Progress in Nutrition 2023; Vol. 24, N. 3: e2023042 DOI: 10.23751/pn.v25i3.14380

Original article

Biochemical and hematological parameters of patients with eating disordered behaviours

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Abstract. *Background and aim*: Eating Disorders (EDs) are serious mental illnesses that can affect people's health and overall well-being irrespective of age, gender, ethnicity, or socioeconomic status. The current study aims to determine selected biochemical and hematological parameters of Saudi women with various types of disordered eating behaviors. *Methods:* This cross-sectional study recruited 100 eating-disordered women, who aged 20-40 years at Taibah University. Blood samples were collected from participants to determine selected micronutrients' levels such as iron, vitamin D, folate, vitamin B_{12}, serum electrolytes, as well as levels of thyroid hormones (T3 and T4). Blood samples were analyzed using immunoassay methods. GraphPad Prism 7 was used for the statistical analysis of the results. *Results:* The EAT-26 test and the DSM-5 test results indicated that women suffered from three types of EDs, specifically, Anorexia Nervosa (18%), Bulimia Nervosa (32%), and Binge Eating Disorder (50%). Low serum iron, vitamin D, vitamin B_{12}, calcium, magnesium, and albumin were prevalent among AN patients compared to their counterparts. The multivariate analysis results indicated a strong or moderate correlation among the variables in AN, BN and BED patients, with a negative correlation between serum P and serum vitamin D, and between serum Ca and Serum P in AN, BN and BED patients. *Conclusions*: The research provides an insight into the various biochemical and hematological abnormalities among women with eating disordered behaviors at a university in Saudi Arabia and emphasizes the need for widespread screening for females in order to identify those individuals who may be suffering from such eating disorders.

Key words: Anorexia Nervosa, Bulimia Nervosa, Binge Eating Disorder, Eating Disorders, Minerals, Vitamins

Introduction

An eating disorder (ED) is a psychiatric illness defined as a typical eating attitude and weight control disorder through psychological, behavioral, and physiological traits unrelated to medical or mental health issues (1). An ED is a severe, chronic health condition that influences males and females of all ages. Eating disorders are a multifaceted phenomenon in which cognitive, behavioral and emotional components influence individual's eating behavior. The shape of body worries and the ED risk in women were twice than in men in countries such as Jordan, Libya, Palestine, and Syria.

Barron et al. (2017) suggested that females follow dietary programs and regimens that endanger their nutritional state, making them more susceptible to eating disorders than men (1). As reported by Marcos in their meta-analysis study, the principal external pressure encountered by young Saudi female students to

lose weight came from their families (2). In addition, the pressure to adhere to cultural norms and societal customs is a catalyst in coercing a person into adopting particular eating habits (3). Media also acts as a source of external pressure on young female students suggesting a parallel between the roles of parents and the media in pressuring a person to engage in unhealthy eating behaviors (4).

Eating disorders can cause severe mental and physical health issues and, in extreme cases, can lead to starvation, heart failure, and possibly death. Purgative actions like self-induced vomiting and improper use of laxatives, diuretics, or enemas can lead to electrolyte abnormalities (5). Hypokalemia and hypochloremic alkalosis may result after vomiting. Abuse of laxatives might result in hypophosphatemia and hypomagnesemia (6). Furthermore, bone disease is common among ED patients, and multiple factors include nutrition, hormonal disturbances, alterations in appetite-regulating peptides, and excessive exercise. For instance, people with EDs frequently have osteoporosis. The body's equilibrium relies on the calcium in the bones to make up for deficits in plasma calcium. Hence calcium insufficiency is frequently not reflected in plasma calcium levels. A long-term calcium shortage is indicated by low bone density (7- 9).

Deficiencies in calcium, vitamin D, folate, vitamin B_{12}, sodium, potassium, and other minerals have been reported in those suffering from EDs (1- 10). Also, serum electrolytes, creatinine, blood urea nitrogen, phosphate, ferritin, albumin, zinc, and manganese levels are some of the elevated biochemical markers reported previously (1- 11).

Eating disorders are challenging to treat, life-threatening disorders. For instance, low-weight patients with AN may have hypotension and osteopenia or life-threatening arrhythmias, often requiring emergency assistance and hospitalization for metabolic stabilization (12). These abnormalities may necessitate emergency supplementing nutrients to meet individual needs (5).

There is a lack of information due to the limited literature available regarding the biochemical and haematological parameters of eating disordered women, especially in Al Madinah Al Muanwarah, Saudi Arabia. This study was undertaken to identify and better understand the pathological anomalies in patients with eating disorders which will assist in the accurate diagnosis and treatment of various eating disorders.

The current study aims to determine selected biochemical and hematological parameters of Saudi women with various types of disordered eating behaviors.

Materials and methods

An epidemiological, cross-sectional study was conducted from January to March 2019 at Taibah University. Women (n = 2000) were recruited from various departments at Taibah University, including both employees (n = 233) and students (1767). The target audience was women between the ages of 18 and 50. Women who were pregnant or nursing, those who had upper or lower gastrointestinal conditions, and those who had chronic illnesses, including diabetes, hypertension, or thyroid conditions that can impair eating habits, were not included in the study. The research population was gathered using a methodical random sampling procedure. First, information on the various colleges, committees, centers, and administrative entities were gathered from Taibah University's official website (www.taibahu.edu.sa). After that, they were added to a poll to randomly choose the locations. Finally, based on the total number of employees and students, the necessary number of participants was chosen proportionally.

Defining and diagnosing ED

Women at risk for developing disordered eating attitudes and practices were identified using the eating attitude test 26 (EAT-26). The EAT-26 is a questionnaire-based test that Garner and Garfinkel developed in 1979. This test is widely used to screen individuals to determine if they have an ED that requires attention. It has already been validated in research carried out in Saudi Arabia. There are three groups of questions: Part A asked participants about their present and goal body weights; Part B asked them 26 questions regarding three subscales: dieting,

bulimia and food obsession, and oral control. Except for item 26, each question had six possible answers, ranging from 0 to 3. Four behavioral questions in Part C sought to identify severe weight-control behaviors and gauge how frequently they occurred, such as self-induced vomiting during the previous six months. In general, women with an EAT-26 score of less than 20 were categorized as being 'at-risk' for disordered eating attitudes and practices (13- 14).

Diagnostic Statistical Manual of mental disorders, fifth edition (DSM-5):

After the EAT-26, all women considered as being 'high risk' for the eating disorder were asked to complete the DSM-5 test. This 23-component self-reported questionnaire acts as a diagnostic criterion which assesses eating-disordered behaviors. It enables physicians to diagnose individuals with certain eating disorders.

The most recent DSM-5 classification characterizes eating disorders as typical EDs, and atypical EDs, Anorexia nervosa, BN, and BED are referred to as the 3 typical EDs. In contrast, other specified feeding or eating disorders (OSFED) and UFED are known as *atypical* forms of ED (15). The OSFED includes the atypical AN, low frequent BN, low frequent BED, night eating syndrome (NES), and purging disease (PD). The DSM-5 questionnaire includes questions concerning physical appearance and how form affects the assessment of a person, followed by questions describing eating episodes that result in a lack of control and feelings during and after overeating, such as eating a lot more quickly. Scores range from 0 to 6, where 0 indicates not at all (not experiencing this issue), and 6 indicates tremendously (highly suffering from the problem). After being informed of the study's objectives, women with eating disorders were encouraged to participate.

Specimen collection and laboratory analysis

Fasting venous blood samples (4 ml) were collected from women to determine serum iron, vitamin D, folate, vitamin B_{12}, serum electrolytes (e.g., sodium, potassium), calcium, phosphate, albumin, zinc, and manganese. Blood samples were analyzed by immunoassay technology using the Cobas b 311 immunoassay analyzer corresponding to the manufacturer's instructions (Roche Diagnostics, GmbH, Germany). Hormone levels (T3 and T4) were detected by a chemiluminescent enzyme-labeled immunometric assay using an IMMULITE 2000 systems analyzer (Siemens, Gwynedd, UK) according to the manufacturer's instructions.

Ethical approval to perform the study was gained from the Ethical Committee at the Faculty of Applied Medical Sciences, Taibah University, Al Madinah Al Munawarah (# CLN201812). Before the study began, women who agreed to participate in the study were asked to sign a consent form stating that they were free to leave at any time and that their privacy would be respected.

Statistical method

Statistical analysis was performed using Graphpad Prism 7 (GraphPad Software, CA, USA). Quantitative data were expressed as mean ± SD. The percentages were calculated to assess the levels of key variables (vitamins, electrolytes, and hormones) among ED patients. A two-way ANOVA and Chi-square test was also used to define the differences among the ED groups. Multiple Linear Regression was used to determine which EDs affected the biomarkers. All differences were statistically significant at the level of $P \leq 0.05$.

Results

Characteristics of women with EDs

Women (n = 100) agreed to participate in the study. The mean age of women with EDs was 35±10.5 years. Their ages ranged from 20 to 30 (55%) and 31 to 40 (45%). The results indicated that women suffered from three types of EDs, precisely, AN (18%), BN (32%), and BED (50%). Overall, patients had low micronutrient levels such as iron, zinc, vitamins D, B_{12}, Na, Ca, magnesium, and albumin. On the contrary, patients had normal T3, T4 and folate (Table 1).

Table 1. The serum levels of Biochemical and haematological parameters of women with EDs.

Parameters	Women with EDs (n=100)	Normal Reference Range
Serum Iron	**8.85 (3.7)**	10-30 μmol/l
Serum Zinc	**9.2 (2.5)**	12.5–18 μmol/l
Serum Vitamin D	**15.8 (5.4)**	20 - 100 ng/mL
Serum Vitamin B_{12}	**108 (47.5)**	190 - 900 ng/L
Serum Folate	32.3 (7.3)	4.5 - 45.3 nmol/L
Serum Na	**110 (14.0)**	135 - 145 mmol/L
Serum K	4.4 (0.2)	3.5 - 5 mmol/L
Serum P	1.2 (0.1)	0.8 - 1.5 mmol/L
Serum Calcium	**1.02 (0.7)**	2.2 - 2.7 mmol/L
Serum Magnesium	**0.79 (0.1)**	1.5 - 2 mEq/L
Serum Albumin	**23 (6.3)**	30- 50 g/L
T3	4.49 (0.5)	3-6.7 pmol/L
T4	12.25 (0.9)	11.5-23 pmol/l

Values are Mean and standard deviation. Values lower than the standards are in bold.

Micronutrient levels of eating disordered women as categorized by the types of EDs

Results showed some differences in the micronutrient levels among women with various ED types. Low serum iron, zinc, vitamin D, vitamin B_{12}, calcium, magnesium, and albumin were prevalent among AN patients compared to their counterparts. Many women with BED suffered from low zinc levels, whereas hyponatraemia was more prevalent among BN patients (Table 2). Overall, irrespective of the type of ED, women had elevated biomarker levels.

Multivariate analysis was based on the Multiple Linear Regression model (types of EDs were the dependent variables). It was used to predict the association between ED types and the micronutrients levels. Women with AN, BN, and BED were at increased risk for having low iron, zinc, vitamin D, and low albumin levels. Women with BN and BED types were at increased risk of low levels of vitamin B_{12}, Na and Ca. In contrast, women with AN, were at higher risk for having low levels of Mg (Table 3). In addition, Pearson's correlation showed that there is a correlation among the biomarkers in the AN, BN and BED patients. For instance, vitamin D correlated with Ca and P (Table 4).

Discussion and conclusion

The current study aimed to determine selected biochemical and haematological parameters of Saudi women with various types of disordered eating behaviors. In this present study most of the patients with ED had a low micronutrient level, including iron, zinc, vitamins D, B_{12}, Na, Ca, magnesium, and albumin, which agreed with results reported previously (16- 17- 18).

Anorexia nervosa is a condition that arises because of persistently limiting the intake of calories, mainly in response to the debilitating fear of becoming fat, which leads to a decline in body weight below the acceptable value (19). Our study further supported this, where many patients with AN suffered from hypoalbuminemia than their BN and BED counterparts, reflecting their low protein consumption. In contrast, the study conducted by Barron and coworkers reported normal albumin levels for AN and BN patients compared to our patients (AN: 46.3 versus 15 g/L, BN: 45.5 versus 20g/L, respectively) (1).

In addition, our study showed a significant reduction in the level of zinc in patients with AN, BN, and BED. On the contrary, in their study, Barron and

Table 2. The levels and prevalence of micronutrient among women based on their EDs classification.

Parameters	Total women (n=100)	AN 18%	BN 32%	BED 50%	*P-value*
Iron levels					
Mean (SD)	8.85 (3.7)	6.4±0.34[b]	7.6±1.43	8.8±2.34	0.02*
Low Iron <10	57(57)*	15(83.3%)*	20(62.5)	22(44.0)	
Normal Iron 10-30	43(43%)	3(16.7)	12(37.5)	28(56.0)	
Zinc levels					
Mean (SD)	9.2 (2.5)	5.1±1.72[a,b]	9.2±3.34	9.1± 2.25	0.04*[a] 0.03*[b]
Low zinc <12.5	59(59)*	14(77.8)*	25(78.1)	20(40.0)	
Normal Zinc 12.5-18	41(41)	4(22.2)	7(21.9)	30(60.0)	
Vitamin D level					
Mean (SD)	15.8 (5.4)	13.75±2.34[a,b]	15.55±3.48	15.7±3.39	0.05*[a] 0.05*[b]
Low vitamin D <20	74(74)*	15(83.3)*	22(68.8)	37(74.0)	
Normal vitamin D 20-100	26(26)	3(16.7)	10(31.3)	13(26.0)	
Vitamin B_{12} level					
Mean (SD)	108 (47.5)	97±24.15[a,b]	103±23.36	107±15.17	0.02*[a] 0.01*[b]
Low vitamin B_{12} <190	39(39)	12(66.7)*	10(31.3)	17(34.0)	
Normal vitamin B_{12} 190-900	61(61)	6(33.3)	22(68.7)	33(66.0)	
Na levels					
Mean (SD)	110 (14.0)	108±10.54[b]	107.36±11.7	106±10.9	0.05*[a] 0.04*[b]
Low Na <135	44(44)	11(61.1) *	21(65.6)	12(24.0)	
Normal Na 135-145	56(56)	7(38.8)	11(34.4)	38(76.0)	
Ca levels					
Mean (SD)	1.02 (0.7)	1.00±0.74[a,b]	1.15±0.79	1.21±0.84	0.04*[a] 0.05*[b]
Low Ca <2.2	73(73)*	16(88.9)*	24(75)	33(66.0)	
Normal Ca 2.2-2.7	27(27)	2(11.1)	8(25.0)	17(34.0)	
Mg levels					
Mean (SD)	0.79 (0.1)	0.69±0.05[a,b]	0.88±0.14	0.89±0.15	0.02*[a] 0.01*[b]
Low Mg <1.5	50(50)	13(72.2)*	15(46.9)	22(44.0)	
Normal Mg 1.5-2	50(50)	5(27.8)	17(53.1)	28(56)	
Albumin levels					
Mean (SD)	23 (6.3)	15±0.54[a,b]	20±0.75	22±0.96	0.04*[a] 0.04*[b]
Low albumin < 30	39(39)	15(83.3)*	11(34.4)	13(26)	
Normal albumin 30-50	61(61)	3(16.7)	21(65.6)	37(74)	

The data are presented as Mean (SD) and number (%) for micronutrient levels; data were analyzed using the two-way Anova test and the result was considered as statistically significant at P ≤0.05. [a]Statistically significant difference between AN and BN; [b]Statistically significant difference between AN and BED; [c]Statistically significant different between BED and BN. AN=Anorexia nervosa; BN = Bulimia nervosa; BED = Binge Eating Disorder.

Table 3. Multiple linear regression showing the association between ED types and micronutrients.

	AN			BN			BED		
Parameters	**B**	**OR (95% CI)**	***P*-value**	**B**	**OR (95% CI)**	***P*-value**	**B**	**OR (95% CI)**	***P*-value**
Serum Iron	-4.5	1.862 - 5.104	0.01*	-4.9	1.993 - 5.236	0.01*	-5.166	1.924 - 6.288	0.02*
Serum Zinc	-4.33	1.216 - 5.198	0.03*	-5.15	1.432 - 6.869	0.04*	-5.376	1.412 - 6.948	0.04*
Serum Vitamin D	-5.26	2.913 - 6.241	0.03*	-5.72	2.983 - 6.386	0.02*	-6.17	1.954 - 6.718	0.01*
Serum Vitamin B_{12}	0.89	0.998 - 1.321	>0.05	-3.96	1.988 - 4.443	0.04*	-4.82	1.818 - 5.528	0.05*
Serum Na	-4.126	1.122 - 4.421	0.04*	1.215	1.213 - 1.909	>0.05	1.198	1.975 - 2.548	0.07
Serum P	1.89	1.163 - 1.224	>0.05	1.78	1.189 - 1.214	0.08	0.87	0.194 -1.948	>0.05
Serum Ca	0.317	0.316 - 1.278	>0.05	-6.68	1.421 - 7.651	0.01*	-7.379	1.914 - 8.321	0.02*
Serum Mg	-4.36	1.963 - 5.126	0.04*	0.72	0.914 - 1.922	>0.05	1.36	0.977 - 1.831	0.08
Serum Albumin	-4.80	1.973 - 5.92	0.05*	-5.87	1.818 - 6.34	0.03*	-7.81	2.840 - 9.128	0.01*
R^2	0.511			0.515			0.652		

Multiple linear Regression was carried out to analyze the association between ED types and Micronutrients. Unstandardized coefficients (B), odds ratios (OR), and 95% confidence intervals (CIs) were statistically significant at P ≤0.05* or ≤ 0.001**. R^2: coefficient of Regression: Unstandardized Coefficients; Value of R^2 ranges from 0-1.

coworkers reported normal zinc levels in patients with AN (11.0 versus 5.1 μmol/L) and BN (11.95 versus 9.2 μmol/L) (1). The prevalence of low zinc levels was higher among AN and BN patients in our study compared to the study by Humpries and coworkers (AN: 77.8 versus 54%; BN: 78.1 versus 40%, respectively) (20). Zinc is crucial for the various enzymatic reactions and the synthesis of neurotransmitters. Low levels of zinc result in a loss of smell and taste perception, which further contributes to a decrease in appetite (1- 21). In addition, low zinc levels might be attributed to impaired mineral absorption, vomiting episodes and binging on low-zinc foods common among BN patients (20). Studies have shown that the administration of zinc supplements in AN patients led to significant weight gain (22).

In our study, all women with eating-disordered behaviours suffered from low serum magnesium levels. Hypomagnesaemia was more common among those with AN. Barron and colleagues showed normal magnesium levels among AN and BN patients in their study, which contradicts the findings in our study (1). Magnesium acts as a co-factor in hundreds of enzymatic reactions throughout the body. It is also required to optimize the muscles, heart, bones, nerves, and immune system. A magnesium deficiency can lead to stress, anxiety and depression episodes commonly seen among AN patients (23). In extreme cases, magnesium deficiency in eating-disordered patients has been associated with osteoporosis, altered insulin production and lipoprotein metabolism and neurological deficits (24).

Moreover, previous studies highlighted an increased prevalence of vitamin D deficiency among people with eating disorders (1- 25- 26- 27). Similarly, in our study, women with AN, BN, and BED had significantly lower vitamin D levels compared to reference values and previous studies. For instance, in the study by Barron and others, patients had normal vitamin D levels, which were far higher than the values obtained in our study (AN: 28.9 versus 13.8 ng/mL; BN: 31.9 versus 15.6 ng/mL, respectively) (1). Moreover, in the current study, the prevalence of hypovitaminosis D among AN and BN patients was higher than in the study by Mehler and colleagues (2018) (AN: 83.3 versus 30%; BN: 68.8 versus 43%, respectively) (28). Furthermore, our study revealed that serum vitamin D correlated positively with serum zinc and calcium and negatively with phosphorous. The vitamin helps the optimal absorption of calcium, and as will be discussed

Table 4. The correlations between Micronutrients among women with eating-disordered behaviors.

AN patients																		
	Serum Iron		**Serum Zinc**		**Serum Vitamin D**		**Serum Vitamin B_{12}**		**Serum Na**		**Serum P**		**Serum Ca**		**Serum Mg**		**Serum Albumin**	
Micronutrients	***r***	***P***	***r***	***P***	***r***	***P***	***r***	***P***	***r***	***P***	***R***	***P***	***r***	***P***	***r***	***P***	***r***	***P***
Serum Iron	1	-	**0.81**	**0.01***	**0.49**	**0.03***	**0.55**	**0.04***	0.30	0.08	0.31	>0.05	0.32	>0.05	**0.49**	**0.05***	**0.57**	**0.03***
Serum Zinc	**0.81**	**0.01***	1	-	**0.46**	**0.04***	0.28	>0.05	0.27	>0.05	0.21	0.07	0.13	>0.05	**0.57**	**0.05***	0.22	>0.05
Serum Vitamin D	**0.49**	**0.03***	**0.46**	**0.04***	1	-	0.36	0.06	0.23	>0.05	**-0.47**	**0.04***	**0.78**	**0.02***	0.33	0.06	0.43	>0.05
Serum Vitamin B12	**0.55**	**0.04***	0.28	>0.05	0.36	0.06	1	-	0.20	0.08	0.18	>0.05	0.32	0.06	0.14	>0.05	0.33	>0.05
Serum Na	0.30	0.08	0.27	>0.05	0.23	>0.05	0.20	0.08	1	-	0.11	0.08	0.35	>0.05	0.19	>0.05	0.21	>0.05
Serum P	0.31	>0.05	0.21	0.07	**-0.47**	**0.04***	0.18	>0.05	0.11	0.08	1	-	**-0.75**	**0.03***	0.32	0.06	0.20	>0.05
Serum Ca	0.32	>0.05	0.13	>0.05	**0.78**	**0.02***	0.36	0.08	0.31	>0.05	**-0.75**	**0.03***	1	-	0.12	0.07	**0.55**	**0.03***
Serum Mg	**0.49**	**0.05***	**0.57**	**0.05***	0.33	0.06	0.14	>0.05	0.19	>0.05	0.32	0.06	0.32	0.06	1	-	0.32	>0.05
Serum Albumin	**0.57**	**0.03***	0.22	>0.05	0.43	>0.05	0.33	>0.05	0.21	>0.05	0.20	>0.05	**0.55**	**0.03***	0.32	>0.05	1	-
BN patients																		
Serum Iron	1	-	**0.83**	**0.01***	**0.52**	**0.03***	**0.57**	**0.03***	0.20	0.08	0.36	>0.05	0.31	>0.05	**0.59**	**0.05***	**0.54**	**0.03***
Serum Zinc	**0.83**	**0.01***	1	-	**0.48**	**0.04***	0.18	>0.05	0.37	>0.05	0.31	0.07	0.23	>0.05	**0.58**	**0.04***	0.12	>0.05
Serum Vitamin D	**0.52**	**0.03***	**0.48**	**0.04***	1	-	0.26	0.06	0.25	>0.05	**-0.57**	**0.04***	**0.88**	**0.02***	0.43	0.07	0.40	>0.05
Serum Vitamin B12	**0.57**	**0.03***	0.18	>0.05	0.26	0.06	1	-	0.21	0.08	0.28	>0.05	0.33	0.06	0.24	>0.05	0.37	>0.05
Serum Na	0.20	0.08	0.37	>0.05	0.25	>0.05	0.21	0.08	1	-	0.19	0.08	0.25	>0.05	0.29	>0.05	0.31	>0.05
Serum P	0.36	>0.05	0.31	0.07	**-0.57**	**0.04***	0.28	>0.05	0.19	0.08	1	-	**-0.65**	**0.03***	0.34	0.07	0.25	>0.05
Serum Ca	0.32	>0.05	0.13	>0.05	**0.78**	**0.02***	0.36	0.08	0.31	>0.05	**-0.75**	**0.03***	1	-	0.12	0.07	**0.56**	**0.03***
Serum Mg	**0.59**	**0.05***	**0.58**	**0.04***	0.43	0.07	0.24	>0.05	0.29	>0.05	0.34	0.07	0.12	0.07	1	-	0.31	>0.05
Serum Albumin	**0.54**	**0.03***	0.12	>0.05	0.40	>0.05	0.37	>0.05	0.31	>0.05	0.25	>0.05	**0.56**	**0.03***	0.31	>0.05	1	-

Table 4 (*Continued*)

Table 4. The correlations between Micronutrients among women with eating-disordered behaviors.

AN patients																		
	Serum Iron		**Serum Zinc**		**Serum Vitamin D**		**Serum Vitamin B_{12}**		**Serum Na**		**Serum P**		**Serum Ca**		**Serum Mg**		**Serum Albumin**	
Micronutrients	***r***	***P***	***r***	***P***	***r***	***P***	***r***	***P***	***r***	***P***	***R***	***P***	***r***	***P***	***r***	***P***	***r***	***P***
BED patients																		
Serum Iron	1	-	**0.80**	**0.02***	**0.53**	**0.03***	**0.58**	**0.03***	0.22	0.07	0.38	0.07	0.33	0.06	**0.69**	**0.03***	**0.57**	**0.03***
Serum Zinc	**0.80**	**0.02***	1	-	**0.58**	**0.03***	0.28	>0.05	0.27	>0.05	0.21	0.06	0.24	>0.05	**0.55**	**0.04***	0.32	0.06
Serum Vitamin D	**0.53**	**0.03***	**0.58**	**0.03***	1	-	0.28	0.06	0.27	>0.05	**-0.58**	**0.04***	**0.89**	**0.01***	0.44	0.06	0.41	>0.05
Serum Vitamin B12	**0.58**	**0.03***	0.28	>0.05	0.28	0.06	1	-	0.24	0.06	0.29	>0.05	0.35	0.07	0.26	>0.05	0.38	>0.05
Serum Na	0.22	0.07	0.27	>0.05	0.24	0.06	0.29	>0.05	1	-	0.18	0.08	0.26	>0.05	0.21	>0.05	0.21	>0.05
Serum P	0.38	0.07	0.21	0.06	**-0.58**	**0.04***	0.29	>0.05	0.18	0.08	1	-	**-0.67**	**0.02***	0.35	0.06	0.27	>0.05
Serum Ca	0.33	0.06	0.24	>0.05	**0.89**	**0.01***	0.35	0.07	0.26	>0.05	**-0.67**	**0.02***	1	-	0.32	0.06	**0.54**	**0.03***
Serum Mg	**0.69**	**0.03***	**0.55**	**0.04***	0.44	0.06	0.26	>0.05	0.21	>0.05	0.35	0.06	0.32	0.06	1	-	0.21	>0.05
Serum Albumin	**0.57**	**0.03***	0.32	0.06	0.41	>0.05	0.38	>0.05	0.21	>0.05	0.27	>0.05	**0.54**	**0.03***	0.21	>0.05	1	-

Note: P-values were obtained from Pearson's correlation; Starred values point to a significant level.

later, due to the low vitamin level, Ca is sub-optimal. Low vitamin D levels are risk factors for deteriorating bone health and can be a precursor for other pathological conditions such as autoimmune disorders (29).

In addition, our study revealed that all the patients with eating disorders had lower vitamin B_{12}, with the highest prevalence among AN patients. Other studies have revealed sufficient vitamin B_{12} levels among patients with AN and BN compared to our study (AN: 234.5 versus 97 ng/mL; BN: 196 versus 103 ng/mL, respectively) (1). Optimal metabolism and formation of red blood cells and nerve tissues require adequate vitamin B_{12} (30). The elevated levels of vitamin B_{12} are indicative of reduced metabolism (37).

Furthermore, iron is stored in the form of ferritin in the human body. Our study showed that 83% of AN patients suffered from anaemia, which was more than double the prevalence reported among American AN patients (39%) (26). However, unlike our study findings, patients with AN or BN did not suffer from anaemia in other studies (1). Iron is required to synthesize red blood cells and haemoglobin, as well as the proper functioning of the brain. In addition, decreased iron levels are associated with fatigue and depression (30), which are common among patients with AN (19).

Furthermore, in our study, all patients suffered from hyponatraemia with the highest prevalence among BN patients (>65%), which is higher than in previous studies, where only 8.5% suffered from the condition (28). Similarly to the study by Mehler and colleagues, Crow and coworkers reported normal serum sodium levels among patients with BN (31). Binge eating disorder is characterized by recurring episodes of binge eating in which a person impulsively consumes a larger portion of food within a limited time (19). Cases of low serum sodium are associated with excessive use of diuretics or laxatives, both of which are commonly used by people suffering from BN or occasionally those with BED (32).

Furthermore, our study revealed that all the patients had hypocalcaemia. Other studies showed that eating-disordered patients had normal calcium levels (AN: 2.32 versus 1.00 mmol/L; BN: 2.27 versus 1.15 mmol/L) (1). Calcium is vital for various body functions such as muscle contraction, nerve conduction, hormone function and healthy bones and teeth (33). As previously stated, one of the possible reasons for hypocalcaemia could be low vitamin D levels which are indicative of inadequate intake of these nutrients. Also, a more reliable indicator for calcium deficiency in patients suffering from ED is examining their bone mineral density (34).

The lower albumin and nutrient levels among women with EDs, can lead to many abnormalities involving the skin, hair, and nails. Dermatological anomalies such as xerosis (a condition characterized by dry and itchy skin), hair loss, acne and nail dystrophy have been seen in patients with severe EDs (35). In addition, patients with BN who commonly engage in forced purging may be at risk of having scars on the posterior surface of their hands, which are usually used for triggering a gag reflex that causes vomiting (36).

One of the limitations of the current study is the small sample size. However, women with EDs hardly agreed to have their blood samples drawn. Also, another drawback of the study is the fact that it only included women. Future studies need to study the biochemical markers of men and find out if there are any sex differences. It would be interesting to follow up with these patients to see whether they would develop other health problems and within what time. One blood sample was only collected, which does not consider the day-to-day variation. An important strong point of the current study is that it is the first study which studied the biochemical markers of women with EDs at Taibah University, including a wide range of ages. Also, the selection criteria were rigorous, thus reducing the risk introduced due to any selection bias.

In conclusion, our research revealed that eating-disordered women had elevated biochemical and haematological characteristics. Our research indicates the need to establish a support program for those suffering from EDs with effective prevention, identification and management preventative measures to assist female students in adopting attitudes and behaviours favourable to a healthy diet. A multidisciplinary team consisting of dietitians, nurses, physicians, psychiatrists and social workers should coordinate and support these women. Routine screening for eating disorders is also encouraged.

Acknowledgements: The authors would like to express thanks all the participants for agreeing to take part in the study.

Conflict of Interest: The authors declare that they have no competing interests.

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Received: 1 March 2023
Accepted: 13 June 2023
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