necessary to promote and enhance adolescent health programmes in primary healthcare centres (PHCC), aiming at improving adolescent health and nutritional status. This study aims at estimating the magnitude and the determinants of iron deficiency among adolescents aged 10–19 years attending PHCC in Qatar.

METHODS

Study setting

A cross-sectional study design was used to conduct the study at the PHCC health centres, which are distributed to cover the whole population across the State of Qatar, through well-defined catchment areas of these centres all over the country that are allocated throughout the (northern, central and western) regions. Four hundred and fifty adolescents were recruited in this study from those who attended the selected health centres and met the eligibility criteria.

Eligibility criteria

Male and female adolescents aged 10–19 years and who are registered in one of the PHCC health centres were eligible. Adolescents with hereditary blood disorders, such as thalassaemia traits, sickle cell disease, glucose-6-phosphate dehydrogenase deficiency, fanconi anaemia, hereditary spherocytosis were excluded.

Sample size calculation and sampling technique

As no previous studies were conducted in Qatar assessing iron deficiency among adolescents, a prevalence of 17.8% for iron deficiency among adolescents was estimated from a population-based study conducted in Kuwait, which was used as a fairly similar population.[18] Hence, the study calculated sample size for 95% confidence level and 5% error rate was 450 participants. A probability cluster sampling with a proportionate allocation of participants was employed as a sampling technique for recruiting the eligible adolescents attending the selected PHCC health centres. A list of all PHCC health centres was obtained (a total of 23 centres during the study period). Then, an automated random number generator was used to select three health centres, one from each region of the health centres catchment areas (northern, central and western).

Study variables

Dependent Variables (outcome): iron deficiency, adolescents were considered iron deficient if serum ferritin level (<15 µg/L).[19] In case of positive C reactive protein (CRP) value of (>5 mg/L), suggesting acute phase status (infection/inflammation), the cut-offs values for serum ferritin level (<70 µg/L) was considered as iron deficiency.[20]

Independent variables (explanatory variables) included sociodemographic information that consisted of the following, age, gender, participants' educational level, parents' educational level, parents' employment status, type of family living in the same household, the number of family members living in the same household. Menstrual history included the following variables, the onset of menarche, length of menstrual period and intermenstrual bleeding. Dietary habits of iron-rich food items included animal and plant sources. This was in refer to a typical week in the last month, which was categorised into consumers and non-consumers, in which non-consumers defined as those who did not consume the iron-rich food item in the last month before the interview, and consumers defined as those who consumed the iron-rich food item at least once in the last month before the interview.

Data collection tool

The research team developed a comprehensive, multi-section, interview-administered questionnaire through discussion with experts in adolescent health and community medicine to establish the content and face validity of the questionnaire as well the extensive literature review for adoption of questions from important and relevant resources. This include, the Arab Teens Lifestyle Study used for the general dietary habits section,[21] and a local study assessed determinants of iron deficiency among pregnant including dietary habits, which was used for iron-rich food dietary habits questions.[16]

After obtaining the Medical Research Center approval (MRC), the principal investigator piloted the study questionnaire to assess the questions clarity, understandability, feasibility and timeliness and assess the overall data collection process, including privacy and confidentiality requirements. The final version of the questionnaire, including the piloting updates, was resubmitted to the MRC for final approval.

Blood samples

Blood samples were collected following infection control procedures according to the PHCC infection control policy. Samples were collected on the same day after completing the questionnaire interview. For serum ferritin levels and CRP, 5 mL blood was collected from each participant in EDTA/heparin tube and was analysed through chemiluminescent micro-particle immunoassay and immunoturbidimetric assay using Abbott architect c system. A coefficient of variation for run precision of 2.5 and 1.6 were considered for levels 1 and 2, respectively. In addition, a measuring range of 10–500 ng/mL and an imprecision of 2.5% were considered per performance specifications according to the Primary Health Care Corporation standard operating procedures.[22]

Data analysis

Statistical Package for Social Sciences (SPSS) V.27 was used to create a database used for the analysis. The analysis was performed and presented as tables and figures for descriptive statistics that included frequency and percentages for categorical variables and mean with SD for continuous variables. For analytic statistics, the analysis was conducted as bivariate analysis by using the χ^2, assessing the association between categorical dependent and independent variables. Furthermore, multivariate analysis was then conducted regression analysis was performed to identify the most influential factors. This was conducted by including factors that showed significance in the bivariate analysis, which were then included in the model. An alpha (p) value of ≤0.05 was the cut-off for the significance level.

Patient and public involvement

There was no involvement of the patients and their families in the study design. However, eligible participants were provided with all needed information about the study and objective and importance. It is expected that the study findings will be shared with the service development section for children and adolescents and the care providers who will use the study findings for guidelines update and effective communication of the suggested recommendations with the patients and their families attending the PHCC.

RESULTS

For this study, eligible adolescents attending the selected health centres were invited to participate. All adolescents who agreed to participate complied with all study requirements, including laboratory investigation. The data collection process was completed by June 2019 over a period of 4 months, and the needed number of study participants was achieved after approaching 500 adolescents, representing a 10% of refusal rate.

The study's main objective was to estimate the prevalence and determinants of iron deficiency among adolescents visiting PHCC. This study revealed that more than one-quarter (26.4%) of the adolescents were iron deficient. The mean age of the participants was 14.00±2.920, and more than half of the participating adolescents were among 10–14 years old age group (56.9%). Fifty-five per cent of the study participants were Non-Qatari, and females consisted of 70.0% of the participants.

Around two-thirds of the participants were in primary and preparatory educational level, one-third were in secondary educational level and 6% were in university level. Regarding parents, educational levels, parents with university and above levels of education accounted for 64.7% among fathers and 61.1% among mothers. Regarding employment status, employment was higher among fathers compared with mothers, 89% and 51%, respectively. About the household status, the majority of the participants (85.3%) were living in a household composite of a nuclear family, and 69.1% were living in a house with more than five members (table 1).

Assessing the relationship between iron deficiency and sociodemographic characteristics showed that iron deficiency was more among female adolescents (29.8%), and more among non-Qatari adolescents (30.3%), and these relations were statistically significant (χ^2= 6.229, df=1, p=0.013) and (χ^2= 4.290, df=1, p=0.038), respectively. Iron deficiency was also more among adolescents whose parents were educated up to high school (32.1%) (χ^2= 4.008, df=1, p=0.045), among fathers and (32.0%) among mothers (χ^2= 4.544, df=1, p=0.033).

The association between iron deficiency and household status revealed a non-statistically significant relation. However, iron deficiency was found to be more among adolescents living in a household of extended family (27.3%) and also more among adolescents living in a household of more than five family members (28.6%), as shown in (table 2).

On studying the relationship between iron deficiency and menstrual history among female participants, the only statistically significant relation was found with those who attained menarche (33.3%) (χ^2= 5.300, df=1, p=0.021). However, a non-statistically significant relation was identified with iron deficiency and females who had menstrual cycles interval of 20 days and less (35.5%), and those who had intermenstrual bleeding (42.9%), shown in (table 3).

Assessing the relation between iron deficiency and the consumption of iron-rich food items did not reveal

Table 1 Frequency distribution of sociodemographic characteristics of adolescents visiting PHCCs, 2019: N=450

Characteristic	Frequency	%
Age		
Early adolescence	256	56.9
Late adolescence	194	43.1
Mean±SD: 14.00±2.920		
Gender		
Male	135	30.0
Female	315	70.0
Nationality		
Qatari	199	44.2
Non-Qatari	251	55.8
Education		
Primary	148	32.9
Preparatory	146	32.4
Secondary	129	28.7
University	27	6.0
Father's education		
Up to high school	159	35.3
University and above	291	64.7
Mother's education		
Up to High School	175	38.9
University and above	275	61.1
Father employment		
Unemployed	48	10.7
Employed	402	89.3
Mother employment		
Unemployed	219	48.7
Employed	231	51.3
Family type		
Nuclear	384	85.3
Extended	66	14.7
Household no		
≤ 5	139	30.9
> 5	311	69.1

PHCCs, Primary Health Care Centres.

Table 2 Prevalence of iron deficiency according to sociodemographic characteristics adolescents visiting PHCCs, 2019, N=450, through univariate analyses

Variable	Iron sufficient	Iron deficient	Total	P value
Age				
Early adolescence	191 (74.6)	65 (25.4)	256	0.560
Late adolescence	140 (72.2)	54 (27.8)	194	
Gender				
Male	110 (81.5)	25 (18.5)	135	0.013
Female	221 (70.2)	94 (29.8)	315	
Nationality				
Qatari	156 (78.4)	43 (21.6)	199	0.038
Non-Qatari	175 (69.7)	76 (30.3)	251	
Education				
Primary	117 (79.1)	31 (20.9)	148	0.070
Preparatory	104 (71.2)	42 (28.8)	146	
Secondary	87 (67.4)	42 (32.6)	129	
University	23 (85.2)	4 (14.8)	27	
Father education				
Up to high school	108 (67.9)	51 (32.1)	159	0.045
University and above	223 (76.6)	68 (23.4)	291	
Mother education				
Up to high school	119 (68.0)	56 (32.0)	175	0.033
University and above	212 (77.1)	63 (22.9)	275	
Father employment				
Unemployed	35 (72.9)	13 (27.1)	48	0.915
Employed	296 (73.6)	106 (26.4)	402	
Mother employment				
Unemployed	154 (70.3)	65 (29.7)	219	0.130
Employed	177 (76.6)	54 (23.4)	231	
Family type				
Nuclear	283 (73.7)	101 (26.3)	384	0.869
Extended	48 (72.7)	18 (27.3)	66	
Household no				
≤5	109 (78.4)	30 (21.6)	139	0.118
>5	222 (71.4)	89 (28.6)	311	

PHCCs, Primary Health Care Centres.

any significant association. However, iron deficiency was more among non-consumers of the iron-rich food items for both animal and plant sources, compared with non-consumers, as shown in (table 4).

The relation between iron deficiency and consumption of iron absorption enhancers and inhibitors with meals was assessed. Iron deficiency was less among those who consume iron absorption enhancers with meals (citrus fruits and juice, eg, orange and grapefruit) (19.2%) (χ^2= 4.891, df=1, p=0.027). On the other hand, iron deficiency was more among adolescents who consume iron absorption inhibitors, for example, milk with meals (36.4%) (χ^2= 3.912, df=1, p=0.048), and non-statistically significant relation was identified with the consumption of other iron absorption inhibitors: coffee, soft drinks and chocolate (table 5).

Assessing the relation between iron deficiency and medical history revealed that a history of anaemia showed a statistically significant association with the current diagnosis of iron deficiency (χ^2= 3.893, df=1, p=0.048). The influence of gender, nationality, parents education, attaining menarche, previous history of anaemia, consumption of iron absorption inhibitors: milk and consumption of iron absorption enhancers were investigated by multivariate logistic regression.

Table 3 Prevalence of iron deficiency according to menstrual history among female adolescents visiting PHCCs, 2019, N=315, through univariate analyses

Variable	Iron sufficient	Iron deficient	Total	P value
Attaining menarche				
No	65 (80.2)	16 (19.8)	81	0.021
Yes	156 (66.7)	78 (33.3)	234	
Age of menarche				
10–14 years	148 (66.1)	76 (33.9)	224	0.361
≥ 15 years	8 (80.0)	2 (20.0)	10	
Average days of bleeding during periods				
≤ 7 days	133 (65.2)	71 (34.8)	204	0.213
> 7 days	23 (76.7)	7 (23.3)	30	
Interval between cycles				
≤ 20 days	49 (64.5)	27 (35.5)	76	0.622
> 20 days	107 (67.7)	51 (32.3)	158	
Bleeding in between the cycles				
No	136 (68.3)	63 (31.7)	199	0.195
Yes	20 (57.1)	15 (42.9)	35	

PHCCs, Primary Health Care Centres.

The only factors that had significant association with iron deficiency were gender (adjusted OR 1.706, 95% CI 1.010 to 2.880, p=0.046), nationality (adjusted OR 1.720, 95% CI 1.061 to 2.786, p=0.028), attaining menarche (adjusted OR 2.095, 95% CI 1.098 to 3.996, p=0.025) and consumption of iron absorption enhancers: citrus fruits and juice (adjusted OR 1.690, 95% CI 1.010 to 2.828, p=0.046) (table 6).

DISCUSSION

During adolescence, the physiological changes can place a high demand on adolescents' nutritional requirements and put them at high risk of iron deficiency, the most common micronutrient deficiency disorder worldwide, including in developed countries.[23] Most of the studies that have been conducted locally either included other age groups or focused on genetic causes such as sickle cell disease or thalassaemia through epidemiological, clinical or hospital-based studies.[24] This study aimed to explore the magnitude and determinants of iron deficiency among adolescents, which can support improving the existing policies and interventions, especially the ones related to lifestyle and behavioural change programmes, as well as guidance for the development of national clinical management guidelines.

The prevalence of iron deficiency among adolescents was 26.4%. This is higher than what was found in a household-based cluster survey that was conducted in Kuwait in 2008. The study found that the prevalence of iron deficiency ranged between 4.2% and 22.6% years among male and female adolescent age groups.[18] However, another study was also conducted in Kuwait and was a school-based cross-sectional study. The study population was students between aged[11–16] years. The study found that 395 study participants (27.9%) had iron deficiency, using a cut-off level of (15 µg/L).[25] Another community-based survey was conducted in Saudi Arabia in 2018 recruited 240 female adolescents aged 13–19 years from Najran city. The study identified an overall

Table 4 Prevalence of iron deficiency according to consuming iron-rich food items, among adolescents visiting PHCCs, 2019, N=450, through univariate analyses

Food item	Iron sufficient	Iron deficient	Total	P value
Animal sources				
Red meat				
Consumers	274 (75.5)	89 (24.5)	363	0.058
Non-consumers	57 (65.5)	30 (34.5)	87	
Chicken				
Consumers	317 (74.1)	111 (25.9)	428	0.279
Non-consumers	14 (63.6)	8 (36.4)	22	
Fish				
Consumers	197 (75.5)	64 (24.5)	261	0.277
Non-consumers	134 (70.9)	55 (29.1)	189	
Eggs				
Consumers	249 (74.3)	86 (25.7)	335	0.526
Non-consumers	82 (71.3)	33 (28.7)	115	
Plant sources				
Legumes				
Consumers	223 (75.9)	71 (24.1)	294	0.130
Non-consumers	108 (69.2)	48 (30.8)	156	
Leafy greens				
Consumers	174 (73.4)	63 (26.6)	237	0.944
Non-consumers	157 (73.7)	56 (26.3)	213	
Cooked vegetables				
Consumers	282 (74.6)	96 (25.4)	378	0.248
Non-consumers	49 (68.1)	23 (31.9)	72	
Breakfast cereals				
Consumers	192 (75.9)	61 (24.1)	253	0.203
Non-consumers	139 (70.6)	58 (29.4)	197	
Whole grains bread				
Consumers	126 (79.7)	32 (20.3)	158	0.244
Non-consumers	205 (70.2)	87 (29.8)	292	
Nuts				
Consumers	219 (76.8)	66 (23.2)	285	0.324
Non-consumers	112 (67.9)	53 (32.1)	165	
Dried fruits				
Consumers	84 (68.3)	39 (31.7)	123	0.121
Non-consumers	247 (75.5)	80 (24.5)	327	
Dates				
Consumers	183 (74.7)	62 (25.3)	245	0.549
Non-consumers	148 (72.2)	57 (27.8)	205	
Fruits				
Consumers	309 (73.6)	111 (26.4)	420	0.977
Non-consumers	22 (73.3)	8 (26.7)	30	

PHCCs, Primary Health Care Centres.

Table 5 Prevalence of iron deficiency according to consuming iron absorption enhancers and inhibitors food items, among adolescents visiting PHCCs, 2019, N=450, through univariate analyses

Variable	Iron sufficient	Iron deficient	Total	P value
Citrus fruits and juice				
No	226 (70.6)	94 (29.4)	320	0.027
Yes	105 (80.8)	25 (19.2)	130	
Coffee				
No	275 (74.3)	95 (25.7)	370	0.426
Yes	56 (70.0)	24 (30.0)	80	
Tea				
No	237 (74.3)	82 (25.7)	319	0.579
Yes	94 (71.8)	37 (28.2)	131	
Soft drinks				
No	249 (75.5)	81 (24.5)	330	0.130
Yes	82 (68.3)	38 (31.7)	120	
Chocolate				
No	298 (73.8)	106 (26.2)	404	0.768
Yes	33 (71.7)	13 (28.3)	46	
Milk				
No	289 (75.3)	95 (24.7)	384	0.048
Yes	42 (63.6)	24 (36.4)	66	

PHCCs, Primary Health Care Centres.

Table 6 Factors influencing iron deficiency among adolescents visiting PHCCs, 2019: N=450, multivariate logistic regression

Determinant	OR (95% CI)	P value
Gender		
Male	1	–
Female	1.706 (1.010 to 2.880)	0.046
Nationality		
Qatari	1	–
Non-Qatari	1.720 (1.061 to 2.786)	0.028
Father education		
University and above	1	–
Up to High School	1.390 (0.845 to 2.286)	0.194
Mother education		
University and above	1	–
Up to High School	1.390 (0.857 to 2.254)	0.182
Attaining menarche		
No	1	–
Yes	2.095 (1.098 to 3.996)	0.025
History of anaemia		
No	1	–
Yes	1.392 (0.818 to 2.370)	0.223
Consumption of iron absorption enhancer (citrus fruits and juice)		
Yes	1	–
No	1.690 (1.010 to 2.828)	0.046
Consumption of iron absorption inhibitors (milk)		
No	1	–
Yes	1.569 (0.883 to 2.789)	0.125

PHCCs, Primary Health Care Centres.

prevalence of 22.5% of iron-deficiency anaemia.[26] In Iran, a study conducted in 2008 among schoolgirls aged 14–20 years from twenty high schools showed a relatively lower prevalence of 23.7% of iron deficiency among the students. However, a low cut-off of ferritin (12 µg/L) was used in that study.[27] This was higher than findings from a study conducted among adolescents in Jordan, including students from seventh to tenth grade from randomly selected schools. The prevalence of iron deficiency was 55.8%, using a plasma ferritin cut-off value of 15 µg/L.[28]

The difference in the identified prevalence between this study and the studies from GCC and Eastern Mediterranean countries can be attributed to several factors. Among which is the variation in the time and settings of conduction of these studies. Moreover, there is a variation in the definitions used in these studies. For example, in this study, adolescence was defined as those aged 10–19 years old, following the WHO definition.[29] However, there was variation in the participants' age included in these studies to represent the adolescent age group.[26 28 30 31] Such variability was also identified regarding cut-offs to diagnose iron deficiency.[27] Moreover, studies did not use acute phase markers to exclude any underlying acute phase status, which requires cut-off adjustment.[32]

Compared with developed countries, the results from this study indicate that Qatar's adolescents are still behind these countries. A study that included 1089 adolescents from 10 cities around Europe concluded that the prevalence of iron deficiency among participants was 17.6%, significantly higher in females than males.[33] Another study conducted in Greece with a sample size of 2492 school students aged 9–13 years old showed a prevalence of 15.3% of iron deficiency among the study participants.[34] Moreover, a cross-sectional study in the USA used the National Health and Nutrition Examination Survey between 2003 and 2006. The data of 1765 female adolescents aged 12–21 showed a prevalence of 13.1% for iron deficiency, which can be attributed to the advance in the implemented programmes and interventions, including school health programmes.[35]

According to the WHO, the public health implication of iron deficiency and anaemia in a population can be determined through prevalence classification, severe: for 40% or higher, moderate: for 20.0%–39.9%, mild: for 5.0%–19.9%, Normal and no public health problem: for 4.9% or lower. This study showed that iron deficiency among adolescents is classified as having moderate public health significance. Screening, especially for those at higher risk, is among the recommended measures needed to implement appropriate control measures.[19 20]

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Determinants that were investigated are sociodemographic (ie, age, gender, nationality, parents' education, parent's employment and household), menstrual history (menarche, menstrual cycle intervals, intermenstrual bleeding) and dietary habits (iron-rich and iron absorption enhancers/inhibitors food items).

Iron deficiency was higher among female adolescents, which could be attributed to blood loss during the menstrual cycles, which mount the risk for iron deficiency and the rapid growth needs. These findings were concurrent with other studies, as the prevalence was higher among females who attained menarche and those with intermenstrual bleeding.[36–38]

There was a difference in iron deficiency between Qatari and non-Qatari adolescents, which could be attributed to other causes such as variance in socioeconomic status, the difference in food patterns and diet quality, including the type and the amount per capita. This was shown in a study that assessed food patterns and diet quality in Qatar.[39]

Iron deficiency was higher among adolescents with parents educated up to high school. These findings were consistent with other studies from different regional countries such as Saudi Arabia, Egypt and India.[26 40 41] This can be explained by the fact that parents' education level is one of the essential determinants, as parental awareness and knowledge about good dietary practices affect their young's nutritional status and the family's socioeconomic status.

Moreover, available studies suggest that household environment, including high crowdedness, may contribute to the development of iron deficiency, as it can be an indicator of the family's socioeconomic status.[42] This was shown in a local study among pregnant women, as iron deficiency was higher among those lives with more than six household members.[16]

Assessing the prevalence of iron deficiency according to the consumption of iron-rich food items, including animal and plant sources, showed a non-statistically significant difference. However, iron deficiency was higher among adolescents not consuming red meat, chicken or fish.

A study in Turkey included more than 1000 male and female young adolescents 12–16 years old. One of the main findings was that iron deficiency was more among adolescents with a lower consumption (once a week) of both animal and plant sources.[43]

A community-based Saudi study that included 500 adolescents showed that around 47% of anaemic adolescents were infrequent or non-consumers of red meat. Moreover, the percentages were less when it comes to the prevalence according to green vegetable consumption (ie, infrequent consumption), as 27% of male and 30% of female participants were anaemic.[44]

Another study that included female adolescents also showed that poor dietary habits of iron-rich food were among the important factors contributing to the development of iron deficiency and anaemia. This study was conducted in Gaza and revealed that anaemia was more among non-consumers of red meat, chicken, fruits and vegetables.[31]

A study conducted in Pakistan found that around 70% of anaemic female adolescents reported consuming a single source of iron, that is, plant sources only, which could contribute to the development of anaemia because of the solitary source.[45] Similar findings were found in a study in India, which showed that the percentage of low consumption among anaemic adolescents were more for meat and poultry than fruits and vegetables, 69% vs 22%, respectively. However, the study included only 170 female adolescents from one town.[46]

The literature provided evidence about ascorbic acid's enhancing effect on iron absorption, which is attributable to its ability to reduce ferric to ferrous (the soluble and absorbable form). In contrast, polyphenols (in tea and coffee), along with calcium, have an inhibiting effect on iron absorption, especially for the non-haem iron.[47–49] However, studies which assessed increased calcium intake for prolonged periods did not show an impact on the iron status. Therefore, it was concluded that the inhibitory effect of calcium on iron absorption is temporary.[50]

In this study, we concluded that there was a difference in iron deficiency prevalence between consumers and non-consumers of iron enhancers/inhibitors food items. However, this difference was statically significant only for citrus fruits/juice and milk consumption.

Several studies showed supporting findings regarding the difference between consumers and non-consumers of iron absorption enhancers/inhibitors. This includes studies from Saudi Arabia, Palestine and Ethiopia, in which these studies found a higher prevalence among adolescents who reported frequent consumption of coffee or tea during the day or those who reported consumption after meals. Moreover, a higher prevalence was found among adolescents who reported no or less fruit juice consumption, which is a good ascorbic acid source.[26 31 51 52]

Regarding the effective strategies to address the adolescent nutrition evidence on approaches to intervention for adolescent nutrition was published recently. The framework suggests that effective interventions to enhance adolescents' nutrition can be achieved through four broad domains: education and health sectors, the food system, and wider community and social influences. The significance of such framework is the fact that it is a comprehensive approach that address the issues considering important factors.[53]

However, such multisectoral approach will not achieve the needed objective without standardised and comprehensive data, aiming at data-informed governance for intersectoral action. Despite the fact of the availability of major global databases on adolescents around the world that include database provided by the United Nations Children's Fund and the WHO, more disaggregated data on adolescents are needed in addition to better sharing of standardised data between countries would support a more data-driven approach to adolescent nutrition policies.[53–55]

Finally, regarding our study, among the achieved benefits are the essential findings and the fact that it is the first study to assess iron deficiency among adolescents in the State of Qatar. Moreover, the PHCC health centres are among the main healthcare services provider for the adolescent population in the country. However, this study includes some limitations that are important to mention. This is a cross-sectional study, so temporality cannot be demonstrated and the potential for recall bias, as the questions about the dietary habits were in reference to the previous 4weeks of the data collection interview. The fact that most of the study participants were female might affect the generalisability of the study findings. Moreover, the differences in the applied diagnostic criteria, including the used laboratory tests (eg, transferrin receptor, hepcidin) to assess iron deficiency across different studies, may limit a precise comparison.

CONCLUSION

According to the WHO classification, iron deficiency among adolescents is of moderate public health concern in the country. The estimated prevalence of iron deficiency was close to what was found in other developing countries; however, it is still behind the developed countries. Gender, attaining menarche and dietary habits are among the important factors associated with iron deficiency. Thus, there is a need to coordinate efforts and resources to address this issue by implementing effective strategies at community and primary healthcare levels.

Contributors All authors of this article have participated in different roles. MA and NS designed the study and wrote the primary proposal. MA and NAK managed approvals for data, samples collection and fieldwork. MA, NAK, SMSA-K and NS contributed to the literature review, data analysis, results interpretation and discussion. MA, NAK, SMSA-K and NS drafted and revised the manuscript. MA completed and submitted the final manuscript. MA is responsible for the overall content as the guarantor.

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Patient consent for publication Consent obtained from parent(s)/guardian(s).

Ethics approval This study involves human participants and was approved by—Independent Ethical Committee (IEC) in the Research Section at the Primary Health Care Corporation, under reference no: HCC/IEC/18/09/ 011—Institutional Review Board (IRB) in the Medical Research Section at Hamad Medical Corporation with Protocol No. MRC-01-18-372. Participants gave informed consent to participate in the study before taking part.

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