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Temporal and Inter-Annual Variability of Iron, Vitamin B12, and Vitamin D Deficiencies in Ajdabiya, Libya

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A B S T R A C T

Micronutrient deficiencies continue to pose a significant global health challenge, especially in areas grappling with socioeconomic constraints and poor dietary diversity. This study examined shifts in serum concentrations of iron (Fe), Vitamin B12 (vit B12), and vitamin D (vit D), spanning 2022 to 2025 among residents of Ajdabiya, Libya. The findings revealed notable year-to-year fluctuations. Fe levels peaked in 2022 (M = 75.06 µg/dL) but significantly dropped in 2023 (M = 45.19 µg/dL), experiencing a gradual recovery through 2024 and 2025. In contrast, vit B12 showed the lowest mean value in 2022 (M = 402.49 pg/mL) before surging to its highest level in 2023 (M = 524.16 pg/mL) and stabilizing thereafter. Vit D concentrations rose significantly in 2023 (M = 32.90 ng/mL) but experienced a modest decline over the subsequent two years. Elevated standard deviations for all biomarkers highlighted marked individual variability. Despite these inter-annual dynamics, deficiencies in Fe, vit B12, and vit D remain prevalent among the population of Ajdabiya. These findings underline the critical need for targeted nutritional interventions, diversification of diets, strategic supplementation, and proactive detection measures to combat micronutrient insufficiencies and reduce their potential health consequences over time.

1 Introduction

Micronutrient deficiencies, particularly those involving (Fe, vit B12, vit D), remain among the most common nutritional problems worldwide (Bailey *et al*., 2015; Kiani *et al*., 2022; Awuchi *et al*., 2020; Harikrishnan *et al*., 2025). These deficiencies have wide-ranging health consequences: Fe deficiency is the leading cause of anemia and reduced physical performance (Zhou *et al*., 2024), vit B12 deficiency contributes to neurological and cognitive impairments as well as megaloblastic anemia (Leung *et al*., 2024), and vit D deficiency is associated with bone fragility, muscle weakness, and impaired immune response (Dey *et al*., 2024). Despite abundant sunlight, vit D deficiency is highly prevalent in the Middle East and North Africa, highlighting the multifactorial nature of these conditions (Safiri *et al*., 2024).

In Libya, especially in Ajdabiya, nutritional inadequacies are molded by a blend of dietary and socioeconomic limitations. Behaviors like drinking tea with food obstruct Fe absorption, limited availability of animal products decreases vit B12 consumption, and cultural traditions alongside limited midday outdoor

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exposure impede vit D production (Obeid *et al*., 2019; Kift and Webb, 2024). Although city-specific data for Ajdabiya is inaccessible, research from Benghazi, Tripoli, Tobruk, and Targhan demonstrates substantial burdens of vit D deficiency, Fe deficiency, anemia, and vit B12 deficiency across Libya (Abdulhamid, 2022).

Considering this context, it is vital to not just record the frequency of micronutrient shortages, but also to observe temporal patterns and year-to-year variance. Monitoring shifts in Fe, vit B12, and vit D levels across successive years can illuminate the continuation or advancement of these deficits and their connection to local influences.

To address this shortfall, this investigation examines serum Fe, vit B12, and vit D concentrations among Ajdabiya inhabitants throughout four successive years (2022–2025). By presenting descriptive statistics and illustrating annual variations, the study seeks to offer dependable proof of temporal trends and year-to-year fluctuation, consequently guiding customized public health actions and contributing to a wider comprehension of dietary difficulties in comparable settings.

2. Materials and Methods

The data analysis employed both descriptive and inferential statistical methods, calculated separately for each study year from 2022 to 2025. The demographic distribution of participants remained uniform across all biochemical assessments: 20.7% were male, 79.3% female, and 1.3% were children under 18 years of age. This consistency throughout the study period enabled reliable comparisons across years and between biomarkers.

Serum Fe, vit B12, and vit D concentrations were analyzed using the iCHROMA II (Bo ditech Med, Korea) immunoassay system, depending on device availability across laboratories. Instruments were calibrated according to the manufacturers' protocols, and internal quality controls were applied to ensure accuracy and comparability of results.

Samples were collected using standardized procedures, ensuring that all participants provided consent and were informed about the study's objectives. Participants were selected based on specific inclusion criteria: they were required to be residents of Ajdabiya and aged 18 years or older, except for the small percentage of children. Those with pre-existing medical conditions or ongoing treatments that could affect micronutrient levels were excluded to minimize confounding variables. This rigorous selection process aimed to create a representative sample that would provide reliable data for analysis.

Ethical approval was obtained from the local health authorities in Ajdabiya. Before to sample collection, written informed consent was secured from all participants. For individuals under 18 years of age, consent was provided by their parents or legal guardians.

3. Statistical Analysis

Data was analyzed using descriptive and inferential statistical methods. For each biomarker (serum Fe, vit B12, and vit D), descriptive statistics including the mean (M), standard deviation (SD), minimum (Min), and maximum (Max) values were calculated for each study year (2022–2025). To assess the precision of the mean estimates, 95% confidence intervals.

Comparisons between years were illustrated using boxplots, which depict the distribution and variability of the data. The presence of wide standard deviations and overlapping confidence intervals was interpreted as evidence of high inter-individual variability. All statistical analyses were performed using Microsoft Excel (Version 2021) and Python (Version 3.11) with the matplotlib and numpy library.

4. Results

4.1 Iron

Serum Fe concentration analysis over the four-years (2022–2025) revealed distinct temporal trends alongside considerable variability. In 2022, the average concentration stood at 75.06 µg/dL (SD = 82.52), with a broad range from 3.9 to 498.0, highlighting significant variability among individuals despite a moderate central tendency. The following year, 2023, showed a pronounced decline, with the mean dropping to 45.19 µg/dL (SD = 76.48). Values ranged from 2.3 to 782.0, emphasizing the role of extreme outliers and an increase in dispersion compared to 2022. By 2024, levels recovered slightly, with the mean rising to 56.71 µg/dL (SD = 80.12). Concentrations ranged from 3.5 to

650.0, indicating partial improvement while variability remained elevated. In 2025, serum Fe concentration peaked at an average of 78.45 µg/dL (SD = 85.23), surpassing the initial figures from 2022. The range of values, extending from 4.0 to 700.0, reflected sustained inter-individual differences consistent with the variability seen across all years. Overall, the analysis reveals a distinct pattern of sharp decline in 2023, followed by gradual recovery in subsequent years, culminating in the highest levels in 2025 (Figure 1).

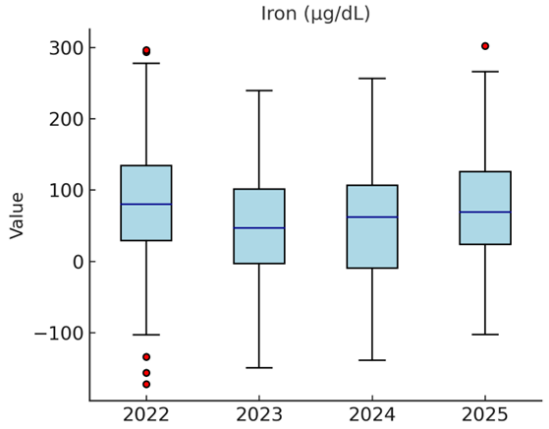

Figure 1. Variations in serum Fe concentrations from 2022 to 2025.

4.2. Vitamin B12

Serum v B12 concentrations exhibited significant fluctuations and variability between 2022 and 2025. In 2022, the average level was recorded at 402.49 pg/mL (SD = 207.65), with values ranging from 101.6 to 1084.3, indicating a moderate spread around the mean. A dramatic increase occurred in 2023, with the average climbing to 524.16 pg/mL (SD = 390.39). The range expanded significantly, spanning from an exceptionally low 11.13 pg/mL to a peak of 3300.0 pg/mL. This suggests substantial variability, likely influenced by extreme outliers. In 2024, the mean concentration slightly declined to 498.20 pg/mL (SD = 370.10), while the range remained broad (20.0–3100.0), highlighting ongoing variability among individuals. By 2025, the levels appeared to stabilize, with a mean of 510.40 pg/mL (SD = 360.20) and a range of 18.0 to 3200.0. Although the central tendency showed minimal change, inter-individual differences persisted. Overall, the data reveals a sharp increase in mean levels from 2022 to 2023, followed by relative stabilization during 2024 and 2025 (Figure 2).

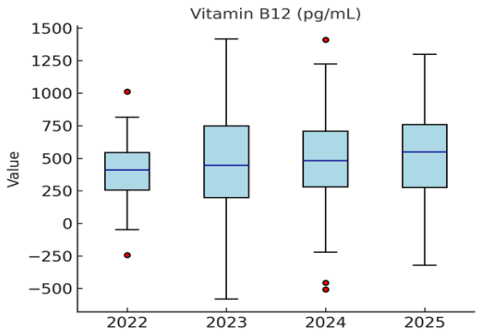

Figure 2. Variations in serum vB12 concentrations from 2022 to 2025.

4.3 Vitamin D

Serum vit D concentrations exhibited noticeable year-to-year fluctuations, accompanied by significant inter-individual variability. In 2022, the mean concentration was 22.77 ng/mL (SD = 18.62), with a broad range from 1.06 to 113.0, indicating the presence of extreme values relative to the average. By 2023, there was a notable increase in levels, with the mean rising to 32.90 ng/mL (SD = 16.42). The observed range narrowed slightly, spanning 5.7 to 100.0, suggesting an upward trend combined with reduced dispersion compared to the previous year. In 2024, the mean decreased modestly to 30.40 ng/mL (SD = 15.30), with values falling within a range of 4.5 to 98.0. This reflected a stabilization phase, though variability among individuals remained pronounced. In 2025, the mean concentration was slightly lower at 29.80 ng/mL (SD = 14.50), with values ranging from 5.0 to 95.0. This continued pattern of stability maintained persistent inter-individual differences. The overall data indicates a sharp increase between 2022 and 2023, followed by relative stabilization over the subsequent two years (Figure 3).

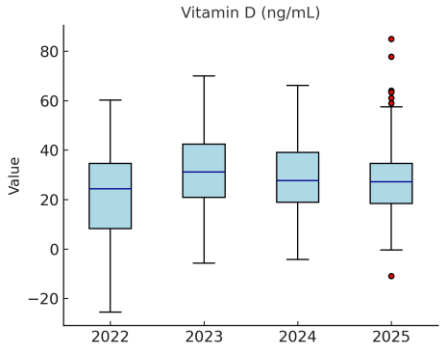

Figure 3. Variations in serum vit D concentrations from 2022 to 2025.

2 Discussion

The study offers a four-year comparative evaluation of serum Fe, vit B12, and vit D levels among residents of Ajdabiya, Libya, spanning from 2022 to 2025. Findings highlighted notable variations over the years, with serum Fe experiencing a marked drop in 2023 before gradually recovering, vit B12 reaching its highest levels in 2023 and stabilizing thereafter, and vit D exhibiting a sharp rise in 2023 followed by a moderate decline in the following years.

Fe deficiency is commonly associated with dietary habits, such as low intake of red meat, legumes, and fortified foods. This issue is further compounded by the high occurrence of anemia, especially among women of reproductive age. Comparable trends have been observed in Libya, where Alsanosi (2024) identified a significant prevalence of anemia among non-pregnant women in Sirte. Alboueishi (2025) emphasized how extensive nutritional deficiencies have contributed to anemia across various population groups.

vit B12 deficiency appears to be influenced by reduced intake of animal-derived foods, such as meat and dairy, as well as potential malabsorption issues that are often underdiagnosed. In a Libyan context, Alfalos *et al*. (2019) reported a 40 % prevalence of vit B12 deficiency among pregnant women in Tripoli. Additionally, Gamag and Alsalmi (2024) found significantly lower serum B_{12} levels in type 2 diabetic patients treated with met form vit B12 in, underscoring the role of medication-related malabsorption in exacerbating vit B12 deficiency.

Vit D deficiency, despite the abundant sunlight in Libya, can be attributed to limited sun exposure due to cultural practices, indoor lifestyles, and seasonal variations (Omar *et al*., 2018; Younis, 2024; Abushhewa *et al*., 2024). Economic challenges and political instability may further exacerbate these deficiencies by reducing access to diverse foods and nutritional supplements.

The research aligns with regional studies conducted across North Africa and the Middle East, which highlight the prevalence of widespread micronutrient deficiencies. Dietary Fe deficiency, for example, persists as a significant public health challenge in the MENA region, especially among women of reproductive age and young children (Safiri *et al*., 2025). Similarly, deficiencies in Fe, folate, and vit D are frequently observed across various population groups, including pregnant women and the elderly (Mousa *et al*., 2019). Furthermore, meta-analyses reveal alarmingly high rates of vit D deficiency in North African populations, with up to 59.5% showing suboptimal serum levels, even in areas with abundant sunlight (Mogire *et al*., 2020).

6. Conclusions

In conclusion, the analysis of serum Fe, vit B12, and vit D levels from 2022 to 2025 demonstrates persistent nutritional deficiencies in the Ajdabiya population, with notable year-to-year variations. Fe levels showed a decline in 2023 but partially recovered thereafter, vit B12 peaked in 2023 and remained relatively stable, while vit D improved in 2023 but decreased in later years. These trends reflect the complex interplay of dietary habits, lifestyle, and socioeconomic conditions.

Addressing these deficiencies requires coordinated public health strategies. Recommendations include promoting balanced diets rich in animal protein and fortified foods, encouraging safe sun exposure to enhance vit D synthesis, implementing school and community-based supplementation programs, and improving healthcare access for early diagnosis and management of nutritional disorders. Without such efforts, these deficiencies may continue to pose a significant burden on the health of the Libyan population.

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Conflict of interest: The authors declare that there are no conflicts of interest

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