Original Article

Access this article online

Quick Response Code:

Website: https://journals.lww.com/jaht

DOI: 10.4103/joah.joah_120_23

Outcome of Intensive Physical Exercise on the Prevalence of Iron-Deficiency Anemia in Saudi Military Trainees

Lamiaa H. Al-Jamea[1], Alexander Woodman[2], Abdullah Saleh Alqarzaee[3], Eidan M. Al Zahrani[4], Fatimah Salim Al-Yami[1], Othman A. Alfahad[4], Ibrahim E. Al Mutawah[5], Wael Nazzal[6], Ahlam D. Alshehri[7], Jenifer V. Quiambao[8]

[1]Department of Medical Laboratory, King Fahad Military Medical Complex, Dhahran, Saudi Arabia, [2]Department of Public Health, School of Health Sciences, University of Salford, Manchester, England, [3]Vice Deanship of Military Training and Education, Prince Sultan Military College of Health Sciences, [4]Biomedical Technology Department, Prince Sultan Military College of Health Sciences, Dhahran, [5]Department of Medical Laboratory, Armed Forces Hospital-Jubail, [6]Obstetrics and Gynaecology Department, King Fahad Military Medical Complex, Dhahran, [7]Directorate of Health Affairs Administration of Public Health, Ministry of Health, Riyadh, Saudi Arabia, [8]Graduate School, St. Paul University Manila, Manila, Philippines

Address for correspondence: Dr. Alexander Woodman, School of Health Sciences, University of Salford, Manchester, UK. E-mail: alexwoodman.ucla@gmail.com

Submitted: 29-Dec-2023
Revised: 14-May-2024
Accepted: 16-May-2024
Published: 13-Jun-2024

Abstract:

BACKGROUND: Iron deficiency (ID) is considered a common health condition among military personnel, particularly soldiers during a period of high-intensity workouts. The causes, prevention, and treatment of ID anemia (IDA) remain the subject of ongoing and extensive research in various populations.

AIM: This is the first research to study the outcome of 14 weeks of intensive physical exercise on the prevalence and factors associated with ID and IDA among Saudi military male trainees.

MATERIALS AND METHODS: A cross-sectional study was conducted among $n = 101$ trainees who completed a questionnaire on sociodemographic data, dietary habits, current or past diagnoses of medical conditions, and physical activity. Two blood samples were collected from each participant to estimate (1) C-reactive protein and iron profile and (2) complete blood counts by the CellDYN Sapphire automated blood cell counter. Hemoglobin (Hb) fractions were identified and quantified by high-performance liquid chromatography using the TOSOH G8 analyzer to exclude hemoglobinopathy and thalassemia.

RESULTS: The prevalence of ID, comprising both ID erythropoiesis and IDA among trainees, was found to be 65.3%. The occurrence of IDA was 5%, while ID erythropoiesis was detected among 60.4%. The prevalence of ID was statistically significantly higher among those drinking coffee during military training ($P = 0.048$).

CONCLUSIONS: Further studies are recommended to validate this study's findings by incorporating a larger sample and extending the duration of the training period and examine the mechanisms that explain the increased risk of ID during vigorous military training.

Keywords:

Iron deficiency, iron-deficiency anemia, male trainees, military training, nutrition, risk factors

Introduction

Iron deficiency (ID) is one of the most prevalent micronutrient deficiencies globally, usually caused by chronic blood loss and insufficient intake or malabsorption of iron in food.[1-3] ID is often characterized as a progressive condition that begins with normal body iron status, becoming subnormal or depleted because of low dietary iron intakes, inadequate intestinal iron absorption, or increased iron losses. As this process continues, the synthesis of iron-containing proteins, such as hemoglobin (Hb), becomes compromised. Finally, when the Hb concentration falls below a specified cutoff value, the ID has progressed to ID anemia (IDA). Anemia is defined by a reduced Hb concentration in the venous blood sample.[1-3]

To control iron levels and diagnose ID, a baseline set of blood tests is often

How to cite this article: Al-Jamea LH, Woodman A, Alqarzaee AS, Zahrani EM, Al-Yami FS, Alfahad OA, *et al*. Outcome of intensive physical exercise on the prevalence of iron-deficiency anemia in Saudi military trainees. J Appl Hematol 2024;15:137-46.

done, including Hb, hematocrit, mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), red blood cell (RBC) distribution width (RDW), and serum ferritin levels.[2] Ferritin is the most widely used parameter for assessing ID, as it acts as an acute-phase protein. Therefore, every inflammatory process must be excluded from the patient's medical history. It should be taken into account that during physical activity, especially intense sports, the amount of acute phase reactants may increase. Ferritin levels may be normal or may rise to 27% depending on the duration and intensity of activity.[4,5]

Hepcidin, the principal iron-regulatory hormone responsible for the maintenance of iron homeostasis, controls the absorption of dietary iron and the distribution of iron among organs and tissues in the body. Therefore, the decreased iron absorption and increased hepatic iron stores observed in the exercised rats may closely relate to the hepatic hepcidin expression. In recent years, many studies on the function of hepcidin in sports anemia have been reported. A 72 h timeline of hepcidin expression postexercise was assessed, which showed that the hepcidin level significantly elevated at 3, 6, and 24 h postexercise, and then declined from there, reaching baseline at 72 h postexercise. These results revealed the association of hepcidin expression with the intensive exercise.[6]

Evidence in the literature shows that one of the most common health conditions that sports medicine physicians encounter is ID among athletes, with the prevalence of females.[2] Thus, the term "athletic anemia" or "sports anemia" has been reported among athletes who participate in various activities such as running, rowing, swimming, and walking, most commonly caused by ID. In contrast, dilutional anemia or pseudoanemia is defined as reduced Hb and hematocrit due to plasma volume expansion with normal erythrocyte mass and total Hb mass. Usually, this type of anemia is only temporary and occurs particularly at the beginning of training.[2,3]

ID has been reported as a common health condition among military personnel, particularly soldiers during a period of high-intensity workouts.[3] Military trainees who practice high-intensity physical activity may be predisposed to ID, which can lead to IDA. They need more iron as they lose more iron through excessive sweating and increased blood loss in urine and gastrointestinal tract. RBCs are also destroyed faster in those who play sports. For example, the mechanical force of a kick during endurance running can increase the destruction of RBCs in the feet, resulting in a shorter RBC lifespan.[6,7]

Malczewska-Lenczowska *et al.* found that the prevalence of ID among male elite athletes was 43%, with iron depletion at 13% and ID at 30%. Nevertheless, IDA was not detected.[8] The authors concluded that athletes should be monitored periodically for ID since an increase in ID, together with an apparent decrease in hematological parameters in subjects with ID erythropoiesis, significantly increases the risk of IDA.[8] While a study of 3,666 military trainees in Taiwan found that ID erythropoiesis could reduce sprinting and middle-distance running performance, but did not affect the performance of aerobic exercise, including short-term squats and push-ups.[9] Mild anemic males had about 1.50-fold higher odds of being among the best 10% performers in the 2-min push-ups but the worst 10% performers in the 3000-m run test. These results broadened the notion that moderate-to-severe anemia can impair aerobic exercise.[9] Further literature data shows that even a small decrease in Hb levels of 1–2 g/dL can cause a decrease in physical and mental performance of military personnel by 20%. On the other hand, ID can negatively impact emotional health, cognitive function, cause muscle and hormonal dysfunction, and predispose to infection.[3]

Materials and Methods

Study design

This was a cross-sectional study among n = 101 Saudi male military trainees, from the military training center, Dhahran, Saudi Arabia. The study group was recruited after 14 weeks of military training, and the results of pretraining were collected from their record from military training centre, Dhahran, Saudi Arabia.

The sample size was calculated based on the available population. In this study, the population size was 189, and hence, a power of 70%–80% was chosen. If a study is considered especially pivotal or large, the power may even be set at 90% to reduce the possibility of a false negative result to 10%. Therefore, we considered the following three criteria to find the sample size.

- Expected dropout rate
- Unequal ratio of allocation to the study arms
- Specific considerations related to the objective and design of the study.

Therefore, the sample size for this research was 96 ± 25.

We have distributed 189 questionnaires to the targeted military trainees; of the 189 trainees, 101 were returned as some of them refused to participate. The military trainees were randomly selected between the ages of 26 and 28 years.

Instrumentation and data collection

Questionnaire was validated by a panel of 5 experts in the field of hematology and physiotherapy, before conducting a pilot study. The pilot study was conducted among 16 military personnel, who were not involved in data collection. The interviews took place directly after the respondents filled out the questionnaire to compare the questionnaire responses with interview responses and ensure the validity and clarity of each item. Data collected from the pilot study were tested for internal consistency of the questionnaire with the use of SPSS version 26 (Armonk, NY: IBM Corp, USA). The reliability analysis through Cronbach's alpha value of 0.65 was obtained. The questionnaire was then administered to the target population.

Two blood samples were collected from each participant. One sample was collected in plain tube to estimate C-reactive protein (CRP) and iron profile including iron level, ferritin, and total iron binding capacity (TIBC), using Alinity ci-series. The second sample was collected in a vacutainer ethylenediaminetetraacetic acid (EDTA) tube. The EDTA sample was analyzed for complete blood counts, including Hb concentration, hematocrit (HCT), RBCs counts, white blood cells (WBCs), MCV, MCH, and MCH concentration (MCHC). Complete blood counts were determined by the Cell-DYN Sapphire automated blood cell counter (Abbott Diagnostics, Santa Clara, CA, USA). Hb fractions were identified and quantified by high-performance liquid chromatography using the TOSOH G8 analyzer (Tosoh Corporation, Tokyo, Japan) to exclude hemoglobinopathy and thalassemia.

Military training

Participants completed six intensive military exercises with a total duration of 45 min daily. Initially, during the introductory phase, which lasted for 45 days, the participants underwent six intensive training sessions, of which four sessions were scheduled in the morning and two in the afternoon:

- The first exercise included four sets of a high jump with open legs and arms high, followed by a high jump with joined legs and arms down to the sides. This was followed by repeating these exercises as instructed
- The second exercise involved extending the left leg to the left to form a suitable opening for the body, arms raised up in straight lines, and palms facing inward. For the first approach, the participant must turn the torso to the left, leaning down, placing the head tightly between the hands and knees, return to the initial position, and repeat the same actions on the right side
- The third exercise included push-ups and repeating these exercises in accordance with the instructions
- The fourth exercise was an aerobic exercise, consisting of a total of two sessions, where each participant had to stand facing a partner, bending the knees, sit on their heels and lean on the metatarsals, placing the thumb and forefinger on the ground behind the heels
- The fifth exercise included the movements of the fourth exercise, followed by lying on the back with straight legs, arms at shoulder level, and palms on the ground. From this position, participants must lower their legs to the left side of the body, straightening the knees and bringing the feet together, locking the middle of the upper torso on the ground and lifting the knees back toward the center of the body tight, and then repeat the same steps on the right side
- The sixth exercise included moving the left leg to the left so that a hole suitable for the body was formed, hands on the waist. Participants should then kneel, sit on their heels, and lean on the metatarsal bone with their arms extended forward at shoulder height and palms down facing the ground. Next, participants should stand with their hands on the waist and tilt the torso from the middle forward, trying to touch the foot, straining their knees. Finally, participants must stand up with their hands on their belts.

Most of the training sessions included running for a gradual increase in endurance. In addition, two races were held: in the first race, the distance was 4 km, and in the second 6 km. After the introductory phase, the participants had only 2 morning intensive exercises, but the number of repetitions of these exercises was gradually increased.

Procedures

The study was approved by the Research and Ethics Committee of Prince Sultan Military College of Health Sciences (IRB-2021-PT-022). After the purpose of the study was explained, all recruited participants were asked to complete and sign an informed consent form agreeing to participate. Participants completed a questionnaire before blood samples were collected and it consisted of the following parts: (1) sociodemographic data; (2) dietary habits and whether participants are following specific dietary patterns - questions about consumption of foods rich in iron and foods that inhibit or improve iron absorption; (3) current or past diagnoses of medical conditions - questions about chronic medical conditions, blood disorders, or blood transfusions, in addition to their personal and family IDA history; (4) physical activity - questions about military training operations, muscle strength training, and aerobic exercises.

Statistical analysis

The data analyses were performed using the Statistical Package for the Social Sciences, version 26 (SPSS, Armonk, NY: IBM Corp, USA). Quantitative data were presented using mean (M) ± standard deviation (SD) or median (min-max) if appropriate. Qualitative data were presented as counts and proportions (%). Paired *t*-test was performed to determine the mean differences in hematological parameters between pre- and postmilitary training. The association between ID and related characteristics of participants was obtained using Fisher's exact test. Similarly, a one way analysis of covariance (ANCOVA) was performed to determine the outcome of ID, which leads to anemia, in regular military training of participants. $P = 0.05$ (two-sided) was considered statistically significant.

Results

A total of $n = 101$ military trainees were involved in this cross-sectional study. The most common age group was 26–28 years (79.2%), with the majority (86.1%) of participants being single [Table 1]. Most of the participants were from Western (40.6%) and Central (34.7%) regions. More than one-third were living in Riyadh (34.7%), 18.8% in Jeddah, 13.9% in Makkah, and 13.9% in Abha. The prevalence of smokers was 40.6%, of which the most common number of cigarettes smoked per day was 12–14 (15.8%). The body mass index (BMI) data showed that 46.5% of participants were of normal weight, 44.6% were overweight, and 8.9% were obese.

Paired *t*-test was conducted to determine the difference in hematological parameters before and after military training [Table 2]. The results showed that the mean values of WBC ($P < 0.001$), RBC ($P < 0.001$), Hgb ($P < 0.001$), HCT ($P < 0.001$), and MCHC ($P < 0.001$) were statistically significantly lower after the training, while the mean values of MCV ($P < 0.001$) and MCH ($P < 0.001$) were statistically significantly higher after the military training. The mean values of specimen counts were similar across the group. The mean value of platelet before the training was 272.2 (SD 55.9), whereas the mean value of RDW after the training was 11.9 (SD 0.63). The mean values of Hb, iron, ferritin TIBC, unsaturated iron-binding capacity, transferrin saturation, and CRP during the training were 14.3, 10.8, 108.4, 48.9, 38.1, 22.3, and 1.89, respectively.

The assessment of physical activity before military training and the prevalence of ID are presented in Table 3. The proportion of trainees who underwent vigorous (VPAs), moderate (MPAs), and light physical activities (LPAs) before military training were 78.2%, 15.8%, and 5.9%, respectively. The proportion of trainees who demonstrated ID including ID erythropoiesis and IDA was 65.3%, while the proportion of trainees with anemia was 5%. Similarly, the prevalence of trainees with IDA was 5%, while ID erythropoiesis was detected among 60.4%.

The proportion of trainees with a family history of hereditary diseases was 5%. As such, IDA (2 cases), diabetes mellitus (2 cases), and glucose-6-phosphate dehydrogenase (1 case) were the specific hereditary diseases identified in family members. With regard to the frequency of physical activity, the median days of VPA before military training was 3 days with a median 0.3 h/day of VPA. The median days of MPA before military training was 1 day with a median of 0-h (range: 0–6 h) hours per day of MPA. Moreover, the median days of walking before military training was 0 day (range: 0–7 days), while the median hours/day of walking was 0 h (range: 0–1 h). The median hours per week of sitting was 0.6 h (range: 0–20 h).

Further analysis of food intake and frequency of eating per week [Figure 1] showed that chicken (29.7%) was the most frequent type of food that trainees ate daily during military training, followed by white bread (24.8%), vegetables (6.9%), and brown bread (6.9%). Fish was the least consumed food by the trainees, with 80.2% consuming fish only 1–2 times a week [Figure 1].

Table 1: Sociodemographic characteristics of the trainees (*n*=101)

Study data	*n* (%)
Age group (years)	
24–25	21 (20.8)
26–28	80 (79.2)
Marital status	
Single	87 (86.1)
Married	14 (13.9)
City of residence	
Riyadh	35 (34.7)
Jeddah	19 (18.8)
Makkah	14 (13.9)
Abha	14 (13.9)
Taif	7 (6.9)
Dammam	6 (5.9)
Others (Tabuk, Jizan, etc.)	6 (5.9)
Region	
Central	35 (34.7)
Eastern	6 (5.9)
Northern	2 (2.0)
Southern	17 (16.8)
Western	41 (40.6)
Smoking	
Yes	41 (40.6)
No	60 (59.4)
Number of cigarettes per day	
Nonsmoker	60 (59.4)
3–5	8 (7.9)
6–8	11 (10.9)
9–11	6 (5.9)
12–14	16 (15.8)
BMI level	
Normal	47 (46.5)
Overweight	45 (44.6)
Obese	9 (8.9)

BMI=Body mass index

Table 2: Paired *t*-test of the hematological parameters before and during military training (*n*=101)

Parameters	Mean±SD		Mean difference	95% CI	$P^§$
	Before	During			
Specimen count	51.0±29.3	51.0±29.3	0.000	--	1.000
WBC	71.1±1.89	64.9±1.53	0.624	0.283–0.966	<0.001**
RBC	5.43±0.39	4.92±0.35	0.510	0.458–0.562	<0.001**
Hgb	15.6±0.91	14.3±0.75	1.263	1.405–17.71	<0.001**
HCT	46.3±2.48	44.3±2.13	2.004	1.568–2.439	<0.001**
MCV	85.6±4.84	90.4±5.28	−4.804	−5.090–−4.517	<0.001**
MCH	28.7±2.08	29.2±2.07	−0.417	−0.513–−0.322	<0.001**
MCHC	33.6±0.89	32.3±0.67	1.345	1.226–22.43	<0.001**
PLT	272.2±55.9	--	--	--	--
RDW	--	11.9±0.63	--	--	--
Hb	--	14.3±0.74	--	--	--
Iron	--	10.8±2.74	--	--	--
Ferritin	--	108.4±63.1	--	--	--
TIBC	--	48.9±6.27	--	--	--
UIBC	--	38.1±6.13	--	--	--
Transferrin saturation	--	22.3±5.49	--	--	--
CRP	--	1.89±2.34	--	--	--

**Significant at $P<0.05$ level, §*P*-value has been calculated using paired sample *t*-test. WBC=White blood cell; RBC=Red blood cell; Hgb=Hemoglobin; HCT=Hematocrit; MCV=Mean corpuscular volume; MCH=Mean corpuscular hemoglobin; MCHC=Mean corpuscular hemoglobin concentration; TIBC=Total iron binding capacity; CRP=C-reactive protein; RDW=Red blood cell distribution width; SD=Standard deviation; CI=Confidence interval; PLT=Platelet; UIBC=Unsaturated iron-binding capacity

Table 4 shows the consumption of drinks and use of supplements by the trainees, with the prevalence of trainees drinking tea (90.1%) after the meal (85.7%). The proportion of trainees who were drinking coffee was 92.1%, usually drunk before the meal (61.5%). Furthermore, 89.1% of trainees were drinking soft drinks with 82.2% drinking during the meal. The proportion of trainees who suffered stomach ulcer was 5.9%. The proportion of trainees who reported having a blood transfusion was 4%, of these 3 indicated that they had a blood transfusion at least 4 times. The most commonly mentioned type of supplements that the trainees were taking was Vitamin C (20.8%).

The analysis of the association between ID and sociodemographic characteristics, physical activity before military training, consumption of beverages, and supplements showed that the only significant factor identified was coffee consumption. The prevalence of ID was statistically significantly higher among those drinking coffee during military training ($P = 0.048$). Other variables, such as age group in years, marital status, smoking, BMI, different physical activity before military training, drinking tea or soft drinks, and taking supplements did not significantly influence ID ($P > 0.05$) [Table 5].

Covariance analysis was conducted to determine the difference of ID in relation to the different vigorous training exercises of the trainees during military training. It can be observed that all vigorous exercises included in the test were not significantly different across the group, including distance running, long step workout, aerobic exercises, high jump workout, abdominal crunch, oblique prone push-up, callisthenic exercise, muscle strength training, tactical road marches, prolonged standing, and military training operation (all $P > 0.05$) [Table 6].

Discussion

ID and IDA affect physical, mental, and immune systems.[1,10,11] As presented earlier, ID has three stages depending on severity. The first and earliest stage of ID involves iron depletion, where iron stores are low or absent but serum iron concentrations and blood hemoglobin levels are normal. The second stage of ID, erythropoiesis, is characterized by a decrease or absence of stored iron, low serum iron concentration and transferrin saturation without severe anemia. Stage three is known as iron deficiency anemia, the most severe stage, characterized by decreased or absent iron stores, low serum concentrations, low transferrin saturation, low hemoglobin concentrations, and low hematocrit values.[1]

Although athletes and military trainees are by definition healthy individuals, research in recent years has led to new understanding of the health consequences, particularly the pathogenesis of anemia in these populations. They often experience abnormalities in hematological or biochemical parameters due to excessive physical activity, training, physiological and psychological stress, and environmental conditions. Thus, the prevalence of IDA is likely to be higher, impairing athletic performance, immune function, and leading to other physiological dysfunctions.[12-14] Previous studies have shown that iron levels may drop during military training, which can

Table 3: Assessment of physical activity before military training (*n*=101)

Variables	*n* (%)
Do you do VPA before military training?	
Yes	79 (78.2)
No	22 (21.8)
Do you do MPA before military training?	
Yes	16 (15.8)
No	85 (84.2)
Do you do LPA before military training?	
Yes	6 (5.9)
No	95 (94.1)
ID	
Yes	66 (65.3)
No	35 (34.7)
Anemic	
Nonanemic	96 (95.0)
Anemic	5 (5.0)
ID	
IDA	5 (5.0)
ID erythropoiesis	61 (60.4)
Nonanemic	35 (34.7)
Is there any hereditary disease in your family?	
Yes	5 (5.0)
No	96 (95.0)
Hereditary diseases (*n*=5)	
IDA	2 (40.0)
DM	2 (40.0)
G6PD	1 (20.0)
Thalassemia	0
Sickle cell anemia	0
	Median (minimum–maximum)
How many days did you do VPA before military training?	3.0 (0–6)
How much time you spent for before military training VPA?	0.3 (0–3)
During Last 7 days how many days you do MPA before military training?	1.0 (0–6)
How much time you spend for MPA before military training?	0.0 (0–6)
During last 7 days how many days you walk before military training?	0.0 (0–7)
How much time you spent for LPA before military training?	0.0 (0–1)
During last 7 days, how much time did you spend for sitting on a week day?	0.6 (0–20)

VPA=Vigorous physical activity; MPA=Moderate physical activity; LPA=Light physical activity; ID=Iron deficiency; IDA=ID anemia; DM=Diabetes mellitus; G6PD=Glucose-6-phosphate dehydrogenase

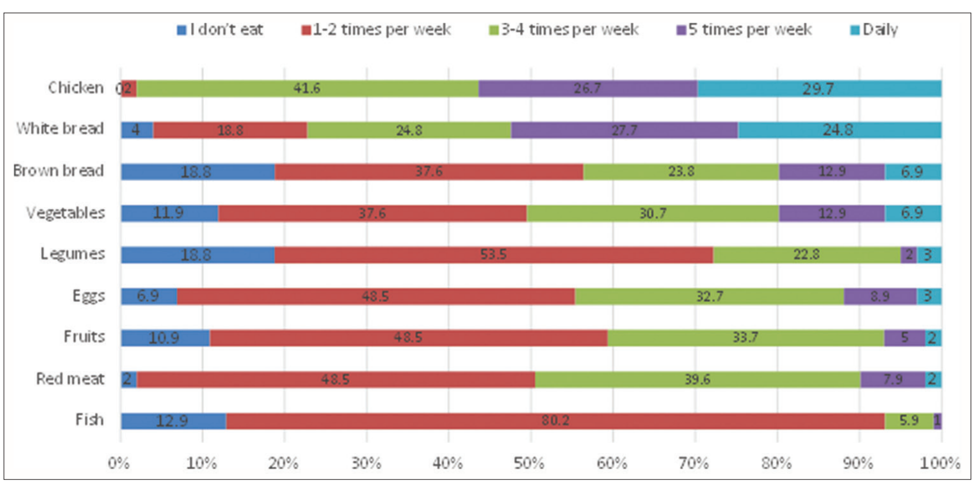

Figure 1: Frequency of eating the following food per week during military training

Table 4: Consumption of drinks and use of supplements of trainees during military training (*n*=101)

Questions	*n* (%)
Do you drink tea?	
Yes	91 (90.1)
No	10 (9.9)
If you drink tea, when will you drink? (*n*=91)	
Before the meal	4 (4.4)
During the meal	9 (9.9)
After the meal	78 (85.7)
Do you drink coffee?	
Yes	93 (92.1)
No	8 (7.9)
If you drink coffee, when will you drink? (*n*=93)	
Before the meal	56 (61.5)
During the meal	3 (3.3)
After the meal	22 (24.2)
All the time	10 (11.0)
Do you drink soft drinks	
Yes	90 (89.1)
No	11 (10.9)
If you drink soft drinks, when will you drink? (*n*=90)	
Before the meal	1 (1.1)
During the meal	74 (82.2)
After the meal	14 (15.6)
Rarely	1 (1.1)
Do you suffer stomach ulcer?	
Yes	6 (5.9)
No	95 (94.1)
Have you ever had blood transfusion?	
Yes	4 (4.0)
No	97 (96.0)
Frequency of blood transfusion (*n*=4)	
2 times	1 (25.0)
4 times	3 (75.0)
Used of supplements	
None	62 (61.4)
Vitamin C	21 (20.8)
Vitamin containing iron	10 (9.9)
Both	5 (5.0)
Others	3 (3.0)

Table 5: Univariate analysis to determine the factors associated with iron deficiency that leads to anemia (*n*=101)

Factor	ID		$P^{§}$
	Yes (*n*=66), *n* (%)	No (*n*=35), *n* (%)	
Age group (years)			
24–25	15 (22.7)	6 (17.1)	0.611
26–28	51 (77.3)	29 (82.9)	
Marital status			
Single	55 (83.3)	32 (91.4)	0.369
Married	11 (16.7)	3 (8.6)	
Smoking			
Yes	26 (39.4)	15 (42.9)	0.832
No	40 (60.6)	20 (57.1)	
BMI level			
Normal	27 (40.9)	20 (57.1)	0.145
Overweight/obese	39 (59.1)	15 (42.9)	
VPA before military training			
Yes	53 (80.3)	26 (74.3)	0.613
No	13 (19.7)	9 (25.7)	
MPA before military training			
Yes	11 (16.7)	5 (14.3)	1.000
No	55 (83.3)	30 (85.7)	
LPA before military training			
Yes	2 (3.0)	4 (11.4)	0.178
No	64 (97.0)	31 (88.6)	
Do you drink tea?			
Yes	59 (89.4)	32 (91.4)	1.000
No	7 (10.6)	3 (8.6)	
Do you drink coffee?			
Yes	58 (87.9)	35 (100)	0.048**
No	8 (12.1)	0	
Do you drink soft drink?			
Yes	58 (87.9)	32 (91.4)	0.743
No	8 (12.1)	3 (8.6)	
Taking supplements			
Yes	23 (34.8)	16 (45.7)	0.294
No	43 (65.2)	19 (54.3)	

**Significant at $P<0.05$ level, §*P*-value has been calculated using Fisher's exact test. VPA=Vigorous physical activity; MPA=Moderate physical activity; LPA=Light physical activity; BMI=Body mass index; ID=Iron deficiency

decrease the functional status of the trainees.[5,8] Myhre *et al*. (2016) reported that the prevalence of anemia was 12.6% (N = 18,827), with the corresponding prevalence of borderline, moderate and severe anemia being 12.6, 10.9 and 1.9% for women and 4.8, 3.8 and 0.3% for men.[7] Although Epstein *et al*. (2018) found that vigorous exercise increased the prevalence of anemia from 19% to 52% and ID increased from 33% to 35%. The authors also reported that 29% of recruits developed IDA during 15 months of follow-up, and nearly two-thirds (65%) showed evidence of IDA.[3]

This research aimed to study the outcomes of 14 weeks of intensive physical exercise on the prevalence and factors associated with ID and IDA among Saudi military male trainees. The participants underwent daily intense military exercises, including military training operations, prolonged standing, tactical road marches, muscle strength training, calisthenics exercise, oblique prone push-up exercises, abdominal crunch, high jump workout aerobic exercise, long step workout, and distance running (1600 m).

The prevalence of ID erythropoiesis was identified among 60.4% of the trainees, while 5% developed IDA. Approximately four-quarters of the trainees (78.2%) were doing VPAs before the military training with median days of 3 (range: 0–6 days). At the same time, 65.3% of participants had ID. These findings are consistent

Table 6: Difference in each military regular exercise per week between iron-deficiency trainees versus normal trainees (*n*=101)

Physical activity	*n*	Mean±SE	*P*
Model 1: Distance running (1600 m)			
ID	66	2.000±0.133	0.899
Normal	35	1.971±0.184	
Model 2: Long step workout			
ID	66	2.096±0.144	0.587
Normal	35	1.962±0.199	
Model 3: Aerobic exercise			
ID	66	1.932±0.133	0.888
Normal	35	1.900±1.536	
Model 4: High jump workout			
ID	66	2.069±0.156	0.455
Normal	35	2.270±0.216	
Model 5: Abdominal crunch			
ID	66	1.912±0.147	0.662
Normal	35	2.023±0.203	
Model 6: Oblique prone push up			
ID	66	1.986±0.149	0.874
Normal	35	2.027±0.206	
Model 7: Callisthenic exercise			
ID	66	2.107±1.817	0.982
Normal	35	2.113±0.201	
Model 8: Muscle strength training			
ID	66	1.702±0.136	0.175
Normal	35	2.020±1.648	
Model 9: Tactical road marches			
ID	66	2.226±1.941	0.890
Normal	35	2.260±1.867	
Model 10: Prolonged standing			
ID	66	2.154±0.129	0.839
Normal	35	2.109±0.177	
Model 11: Military training operation			
ID	66	1.991±0.128	0.803
Normal	35	2.046±0.177	

All models had been adjusted with age, BMI and smoking. These variables were chosen as they are likely contributed for the ID of the trainees. BMI=Body mass index; SE=Standard error; ID=Iron deficiency

with the study by Dubnov *et al*. among female military personnel, showing that the prevalence of iron depletion was 77%, 15% developed ID, and 10% IDA.[15] Similarly, most female military recruits were physically active at baseline and engaged in running, dancing, gym activities, swimming, and ball games. The average time spent was 6 h/week (range, 0.5–24 h/week).[15]

Further findings of the current research showed that only 15.8% and 5.9% of participants were doing MPA and LPA before the military training, respectively. Regarding the differences in regular exercise per week during military training between participants with ID and normal iron levels, 11 vigorous military exercises were performed to test whether each military exercise had an outcome on ID. The iron levels of the trainees in all military exercises were the same for the entire group and did not show a significant outcome on the deficiency of iron stores. This finding contradicted the study by Myhre *et al*. (2016), who reported that nonanemic trainees improved slightly more running time than borderline and moderate anemics. They also pointed to differences between baseline and final fitness data for all measures for both genders.[7] A recent study by O'Leary *et al*. among the British Army basic training resulted in iron status impairment, indicating a deterioration in iron status at the end of training in both males and females, with males reporting greater declines.[16] The authors suggested that differences between the results of their study and previous studies may be due to differences in participant demographics, duration of training, teaching methods, and sample size.[16] This assumption holds true for the current study as the fact that the trainees did not develop severe IDA may be due to the fact that military training was interrupted due to the pandemic.

Both undernutrition and overnutrition can trigger IDA, as well as non-IDA, and it is likely that dietary choices account for much of a negative iron balance.[14-16] Therefore, this study also examined additional factors that may affect iron levels in military personnel, such as foods that trainees frequently consume on a daily basis. The most common foods that trainees ate daily were chicken (29.7%), bread (24.8%), and vegetables (6.9%). Although the concentration of iron in different types of meat varies greatly, poultry provides this mineral, and the level of iron in poultry meat makes it suitable for reducing the risk of unbalanced nutrient intake.[17,18] Further evidence in literature suggests that the optimal amount or frequency of poultry consumption required to maintain or achieve healthy iron levels is the subject of ongoing research. Thus, additional studies are required to determine the exact amount and frequency of consumption per population group and to determine optimal intake to reduce the development of ID.[17,18] In this research, the second most consumed product was bread. Data on the presence of iron in bread vary across the world.[19-21] Thus, the most recent study conducted in Iran, where an iron fortification program for flour was introduced in 2001, found that despite this regulation, iron levels did not meet the minimum recommended level set by the Iranian Ministry of Health and Medical Education (40 ppm), and the iron content of all flours was well below recommended levels.[19] On the other hand, another study found that the traditional Iranian bread Sangak has high levels of vitamins, calcium, protein, and iron and is easily digestible due to its high fiber content.[20] An earlier study in Chile found that the iron content of bread was normally distributed. Most bakeries used wheat flour with sufficient iron content.[21] These findings suggest that future research in Saudi Arabia should focus on examining the nutrient and microcurrent contents of the most consumed food items in the daily basket of Saudis and specific populations (e.g., military trainees). The third most consumed food group in this study was vegetables, although the types were not specified. Evidence from the cumulative literature shows that animal foods such as meat, poultry, and fish contain ferrous iron (heme iron), and humans can absorb 15%–40% of this heme iron from their diet, whereas plant foods are composed of ferric iron of which the body can only absorb about 1%–15%.[22,23] On the other hand, the assessment of iron content in vegetables and legumes was limited and varied depending on geographical origin, sampling methods, and analytical methods.[22,23] Therefore, as with bread, future research is recommended to examine the types of vegetables consumed and preferred by the general public, military trainees, and athletes, as diet composition is critical for iron provision.

In addition, the trainees consumed plenty of drinks and beverages during military training, including tea (90.1%), coffee (92.1%), and soft drinks (89.1%), which they drank before, during, and after meals regularly. Therefore, it has been suggested that this behavior may have contributed to ID.[24-27] The prevalence of ID was more common among those who were drinking coffee ($P = 0.048$). On the other hand, only 5% of the subjects were drinking vitamins containing iron. Similarly, a study conducted among Korean adults found that increased coffee consumption was associated with decreased serum ferritin levels, suggesting that regular coffee consumption may be associated with IDA in Korean adults.[24] In the Japanese study, drinking three or more cups of coffee was associated with a higher prevalence of ID compared with those who drank almost one.[25] These findings were supported by other studies that suggested that excessive consumption of caffeinated drinks and soft drinks may absorb iron, leading to anemia.[24-27]

The comparison of hematological parameters before and during a military training exercise showed several parameters with a significant decrease in values during the military training; WBC, RBC, Hgb, HCT, and MCHC ($P < 0.001$). In contrast, MCV and MCH showed an increase in mean values ($P < 0.001$). These factors could also affect the iron levels of the trainees. Thus, Martin *et al*. reported that combat trainees' serum ferritin and transferrin saturation increased from the baseline to the end of combat training.[28] An earlier study by McClung *et al*. among three populations of female military personnel in the US Army reported that serum ferritin and transferrin saturation were reduced, and RDW was increased in the basic combat training group as compared to the initial entry to the army group.[29] The findings of the current study showed that the values of serum ferritin (108.4), transferrin saturation (22.3), and RDW (11.9%) during the military training were within the normal range, as the normal values of serum ferritin, transferrin saturation, and RDW for males are considered 20–250 ng/mL, 15% to 50%, and 11.5% to 14.5%, respectively.[30]

The findings of the current research have shown that vigorous exercise during military training had a similar outcome between ID and normal trainees, although the length of training and the sample size probably influenced the outcome. Iron is critical for optimal athletic performance due to its role in muscle function, energy metabolism, oxygen transport, and acid-base balance. It is recommended that future studies examine the mechanisms that explain the increased risk of ID during vigorous military training, including exercise-related inflammation and hepcidin release, duration of training, food basket, and suggestions for increasing iron intake through dietary modification or iron supplementation. In addition, it is recommended that these studies include a larger sample and a longer duration of study.[28-31]

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Haas JD, Brownlie T 4th. Iron deficiency and reduced work capacity: A critical review of the research to determine a causal relationship. J Nutr 2001;131:676S-88S.
2. Clénin G, Cordes M, Huber A, Schumacher YO, Noack P, Scales J, *et al.* Iron deficiency in sports – Definition, influence on performance and therapy. Swiss Med Wkly 2015;145:w14196.
3. Epstein D, Borohovitz A, Merdler I, Furman M, Atalli E, Sorkin A, *et al.* Prevalence of Iron deficiency and Iron deficiency anemia in strenuously training male army recruits. Acta Haematol 2018;139:141-7.
4. Schumacher YO, Schmid A, König D, Berg A. Effects of exercise on soluble transferrin receptor and other variables of the iron status. Br J Sports Med 2002;36:195-9.
5. Magge H, Sprinz P, Adams WG, Drainoni ML, Meyers A. Zinc protoporphyrin and iron deficiency screening: trends and therapeutic response in an urban pediatric center. JAMA Pediatr 2013;167:361-7.
6. Kong WN, Gao G, Chang YZ. Hepcidin and sports anemia. Cell Biosci 2014;4:19.
7. Myhre KE, Webber BJ, Cropper TL, Tchandja JN, Ahrendt DM, Dillon CA, *et al.* Prevalence and impact of anemia on basic trainees in the US air force. Sports Med Open 2016;2:23.
8. Malczewska-Lenczowska J, Stupnicki R, Szczepańska B. Prevalence of iron deficiency in male elite athletes. Biomed Hum Kinet 2009;1:36-41.
9. Tsai KZ, Lai SW, Hsieh CJ, Lin CS, Lin YP, Tsai SC, *et al.* Association between mild anemia and physical fitness in a military male cohort: The CHIEF study. Sci Rep 2019;9:11165.
10. Dallman PR. Biochemical basis for the manifestations of iron deficiency. Annu Rev Nutr 1986;6:13-40.
11. Beard JL. Iron biology in immune function, muscle metabolism

and neuronal functioning. J Nutr 2001;131:568S-79S.

12. Banfi G. Biochemical and haematological parameters in football players. In: Football Traumatology: Current Concepts: From Prevention to Treatment. Milano: Springer Milan; 2006. p. 43-52.
13. Beard J, Tobin B. Iron status and exercise. Am J Clin Nutr 2000;72:594S-7S.
14. Sales CH, Rogero MM, Sarti FM, Fisberg RM. Prevalence and factors associated with Iron deficiency and anemia among residents of Urban Areas of São Paulo, Brazil. Nutrients 2021;13:1888.
15. Dubnov G, Foldes AJ, Mann G, Magazanik A, Siderer M, Constantini N. High prevalence of iron deficiency and anemia in female military recruits. Mil Med 2006;171:866-9.
16. O'Leary TJ, Jackson S, Izard RM, Walsh NP, Coombs CV, Carswell AT, *et al.* Sex differences in iron status during military training: A prospective cohort study of longitudinal changes and associations with endurance performance and musculoskeletal outcomes. Br J Nutr 2024;131:581-92.
17. Marangoni F, Corsello G, Cricelli C, Ferrara N, Ghiselli A, Lucchin L, *et al.* Role of poultry meat in a balanced diet aimed at maintaining health and wellbeing: An Italian consensus document. Food Nutr Res 2015;59:27606.
18. Jackson J, Williams R, McEvoy M, MacDonald-Wicks L, Patterson A. Is higher consumption of animal flesh foods associated with better iron status among adults in developed countries? A systematic review. Nutrients 2016;8:89.
19. Mohamadi S, Yazdanfar N, Ebrahiminejad B, Shokri S, Pirhadi M, Sadighara P, *et al.* Evaluation of iron content in bakery flour samples of Tehran, Iran. Heliyon 2023;9:e12937.
20. Aghalari Z, Dahms HU, Sillanpää M. Evaluation of nutrients in bread: A systematic review. J Health Popul Nutr 2022;41:50.
21. Peña G, Pizarro F, Hertrampf E. Contribution of iron of bread to the Chilean diet. Rev Med Chil 1991;119:753-7.
22. Welk AK, Mehlhose C, Daum D, Enneking U. Vegetables with enhanced iron bioavailability-German consumers' perceptions of a new approach to improve dietary iron supply. Nutrients 2023;15:2291.
23. Eberl E, Li AS, Zheng ZY, Cunningham J, Rangan A. Temporal change in iron content of vegetables and legumes in Australia: A scoping review. Foods 2021;11:56.
24. Sung ES, Choi CK, Kim NR, Kim SA, Shin MH. Association of coffee and tea with ferritin: Data from the Korean national health and nutrition examination survey (IV and V). Chonnam Med J 2018;54:178-83.
25. Nanri H, Hara M, Nishida Y, Shimanoe C, Iwasaka C, Higaki Y, *et al.* Association between green tea and coffee consumption and body iron storage in Japanese men and women: A cross-sectional study from the J-MICC study Saga. Front Nutr 2023;10:1249702.
26. Hallberg L, Rossander L. Effect of different drinks on the absorption of non-heme iron from composite meals. Hum Nutr Appl Nutr 1982;36:116-23.
27. Fan FS. Iron deficiency anemia due to excessive green tea drinking. Clin Case Rep 2016;4:1053-6.
28. Martin NM, Conlon CA, Smeele RJ, Mugridge OA, von Hurst PR, McClung JP, *et al.* Iron status and associations with physical performance during basic combat training in female New Zealand army recruits. Br J Nutr 2019;121:887-93.
29. McClung JP, Marchitelli LJ, Friedl KE, Young AJ. Prevalence of iron deficiency and iron deficiency anemia among three populations of female military personnel in the US Army. J Am Coll Nutr 2006;25:64-9.
30. University of Rochester Medical Center. Health Encyclopedia; 2021. Available from: https://www.urmc.rochester.edu/encyclopedia.aspx. [Last accessed on 2021 Sep 17].
31. Scientific Committee for Food of the European Committee. Proposed nutrient and energy intakes for the European community: A report of the scientific committee for food of the European community. Nutr Rev 1993;51:209-212. [doi: 10.1111/j. 1753 4887.1993.tb03106.x].