

# Impact of BMI and Dietary Factors on Saudi Adults' Heme Iron Intake

**Running Title: Obese Saudis Consume Less Heme Iron**

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**Abstract Objective:** The objective of this investigation was to compare the consumption of heme iron between Saudi adults with overweight and/or obesity and adults with normal weight, using data derived from seven-day food records. **Design:** A cross-sectional study was employed to assess heme iron consumption among the study participants. They were interviewed by a nutritionist and instructed to complete seven-day food records. Heme iron consumption was extracted from these records, and Body Mass Index (BMI) was categorized and compared between participants with and without overweight and/or obesity and their consumption of heme iron. **Settings:** The study was conducted in Tabuk City, Saudi Arabia. Participants were recruited through invitations via social media platforms and encountering in the streets of Tabuk City. **Participants:** The participants included Saudi adults with overweight and/or obesity as well as adults with normal weight. **Results:** Results revealed that participants with overweight and/or obesity had significantly lower heme iron consumption compared to participants with normal weight (Difference = 1.94, T-value = 2.10,  $p < 0.04$ ). Additionally, after adjusting for several confounding factors, individuals with excess weight were found to be 9.5% less likely to consume heme iron in comparison to Saudis with normal weight ( $\beta = -0.10$ ,  $\chi^2 = 4.24$ ,  $P < 0.04$ ). **Conclusion:** Following adjustment for several confounding factors, the findings suggest that Saudi adults with excess weight tend to consume large portions of meals but were less likely to consume good sources of heme iron

in comparison with those with normal weight.

**Keywords** Obesity, Saudi Obesity, Heme Iron

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## 1. Introduction

Obesity is one of the main risk factors that may lead to type two diabetes with approximately 85% of individuals with this chronic disease living with overweight or obesity [1]. Despite their higher dietary intake, they have been reported with micronutrient deficiencies [2]. A report by Zhao et al. [3] found that there is a significant association between obesity and iron deficiency. Iron deficiency in people with obesity could be related to their dietary pattern and could be affected by multiple factors such as sociodemographic factors [3-4]. However, there is a mixed results regarding investigating the possibility of higher dietary intake of heme iron and whether this is related to their dietary pattern in comparison with people with normal body weight [5-9]. Insufficient adjustment for possible nutritional confounding factors and other sociodemographic factors might explain the current divergence between such findings [10]. Moreover, a few studies compared between people with overweight and/or obesity and people without overweight or obesity living in Saudi Arabia. The aim of this investigation is to compare the dietary intake of heme iron among Saudis with normal

body weight and those with overweight and/or obesity after adjusting for nutritional and sociodemographic factors. Furthermore, this study will investigate the impact of overweight and/or obesity on consumption of heme iron, in comparison to individuals with normal body weight.

## 2. Methodology

### 2.1. Study Design

Participants were invited via social media and by encountering in the streets of Tabuk city. Once the participants signed a consent form, they sat for an interview with a nutritionist and were instructed to fill out seven-day food records (survey 1, supplementary 1). The records were analyzed using Intake 24. co.uk- Middle East, and the heme iron was derived from the surveys along with possible confounding factors. These factors were macronutrients (carbohydrates, fat, protein, and energy intake), and total sugar, micronutrients such as vitamins A, D, C, and E. All the macronutrients and micronutrients units follow National Diet and Nutrition Survey (NDNS) (Nutrients confounding factors, supplementary 2). Also, they filled out a sociodemographic survey (survey 2). The sociodemographic survey included possible confounding factors such as age, gender, employment (employed, unemployed), income (no income, between 0 and 5000 Saudi Riyals, between 5001 and 10000 Saudi Riyals, between 10001 and 14999 Saudi Riyals, between 15000 and 19999 Riyals, and above 20000 Saudi Riyals), the number of people living in their households. Also, they were asked about their dietary habits whether they follow a specific diet or only a regular diet. We asked them about their physical activity and were given four options (inactive, do physical activity between 3 and 4 times a week, do physical activity once a week, do physical activity daily), and marital status with four options (married, single, divorced, or widowed). This survey included males and females who were 18 years old or above. Pregnant women were excluded. In the seven-day food records, participants were instructed to write down all what they ate and drank throughout the week. Body Mass Index (BMI) was estimated based on the participants' self-report of their body weight in kilograms divided by their self-reported height in meters squared.

### 2.2. Statistical Analysis

Microsoft Excel was used to collect all the participants' responses, and all the data were coded and anonymized.

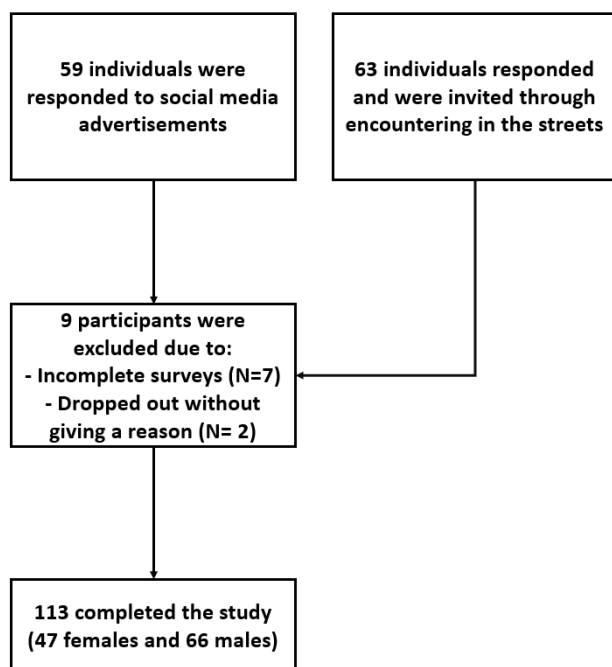
The sociodemographic data were translated into mean, standard deviation, and percentage. All the descriptive sociodemographic data are shown in Table 1. The BMI was corrected for possible confounding factors (age, gender, employment, income, household density, level of physical activity, and marital status). The adjustment of the BMI was by deriving the residuals from General Linear Model and adding them back to the mean of BMI. This method was used previously in our work [11-13].

In this study, the heme iron consumption was derived from the food records over seven days that were given to the participants. Then, the amount of heme iron consumed was adjusted for carbohydrates, fat, protein, and energy intake, total sugar, vitamins A (retinol), D (Calciferol or cholecalciferol), C (Ascorbic acid), and E (Tocopherol) in the same way of adjusting BMI. The correction of the heme iron was done by deriving the residuals from the General Linear Model (GLM) and adding them back to the mean heme iron. In this study, two models were used, Binary logistic regressions and two sample- *t*- test, to compare between the participants. We used Binary logistic regression using unadjusted and adjusted BMI as a category (participants with overweight and/or obesity with  $BMI \geq 25$  versus participants without overweight and/or obesity with  $BMI < 25$ ) against unadjusted and adjusted dietary heme iron. In this model, we used heme iron as a continuous predictor and BMI as a binary dependent variable to compare the probability between participants based on their BMI category. Also, we compared the consumption of heme iron among the participated individuals with overweight and/or obesity and those without overweight or obesity using two sample *t*-test before and after adjustment for possible confounding factors. In this investigation, *P*-value  $< 0.05$  was considered statistically significant. The statistical analysis software that was used in this study was SPSS version 24 (IBM Corp, Armonk, New York, NY, US).

## 3. Results

### 3.1. Characteristics of the Participants

The total number of participants who responded via social media was 59 and 63 were encountered in the streets of Tabuk City and agreed to take part in the study. Seven participants were removed due to incomplete seven-day food records. Two participants dropped out without giving a reason. The total number of participants who completed the study was 113 (figure 1).



**Figure 1.** Flow chart of inclusion and exclusion of participants

Table 1 shows the descriptive data of the participants who completed the study. The mean age of the study's sample was  $36 \pm 9.5$  years. Females represented 41.5% (47) of the investigation population. The mean size of the household was  $5.7 \pm 3.05$ . The percentage of participants who reported that they were employed was 82%, and 13.2% reported that they were unemployed. The students represented 2.6% and retired participants represented 1.7%. Regarding the status of marriage, 52.2% of the population were married and 47.7% reported that they were single, none of them reported either widowed or divorced. The percentage of the sample that reported they do physical activity between three and four times a week was 30.9%, and those who reported that they do physical activity daily represented 17.6%. Those who do physical activity once a week represented 24.7% and those who do not do any physical activity represented 26.5%. Regarding income, 4.4% reported that they have no income; 21.2% have income below 5000 riyals (1,333 \$); 22.1% noted that they earn between 5,001 and 10,000 riyals (1,336 and 2,662 \$) each month. Twenty-six percent have between 10,001 and 14,999 riyals (between 2,666 and 3,999 \$) a month, and 17.6% reported that they earn monthly between 15,000 and

19,999 riyals (4,000, 5,333 \$). Those who received more than 20,000 riyals represented 7.9% of the study's population. Fifty-seven percent of the participants were overweight or obese, while 42.2% were within the normal range (18.9 and 24.9 on Body Mass Index (BMI)).

**Table 1.** Descriptive data: Sociodemographic characteristics of the study population

Age: Mean (Standard Deviation)	36 ( $\pm 9.5$ )
Sex: number (%)	
Females	47 (41.5%)
Males	66 (58.4%)
BMI: mean (Standard Deviation)	
Females	25.9 ( $\pm 5.5$ )
Males	27 ( $\pm 5.5$ )
Household size: Mean (Standard Deviation)	5.7 $\pm$ 3.05
Employment: number (%)	
Employed	93 (82.3%)
Unemployed	15 (13.2%)
Students	3 (2.6%)
Retired	2 (1.7%)
Marital status: number (%)	
Married	59 (52.2%)
Single	54 (47.7%)
Physical activity	
Inactive	30 (26.5%)
Do physical activity once a week	28 (24.7%)
Do physical activity between 3 and 4 times a week	35 (30.9%)
Do physical activity daily	20 (17.6%)
Income: number (%)	
No income	5 (4.4%)
5000 or less	24 (21.2%)
Between 5001 and 10000	25 (22.1%)
Between 10001 and 14999	30 (26.5%)
Between 15000 and 19999	20 (17.6%)
More than 20000	9 (7.9%)

BMI: Body Mass Index.

### 3.2. Comparison between Unadjusted Heme Iron Consumption among Saudi Individuals Living with Overweight and/or Obesity versus Individuals Living without Overweight and/or Obesity before Adjusting for Possible Confounding Factors

In comparison between Saudis with and without overweight and/or obesity, there was no significant difference in unadjusted consumed heme iron (Difference = - 0.41, T-value = - 0.36,  $p = 0.71$ ), Figure 2.A.

### 3.3. Probability of Having Consumed Heme Iron among Saudi Individuals Living with Overweight and/or Obesity in Comparison with Saudi Individuals Living without Overweight and/or Obesity before Adjusting for Possible Confounding Factors

In the binary logistic regression model, we found that Saudis who are living with overweight and/or obesity have no significant association with heme iron consumption in comparison with those who were with normal body weight ( $\beta = 0.02$ ,  $\chi^2 = 0.28$ ,  $P = 0.59$ ), figure 2.B.

### 3.4. Mean BMI versus Possible Confounding Variables

In this study, the link between various possible confounding factors and mean BMI was explored (Table. 2). These factors were included in the General Linear Model individually and the mean BMI was adjusted to those that were significant. There was a significant positive association between ages ( $\beta = + 0.24$ ,  $p < 0.0001$ ,  $R^2 = 16.92$ ), and a significant inverse link between the number of people per household and BMI ( $\beta = - 0.59$ ,  $p < 0.0001$ ,  $R^2 = 16.92\%$ ). No association was found between males and females and mean BMI ( $\beta = -1.03$ ,  $p = 0.34$ ,  $R^2 = 0.80\%$ ). A positive significant association was noticed between the participants who reported that they were employed and mean BMI ( $\beta = + 3.62$ ,  $p < 0.003$ ,  $R^2 = 9.79\%$ ), however, no association was found between mean BMI and those who reported that they were retired, students, or unemployed. Regarding income and mean BMI, participants who reported that they earn between 5001 and 10000 Saudi Riyals and those who earn between 15000 and 19999 have a significant positive association with mean BMI (between 5001 and 10000 Saudi Riyals:  $\beta = + 0.57$ ,  $p < 0.004$ ; between 15000 and 19999 Saudi Riyals:  $\beta = + 3.64$ ,  $p < 0.002$ ). The model for income explained 10.78 % of the variation in BMI. Those who noted that they are physically active every day had a negative significant association with the mean BMI ( $\beta = -2.74$ ,  $p < 0.002$ ), while those who said that they do physical activity once a week had a positive significant association ( $\beta = + 1.92$ ,  $p < 0.03$ ), no link between the mean BMI and those who reported that they do physical activities three to four times a week nor those who noted that they are inactive. The explanation for the variation of the mean BMI in the model of physical activity was 5.59%, no correlation between marital status and the

mean BMI.

### 3.5. Heme Iron versus Possible Confounding Factors

In the unadjusted model, we examined if there were possible confounding factors associated with heme iron consumption. These factors were macronutrients (protein, fat, carbohydrates, and energy), total sugars and micronutrients (vitamins A, D, C, and E). In a general linear model, heme iron was entered as response and protein, fat, carbohydrates, and energy and total sugar, vitamins A, D, C, and E as predictors. Table 3 shows the correlation between heme iron and the latter possible confounding factors.

There was a significant association between heme iron and the macronutrients protein, and carbohydrates but not fat (protein:  $\beta = + 0.15$ ,  $p < 0.0001$ ,  $R^2 = 26.80$ ; carbohydrates: ( $\beta = + 0.04$ ,  $p < 0.0001$ ,  $R^2 = 16.9$ ; fat: ( $\beta = + 0.02$ ,  $p = 0.13$ ,  $R^2 = 2.05$ ). There was a significant correlation between heme iron and energy intake ( $\beta = + 0.003$ ,  $p < 0.003$ ,  $R^2 = 7.55$ ). No link was found between heme iron consumption and sugar intake ( $\beta = - 0.0003$ ,  $p = 0.99$ ,  $R^2 = 0.01$ ). While there was a significant association between vitamin A, and E (vitamin A: ( $\beta = + 0.001$ ,  $p < 0.0001$ ,  $R^2 = 61.49$ ; vitamin E:  $\beta = + 0.65$ ,  $p < 0.01$ ,  $R^2 = 5.82$ ), there was no correlation between the intake of heme iron and vitamin D and C (vitamin D:  $\beta = + 0.009$ ,  $p = 0.98$ ,  $R^2 = 0.01$ ; vitamin C:  $\beta = - 0.008$ ,  $p = 0.70$ ,  $R^2 = 0.13$ ). The explanation in the variation of the mean heme iron consumption and the included possible confounding factors in the model was 79.79%.

### 3.6. Comparison between Adjusted Heme Iron Consumption among Saudi Individuals Living with Overweight and/or Obesity versus Individuals Living without Overweight and/or Obesity after Adjusting for Possible Confounding Factors

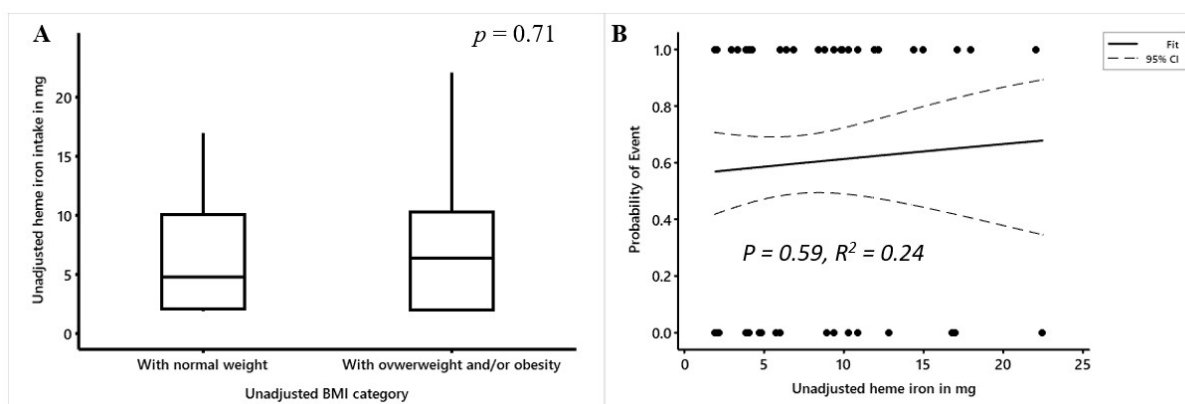
After adjusting dietary heme iron for macronutrients (protein, fat, carbohydrates, total sugar, micronutrients: vitamins A, D, C, and E), and after adjusting the mean BMI for age, gender, employment, income, household density, level of physical activity, and marital status, we found that the participants with overweight and/or obesity have significantly lower heme iron consumption than participants without overweight and/or obesity (Difference = 1.94, T-value = 2.10,  $p < 0.04$ ), Figure 3.A.

### 3.7. Probability of Having Consumed Heme Iron among Saudi Individuals Living with Overweight and/or Obesity in Comparison with Saudi Individuals Living without Overweight and/or Obesity after Adjusting for Possible Confounding Factors

After adjusting the BMI for possible sociodemographic

factors and after adjusting heme iron for several macronutrients and micronutrients as potential confounding factors, we found that Saudis with overweight

and/or obesity were less likely to consume heme iron by 9.5% in comparison with Saudis with normal weight ( $\beta = -0.10$ ,  $\chi^2 = 4.24$ ,  $P < 0.04$ ), figure 3.B.



**Figure 2.** (A): Comparison between unadjusted heme iron consumption among Saudi individuals living with overweight and/or obesity versus individuals living without overweight and/or obesity. (B): Binary logistic regression analysis of the association between unadjusted consumption of heme iron and individuals with unadjusted BMI. BMI = Body Mass Index, mg= milligram,  $N = 113$ .  $P$ -value  $< 0.05$

**Table 2.** General linear model analysis: BMI versus possible sociodemographic confounding factors

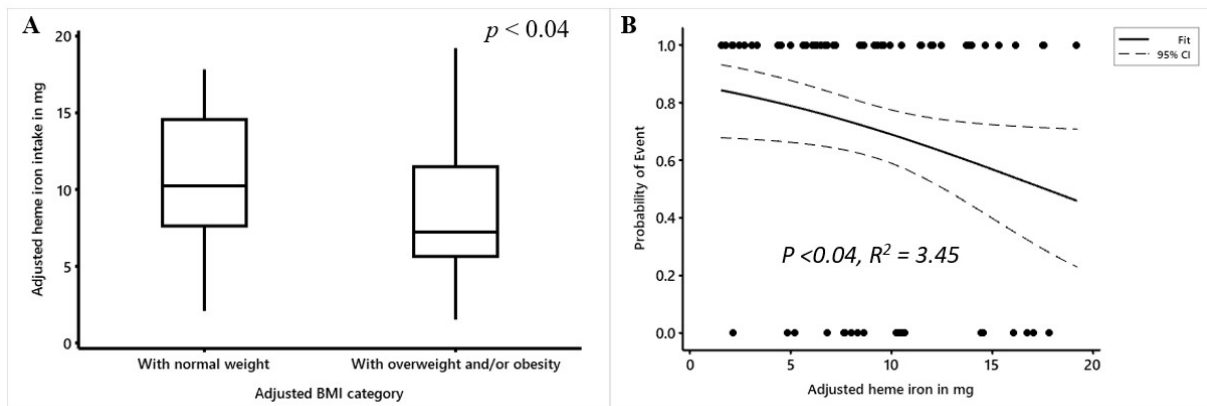
Factors	$\beta$	Mean BMI (SD)	P-Value	R <sup>2</sup> (%)
<b>Age</b>	+0.24	26.6 (5.58)	<0.0001	16.92
<b>Household size</b>	-0.59	26.6 (5.58)	<0.0001	10.55
<b>Sex</b>				0.80
Female	-1.03	25.98	= 0.34	
Male	+1.03	27.008	= 0.34	
<b>Employment</b>				9.79
Employed	+3.62	27.51 (5.47)	<0.003	
Not employed	-1.55	22.34 (4.68)	= 0.33	
Retired	-0.39	23.5 (0)	= 0.89	
Student	-1.68	22.22 (0.99)	= 0.50	
<b>Income</b>				10.78
No income	-0.78	25.70 (5.90)	= 0.70	
5000 or less	-3.09	23.39 (6.01)	<0.005	
Between 5001 and 10000	+0.57	27.05 (5.50)	<0.004	
Between 10001 and 14999	+0.47	29.94 (3.59)	= 0.63	
Between 15000 and 19999	+3.64	30.12 (6.77)	<0.002	
More than 20000	-0.82	25.65 (2.17)	= 0.59	
<b>Level of physical activity</b>				5.59
Inactive	+1.04	27.46 (4.92)	0.23	
Do physical activity once a week	+1.92	28.35 (7.19)	<0.03	
Do physical activity between 3 and 4 times a week	-0.23	26.18 (5.09)	= 0.77	
Do physical activity daily	-2.74	23.68 (3.47)	<0.02	
<b>Marital status</b>				2.3
Married	+1.005	27.57 (5.16)	0.05	
Single	-1.005	25.56 (5.87)	0.05	

$\beta$  = coefficient, BMI = Body Mass Index, SD = Standard Deviation.

**Table 3.** The relationship between heme iron and possible confounding factors

Term	B	Mean	SD	P-Value	R <sup>2</sup> (%)
Protein (g)	+0.15	110.	40.98	<0.0001	26.80
Fat (g)	+0.02	95	68.57	=0.13	2.05
Carbohydrate (g)	+0.04	242	107.8	<0.0001	16.93
Energy (kcal)	+0.003	2171	922.1	<0.003	7.55
Total sugars (g)	-0.0003	39.7	33.69	<0.99	0.01
Vitamin A (mcg)	+0.001	193	5077	<0.0001	61.49
Vitamin D (mcg)	+0.009	3.28	3.132	=0.98	0.01
Vitamin C (mg)	-0.008	36.36	50.43	=0.70	0.13
Vitamin E (mg)	+0.65	8.08	4.397	<0.01	5.82

β = coefficient, BMI = body mass index, SD = standard deviation, g = gram, Kcal = calories, mcg = microgram, mg= milligram.



**Figure 3.** (A): Comparison between adjusted heme iron consumption among Saudi individuals living with overweight and/or obesity versus individuals living without overweight and/or obesity adjusting for sociodemographic confounding factors (age, sex, marital status, household size, employment, income, physical activity). (B): Binary logistic regression analysis of the association between adjusted consumption of heme iron and individuals with adjusted normal weight versus individuals with adjusted overweight and/or obesity. Heme iron adjusted for: carbohydrates, fat, protein, and energy intake, total sugar, vitamins A (retinol), D (Calciferol or cholecalciferol), C (Ascorbic acid), and E (Tocopherol), BMI = Body Mass Index, mg= milligrams,  $N= 113$ . Significance is where  $P\text{-value} < 0.05$

### 4. Discussion

This study countered several confounding factors that may affect the link between BMI and heme iron in the light of comparing those with overweight and/or obesity and the ones with normal weight. It is possible that other studies may have not adjusted BMI for confounding variables such as household size for example. Moreover, heme iron was found to be correlated with macronutrients and micronutrients such as protein, carbohydrates, energy intake, and vitamin E.

This study addressed several confounding factors that could influence the relationship between BMI and heme iron, specifically when comparing individuals with overweight and/or obesity to those with normal weight. It is possible that other studies did not sufficiently adjust for confounding variables, such as household size which led to a skewed result. Moreover, the findings in this study revealed that heme iron was significantly correlated with several macro and micronutrients such as protein, fat,

energy, and vitamin E. As a result, before the adjustment, there was no difference between Saudi adults living with overweight and/or obesity and Saudis with normal weight regarding their intake of heme iron, however, after the adjustment, there was a significant difference. The Saudi adults with overweight and/or obesity have lower consumption of heme iron in comparison with Saudi individuals living within a normal range of weight on the BMI scale. This could be related to several possible explanations. First, this may support the notion that people with excess weight or BMI higher than the normal range may follow a poor diet that is in heme iron [14]. An investigation that is aligned with our results showed that individuals with obesity have poor diets in comparison with people with normal weight [15]. Second, people with overweight or obesity tend to underreport their diet in their dietary records [16]. Third, according to Micha et al. [17], the average content of heme iron in processed meat is lower than the content in unprocessed meat and they also noted that processed meat has a higher content of fat and

lower protein. This could lead to lower consumption of heme iron specifically among people with overweight and/or obesity even if it shows that they consume a high amount of animal sources, but processed types of meat will not supply their needs of heme iron as much as unprocessed meats. Results from several studies found that people with obesity have lower blood iron concentrations and are more susceptible to iron deficiency than individuals with normal body weight [18-20]. The latter studies used the Nutrition Data System for Research (NDSR) software for analyzing heme iron consumption. This could be attributed to inadequate diets characterized by low levels of heme iron, which may consequently place them at risk of developing iron deficiency anemia.

## 5. Strengths and Limitations

To our knowledge, this is the first study that was conducted in Saudi that compared the consumption of heme iron among Saudi adults with or without overweight and/or obesity. Moreover, this study included in its models many possible confounding factors that could disturb the results. The adjustment of these confounding factors was by implementing residual correction for mean BMI and heme iron [11-12]. Food records were instructed by a specialized nutritionist and all the participants were interviewed and instructed on how to record their diets.

However, there were several limitations in our study. First, this study depended on recall surveys which could be underreported by the participants, however, the type of food records (seven-day food records) that were used was verified and used by many studies [21-23]. Second, this investigation is cross-sectional and does not show a causative link between heme iron and obesity. Furthermore, we could not take blood samples to analyze the concentration of serum ferritin to see if this is also related to iron deficiency. Third, we were not able to collect blood samples to see if the participants had iron deficiency. Also, the BMI was calculated using self-reported weights and heights, which are subject to potential bias and inaccuracies.

## 6. Conclusions

In this study, we compared the consumption of heme iron between Saudi individuals who live with obesity and/or overweight to Saudi adults living with a normal weight. Saudi adults with obesity and/or overweight were significantly less likely to consume heme iron than those who have normal weight after adjusting several confounding factors. This could be related to the notion that people with excess weight may consume high portion sizes of meals, but they are poor diets with low content of heme iron. However, this is a cross-sectional study which does not reflect a causative relationship. Moreover, there

was no blood sampling included in this investigation which may not show whether this is related to iron deficiency among the participants.

## Supplementary

Seven-day food records form (survey 1, Supplementary 1):

<https://docs.google.com/spreadsheets/d/1C6YMO3Vd1ccG03P-T4v-25LWzKZyHoD/edit?usp=sharing&ouid=107093717130537500925&rtpof=true&sd=true>

Nutrients confounding factors (supplementary 2):

<https://docs.google.com/spreadsheets/d/1n3zu2elDmaYZVeDmRfVSP33nFK9B8kn-/edit?usp=sharing&ouid=107093717130537500925&rtpof=true&sd=true>

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## Conflict of Interest

None declared.

## Authorship

The author confirms solo responsibility for the following: study conception and design, collection of data, analysis, and interpretation, of results, and paper writing and preparation.

## Ethical Standards Disclosure

This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving research study participants were approved by the [Research Ethics Committee at University of Tabuk, Saudi Arabia, approval number: UT-285-128-2023]. Written [or Verbal] informed consent was obtained from all subjects. Verbal consent was witnessed and formally recorded.

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