Evaluation of Vitamin B12, Folate and Ferritin Serum Levels in Jordanian Population

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Summary Vitamin B12, folate, and ferritin are vital for the development of the nervous system, blood formation, and diverse metabolic functions. The aim of the current study is to evaluate the status of vitamin B12, folate and ferritin in the Jordanian population across distinct geographical locations. In this retrospective study, the cohort population included 2,880 Jordanian individuals with an average age of 47 y for males and 34 y for females (January 2014–December 2016). Vitamin B12, folate, and ferritin were measured in the blood samples by immunoassay on an automated instrument. Prevalence of low levels of vitamin B12 among males and females was similar across the four regions (24%). Equivalently high levels of folate were reported in males (24.4%) and females (23.4%). Additionally, 37.4% of males and 20.4% of females showed low levels of ferritin. Pearson’s correlations did not show any association between age, vitamin B12, folate, and ferritin levels in both sexes. Univariate odd ratio (OR) and age-adjusted OR in males showed a significant decrease in low vitamin B12 risk in the region of Tafela when compared to Irbid. In conclusion, our results showed a significant difference in vitamin B12 levels between populations according to their geographical locations. Ferritin levels were low in almost a quarter of the Jordanian population with a high prevalence in males and females in Irbid and Maan, respectively. These differences might be associated with the genetic, dietary and lifestyle situation which requires further studies to elucidate the risk factors for vitamin B12 and ferritin deficiency.

Key Words cobalamin, geographical location, micronutrients, folic acid, iron deficiency

Cobalamin (Vitamin B12) is an essential vitamin for the synthesis of methionine, DNA, red blood cells and the myelin of the nerve cells (1–3). Therefore, it is crucial to be obtained from natural sources such as meat, milk, and eggs (4). Naturally, vitamin B12 deficiency is caused by malnutrition, malabsorption or genetic predisposition and it takes up to 5 y to develop (5–7). Vitamin B12 deficiency can lead to serious pathology including megaloblastic anemia and certain neurological disorders (8–12). Moreover, vitamin B12 is required for the metabolism of folic acid.

In Jordan, vitamin B12 deficiency is a serious health concern. However, few studies have evaluated the level of vitamin B12 in the Jordanian population with different prevalence (13–17). Many factors have been proposed to be associated with the deficiency of vitamin B12 including genetic predisposition, lifestyle, environment, socioeconomic status and geography (17–19). For instance, certain polymorphisms in the gastric intrinsic factor, MTHFR, and transcobalamins have been found to be related to the level of vitamin B12 (20–23). Furthermore, in an interesting Chilean study, Cabrera et al, reported that the deficiency of vitamin B12 is associated with UV light exposure (19).

Geographically, Jordan is a Middle East country, located in Southwest Asia and northern of Tropic of Cancer. Despite the small size of Jordan, the geography in Jordan is very diverse and includes the lowest point on the earth (Dead Sea).

In this study, we evaluated the prevalence of vitamin B12 deficiency, folate and ferritin levels in the Jordanian population in different geographical locations.

MATERIALS AND METHODS

Sample collection and IRB approval. In this retrospective study, which is compiled with the code of ethics of the World Medical Association (Declaration of Helsinki),
was conducted between January 2014 and December 2016, the cohort population included 2,880 Jordanian individuals (890 males and 1,990 females) from four governorates covering three geographical locations in Jordan (Irbid, Karak, Maan, and Tafela). Blood samples were collected after signing the informed consent form which was approved by the research ethics committee at Yarmouk University (CommetteDecision #19/2008).

Vitamin B12, folate and ferritin levels were measured using the ElectroChemoLuminescence (ECL) immunoassay technology (Cobas e 411, Roche Diagnostics, Japan) on the same day as blood collection. The ECL technology provides superior analytical performance and increased sensitivity such as extremely low levels of molecules, as well as subtle changes in levels, can be detected. In brief, 10 μL of sample, a biotinylated monoclonal (vitamin B12, folate, ferritin)-specific antibody and a monoclonal (vitamin B12, folate, ferritin)-specific antibody labeled with ruthenium complex form a complex which will be bound to streptavidin-coated microparticles. The reaction mixture is captured onto the surface of the instrument electrode and application of voltage induces chemiluminescent emission which is measured by a photomultiplier.

We adopted the following criteria for the evaluation of vitamin B12 concentrations: Vitamin B12 deficiency was considered when the concentration <200 ng/L with a normal range of (200–900 ng/L) (24, 25). For ferritin, the normal range for males was considered from 20 to 500 ng/mL and from 20 to 200 ng/mL for females (https://www.mayoclinic.org/tests-procedures/ferritin-test/about/pac-20384928, accessed 2017, URL is excluded from reference). Finally, the folate normal range was considered between 4.5–45.3 nmol/L (26).

Statistical analysis. Prevalence of abnormal levels of vitamin B12, folate and ferritin, was evaluated in four geographical regions in Jordan. Chi-square test of independence was used to analyze the relationship between categorical variables such as vitamin B12, folate, and ferritin levels and other risk factors. Pearson’s correlation was used to evaluate raw data of age, vitamin B12, folate, and ferritin levels. Risk factor analysis was carried out by binary logistic regression to calculate the odds ratio (OR). For the dependent variable, the abnormal level of vitamin B12, folate or ferritin test (value=1) was used in comparison to a normal level (value=0).

### Table 1. Features of 2,880 subjects.

|                     | Male | Female | Total | p-value |
|---------------------|------|--------|-------|---------|
| **n**               | 890 (30.9%) | 1,990 (69.1%) | 2,880 |         |
| Age median (range)  | 47 (9–91) | 34 (5–90) |       | <0.001  |
| Age groups          |      |        |       |         |
| <20                 | 27 (16%) | 140 (83.8%) | 167 |         |
| 20–29               | 145 (20.2%) | 574 (79.8%) | 719 |         |
| 30–39               | 148 (20.7%) | 568 (79.3%) | 716 |         |
| 40–49               | 134 (35.7%) | 241 (64.3%) | 375 |         |
| 50–59               | 130 (47.4%) | 144 (52.6%) | 274 |         |
| 60–69               | 154 (51.7%) | 144 (48.3%) | 298 |         |
| ≥70                 | 151 (46.2%) | 176 (53.8%) | 327 |         |
| Region              |      |        |       | 0.1     |
| Irbid               | 153 (34.9%) | 286 (65.1%) | 439 |         |
| Karak               | 166 (172.7%) | 393 (70.3%) | 559 |         |
| Maan                | 188 (32.5%) | 391 (67.5%) | 579 |         |
| Tafela              | 383 (29.4%) | 920 (70.6%) | 1,303 |         |
| Pregnancy           |      |        |       | 0.9     |
| No                  | 951 (48%) |        |       |         |
| Yes                 | 1,039 (52%) |        |       |         |
| Newborn             |      |        |       |         |
| No                  | 1,610 (81%) |        |       |         |
| Yes                 | 380 (19%) |        |       |         |
| Vitamin B12         |      |        |       |         |
| Low                 | 197 (30.4%) | 451 (69.6%) | 648 |         |
| Normal              | 604 (30.4%) | 1,386 (69.6%) | 1,990 |         |
| High                | 7 (26.9%) | 19 (73.1%) | 26 |         |
| Folate              |      |        |       | 0.3     |
| Low                 | 1 (10%) | 9 (90%) | 10 |         |
| Normal              | 266 (30.9%) | 594 (69.1%) | 860 |         |
| High                | 86 (31.9%) | 184 (68.1%) | 270 |         |
| Ferritin            |      |        |       | <0.001  |
| Low                 | 139 (44.6%) | 173 (55.4%) | 312 |         |
| Normal              | 212 (26.2%) | 597 (73.8%) | 809 |         |
| High                | 21 (30.6%) | 74 (77.9%) | 95 |         |
For univariate OR, factors (covariates) were added to test separately by “entry” method. For age-adjusted OR, a categorized age variable was added to each covariate by direct entry method. For a simple comparison, an indicator (reference with OR = 1) was chosen for each categorical variable. All statistical analysis was performed using IBM SPSS version 21 program (IBM Corp, Armonk, NY, USA).

RESULTS

Prevalence of abnormal levels of vitamin B12, folate and ferritin

We collected data from 890 males and 1,990 females. The median age higher in the male cohort (47 y) compared to the female cohort (34 y). The distribution of age groups among males and females was significantly biased (p<0.001; Table 1), and thus age-adjusted measures were used in statistical analysis. Data from 439 subjects were from Irbid region in the north of Jordan. The rest of the data were from three southern regions: 559 subjects from Karak, 579 subjects from Maan, and 1,303 subjects from Tafels. Among the females, 52.2% reported during pregnancy. Females with newborns were approximately 19.1% of total females in this study. Overall, the distribution of normal and abnormal levels of vitamin B12 and folate was similar in males and females; however, low levels of ferritin were significantly more prevalent in males than females (p<0.001; Table 1). Prevalence of low levels of vitamin B12 among
males (24.4%) and females (24.3%) was similar in the four regions (Fig. 1A and 1B). High levels of folate were reported in males (24.4%) and females (23.4%). Improved levels of folate were observed in the Karak region, in males (Fig. 1C) and particularly in females (Fig. 1D). Prevalence of low levels of ferritin was significantly higher in males, particularly in the Irbid and Maan regions ($p<0.05$) (Fig. 1E). In females, low levels of ferritin were observed in the Maan region (Fig. 1F) while several cases of high ferritin were reported in Karak and Tafela. Overall, nearly 37.4% of males and 20.4% of females showed low levels in ferritin.

Among different age groups, males below the age of 20 y showed a noticeable incidence of low vitamin B12 in Karak in contrast to no prevalence in Maan for males of the same age (Fig. 2A). We believe that a larger number of samples is required to study variations in this age group. Males above 50 in Irbid also showed low vitamin B12 levels (Fig. 2A). Females in Irbid showed a noticeable incidence of low vitamin B12 until the age of 50 (Fig. 2B). Again, improved levels of folate were observed in the Karak region in males (Fig. 2C) and females (Fig. 2D) in all age groups.

Pearson’s correlations between age, vitamin B12, folate, and ferritin levels were very close to zero, indicating a weak relationship between variables in males and females (Table 2). When these variables were categorized (e.g. low, normal and high categories), chi-square showed significant dependence between vitamin B12 and ferritin in females ($p<0.05$) (Table 2). Approxi-
Table 2. Correlation between age, vitamin B12, folate, and ferritin levels among male and female subjects.

(a) Pearson’s correlation was used for raw data

|                  | Pearson’s correlation |
|------------------|-----------------------|
|                  | Vitamin B12 | Folate | Ferritin |
| Males Age        | -0.034       | 0.047  | -0.055   |
| Vitamin B12      | 0.053        | 0.028  |           |
| Folate           |             | 0.009  |           |
| Females Age      | 0.039*       | 0.034  | 0.030    |
| Vitamin B12      | 0.004        | 0.006  |           |
| Folate           |             | 0.001  |           |

*p-value <0.05.

(b) Chi square test was used for categorical data

|                  | Chi Square test |
|------------------|-----------------|
|                  | Vitamin B12 | Folate | Ferritin |
| Males Age        | 2.153        | 2.365  | 2.065    |
| Vitamin B12      | 2.928        | 0.662  | 1.128    |
| Folate           |              |        |          |
| Females Age      | 2.754        | 3.538  | 2.921    |
| Vitamin B12      | 1.958        | 14.200*|           |
| Folate           |              | 6.079  |           |

*p-value <0.05.

Results from our study revealed a total of 52 out of 782 female (6.6%) subjects shared a decrease in vitamin B12 levels, whereas 417 (53.3%) female subjects shared normal levels in these tests. Nearly 112 (14.3%) females had normal vitamin B12 and low ferritin, whereas 128 (16.4%) females had low vitamin B12 and normal ferritin.

Risk factor analysis

The association between low levels of vitamin B12 and demographic risk factors are summarized in Table 3. Univariate OR showed an increase in the risk of low vitamin B12 with increasing age in males and females, and showing one to two folds increase, however, this increase was not significant. Both univariate OR and age-adjusted OR in males showed a significant decrease in low vitamin B12 risk in the region of Tafela when compared to Irbid (p<0.05). The similar significant lower risk was observed in females from Maan and Tafela. No significant change in risk was found in females reporting pregnancy or newborns.

The association between high levels of folate and demographic risk factors are summarized in Table 4. Univariate OR showed an increase in the risk of high folate with increasing age in males and females, showing two to four folds risk increase, however, this increase was not significant. Both univariate OR and age-adjusted OR in females showed a significant decrease in high folate risk in the region of Karak when compared to Irbid. The similar decrease in risk was observed in males but was not significant. No significant change in risk was found in females reporting pregnancy or newborns.

The association between low levels of ferritin and demographic risk factors are summarized in Table 5. Univariate OR showed a decrease in risk of low ferritin with increasing age in males and females. This finding contrasts with the previous vitamin B12 and folate tests; however, this decrease in risk was not significant. Both univariate OR and age-adjusted OR in males showed a significant decrease in low ferritin risk in the regions of Karak and Tafela when compared to Irbid (p<0.05). Surprisingly, females showed the opposite results in univariate and age-adjusted OR for these regions. Females from Maan reported significant (~2.47 fold) increase in the risk of low ferritin when compared to females from Irbid. Age-adjusted OR (~2.41) did not deviate from univariate OR and it was also significant (p<0.05). Females reporting pregnancy were 1.54 fold higher risk of having low levels of ferritin (p<0.05). Age-adjusted OR for this risk factor was 1.67 and was also significant (p<0.05).

DISCUSSION

Vitamin B12 is an essential vitamin for a group of physiological and metabolic functions such as red blood cells formation and nerve cells myelination (1–3). Therefore, vitamin B12 deficiency is associated with megaloblastic anemia and a group of neurological disorders including dementia (8–12, 27, 28). Moreover, folate is another water-soluble B-complex vitamin that is associated with megaloblastic anemia and neurological problems of neonates (27, 28). Furthermore, ferritin is an indicator of iron level which can lead to macrocytic anemia in cases of iron deficiency. In the current study, we aimed to address the situation of vitamin B12 in the Jordanian population and to demonstrate the differences of vitamin B12, folate and ferritin levels among different groups of populations according to the geographical location from northern to southern governorates.

In this report, the studied population showed vitamin B12 deficiency in 22.5% of the Jordanian population, which is higher than a previous report 3.6% (17) and lower than other previous studies 32.1% (29), 44.6% (30) and 48.5% (31). These differences are related to many factors including the study population and cutoff value of the normal level of vitamin B12. The previous studies included a relatively small sample size and a limited geographical area in comparison with our study (17, 30, 31). Besides, the cutoff value of vitamin B12 level in the previous studies (>200 ng/mL) may overestimate the deficiency in the Jordanian population.

In our study, we found a significant difference in vitamin B12 level between different geographical groups. On the contrary to our expectations, the northern population which was represented by Irbid’s governorate showed the lowest level of vitamin B12 and the highest percentage of deficient individuals in comparison with the other groups; the deficiency of vitamin B12 is higher in males older than 50 y. On the other hand, the southern populations showed a higher level of vitamin...
Table 3. Odds ratios for low levels in vitamin B12 in comparison to normal subjects in the population.

| Vitamin B12 | Males | | Females | |
|-------------|-------|---|--------|---|
| OR (CI 95%) | Age-adjusted OR (CI 95%) | OR (CI 95%) | Age-adjusted OR (CI 95%) |
| Age groups | | | | |
| <20 | 1 | | 1 |
| 20–29 | 0.89 (0.31–2.62) | 1.13 (0.72–1.77) |
| 30–39 | 1.43 (0.50–4.09) | 1.30 (0.83–2.03) |
| 40–49 | 1.83 (0.64–5.22) | 1.07 (0.64–1.78) |
| 50–59 | 1.26 (0.43–3.66) | 0.81 (0.45–1.47) |
| 60–69 | 1.14 (0.40–3.28) | 1.17 (0.67–2.05) |
| ≥70 | 1.89 (0.67–5.33) | 0.96 (0.55–1.67) |
| Region | | | | |
| Irbid | 1 | 1 | 1 |
| Karak | 0.88 (0.52–1.47) | 0.91 (0.54–1.54) | 0.84 (0.59–1.20) | 0.84 (0.58–1.20) |
| Maan | 0.77 (0.47–1.27) | 0.80 (0.48–1.32) | 0.66 (0.46–0.95)* | 0.66 (0.46–0.96)* |
| Tafela | 0.51 (0.32–0.81)* | 0.53 (0.33–0.84)* | 0.66 (0.48–0.90)* | 0.63 (0.46–0.87)* |
| Pregnancy | | | | |
| No | 1 | 1 | 1 |
| Yes | 1.19 (0.96–1.47) | 1.12 (0.86–1.46) |
| Newborn | | | | |
| No | 1 | 1 | 1 |
| Yes | 0.90 (0.69–1.19) | 0.94 (0.71–1.25) |
| Folate | | | | |
| No | 1 | 1 | 1 |
| Yes | 0.90 (0.69–1.19) | 0.94 (0.71–1.25) |
| Ferritin | | | | |
| No | 1 | 1 | 1 |
| Yes | 0.90 (0.69–1.19) | 0.94 (0.71–1.25) |

*p-value <0.05.

Table 4. Odds ratios for high levels in folate in comparison to normal subjects in the population.

| Folate | Males | | Females | |
|--------|-------|---|--------|---|
| OR (CI 95%) | Age-adjusted OR (CI 95%) | OR (CI 95%) | Age-adjusted OR (CI 95%) |
| Age groups | | | | |
| <20 | 1 | | 1 |
| 20–29 | 2.54 (0.29–22.27) | 1.33 (0.66–2.67) |
| 30–39 | 3.92 (0.46–33.45) | 1.32 (0.83–2.03) |
| 40–49 | 1.80 (0.20–16.26) | 1.39 (0.64–3.03) |
| 50–59 | 3.43 (0.40–29.28) | 0.98 (0.40–2.39) |
| 60–69 | 2.47 (0.29–21.19) | 0.94 (0.38–2.33) |
| ≥70 | 3.72 (0.44–31.41) | 1.28 (0.56–2.96) |
| Region | | | | |
| Irbid | 1 | 1 | 1 |
| Karak | 0.65 (0.30–1.44) | 0.64 (0.29–1.42) | 0.39 (0.21–0.76)* | 0.38 (0.20–0.74)* |
| Maan | 1.00 (0.47–2.13) | 0.94 (0.44–2.02) | 1.24 (0.71–2.14) | 1.23 (0.71–2.13) |
| Tafela | 0.63 (0.31–1.29) | 0.60 (0.29–1.24) | 0.87 (0.52–1.47) | 0.85 (0.50–1.45) |
| Pregnancy | | | | |
| No | 1 | 1 | 1 |
| Yes | 0.98 (0.71–1.37) | 0.87 (0.58–1.29) |
| Newborn | | | | |
| No | 1 | 1 | 1 |
| Yes | 1.26 (0.86–1.83) | 1.38 (0.92–2.05) |
| Vitamin B12 | | | | |
| No | 1 | 1 | 1 |
| Yes | 1.00 (1.00–1.00) | 1.00 (1.00–1.00) |
| Ferritin | | | | |
| No | 1 | 1 | 1 |
| Yes | 1.00 (1.00–1.00) | 1.00 (1.00–1.00) |

*p-value <0.05.
Vitamin B12, Folate, Ferritin and Geography

B12 and lowest percentage of vitamin B12 deficiency; however, individuals of less than 20 y old in Karak showed an increase in the low level of vitamin B12. Our findings are consistent with previous reports that underscored the health problem of vitamin B12 deficiency in Jordan (17, 30–32). However, our findings are inconsistent with another report about the geographical location attribute; Cabrera et al. have reported a low level of vitamin B12 in the northern Chilean population (65±1 y old) who are close to the Equator, they hypothesized that there is an association between geographical latitude and vitamin B12 level (19). In our study, the southern population showed a higher level of vitamin B12 and a lower percentage of deficiency. Therefore, we are suggesting the role of other genetic, lifestyle, dietary and environmental factors that could be associated with vitamin B12 level in Jordan.

Despite the small size of the country, the lifestyle in Jordan is uneven, for instance, the urban areas such as Amman—the capital of Jordan—and Irbid have a similar way of life. On the other hand, the other areas can be classified as suburban to Bedouin (Desert residents), that includes Karak, Tafela, and Maan. According to the previous reports as well as our results, there is a trend of vitamin B12 deficiency in the urban areas in comparison with other areas in Jordan (17, 31). Environmental, genetic, dietary and lifestyle are proposed to be associated with the status of vitamin B12 in Jordan. Therefore, we are addressing the geographical location as a factor that is associated with vitamin B12 level in Jordan, which is not detached from the other factors. For instance, the lifestyle and dietary in Jordan is associated with the geographical location. In Bedouin areas, there are available natural sources of vitamin B12 such as red meat and dairy products.

In the study population, around 25% showed a low level of ferritin with a higher prevalence in males. In particular, males in Irbid showed a significant increase in the low level of ferritin while Maan’s females showed a low level of ferritin in comparison with other areas (Karak and Tafela). Pregnancy history was associated with the risk of ferritin low level but not with folate level. A previous study showed a significant improvement in ferritin level among children and a non-significant increase in ferritin level among females from 2002 to 2010 (16), this is because of the national fortification program started in 2002. However, there is no change in the prevalence of low level of ferritin among Jordanian females since 2010. Therefore, it is recommended to evaluate the ferritin level and iron deficiency anemia in Jordan. Interestingly, our results showed approximately 7% of the study population shared a low level of vitamin B12 and ferritin. However, the current study showed significant improvement in females’s folate level (1.1%) in comparison with a previous report in 2010 (13.8%) (16).

The majority of data on the status of vitamin B12, folate and ferritin are derived from relatively small, local surveys. Our data represents, to the best of our knowledge, the first study to evaluate the levels of vitamin

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**Table 5. Odds ratios for low levels in Ferritin in comparison to normal subjects in the population.**

| Ferritin | Males | | Males | | Females | | Females |
|----------|-------|----------|-------|----------|-------|----------|-------|
| OR (CI 95%) | Age-adjusted OR (CI 95%) | OR (CI 95%) | Age-adjusted OR (CI 95%) |
| Age groups | | | | | | | |
| <20 | 1 | 1.11 (0.54–2.25) | 0.93 (0.45–1.94) | | | | |
| 20–29 | 1.00 (0.33–3.07) | 0.94 (0.42–2.09) | 0.74 (0.30–1.82) | | | | |
| 30–39 | 0.88 (0.29–2.69) | 0.94 (0.42–2.09) | 0.74 (0.30–1.82) | | | | |
| 40–49 | 0.67 (0.21–2.17) | 0.94 (0.42–2.09) | 0.74 (0.30–1.82) | | | | |
| 50–59 | 0.68 (0.22–2.11) | 0.94 (0.42–2.09) | 0.74 (0.30–1.82) | | | | |
| 60–69 | 0.96 (0.32–2.92) | 0.94 (0.42–2.09) | 0.74 (0.30–1.82) | | | | |
| ≥70 | 0.80 (0.26–2.44) | 1.13 (0.49–2.59) | 0.74 (0.30–1.82) | | | | |
| Region | | | | | | | |
| Irbid | 1 | 1 | 1.24 (0.68–2.26) | 1.29 (0.70–2.38) | | | |
| Karak | 0.35 (0.17–0.71)* | 0.33 (0.16–0.69)* | 2.47 (1.43–4.27)* | 2.41 (1.39–4.18)* | | | |
| Maan | 0.73 (0.37–1.42) | 0.70 (0.35–1.38) | 1.13 (0.66–1.91) | 1.05 (0.61–1.80) | | | |
| Tafela | 0.47 (0.26–0.84)* | 0.43 (0.23–0.79)* | 1.13 (0.66–1.91) | 1.05 (0.61–1.80) | | | |
| Pregnancy | | | | | | | |
| No | 1 | 1 | 1.54 (1.09–2.16)* | 1.67 (1.08–2.58)* | | | |
| Yes | 1.54 (1.09–2.16)* | 1.67 (1.08–2.58)* | 1.54 (1.09–2.16)* | 1.67 (1.08–2.58)* | | | |
| Newborn | | | | | | | |
| No | 1 | 1 | 0.89 (0.60–1.32) | 0.93 (0.61–1.41) | | | |
| Yes | 0.89 (0.60–1.32) | 0.93 (0.61–1.41) | 0.89 (0.60–1.32) | 0.93 (0.61–1.41) | | | |
| Vitamin B12 | 1.00 (1.00–1.00) | 1.00 (1.00–1.00) | 1.00 (1.00–1.00) | 1.00 (1.00–1.00) | | | |
| Folate | 1.00 (0.99–1.00) | 1.00 (1.00–1.00) | 0.99 (0.97–1.00) | 0.99 (0.97–1.00) | | | |

*p-value <0.05.
B12, folate and ferritin in different geographical locations in Jordan, given their differences in nutritional and socioeconomic indicators. Furthermore, the aim of this study was to better identify a consensus on the cut-offs values for vitamin B12, folate and ferritin as there is a lack of internationally accepted cut off levels for deficiencies due to the use of different methods and instrumentation for assessment of concentrations. Our data point to deficiencies in vitamin B12 and ferritin levels in different population groups particularly, females. Deficiencies in vitamin B12, folate and ferritin are linked to several diseases including, among others, megaloblastic and pernicious anemia, neural tube defects, low birthweight, pregnancy complications (i.e., the risk of placental abruption, delivering preterm), and the risk of birth defects including orofacial and heart defects. Additionally, changes in the levels of vitamin B12, folate and ferritin are linked to poor developmental growth in children and impaired memory and cognitive performance.

Taken together, our findings demonstrated the significant difference in vitamin B12 levels between populations according to their geographical locations. These differences might be associated with the genetic, dietary and lifestyle situation which requires further studies to elucidate the risk factors of vitamin B12 deficiency in the Jordanian population. Moreover, the ferritin level was found to be low in almost a quarter of the Jordanian population with a high prevalence in males and females in Irbid and Maan, respectively.

Micronutrient deficiencies are a significant health problem in the Middle East including Jordan. The WHO pointed to deficiencies in the levels of iron, vitamin B complex, calcium, iodine, zinc, vitamin D, and vitamin A, particularly in children and females in the Middle East countries including Jordan. The strategy of the ministry of health resulted in an increase in ferritin levels and a reduction in iron deficiency and iron deficiency anemia in different population groups however, females still showed low levels of ferritin as shown by data in this study. In addition, programs to educate the population on the association between malnutrition and diseases, particularly anemia, have to be launched in different parts of the country. In particular, these programs should be geared towards those with the highest risk including children and females of different age groups and the elderly. We believe that the data in this study can be used as a guideline to further screen and monitor levels of vitamin B12, folate and ferritin in different population groups and create a national database for nutritional indicators in order to reduce micronutrient deficiencies and thus reduce the disease associated with it.

Disclosure of State of COI

The authors declare there is no conflict of interest.

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