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運動員鐵耗損及鐵缺
乏的檢測和治療
Assessment and
Treatment of Iron
Depletion and Iron
Deficiency in Athletes



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簡介

鐵是身體內含量最多的微量元素，成人體內有3-5克¹³。鐵是製造運送氧氣的血紅蛋白和肌紅蛋白基礎結構的物質，所以對運動很重要。而且，鐵是組成能量代謝酶的成分。所以，鐵儲備不足會影響運動表現。



鐵耗損或鐵缺乏是運動員最常見的營養不足問題之一^{3,7}。運動員較易鐵儲備不足因為^{5,18,20}：

- 汗液、尿液、消化道出血和足部衝擊引起的紅血球破裂症會增加流失；
- 節食或素食，使未能攝取足夠的鐵；
- 高強度訓練促使紅血球產量上升及令鐵的代謝增加，從而增加對鐵的需求；
- 兒童和青少年因發育及運動訓練而令鐵需求增加；
- 女性運動員如有異常大量的經血流失會令鐵需求增加。

Garza等(1997)指視乎驗血結果，鐵缺乏症可分為三個階段（見表1）。

Introduction

Iron is a trace element found in the greatest amount in the body, about 3 – 5g in adults¹³. Iron is an important nutrient in exercise since it is a structural component of hemoglobin and myoglobin for oxygen delivery. In addition, iron is involved with some enzymes that promote energy production. Therefore, insufficient iron storage may affect exercise performance.

Iron depletion or iron deficiency is one of the most prevalent nutrient deficiencies in athletes^{3,7}. Athletes are more prone to low iron store due to^{5,18,20}:

- Increased losses via sweat, urine, gastrointestinal bleeding and foot strike hemolysis,
- Inadequate iron intake due to restricted energy intake and vegetarian diet,
- Hard training stimulating an increase in red blood cell (RBC) production and metabolic iron use, increases the requirements for iron,
- Growth spurt in children and adolescents coupled with sport training increases demands for iron, and
- Abnormally high menstrual blood loss in female athletes also increases requirements for iron.

Garza et al (1997) classified iron deficiency into three stages based on hematological results (Table 1).

表1) 鐵缺乏症的階段¹²

第一階段：鐵耗損 (前隱性鐵缺乏)			
低血清鐵蛋白	及	正常的	總鐵結合力
		正常的	轉鐵蛋白飽和度
		正常的	血清鐵
		正常的	血紅蛋白
第二階段：紅細胞生成缺鐵 (隱性鐵缺乏)			
低血清鐵蛋白	及	上升的	總鐵結合力
		下降的	轉鐵蛋白飽和度
		正常的	血紅蛋白
	或		
低血清鐵蛋白	及	下降的	血清鐵
		正常的	血紅蛋白
第三階段：缺鐵性貧血			
低血清鐵蛋白	及	上升的	總鐵結合力
		下降的	轉鐵蛋白飽和度
		下降的	血清鐵
		下降的	血紅蛋白

Table 1. Stages of iron deficiency¹²

Stage I: Iron Depletion (Prelatent iron deficiency)		
Low serum ferritin	and	Normal total iron binding capacity (TIBC)
		Normal transferrin saturation
		Normal serum iron
		Normal hemoglobin
Stage II: Iron Deficient Erythropoiesis (Latent iron deficiency)		
Low serum ferritin	and	Increased TIBC
		Decreased transferrin saturation
		Normal hemoglobin
	OR	
Low serum ferritin	and	Decreased serum iron
		Normal hemoglobin
Stage III: Iron deficiency anemia		
Low serum ferritin	and	Increased TIBC
		Decreased transferrin saturation
		Decreased serum iron
		Low hemoglobin

鐵儲備的生物標誌物及其意義

有多個生物標誌物可用於評估鐵儲備。以單一血液測試來確認鐵儲備是不可靠和誤導的。感染、炎症和身體水份狀態可能會影響鐵儲備的測試結果。詳情請參閱附錄1及2。

鐵儲備檢測和鐵補充劑使用指引

每年身體檢查都會進行血常規(CBP)檢測。而鐵質常規檢測，包括血清鐵蛋白、血清鐵、轉鐵蛋白、轉鐵蛋白飽和度和總鐵結合力，會隔年檢查。有缺鐵過往史的運動員每年都應做鐵質常規檢測。血液樣本必須於運動前抽取。患感染或炎症的運動員應延遲血液測試。

當遇CBP或鐵質常規檢測結果偏離正常指標，運動員需約見顧問醫生，再被轉介見營養師，獲取飲食建議。介入治療如下(見表2)：

Biomarkers of Iron Status and Their Interpretation

Several biomarkers are used to assess iron status. It is unreliable and misleading to use single blood test to confirm iron status. Infection, inflammation and hydration status may affect the laboratory measures of iron status. Please refer to Appendices 1 and 2 for details.

Iron Screening and Iron Supplement Protocols

Complete blood picture (CBP) is tested at medical screening annually. Under normal condition, iron profile, including serum ferritin, serum iron, transferrin, transferrin saturation and TIBC, is performed in alternate year. Athletes with history of low iron stores are tested at medical screening annually. All blood tests should be taken prior to exercise. Athletes who are suffering from infection and inflammation should postpone the blood test.

When deranged CBP and/or iron profile are found, athletes are required to see Medical Consultant and then referred to Sport Nutritionist for dietary advices. The following interventions will be implemented (Table 2).

表2) 運動員鐵耗損及缺乏鐵的介入治療

驗血結果	介入治療
鐵蛋白 - 男: 30-45ng/mL - 女: 30-35ng/mL 而 血紅蛋白: 正常	<ol style="list-style-type: none"> 1. 查詢飲食及藥物 2. 查詢鐵流失 (如腸道、經期) 3. 諮詢運動營養主任有關高鐵飲食 4. 可服用多種維他命、礦物質補充劑, 但未需要服食鐵補充劑 5. 之後3個月, 每月見運動營養主任, 跟進飲食和補充劑 6. 之後3個月, 每月檢查CBP及鐵質常規
鐵蛋白: 正常 而 血紅蛋白: 低於正常	<ol style="list-style-type: none"> 1. 查詢飲食及藥物 2. 查詢鐵流失 (如腸道、經期) 3. 查詢最近訓練強度 4. 可能是高強度訓練後引致血漿容量擴充, 不需服食鐵補充劑 5. 一星期後檢查CBP及鐵質常規。如情況持續, 轉介顧問醫生檢查低血紅蛋白的原因
鐵蛋白: <30ng/ml* 而 血紅蛋白: 正常或低於正常	<ol style="list-style-type: none"> 1. 查詢飲食及藥物 2. 查詢鐵流失 (如腸道、經期) 3. 諮詢運動營養主任有關高鐵飲食及鐵補充劑服食方法 4. 之後三個月, 每日空腹服食鐵補充劑一粒 (含100mg鐵元素), 另可同服維他命C 500mg 5. 之後三個月, 每月見運動營養主任, 跟進飲食和補充劑 6. 之後3個月, 每月檢查CBP及鐵質常規

* 暫時未有確定指引鐵蛋白在哪個水平才需要使用補充劑 (介乎 <12 至 <35 ng/mL)⁹。有些與運動有關的個案會於血清鐵蛋白<30ng/mL, 建議運動員服食鐵補充劑^{9,10}。

Table 2. Iron depletion and iron deficiency interventions

Blood test results	Interventions
Ferritin is 30 – 45ng/ml (male) or 30 – 35ng/ml (female) but hemoglobin is normal	<ol style="list-style-type: none"> 1. Check dietary and drug intakes 2. Check for iron losses (e.g. gastrointestinal (GI), menstrual) 3. See Sport Nutritionist for dietary advice on a high iron diet 4. No iron supplement, but may take multi-vitamin and–mineral supplement 5. Follow up with Sport Nutritionist once per month for 3 consecutive months to check diet compliance and supplementation 6. Recheck CBP and iron profile once per month for 3 consecutive months
Ferritin is normal but hemoglobin is below normal	<ol style="list-style-type: none"> 1. Check dietary and drug intakes 2. Check for iron losses (e.g. GI, menstrual) 3. Check recent training intensity 4. No iron supplement, may be due to plasma expansion after strenuous training 5. Recheck CBP and iron profile in one week. If this condition persists, then refer to Medical Consultant to check for other underlying causes of low hemoglobin
Ferritin <30ng/ml* and hemoglobin is either normal or below normal	<ol style="list-style-type: none"> 1. Check dietary and drug intakes 2. Check for iron losses (e.g. GI, menstrual) 3. See Sport Nutritionist for dietary advice on a high iron diet and iron supplementation 4. Iron supplement (100 mg elemental iron) 1 tab daily for 3 months on empty stomach, can be taken with 500mg vitamin C supplement 5. Follow up with Sport Nutritionist once per month for 3 consecutive months to check diet compliance and supplementation 6. Recheck CBP and iron profile once per month for 3 consecutive months

*The level of serum ferritin at which supplementation should commence is still controversial (ranged from <12 to <35 ng/ml)⁹. In some cases in sports, serum ferritin level <30ng/ml is an indication for iron supplementation^{9,10}.

補充鐵儲備需要2 — 3個月，每日攝取100mg鐵元素的治療。服食鐵補充劑的運動員可預期血清鐵蛋白重上60ng/mL(即60 μ g/L)的水平¹⁸。此外，須於停服鐵補充劑後的第一及第三個月檢查CBP及鐵質常規，以確保鐵儲備正常。

香港售賣的鐵補充劑

- Fortifer: 富馬酸亞鐵300mg (含肝臟成分)
- Ferrum Hausmann咀嚼片: 100mg iron polymaltose complex (適合素食者)

鐵補充劑的副作用

有些服用者或會出現便秘、糞便變黑和肚痛，少部分更會有腹瀉、噁心和嘔吐。將鐵補充劑與食物同服將有助減輕不適⁵。

當運動員使用鐵補充劑時，有機會產生鐵超負荷。很多未被診斷為缺鐵的運動員，會每天或間歇地使用鐵補充劑作為強力劑，或者預防缺鐵。有證據顯示定期使用鐵注射劑或服用鐵補充劑的運動員會出現鐵超負荷^{6,24}。長期攝取過量鐵對健康人士的影響還未確定，但有可能出現類似「血色病」的徵狀⁵。

「血色病」是一種遺傳疾病，患者體內的鐵積聚太多。鐵積聚在肝臟、心臟、胰臟、關節及其他器官。最常見的臨床病變為膚色變深、糖尿病和關節病，而病徵包括疲倦嗜睡、尿頻、口渴、關節痛和性慾減退¹¹。由於鐵是促氧化劑，它會增加自由基及氧化水平，從而令身體組織受損。有多個研究指出體內高鐵儲備與心血管疾病^{19,22}、高膽固醇¹⁵和癌症^{21,23}有關。沒有任何證據指服食鐵補充劑可

It takes 2 – 3 months of treatment with 100mg elemental iron per day to replenish iron store. Athletes who take iron supplementation should aim to restore the serum ferritin level to a target level of about 60ng/ml (or 60 μ g/L)¹⁸. Moreover, recheck CBP and iron profile in 1 month and 3 months after discontinuing iron supplement to ensure iron status is normal.

Iron Supplements Currently Available in Hong Kong

- Fortifer: 300mg ferrous fumarate (contains whole dried liver)
- Ferrum Hausmann chewable tablet: 100mg iron polymaltose complex (suitable for vegetarians)

Side Effects of Iron Supplementation

Some people may experience constipation, black stools, abdominal cramps and to a lesser extent, diarrhea, nausea and vomiting. These adverse effects usually subside when iron supplement is taken with food⁵.

Iron overload is another concern when athletes use iron supplements. Many athletes, without being diagnosed with iron depletion, use iron supplements daily or intermittently as an ergogenic aid or as a preventive measure. Some evidence showed iron overload happened in athletes who regularly have iron injections and/or take iron supplements^{6,24}. The long-term consequences of taking excessively high doses of iron supplements or iron injections in healthy people are unknown, but it may mimic the effects of the genetic disorder called “hemochromatosis”⁵. Hemochromatosis is a genetic disorder in which too much iron builds up in the body leading to deposition in the liver, heart, pancreas, joints and other organs. The most common clinical presentations of hemochromatosis are skin pigmentation, diabetes and arthropathy and presenting symptoms include lethargy, polyuria, excessive thirst, arthralgia and loss of libido¹¹. Moreover, iron has pro-oxidant properties. It can generate free radicals and oxidative stress which may damage tissues. Several studies indicated that high body iron stores were positively associated with cardiovascular diseases^{19,22},

提升非貧血運動員的表現¹⁸。由此可見，CBP及鐵質常規水平正常的運動員是不應該服食鐵補充劑。如想服食鐵補充劑，請先諮詢顧問醫生或運動營養主任。

總結

鐵質對人體及運動表現十分重要。運動員，尤其是女性及青少年，有較大風險出現低鐵儲備。如不及時處理，鐵耗損可惡化，繼而導致貧血；這必定會影響運動表現。及早發現低鐵儲備可預防貧血。有低鐵儲備過往史的運動員應作定期的鐵儲備檢查。鐵補充劑只會對缺鐵人士有裨益。到目前為止，大多數研究指服食鐵補充劑對非貧血運動員沒有提升運動表現的作用¹⁸。而鐵超負荷則對健康有害。正常鐵儲備的運動員不應服食鐵補充劑來作強力劑或預防缺鐵。

附件一）檢查鐵儲備的生物標誌物^{2,14}

參數 Parameters	說明 / 意思 Description
血紅蛋白 Hemoglobin (Hb)	<ul style="list-style-type: none"> 紅血球中一種含鐵的蛋白 Iron containing protein in RBC 運輸氧氣及二氧化碳 Carries oxygen and carbon dioxide 調節體內的酸鹼平衡 Acts as a buffering agent 未能反映早期缺鐵 Less sensitive to iron depletion
血壓積 Hematocrit (Hct)	<ul style="list-style-type: none"> 紅血球佔血液容量的百分比 Percentage of RBC in a volume of whole blood 不能作為診斷鐵缺乏 Not a conclusive measure of iron deficiency

hypercholesterolemia¹⁵ and cancer^{21,23}. There is no evidence that iron supplementation results in improved performance in non-anemic athletes¹⁸. Consequently, athletes whose CBP and iron profile are normal should not take iron supplements. Athletes who wish to use iron supplements should consult with Medical Consultant or Sport Nutritionist before use.

Conclusion

Iron plays a critical role in the human body and to exercise performance. Athletes, particularly females and adolescents, are at high risk of low iron stores. If untreated, iron depletion can ultimately progress to anemia, which can adversely affect exercise performance. Early detection of depleted iron stores may prevent anemia. Athletes with history of low iron stores should regularly monitor iron status. Iron supplementation is only beneficial to individuals who are iron depleted. At present, most of the studies in non-anemic athletes did not show iron supplementation to produce any improvement in exercise performance¹⁸. Iron overload may be detrimental to health. Athletes whose iron stores are normal should not take iron supplements as an ergogenic aid or as a preventive measure.

Appendix 1: Biomarkers for assessing iron status^{2,14}

參考範圍 Reference Range	表示 Indication
男 (male) : 14 – 16 g/dL 女 (female) : 12 – 14 g/dL	↑ : 脫水 · 身處高原 dehydration, exposure to high altitude ↓ : 貧血 · 內出血 · 水腫 · 運動性貧血 (高強度訓練引起的血漿容量擴充) anemia, hemorrhage, fluid retention; sport anemia (plasma expansion induced by intensive training)
男 (male) : 40 – 50% 女 (female) : 35 – 46%	↑ : 脫水 · 血液濃縮 dehydration, hemoconcentration ↓ : 過度水份補充 · 貧血 over-hydration, anemia

參數 Parameters	說明 / 意思 Description	參考範圍 Reference Range	表示 Indication
平均紅細胞容積 Mean Cell Volume (MCV)	<ul style="list-style-type: none"> 紅血球的平均體積 Average size of RBC 	80.0 – 98.0fL	↑ : 肝病 · 酒精中毒 · 大細胞性貧血 · 惡性貧血 liver disease, alcoholic toxification, macrocytic anemia, pernicious anemia ↓ : 缺鐵性貧血 · 地中海貧血 (初步指標) · 小細胞性貧血 iron deficiency anemia, thalassemia (first indicator), microcytic anemia
平均紅細胞血色素含量 Mean Corpuscular Hemoglobin (MCH)	<ul style="list-style-type: none"> 平均每個紅血球所含有的血紅蛋白 Average amount of Hb inside a RBC 	27.0 – 35.6 pg	↑ : 大細胞性貧血 · 惡性貧血 macrocytic anemia, pernicious anemia ↓ : 缺鐵性貧血 · 小細胞性貧血 · 地中海貧血 iron deficiency anemia, microcytic anemia, thalassemia
平均紅細胞血色素濃度 Mean Corpuscular Hemoglobin Concentration (MCHC)	<ul style="list-style-type: none"> 指定紅細胞壓積內的血紅蛋白濃度 Concentration of Hb in a given volume of packed red blood cells 	32.6 – 36.6g/dL	↑ : 嚴重脫水 severe dehydration ↓ : 缺鐵性貧血 · 地中海貧血 iron deficiency anemia, thalassemia
紅細胞分佈寬度 Red Blood Cell Distribution Width (RDW)	<ul style="list-style-type: none"> 紅血球體積之間最大至最小的範圍 Range that covers the smallest and largest RBC in the body 反映紅血球大小不等的程度 Reflects the degree of difference in size of the RBC 	11.0 – 15.0%	↑ : 惡性貧血 · 地中海貧血 · 缺鐵性貧血 · 葉酸 / 維他命 B12 缺乏 (MCV 正常) pernicious anemia, thalassemia, iron deficiency anemia, folic acid/vitamin B12 deficiency (MCV is normal) ↓ : 未能將鐵再利用 defects in iron reutilization
網織紅細胞血紅蛋白含量 (CHR), 或網織紅細胞血紅蛋白等量 (Ret He) Reticulocyte Hemoglobin Content (CHR) or Reticulocyte hemoglobin equivalent (Ret He)	<ul style="list-style-type: none"> 網織紅細胞是最早從骨髓釋放的紅血球 Earliest RBC released from the bone marrow 早期缺鐵的有效指標 Sensitive indicator of early iron deficiency CHR 要靠 MCV 來計算 · 因此高 MCV 或地中海貧血會影響 CHR 結果 MCV is used for calculation of CHR, therefore, elevated MCV and thalassemia may affect the result of CHR 	30.2 – 36.7pg ¹	↑ : 促紅細胞生成素 (EPO) 治療 EPO treatment ↓ : 缺鐵性貧血 iron deficiency anemia 備註： 當缺鐵人士服食鐵丸時 · CHR 能反映紅細胞生成 ¹⁶ Remark: CHR may reflect the response of erythropoiesis to iron medication in iron-deficient subjects ¹⁶

參數 Parameters	說明 / 意思 Description	參考範圍 Reference Range	表示 Indication
血清鐵蛋白 Serum Ferritin	<ul style="list-style-type: none"> 儲鐵的蛋白 Iron-storing protein 有效反映早期的缺鐵及缺鐵性貧血 Useful indicator of early stage of iron deficiency and iron deficiency anemia 	男 (male) : 45 – 300ng/ml 女 (female) : 35 – 150ng/ml	↑ : 鐵超負荷 · 炎症 · 感染 · 肝、脾、骨髓的損傷 iron overload, inflammation, infection, damage to liver, spleen or bone marrow ↓ : 鐵耗損 · 紅細胞生成缺鐵 · 缺鐵性貧血 · 長期高強度體育訓練 iron depletion, iron deficient erythropoiesis, iron deficiency anemia, long term rigorous athletic training
血清鐵 Serum Iron	<ul style="list-style-type: none"> 未依附的鐵 Unbound iron 早晚量度差異大 (早上值最高) Large diurnal variation (the highest value occurs in the morning) 	男 (male) : 65 – 170µg/dL 女 (female) : 50 – 170µg/dL	↑ : 鐵超負荷 · 溶血性貧血 · 惡性貧血 · 鐵粒幼細胞性貧血 · 地中海貧血 · 維他命B6缺乏症 iron overload, hemolytic anemia, pernicious anemia, sideroblastic anemia, thalassemia, vitamin B6 deficiency ↓ : 感染 · 鐵耗損 · 紅細胞生成缺鐵 · 缺鐵性貧血 · 月經初期 infection, iron depletion, iron deficient erythropoiesis, iron deficiency anemia, beginning of menses
血清轉鐵蛋白 Serum Transferrin	<ul style="list-style-type: none"> 與鐵結合的蛋白 · 負責運輸鐵 Binds iron in the blood for transport 	230 – 450mg/dL	↑ : 缺鐵性貧血 iron deficiency anemia ↓ : 鐵超負荷 · 炎症 iron overload, inflammation
總鐵結合力 Total Iron Binding Capacity (TIBC)	<ul style="list-style-type: none"> 量度轉鐵蛋白所能結合的最大鐵量 Maximum amount of iron that can be bound to transferrin 	250 – 400µg/dL	↑ : 紅細胞生成缺鐵 · 缺鐵性貧血 iron deficient erythropoiesis, iron deficiency anemia ↓ : 鐵超負荷 · 內出血 · 惡性貧血 · 地中海貧血 · 炎症 iron overload, hemorrhage, pernicious anemia, thalassemia, inflammation
轉鐵蛋白飽和度 Transferrin Saturation	<ul style="list-style-type: none"> 血清鐵與總鐵結合力的百分比 Percentage of serum iron compare to TIBC 	15 – 50%	↑ : 鐵超負荷 iron overload ↓ : 紅細胞生成缺鐵 · 缺鐵性貧血 iron deficient erythropoiesis, iron deficiency anemia

*備註：須謹記有很多生理因素都會影響驗血結果。如有疑問，請諮詢顧問醫生或運動營養主任。

* NOTE: It is important to remember that many physiological factors can influence the results. If you have any question, please contact Medical Consultant or Sport Nutritionist for further information.

附錄2) 影響鐵儲備測試結果的因素⁴ Appendix 2: Factors influencing interpretation of laboratory measures of iron status⁴

	血紅蛋白 Hemoglobin	轉鐵蛋白 飽和度 Transferrin saturation	血清鐵 Serum iron	血清鐵 蛋白 Serum ferritin	可溶性轉鐵 蛋白受體 Soluble transferrin receptor (sTfR)
測試時缺水 Dehydration at the time of testing	↑	↑	↑	↑	↑
慢性炎症、 惡性腫瘤 Chronic inflammation, malignancy	↓ 或 正常 or Normal	↓	↓	↑	大置沒變 Minimal Change
感染 Infection	正常 Normal	↓	↓	↑	大置沒變 Minimal Change
剛剛完成激 烈、長時間 運動* After intense prolonged exercise*	↓	↓	↓	↑	不詳 Not available

* 研究顯示劇烈運動之後，鐵蛋白水平可持續升高3-4天^{6,17}

* Studies indicated that increased ferritin levels may persist for 3 – 4 days following strenuous exercise^{6,17}.

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