

# The need to screen for anemia in exercising women

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## Abstract

Anemia is common, affecting 1 in 3 women in their lifetime. Despite high prevalence rates, awareness is poor. This is relevant for women undertaking sport as anemia can lead to reduced physical performance. There is no current screening program for testing of anemia for exercising women. Therefore, the objective of the present study was to assess a simple screening tool to predict anemia in exercising women.

Cross sectional survey study.

National fitness festival.

Three hundred exercising women.

Screening methodology (Female Health Questionnaire and a haemoglobin concentration measurement).

The Female Health Questionnaire inquired about; previous iron status, menstrual blood loss, diet, and motherhood. Participants were asked to self-report any symptoms of iron deficiency, including; brain fog, palpitations, shortness of breath, restless legs, hair loss, and pica. Results were compared to fingerprick haemoglobin levels with anemia defined as [Hb] < 120g/L.

Average age was 31.21years (s.d.7.72), average [Hb] was 131.76g/L (s.d.11.5) and 36 (12%) had anemia. A history of iron deficiency was reported by 127 (43.49%), 127 (43.49%) reported heavy menstrual bleeding (HMB), 75 were vegetarian (18%) or vegan (8%) and 33 were mothers (11%). In total 80 reported taking time off work (total 1612 days). Women with anemia more commonly reported HMB (58.33% vs. 41.57%,  $P = .04$ ), and those with HMB were more likely to report days off (39.37% vs. 18.18%,  $P < .001$ ).

Anemia was common in exercising women, particularly those with HMB. A simple screening tool for HMB and finger prick haemoglobin testing for anemia is recommended in women undertaking exercise.

**Abbreviations:** FHQ = female health questionnaire, Hb = haemoglobin, HMB = heavy menstrual bleeding.

**Keywords:** anemia, heavy menstrual bleeding, haemoglobin, women's health

## 1. Introduction

Anemia is the commonest disease to affect women's health and a World Health Organization top ten cause of disability leading to an average of 8 years of living with disability.<sup>[1]</sup> One in ten women will have anemia at any point in time and one in 3 women suffer with anemia at some point in their lifetime.<sup>[2]</sup> The

predominant cause of anemia is iron deficiency, which can arise from reduced iron intake (poor diet), excess iron loss (bleeding) or iron sequestration (chronic disease). The primary cause of both iron deficiency and anemia in females of reproductive age is menstrual blood loss.<sup>[3]</sup> Indeed, iron losses in women with heavy menstrual bleeding (HMB) are on average 5 to 6 times greater

Editor: Mohammed Nader Shalaby.

Dr. Richards reports grants from UK, NIHR HTA, grants from Australian, NHMRC, grants, personal fees and non-financial support from Pharmocosmos, grants, personal fees and non-financial support from Vifor Pharma, grants from NIHR EME, personal fees from Medtronic, grants from Australian MRFF, outside the submitted work; and TR is a regular speaker at national and international conferences on anemia, blood transfusion, wound healing and vascular diseases for which he has received expenses for travel, accommodation and sundries. TR has worked with several agencies promoting meetings or healthcare. TR is a director of The Iron Clinic Ltd and director of Veincare London Ltd also TR is the vascular lead for 18-week wait Ltd.

The authors have no funding and conflicts of interests to disclose.

Supplemental Digital Content is available for this article.

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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How to cite this article: Dugan C, Scott C, Abeysiri S, Baikady RR, Richards T. The need to screen for anemia in exercising women. *Medicine* 2021;100:39(e27271).

Received: 12 July 2021 / Received in final form: 29 August 2021 / Accepted: 31 August 2021

<http://dx.doi.org/10.1097/MD.00000000000027271>

than those without every cycle.<sup>[4]</sup> As the body has over 1000 mg of iron in reserve (stored in ferritin) and the normal metabolic turnover of iron is only 2 to 4 mg per day, the development of iron deficiency can be insidious, developing over many years. As a result, many women may be unaware of the problem.<sup>[5]</sup>

Physical symptoms of iron deficiency include tiredness and fatigue,<sup>[6]</sup> as well as; the inability to think clearly (brainfog), headaches, dizziness, restless legs, and pica (unexplained eating of soil or ice).<sup>[7,8]</sup> If untreated, iron levels will continue to deplete to the point of anemia, where the body can no longer keep up with the demands of haemoglobin (Hb) synthesis, consequently creating a reduction in erythrocytes.<sup>[9]</sup> Anemia is linked to a further detriment of work capacity and quality of life.<sup>[10]</sup> From a fitness perspective, iron deficiency and anemia impact exercise performance and work productivity, due to the inevitable decrease in the maximum rate of oxygen consumption ( $VO_{2max}$ ).<sup>[11]</sup>

In high income countries, iron deficiency is commonly seen in women due to menstrual bleeding (>80 mL blood=40 mg iron per month) or meat exclusion diets. Heavy menstrual bleeding affects approximately a quarter of the female population, with over half of those individuals experiencing iron deficiency.<sup>[12,13]</sup> Both qualitative (excessive menstrual blood loss leading to interference with the physical, emotional, social, and material quality of life of a woman) and quantitative (blood loss of more than 80 mL per cycle) definitions of HMB have been used for diagnosis.<sup>[14,15]</sup> In both instances, HMB has been demonstrated to negatively influence a female's quality of life,<sup>[16–18]</sup> with reductions in energy levels, work productivity, mood states, social interactions and libido.<sup>[3,19–22]</sup> Moreover, the increased blood loss may also contribute to the detriment in quality of life through compromised iron stores.<sup>[18]</sup> Improvements in quality of life demonstrated after treatment of HMB are also associated with the correction of anemia.<sup>[10]</sup>

Despite current prevalence rates, the awareness of HMB is poor.<sup>[5]</sup> Estimates of the proportion of females with HMB who actually consult clinicians about their symptoms have been reported as low as 6%.<sup>[5]</sup> The issue of women's health in sport has not been well addressed.<sup>[23]</sup> Indeed, HMB is common both in marathon runners and elite athletes.<sup>[24–26]</sup> However, the association with anemia has not been assessed. Therefore, we wished to assess;

1. The use of a screening tool (questionnaire) to identify risk factors for anemia in exercising women and;
2. Assess the current prevalence rates of HMB and anemia.

## 2. Materials and methods

### 2.1. Participants

Three hundred women were randomly surveyed at a large UK fitness show (December, 2019). Participants were attendees and voluntarily presented to a testing station, where they undertook both a survey and fingerprick blood test for haemoglobin concentration (HemoCue Hb 201+, Hemocue, Radiometer, Crawley, UK). Investigators had no bias in selecting women to participate in the study, and a scripted introduction was used to ask women “if they would help with an ongoing study on women's health”. Participants were informed about the details of the study and provided consent (UCL Ethics ID: 12477/001). Inclusion criteria were pre-menopausal females aged between 18 and 65 who currently undertook exercise. Women were only

excluded after consent if their age was outside this range or they were post-menopausal.

### 2.2. Female health questionnaire

A 13 item FHQ including yes-no polar questions was developed that took approximately 3 to 5 minutes to complete (supplemental file S1, <http://links.lww.com/MD2/A448>). The FHQ collected information on risk factors for iron deficiency; previous knowledge of iron status (self-reported), and iron supplementation strategy (if any). Risk factors identified were; non-meat diet, pregnancy, previous blood donation, and the symptom of HMB. Heavy menstrual bleeding was defined as 2 or more of the following symptoms;

1. Need double sanitary protection (tampons and towels);
2. Need to frequently change your protection (every 2 hours or less or more than 12 sanitary items per period);
3. Had or worried about flooding through to clothes or bedding;
4. Pass large blood clots.<sup>[13]</sup>

The FHQ included 7 symptoms relating to iron deficiency that had been identified from a previous online survey,<sup>[27]</sup>

1. Fatigue;
2. Brain Fog (inability to think clearly, forgetful, foggy);
3. Shortness of Breath (air hunger, out of breath, puffed easily);
4. Palpitations (thumping heart, rapid pulse, high pulse);
5. Restless legs (wake at night, cramps, legs always moving);
6. Hair Loss (brittle / cracking hair, reduced 'bun');;
7. Pica (desire to eat odd foods such as ice or paper).

If respondents had selected yes to any symptom, the number of days missing from life commitments were recorded.

### 2.3. Haemoglobin concentration measurement

Participants underwent a haemoglobin concentration measurement (via a fingerprick blood assessment) in conjunction with the FHQ. For fingerpick blood sampling, a 23G lancet (Unistik3; Owen Mumford) was used to obtain a drop of capillary blood, with the first drop of blood discarded to avoid contamination with interstitial fluid, and the second drop used for haemoglobin concentration measurement in a HemoCue microcuvette (HemoCue Hb 201+, Hemocue, Radiometer, Crawley, UK). Anemia was defined as a haemoglobin concentration of less than 120 g/L, consistent with those definitions defined by the World Health Organization.<sup>[28]</sup>

### 2.4. Data analysis

Statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS) version 25.0 (IBM, Inc., New York, NY). After initial screening of the data, descriptive characteristics were summarized for the purposes of calculating participant demographics, variable prevalence rates and the self-reported symptom frequencies. Differences in FHQ responses between those that were anemic and not anemic was assessed by contingency table Chi-Squared assessments. Association between reported symptoms or characteristics and:

1. HMB;
2. Anemia
3. Days off work were assessed.

To achieve this, the relationship between haemoglobin concentration and the binary survey outcomes were assessed using a point-biserial correlation test. Pearson correlation tests were then used to determine the relationship between haemoglobin concentration and age. To ascertain the true impact of HMB and anemia on day-to-day life, the total number of reported days off were summated. Subsequent Chi-Squared tests were then employed for the purposes of determining any significant differences between survey responses (both symptoms and characteristics) and the number of days lost, in addition to determining any associations between characteristics or symptoms.

Finally, an enter method logistic regression was conducted with all variables to determine which variables (if any) were significant contributors to;

1. Anemia;
2. HMB and;
3. Days off work.

Following this, a stepwise logistic regression was employed with the removal of unnecessary variables, so as to eliminate errors and accurately determine any significant contributors.

Statistical significance was considered as  $P < .05$ . Interpretation of bivariate correlations was done with the following  $r$  value thresholds;

1. Probably not meaningful ( $r = 0-0.019$ );
2. Weak but possibly meaningful ( $r = 0.20-0.35$ );
3. Moderate and likely to be meaningful ( $r = 0.36-0.65$ );
4. Strong and almost certainly meaningful ( $r = 0.66$  and above).

All data was reported as means and standard deviations together with frequency and the corresponding percentage relative to sub-population size.

### 3. Results

#### 3.1. Descriptive data

Of the 300 females surveyed, 292 were included in the final analysis. Exclusions were those; outside inclusion criteria ( $n = 6$ ), withdrawals ( $n = 1$ ) and incomplete haemoglobin concentration measurement ( $n = 1$ ). Average age was 31.2 years (s.d. 7.7). The average Hb was 131.8 g/L (s.d. 11.5) and 36 women (12.3%) were anemic (Hb < 120 g/L).

Overall, risk factors for anemia were reported by 231 (79.1%) women. Previous history of iron deficiency was reported by 127 (43.5%), 75 were vegetarian (18%) or vegan (8%) and 33 were

mothers (11%). Heavy menstrual bleeding was reported by 127 (43.5%) (Table 1).

Symptoms relating to iron deficiency and/or anemia were also commonly reported, with 235 (80.5%) women reporting at least 1 symptom (Table 2). The average number of symptoms reported per participant was 1.80 (s.d. 1.3). The most common symptom was Brain fog (51.7%). Eighty women reported taking time off work due to symptoms (median 20 days; range 1–50 days). Collectively, a total of 1612 days was reported to be lost.

#### 3.2. Associative and comparative data

**3.2.1. Anemia.** Overall, the FHQ reporting of risk factors or symptoms relating to anemia appeared nonspecific, with little correlation to haemoglobin levels (Table 3). The self-reporting of heart palpitations was significantly associated to haemoglobin concentration ( $P = .017$ ) but whilst the nature of this relationship was positive, it is likely not meaningful ( $r = 0.14$ ). All other risk factors (blood donor, diet, HMB status, childbirth) and symptoms (brainfog, shortness of breath, palpitations, restlessness, hair loss, pica) failed to significantly correlate with haemoglobin concentration ( $P > .05$ ). A significant association was found between haemoglobin concentration and the reporting of more than 1 risk factor ( $P < .05$ ), although again, the nature of this relationship was likely not meaningful ( $r = -0.118$ ).

**3.2.2. Heavy menstrual bleeding.** Those with HMB were significantly more likely to report a history of iron deficiency (51.18% vs 37.58%,  $P = .024$ ) and there was a significant correlation between HMB and the overall self-reporting of symptoms relating to anemia ( $r = 0.252$ ,  $P < .001$ ). Women who reported the symptom of HMB were significantly more likely to report symptoms of brainfog ( $P = .002$ ), palpitations ( $P = .009$ ), restlessness in the legs ( $P = .010$ ) and or pica ( $P = .001$ ).

**3.2.3. Reporting of days off.** The likelihood of women reporting time off was not related to the presence of anemia (25% vs 27.40%;  $P > .05$ ), but related to the symptom of HMB, where women who reported HMB were significantly more likely (39.37% vs 18.18%) to report days off ( $P < .001$ ).

#### 3.3. Relationship between anemia, heavy menstrual bleeding and reported days off

**3.3.1. Logistic regression- presence of anemia.** Using a stepwise logistic regression, a significant model emerged (Chi-squared 2 = 7.97,  $P = .019$ ), with 87.6% accuracy. Interestingly, when accounting for the unnecessary variables, HMB status became a significant predictor of anemia (beta = 0.80,  $P = .03$ ),

**Table 1**

**Female health questionnaire results for risk factors for iron deficiency anemia (n=292).**

	Total sample (n=292)	Anemic (n=36)	Non-anemic (n=256)
Characteristic, mean $\pm$ SD			
Age (yrs)	31.21 $\pm$ 7.72	30.39 $\pm$ 6.27	31.44 $\pm$ 7.93
Average haemoglobin concentration (g/L)	131.76 $\pm$ 11.47	112 $\pm$ 6.76	134.42 $\pm$ 9.32
Risk factor prevalence, % (n)			
History of iron deficiency	127 (43.49%)	18 (50%)	91 (45.05%)
Previous blood donor	51 (17.47%)	9 (25%)	34 (16.83%)
Vegetarian	53 (18.15%)	10 (27.78%)	37 (18.32%)
Vegan	22 (7.53%)	3 (8.33%)	12 (5.94%)
HMB positive	127 (43.49%)	21* (58.33%)	92 (45.54%)
Childbirth	33 (11.30%)	3 (8.66%)	25 (12.38%)

\*=significantly different from non-anemic with no reported symptoms ( $P < .05$ ).

**Table 2**  
Self-reported symptom frequencies of the FHQ (n = 292).

	Total sample (n=292)	Anemic (n=36)	Non-anemic, reported symptoms (n=202)
Symptom frequency, % (n)			
Brain fog	151 (51.71%)	20 (55.56%)	131 (64.85%)
Shortness of breath	76 (26.03%)	11 (30.56%)	65 (32.18%)
Palpitations	102 (34.93%)	8 (22.22%)	94 (46.53%)
Restless legs	89 (30.48%)	13 (36.11%)	75 (37.13%)
Hair Loss	95 (32.53%)	13 (36.11%)	82 (40.59%)
Pica	11 (3.77%)	3 (8.33%)	8 (3.96%)

\* = significantly different from non-anemic with no reported symptoms ( $P < .05$ ).

whereby anemia was significantly more likely to occur in the presence of HMB (Table 4A). Suggesting that women were significantly more likely to present with anemia if they reported the symptom of HMB.

**3.3.2. Logistic regression- prediction of heavy menstrual bleeding.** Using the forced entry method, a significant model emerged (Chi-squared  $4 = 36.12$ ,  $P < .001$ ) that accounted for 15.6% of the variance (adj.  $R^2 = 15.6$ ). The main model was shown to be 65.3% accurate in predicting HMB status. The reporting of days lost (beta = 0.893,  $P = .002$ ), pica (beta = 2.52,  $P = .019$ ) and restless leg syndrome (beta = 0.654,  $P = .016$ ) all significantly contributed to the prediction of HMB occurrence (Table 4B).

**3.3.3. Logistic regression- prediction of days off.** Using the forced entry method, a significant model emerged (Chi-squared  $14 = 64.19$ ,  $P < .001$ ). Approximately 28.3% of the variance in reporting of days off was explained by the 12 predictors (adj.  $R^2 = 0.283$ ). The main model was shown to be 78.7% accurate (Table 4C). Vegan diets (beta = 0.97,  $P = .09$ ), HMB presence (beta = 0.83,  $P = .01$ ) and history of iron deficiency (beta = 0.83,  $P = .01$ ) all significantly contributed to the prediction of subsequent days off. Further to this, the self-reported symptoms of brainfog (beta = 0.84,  $P = .01$ ), palpitations (beta = 0.99,  $P < .001$ ) and hair loss (beta = 0.58,  $P = .07$ ) also significantly contributed to the accurate prediction of number of days taken

**Table 3**  
Association between haemoglobin concentration and survey outcomes.

	[Hb]	
	Correlation coefficient	P value
Risk factors		
Blood donor	-0.02	.74
Vegetarian	-0.025	.67
Vegan	-0.103	.08
HMB status	-0.027	.648
Childbirth	-0.72	.219
>1 risk factor reported	-0.118	.044
Symptoms		
Brainfog	-0.059	.319
Shortness of breath	-0.042	.474
Palpitations	0.14*	.017
Restlessness	-0.032	.588
Hair loss	-0.007	.904
Pica	-0.021	.717
Days lost (yes/no)	0.063	.282

\* = significant correlation coefficient ( $P < .05$ ); [Hb] – haemoglobin concentration.

off. All other symptoms and variables failed to make a significant contribution to the model's prediction accuracy ( $P > .05$ ).

#### 4. Discussion

In this cohort study, we found that of 292 exercising women, 36 were anemic (12.3%). Whilst there were many potential risk factors and symptoms reported, the main association was in those who reported HMB. Results are in keeping with the high prevalence and poor awareness of both anemia and HMB. This has been well documented in the literature but raises the problems in a population of women who regularly undertake exercise and who are regarded as fit and healthy.

In line with previous research, the present study demonstrated that women with anemia were significantly more likely to have HMB, which in-turn, was a significant predictor to the number of days required to have off as a result of these adverse health complications. It should be noted, the observations made in the present study were made in an exercising population, which validates the notion that there is generally poor awareness of anemia in fit and healthy individuals. Considering this, alongside the known ability for both anemia<sup>[10,28,29]</sup> and HMB<sup>[10,13,24,30-32]</sup> to impact upon quality of life, and that HMB increases the risk of anemia,<sup>[12,16-18,29,33]</sup> it can be concluded that they are both significant issues.

The prevalence rate of HMB (43.49%) observed in the present study is higher than that of the general population (25%).<sup>[15]</sup> Menstrual blood loss has previously been established as a primary cause of both iron deficiency and anemia,<sup>[34]</sup> which explains the higher prevalence rates seen in women of reproductive age. If left untreated, iron stores will deplete progressively towards a state of anemia, prevalence for which was observed to be 12.33% in the present study. Interestingly, of the women that reported some form of symptom, the frequency of symptoms did not significantly differ between those that were anemic vs. non-anemic. This suggests that the impact on quality of life presents prior to the decline in haemoglobin concentration, whereby these individuals may be in a state of iron deficiency non-anemia (IDNA). Unfortunately, iron studies were not measured in the blood samples, making this speculation. However, the lack of association between haemoglobin concentration and the symptom frequencies (Table 3) provides further evidence to support this.

Previous literature has clearly established a relationship between HMB, anemia and quality of life.<sup>[12,13,16,17,19,20,22,24,27,35,36]</sup> Specifically, HMB is a significant predictor or both iron deficiency and anemia, all of which can worsen quality of life. However, to the best of our knowledge, no research has examined the underlying mechanisms which might predict

**Table 4**  
**Binary logistic regression analysis output for the prediction of: (A) Anemia; (B) HMB; (C) Reported days off (n=292).**

(A) Predictor	Unadjusted model				Adjusted model			
	B (SE)	P	odds ratio	95% CI for odds ratio (low, high)	B (SE)	P	odds ratio	95% CI for odds ratio (low, high)
History of iron deficiency	0.29 (0.39)	.46	1.33	0.62, 2.85				
Previous blood donor	0.49 (0.45)	.27	1.64	0.68, 3.92				
Vegetarian	0.6 (0.45)	.18	1.82	0.76, 4.4				
Vegan	0.21 (0.69)	.75	1.24	0.32, 4.76				
HMB positive	0.67 (0.39)	.09	1.96	0.9, 4.24	0.80 (0.37)	.03	2.22	1.08, 4.57
Childbirth	-0.4 (0.67)	.55	0.67	0.18, 2.49				
Brain Fog	0.088 (0.4)	.83	1.09	0.5, 2.4				
Shortness of Breath	0.38 (0.45)	.40	1.46	0.61, 3.5				
Palpitations	-1.05* (0.47)	.03	0.35	0.14, 0.88	-0.85 (0.43)	.047	0.426	0.18, 0.99
Restless legs	0.22 (0.41)	.58	1.25	0.56, 2.79				
Hair Loss	0.3 (0.4)	.45	1.35	0.62, 2.97				
Pica	0.76 (0.77)	.32	2.13	0.47, 9.59				
Days lost	-0.38 (0.47)	.41	0.68	0.27, 1.7				

Note: R<sup>2</sup>=0.053 (Cox & Snell), .1 (Nagelkerke). Model X<sup>2</sup> (13)=15.74, p=0.263  
 Percentage correct=87.6% (beginning block), 88.3% (main model)

Note: R<sup>2</sup>=0.027 (Cox & Snell), .051 (Nagelkerke). Model X<sup>2</sup> (2)=7.97, P=.019.  
 Percentage correct=87.6% (beginning block), 87.6% (main model).

(B) Predictor	Unadjusted model			
	B (SE)	P	Odds ratio	95% CI for odds ratio (low, high)
Brainfog	.484 (.260)	.063	1.623	0.974, 2.704
Restless legs	.654* (.271)	.016	1.923	1.129, 3.274
Pica	2.52* (1.07)	.019	12.363	1.521, 100.497
Days lost	.893* (.289)	.002	2.442	1.387, 4.301

Note: R<sup>2</sup>=0.117 (Cox & Snell), .16 (Nagelkerke). Model X<sup>2</sup> (4)=36.12, P<.001  
 Percentage correct=56.4% (beginning block), 65.3% (main model)

(C) Predictor	Unadjusted model			
	B (SE)	P	odds ratio	95% CI for odds ratio (low, high)
History of iron deficiency	0.83* (0.31)	.01	2.30	1.26, 4.20
Previous blood donor	0.27 (0.38)	.49	1.31	0.62, 2.77
Vegetarian	0.51 (0.38)	.18	1.67	0.79, 3.52
Vegan	0.97* (0.57)	.09	2.65	0.87, 8.08
HMB positive	0.83* (0.31)	.01	2.29	1.24, 4.21
Childbirth	0.47 (0.47)	.32	1.59	0.64, 3.99
Brain Fog	0.84* (0.33)	.01	2.31	1.22, 4.36
Shortness of Breath	0.31 (0.34)	.37	1.36	0.69, 2.67
Palpitations	0.99* (0.32)	.00	2.69	1.43, 5.05
Restless legs	-0.27 (0.33)	.41	0.76	0.40, 1.46
Hair Loss	0.58* (0.32)	.07	1.79	0.96, 3.35
Pica	-0.02* (0.71)	.97	0.98	0.24, 3.94

Note: R<sup>2</sup>=0.196 (Cox & Snell), .283 (Nagelkerke). Model X<sup>2</sup> (14)=63.42, P<.001.  
 Percentage correct=72.5% (beginning block), 78.7% (main model).

CI=confidence interval, SE=standard error.  
 \* =significant predictor (P<.05).

individual risk and subsequent impact of anemia. Using statistical prediction models, the present study was able to identify primary underlying characteristics and symptoms that had maximum impact on an individual's ability to carry out daily activities. Significant predictors of anemia included HMB status and the self-reporting of heart palpitations. Whereas vegan diets, HMB presence and a history of iron deficiency all significantly contributed to the prediction of subsequent days off. Further to this, the self-reported symptoms of brainfog, heart palpitations and hair loss also significantly contributed to the accurate prediction of number of days taken off. The associated annual cost of lost productivity and days taken off has previously been estimated to be \$2000 USD per patient,<sup>[37,38]</sup> not to mention the significant detriment to the individual's quality of life. Taken

together, this highlights the need for an increased awareness of both anemia and HMB in the general population.

It is clear that there is a need for increased awareness of both anemia and HMB in the general population. This could potentially be achieved through similar observational studies, which extend out to differing populations. Educational interventions should also be considered to increase the knowledge of the signs and symptoms, as well establishing pathways for treatment for both HMB and anemia. Such treatment of HMB has previously been associated with the correction of anemia.<sup>[10]</sup> Alternatively, given the significant link to iron status, future investigation should consider more accurate measurement methodologies as well as treatment interventions that correct iron stores. Regardless of the supplementation method (oral or

intravenous), where serum ferritin is  $<40 \mu\text{g/L}$ , research suggests that there will be significant increases in serum ferritin if some form of intervention is undertaken.<sup>[39,40]</sup> Indeed, research involving intravenous and oral supplementation ranging from 40 to 400 mg/day for a duration of 6 to 24 weeks have all demonstrated significant increases in an individual's serum ferritin values.<sup>[40]</sup> One such carbohydrate encased intravenous compound, ferric carboxymaltose, has been successful in treating anemia,<sup>[41]</sup> resulting in improved fatigue scores, mood states and quality of life.<sup>[42,43]</sup> Further research is required to determine the efficacy of this drug on iron deficient non anemic individuals, as current literature is divergent.<sup>[6,39,40,42,44–47]</sup>

One of the major limitations of this study was the absence of serum ferritin measurements to accurately categorize women in terms of iron status. Therefore, conclusions regarding iron deficient non anemic women could not be made. Also, given that data was collected at a single time point, it is not relative to point in the menstrual cycle, meaning associated symptoms could not be controlled for. Underlying medical conditions may also have influenced the results. Although this was an exercising population, this form of confounding should not be dismissed. The major strength of the study was the novel measurement of subsequent time off, which allowed for the identification of the symptoms and characteristics which have maximum impact on day-to-day life. This measurement should assist in the goal of raising population awareness of subsequent impact, given it is expressed in a way to easily understand.

## 5. Conclusions

Overall, the relationship between HMB and anemia is clear, as is the impact to quality of life. Indeed, the present study demonstrated that HMB status predicted anemia. Further to this, HMB status, history of iron deficiency and vegan diets were all significant predictors of subsequent days off due to clinical symptoms, which has been previously estimated to cost \$2000 USD per patient per year.<sup>[37,38]</sup> Therefore, screening for anemia in exercising female populations should be undertaken to increase awareness and decrease prevalence. The present study demonstrated a quick and effective screening method for anemia using fingerprick hemoglobin testing, which was able to be performed quickly without complications.

## Author contributions

**Conceptualization:** Toby Richards.

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**Formal analysis:** Cory Dugan.

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**Resources:** Toby Richards.

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