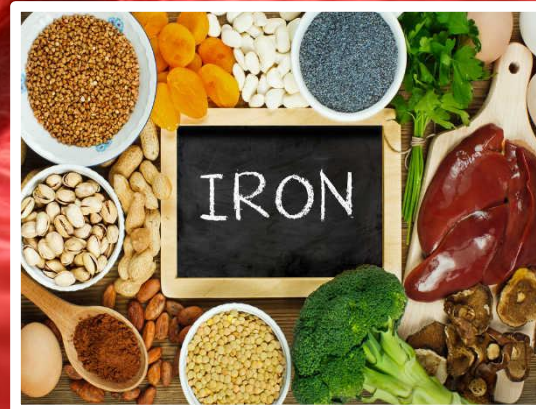
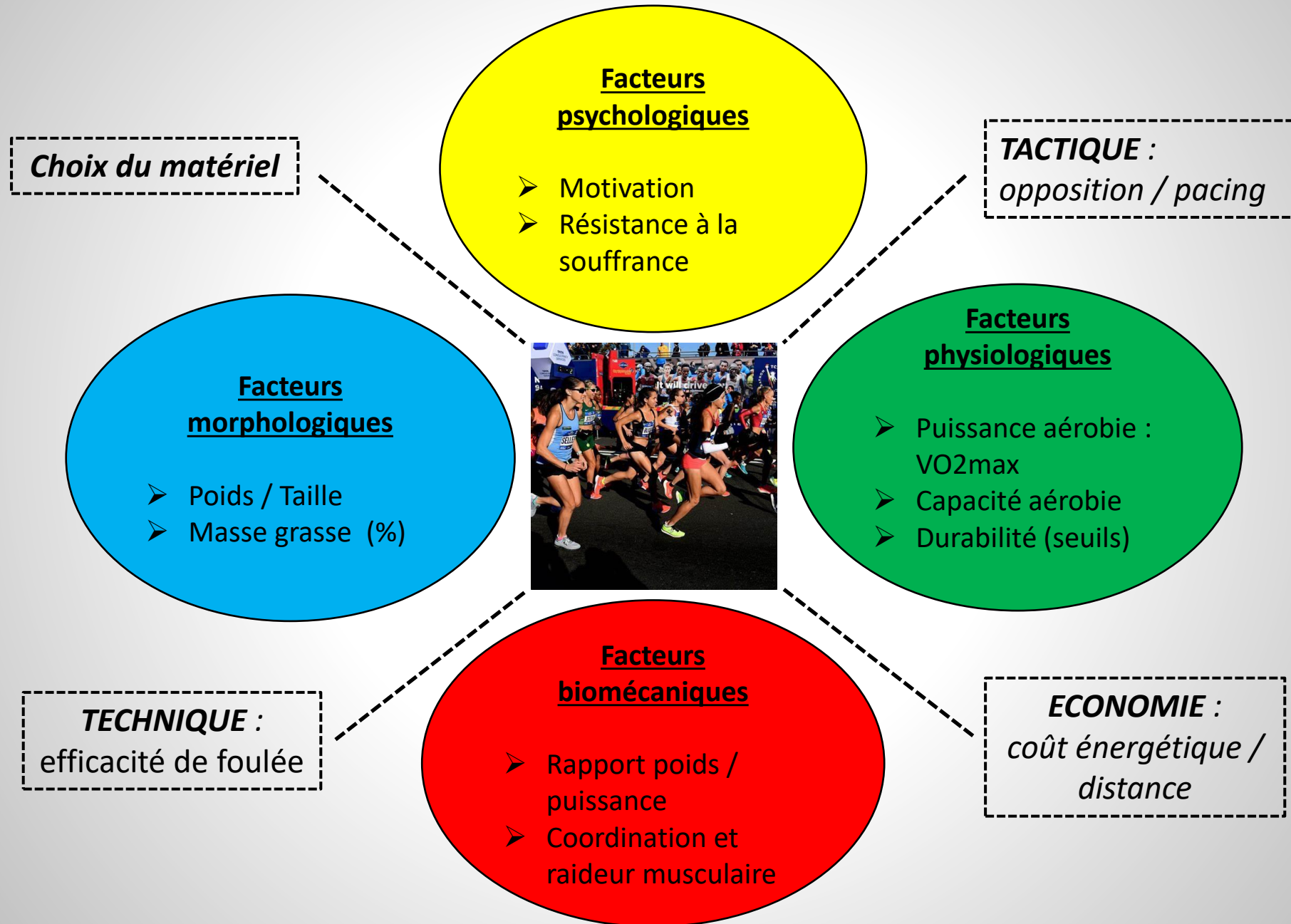


Supplémentation en fer pour une marathonienne de niveau international

Oui ? Non ? Quand ? Comment ?

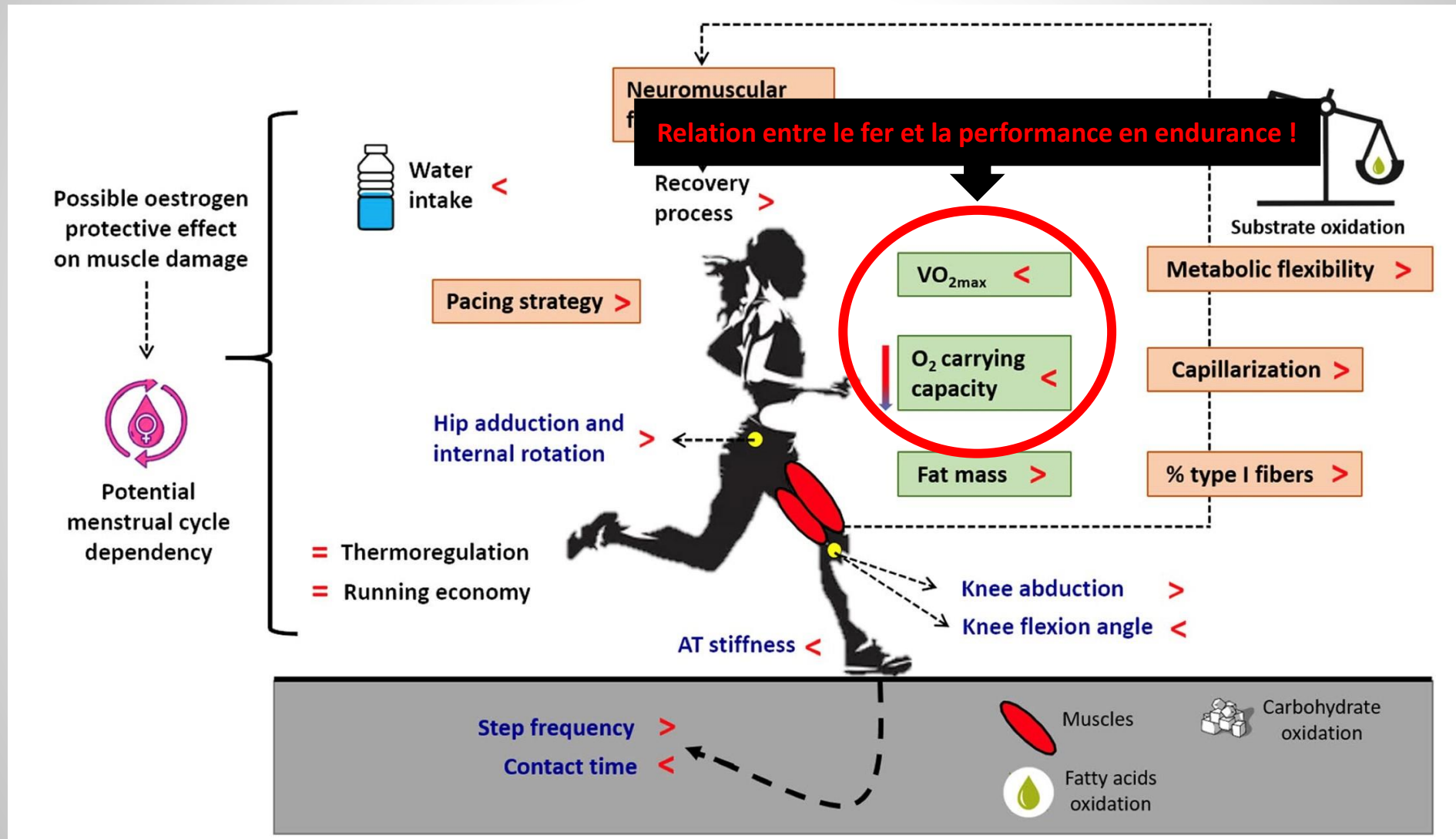


Modèle général de performance en marathon

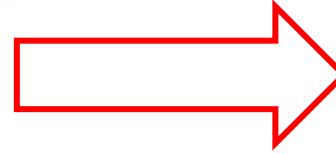
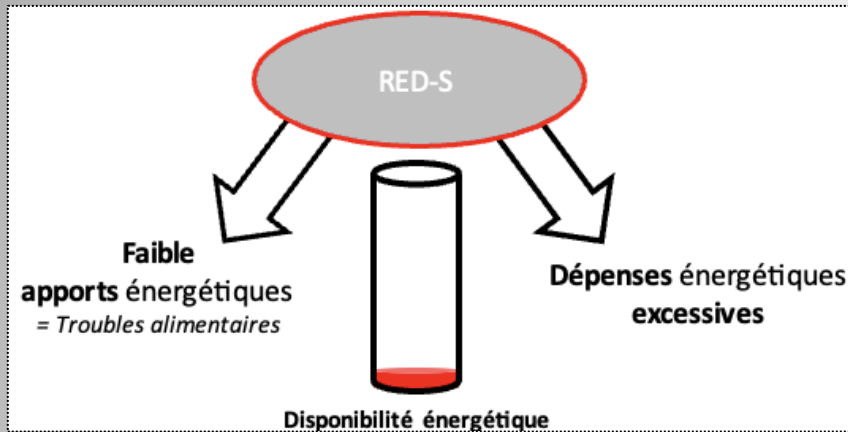


Différences HOMMES – FEMMES en sport d'endurance

Dimensions psychologiques, physiques, neuromusculaires et biomécaniques



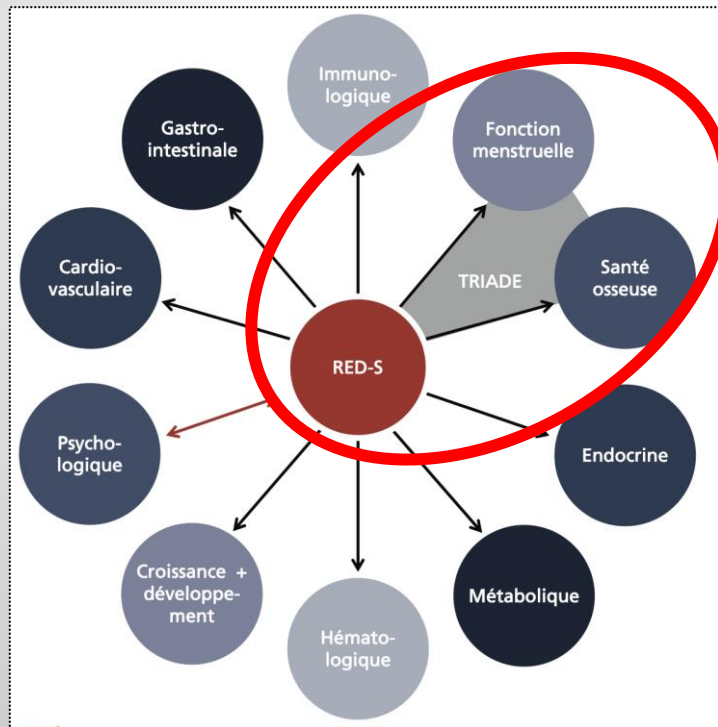
Déficiences Energétiques Relatives dans le sport (RED-s)



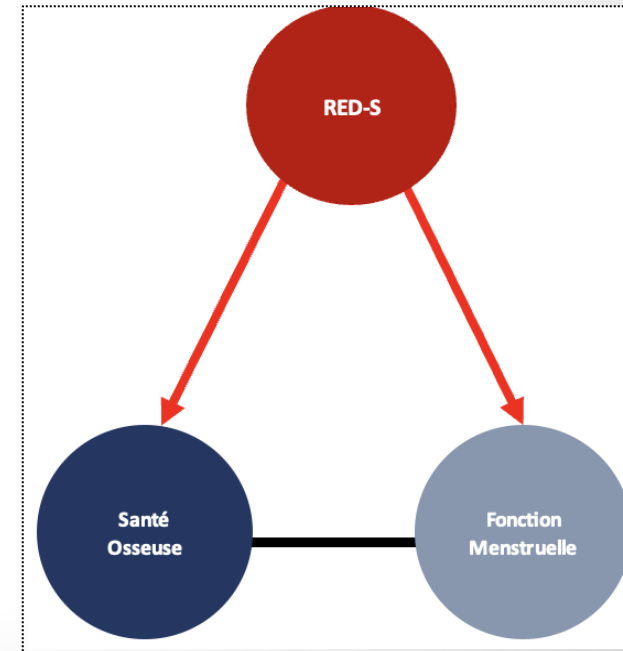
Objectifs principaux :

- ✓ Diminuer la masse grasse libre (en kg)
- ✓ Augmenter le rapport Puissance / Poids (en Watt/kg)

Conséquences du syndrome RED-S :



Triade des athlètes féminines

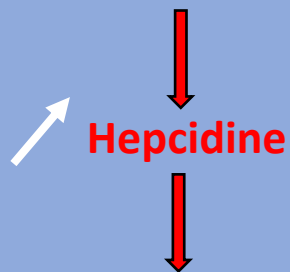


Spécificités influençant le statut martial de notre marathoniennne internationale

Pertes de Fe accrues

- ☐ Gastro-intestinal
- ☐ Tractus
- ☐ Hématurie
- ☐ Sueur

Hémolyse et inflammation à l'effort



Altération de l'absorption intestinale de Fe

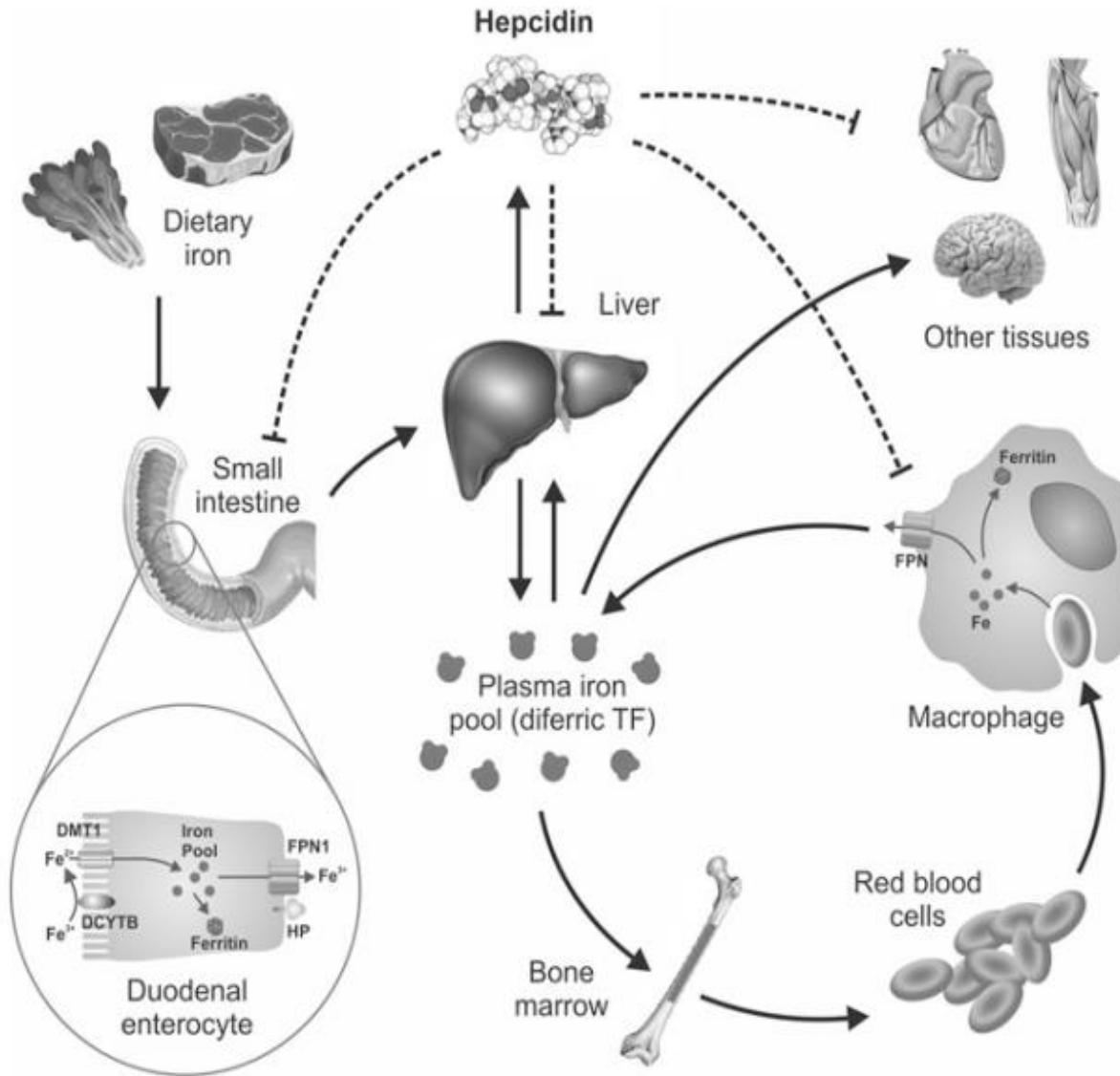


Statut menstruel de notre athlète

- ☐ Cycles menstruels réguliers
- ☐ Règles irrégulières
- ☐ Dysménorrhées
- ☐ Ménorragies
- ☐ Aménorrhées

Mauvaise alimentation
apports insuffisants (surveillance du rapport puissance/poids)

Vitamine D - Fer - Calcium



Transferrine → protéine de **transport** (Fe³⁺)

→ saturation normale entre 30 à 40 %

Ferritine → protéine de **stockage cellulaire**

→ témoin **stocks martiaux** (*Attention protéine de phase aigu / statut inflammatoire de bas grade ?*)

→ Protéines **imports** (DMT1, TFR1, ZIP's)

→ Protéines **exports** (ferroportine, FLVCR1)

Aspect cellulaire → lien avec la performance

$$V_{O2max} = FC \times VES \times d(a-v_{O2})$$

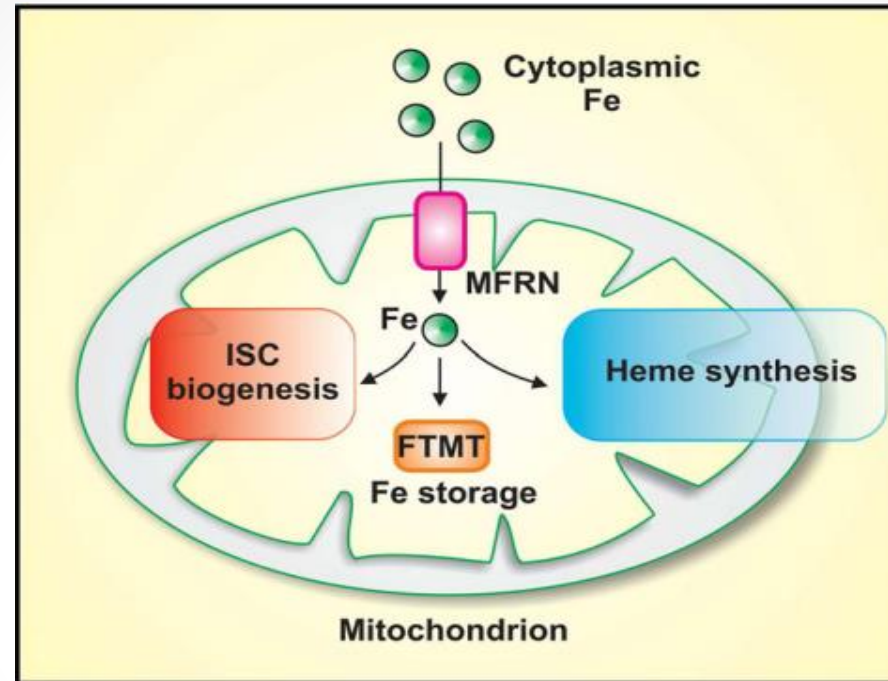
Périphérique cellulaire



Formation Fe-S

Chaine transport des électrons –
enzymes dépendantes –
Cytochromes

Processus oxydatif



Centraux / périphérique



Formation hème

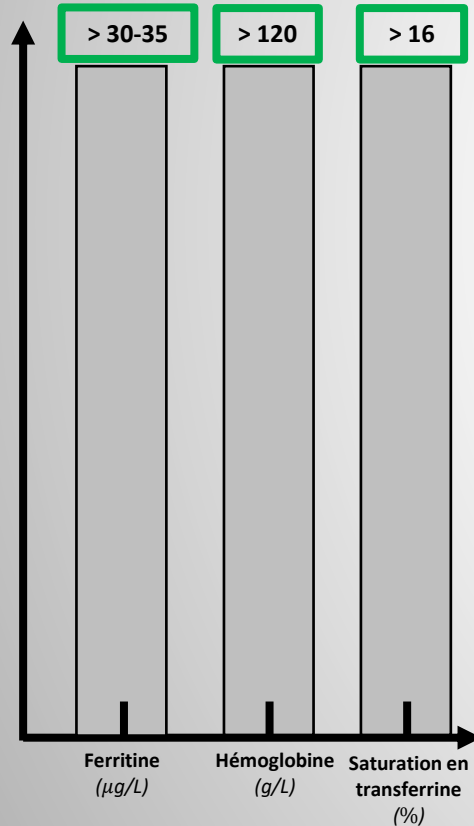
Incorporation apo-
hémoglobine/myoglobine

Transport – diffusion dioxygène /
tamponnage / stockage

Statut martial normal

Théorie : **Pas d'intérêt à supplémenter en fer**
(circuit fermé et risque de toxicité)

Statut en fer normal → **condition optimale pour s'adapter physiologiquement**



Données hématologiques (normales)

Santé

Maintien des fonctions corporelles, et de l'homéostasie, aucuns symptômes en rapport avec le fer.

Adaptations à l'entraînement

Conditions optimales pour l'adaptation du corps, vis-à-vis du stress impliqué par l'entraînement

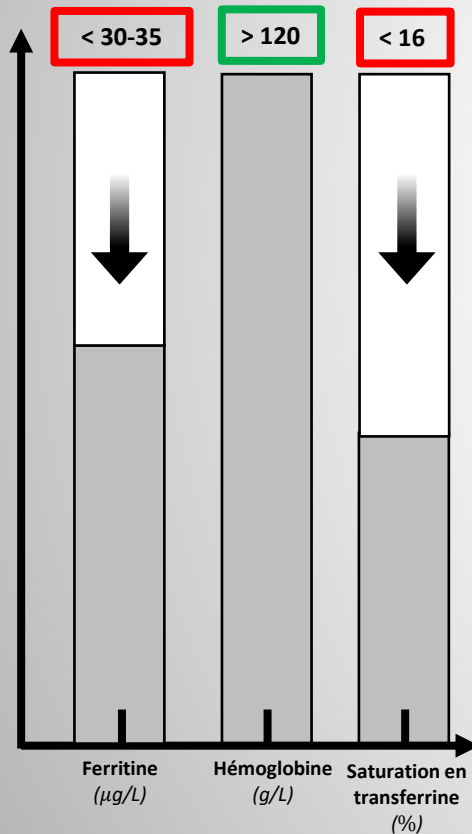
Complémentation en fer

La complémentation ne semble pas appropriée dans cette condition.

Phase A : déficient en fer non anémié (ID + IDNA)

Théorie : Impact sur la santé de l'athlète ?

Diminution de la performance liée à l'activité enzymatiques / efficacité mitochondriale ?



Données hématologiques (ID + IDNA)



Santé

Variables *	Placebo (N = 23)			Cohen's d	Fe-treatment (N = 26)			Cohen's d	P-Value & F-Value (Between groups)	Repeated measure MANCOVA (Group by Time)
	0W	2W *	4W		0W	2W	4W			
Anger-Hostility (AH)										
Mean ± sem	5.3 ± 1.03	4.5 ± 0.94	5.3 ± 0.95	2W: -0.15	4.5 ± 0.84	3.4 ± 0.80	3.4 ± 1.10	2W: -0.23	0W-2W: P = 0.439; F = 0.61	P = 0.289; F = 1.11
95% CI	3.3-7.3	2.7-6.4	3.4-7.2	4W: 0.01	2.9-6.2	1.8-5.0	1.2-5.5	4W: -0.19	0W-4W: P = 0.257; F = 1.32	
Depression-Dejection (DD)										
Mean ± sem	13.1 ± 0.94	5.9 ± 1.23	5.7 ± 1.27	2W: -1.10	11.5 ± 0.67	3.3 ± 0.86	2.9 ± 0.86	2W: -1.63	0W-2W: P = 0.040; F = 4.49	P = 0.032; F = 4.88
95% CI	11.3-14.9	3.5-8.3	3.2-8.2	4W: -1.08	10.2-12.8	1.6-5.0	1.2-4.6	4W: -1.71	0W-4W: P = 0.041; F = 4.41	
Fatigue-Inertia (FI)										
Mean ± sem	9.9 ± 0.58	6.3 ± 0.72	7.6 ± 0.94	2W: -0.93	9.4 ± 0.55	5.6 ± 0.83	5.4 ± 0.77	2W: -0.81	0W-2W: P = 0.455; F = 0.57	P = 0.136; F = 2.35
95% CI	8.8-11.1	4.9-7.8	5.8-9.5	4W: -0.47	8.3-10.5	4.0-7.2	3.9-6.9	4W: -0.90	0W-4W: P = 0.075; F = 3.32	

M.P. Kapoor et al. (2023)

Pal et al. (2021)

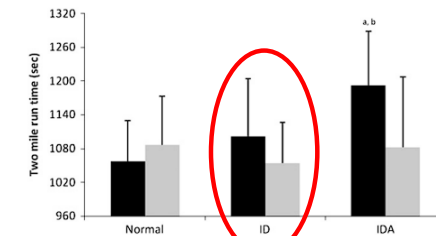
- Mauvaise concentration
- Alopécie
- Ongles striés/cassants
- Jambes douloureuses
- Tolérance réduite à l'exercice
- Mauvaise humeur
- Dépression
- Difficultés au travail
- Altère résistance infection



Adaptations à l'entraînement / performance

	Pretreatment	Posttreatment
15-km time, min		
P	31.9 ± 0.5	30.3 ± 0.7*
S	33.0 ± 0.5	29.6 ± 0.6*†
Total VO ₂ , l/min		
P	76.2 ± 3.7	77.0 ± 2.9
S	69.3 ± 3.0	73.5 ± 3.1
TT VO ₂ , l/min		
P	1.51 ± 0.06	1.56 ± 0.06
S	1.42 ± 0.06	1.51 ± 0.04*
VO _{2max} , l/min		
P	2.39 ± 0.11	2.56 ± 0.11*
S	2.11 ± 0.09	2.48 ± 0.08*
TT %VO _{2max} , %		
P	63.5 ± 1.6	60.7 ± 1.5
S	67.9 ± 1.5	61.8 ± 1.5*

P. S. Hinton et al. (2000)



J. P McClung et al. (2009)

Impact sur la santé globalement reconnue, impact sur la performance reste encore ambigu ... Conséquence de la supplémentation ferrique sur ce type de statuts martiaux ?

Phase A : déficient en fer non anémié (ID + IDNA)



Supplémentations en fer → impact sur le statut martial

	Baseline	3 wk	6 wk
Hb, g/l	132.6 ± 3.9	128.1 ± 3.7	130.8 ± 2.9
P	134.2 ± 2.6	133.6 ± 3.6	135.2 ± 2.0
Hct, %	37.9 ± 0.6	37.2 ± 0.7	38.0 ± 0.7
P	38.5 ± 0.5	37.7 ± 0.6	39.8 ± 0.6
sFer, µg/l	8.07 ± 0.77	9.01 ± 1.06	8.11 ± 0.90
P	10.38 ± 0.82	13.71 ± 1.35*†	14.52 ± 1.5*†
sTfR, mg/l	7.94 ± 0.73	7.45 ± 0.85	7.93 ± 0.77
P	7.92 ± 0.87	6.59 ± 0.53	6.78 ± 0.42*†
sFe, µmol/l	13.4 ± 1.6	15.6 ± 2.0	12.2 ± 1.8
P	12.2 ± 2.5	19.0 ± 2.9*†	19.4 ± 2.7*†
TIBC, µmol/l	65.0 ± 2.5	64.7 ± 3.5	60.7 ± 3.0
P	64.9 ± 3.6	62.1 ± 3.8	
TS, %	20.9 ± 2.0	24.1 ± 2.9	22.0 ± 3.7
P	18.7 ± 3.7	30.9 ± 3.7*†	31.9 ± 4.2*†

P. S. Hinton et al. (2000)

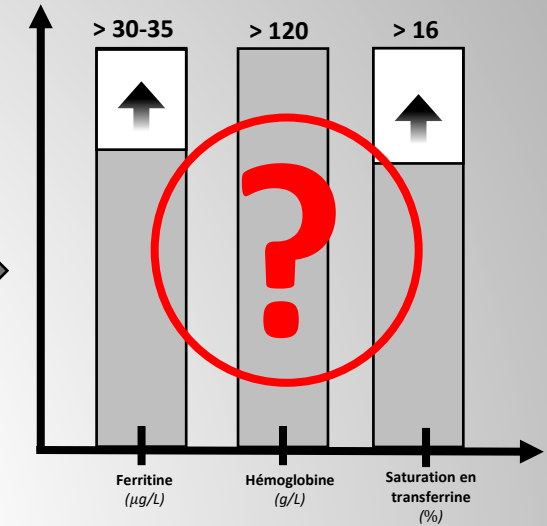
Table 2 Hematological Data Pre- and Postsupplementation (Mean ± Standard Error)

Blood marker	Iron Group			Placebo Group		
	Baseline	Day 20	Day 28*	Baseline	Day 20	Day 28
Serum iron (µmol/L)	17 ± 2	16 ± 2	14 ± 2	19 ± 2	20 ± 3	17 ± 2
Serum transferrin (µmol/L)	39 ± 3	37 ± 3	39 ± 4	34 ± 2	35 ± 1	34 ± 1
Transferrin saturation (%)	23 ± 4	23 ± 4	21 ± 6	27 ± 2	30 ± 4	26 ± 3
Serum ferritin (µg/L)	19 ± 3†	65 ± 11**†	57 ± 12**	30 ± 2	33 ± 4	37 ± 4*
Serum ferritin (% change)		276 ± 53††	243 ± 40††		8 ± 10	23 ± 8
Serum transferrin receptor (µg/mL)	5.9 ± 0.7	5.8 ± 0.8	5.5 ± 0.6	5.0 ± 0.4	4.8 ± 0.4	4.8 ± 0.4
Hemoglobin (g/L)	127 ± 3	127 ± 2	125 ± 3	128 ± 3	125 ± 2	127 ± 3

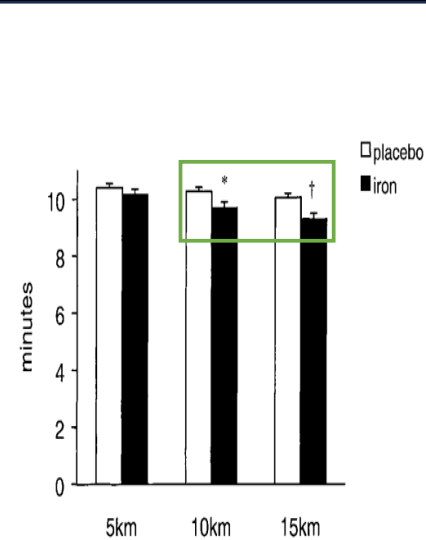
Peeling et al. (2007)

	ID (placebo, n = 14; iron, n = 14)		Effect
	Baseline	After treatment	
Hemoglobin (g/dL)			
Placebo	12.9 ± 1.6	12.8 ± 0.7	
Iron	12.7 ± 0.6	13.3 ± 0.6	
RDW (%)			
Placebo	16.8 ± 1.1	17.0 ± 1.1	T
Iron	16.3 ± 1.1	17.0 ± 1.2	
Ferritin (ng/mL)			
Placebo	26.0 ± 23.7	17.1 ± 10.4	T
Iron	30.8 ± 16.2	23.6 ± 8.3	
TS (%)			
Placebo	13.7 ± 8.6	15.4 ± 10.9	
Iron	12.1 ± 2.0	16.7 ± 8.9	
sTfR (nmol/L)			
Placebo	23.3 ± 7.5	29.4 ± 9.4	T
Iron	22.3 ± 6.8	25.8 ± 4.5	

J. P McClung et al. (2009)



Supplémentations en fer → adaptation / performance



P. S. Hinton et al. (2000)

TABLE 3. Physical performance of rowers with baseline sFer < or > 20 µg L⁻¹.

	sFer > 20 µg L ⁻¹			sFer < 20 µg L ⁻¹		
	Baseline (n = 15)	After Treatment (n = 15)	Significant Effects	Baseline (n = 16)	After Treatment (n = 16)	Significant Effects
Absolute VO _{2peak} (L·min ⁻¹)						
Placebo	3.2 ± 0.3	3.4 ± 0.2	Time, P = 0.004	3.1 ± 0.5	3.3 ± 0.6	Time, P = 0.012
Iron	3.5 ± 0.4	3.7 ± 0.3		3.1 ± 0.3	3.2 ± 0.3	
Total EE (kcal)						
Placebo	226.1 ± 26.0	233.0 ± 28.3	NS	223.6 ± 15.9	231.0 ± 15.8	Group × time, P = 0.01
Iron	239.1 ± 23.6	242.9 ± 23.7		231.1 ± 17.5	223.5 ± 15.0	
EF (%)						
Placebo	17.1 ± 1.5	17.3 ± 1.9	NS	17.4 ± 2.5	16.9 ± 2.1	Group × time, P = 0.03
Iron	17.2 ± 0.6	17.5 ± 1.6		16.7 ± 1.5	17.5 ± 1.2	
400-m time (s)						
Placebo	99.8 ± 12.2	92.2 ± 5.2	Time, P = 0.01	97.7 ± 12.0	95.4 ± 12.2	Time, P = 0.001
Iron	93.3 ± 5.6	87.2 ± 3.1		98.2 ± 3.2	93.7 ± 4.4	

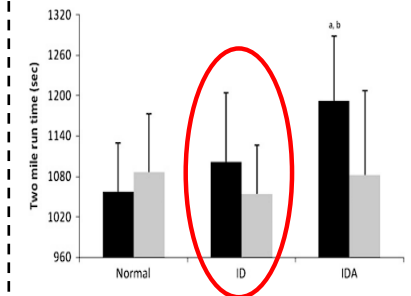
	Pretreatment	Posttreatment	Change*
4-km time, min			
Placebo (n = 16)	18.0 ± 1.0	17.7 ± 1.4	-0.2 ± 0.9
Iron (n = 15)	17.4 ± 1.3	17.8 ± 1.9	0.4 ± 1.3
Absolute VO _{2peak} , L·min ⁻¹			
Placebo	3.1 ± 0.4	3.3 ± 0.4*	0.2 ± 0.2
Iron	3.3 ± 0.4	3.4 ± 0.4*	0.2 ± 0.2
Relative VO _{2peak} , mL·kg ⁻¹ ·FFM·min ⁻¹			
Placebo	62.9 ± 5.1	65.1 ± 6.2	2.3 ± 4.5
Iron	65.2 ± 5.7	66.5 ± 5.4	1.3 ± 5.0
Maximal work rate, W			
Placebo	225.8 ± 51.1	243.1 ± 64.6**	17.3 ± 35.0
Iron	227.3 ± 25.9	254.3 ± 43.7**	27.0 ± 38.2

D.M. Dellavalle et al. (2014)

Table 3 Steady-State Submaximal Economy Exercise-Test Results, Pre- and Postsupplementation (Mean ± Standard Error)

Variable	Iron Group		Placebo Group	
	Pre	Post	Pre	Post
VO ₂ (L/min)	1.98 ± 0.09	1.98 ± 0.08	2.04 ± 0.07	1.97 ± 0.07
VO ₂ (mL·kg ⁻¹ ·min ⁻¹)	32.3 ± 1.9	32.4 ± 1.8	36.2 ± 1.5	35.2 ± 1.4
% VO _{2max}	69 ± 1	69 ± 2	70 ± 1	69 ± 2
Respiratory-exchange rate	0.97 ± 0.01	0.96 ± 0.01	0.94 ± 0.01	0.95 ± 0.08
Heart rate (beats/min)	152 ± 3	151 ± 3	144 ± 2	142 ± 2
Lactate 1 min post (mM)	1.7 ± 0.3	1.5 ± 0.2	1.4 ± 0.2	1.2 ± 0.1

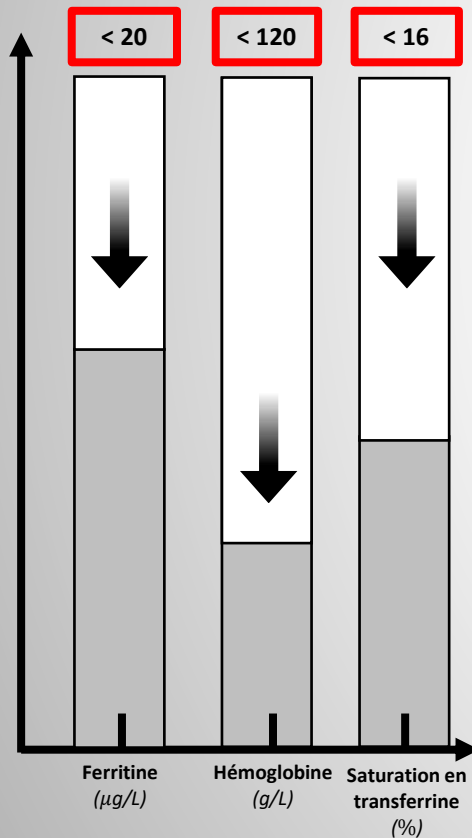
Peeling et al. (2007)



J. P McClung et al. (2009)

Phase B : déficient en fer anémié (IDA)

Théorie : Impact sur la santé et sur la performance
→ **transport du dioxygène et utilisation cellulaire**



Données hématologiques (IDA)



Santé

	Normal (placebo, n = 52; iron, n = 54)			ID (placebo, n = 14; iron, n = 14)			IDA (placebo, n = 17; iron, n = 18)		
	Baseline	After treatment	Effect	Baseline	After treatment	Effect	Baseline	After treatment	Effect
Tension									
Placebo	11.8 \pm 5.4	7.9 \pm 5.4	T	9.6 \pm 5.8	6.9 \pm 5.5	T	10.6 \pm 5.3	6.3 \pm 4.8	T
Iron	12.7 \pm 6.4	8.7 \pm 6.6		9.0 \pm 4.8	5.1 \pm 4.1		16.4 \pm 6.0	12.4 \pm 6.9	
Depression									
Placebo	11.6 \pm 9.1	6.2 \pm 9.1	T	6.7 \pm 6.9	3.8 \pm 5.9	T	10.8 \pm 9.4	4.4 \pm 7.2	T
Iron	13.4 \pm 10.2	8.1 \pm 10.5		9.7 \pm 10.4	3.4 \pm 6.6		16.8 \pm 11.5	9.3 \pm 11.4	
Anger									
Placebo	8.4 \pm 7.5	5.9 \pm 8.0	T	7.6 \pm 10.4	6.4 \pm 11.2		6.3 \pm 5.2	2.6 \pm 4.8	T
Iron	9.2 \pm 8.7	7.4 \pm 9.0		6.5 \pm 7.8	3.9 \pm 6.1		12.6 \pm 10.0	8.3 \pm 9.4	

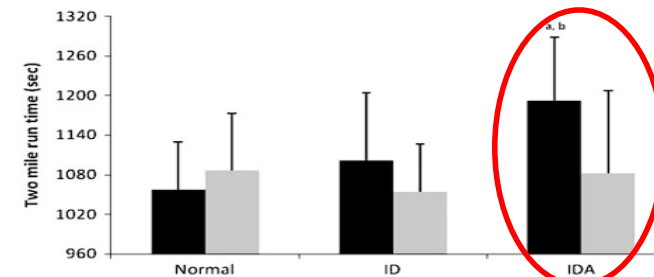
J. P McClung et al. (2009)

- Une mauvaise concentration
- Alopécie
- Ongles striés/cassants
- Jambes douloureuses
- Tolérance réduite à l'exercice
- Mauvaise humeur
- Dépression
- Difficultés au travail
- Altère résistance infection

Pal et al. (2021)



Adaptations à l'entraînement / performance



J. P McClung et al. (2009)

Impact sur la santé évident mais également sur la performance →
Conséquence de la supplémentation ferrique sur des statuts martiaux
anémiés ?

Phase B : déficient en fer anémié

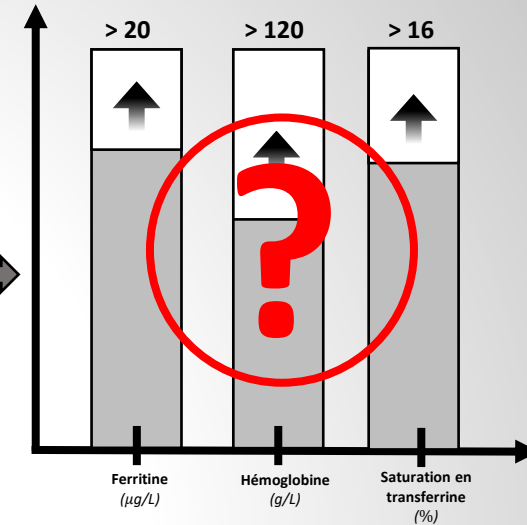


Supplémentations en fer → impact sur le statut martial

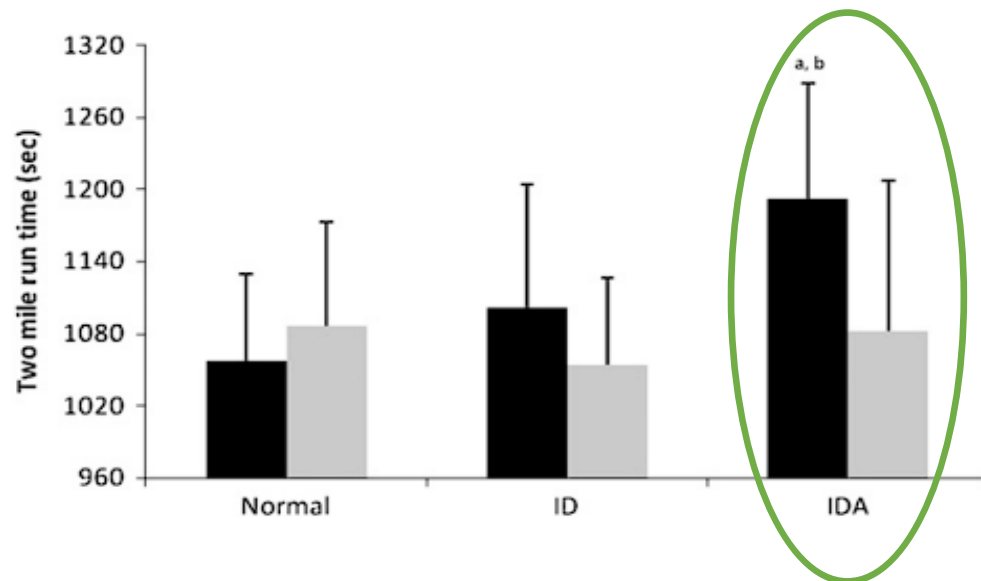
TABLE 3
Longitudinal changes in iron status during military training stratified by iron status at baseline^a

	Normal (placebo, n = 51; iron, n = 52)			ID (placebo, n = 14; iron, n = 14)			IDA (placebo, n = 17; iron, n = 18)		
	Baseline	After treatment	Effect	Baseline	After treatment	Effect	Baseline	After treatment	Effect
Hemoglobin (g/dL)									
Placebo	12.6 ± 0.9	13.2 ± 0.7	T	12.9 ± 1.6	12.8 ± 0.7		11.0 ± 1.0	11.6 ± 1.3 ²	T, G × T
Iron	12.6 ± 0.9	13.1 ± 0.7		12.7 ± 0.6	13.3 ± 0.6		11.0 ± 0.8	12.2 ± 1.2 ²	
RDW (%)									
Placebo	15.5 ± 1.1	16.2 ± 0.9	T	16.8 ± 1.1	17.0 ± 1.1	T	17.5 ± 1.8	18.3 ± 1.9	T
Iron	15.5 ± 0.9	16.2 ± 0.9		16.3 ± 1.1	17.0 ± 1.2		17.9 ± 2.2	18.8 ± 1.8	
Ferritin (ng/mL)									
Placebo	51.9 ± 30.3	33.8 ± 18.2 ²	T, G × T	26.0 ± 23.7	17.1 ± 10.4	T	14.0 ± 10.3	9.7 ± 5.5 ²	G × T
Iron	47.9 ± 30.6	40.3 ± 23.5 ²		30.8 ± 16.2	23.6 ± 8.3		10.4 ± 8.1	14.5 ± 8.7 ^{2,3}	
TS (%)									
Placebo	23.3 ± 6.0	21.0 ± 8.3		13.7 ± 8.6	15.4 ± 10.9		7.7 ± 2.8	10.3 ± 6.2	T
Iron	24.0 ± 8.3	23.8 ± 10.0		12.1 ± 2.0	16.7 ± 8.9		8.7 ± 5.1	14.6 ± 8.7	
sTfR (nmol/L)									
Placebo	18.7 ± 4.3	23.1 ± 5.3 ²	T, G × T	23.3 ± 7.5	29.4 ± 9.4	T	29.8 ± 11.0	37.6 ± 15.1 ²	T, G × T
Iron	18.5 ± 4.2	20.6 ± 5.2 ^{2,3}		22.3 ± 6.8	25.8 ± 4.5		29.6 ± 14.8	30.9 ± 16.6 ²	

J. P McClung et al. (2009)



Supplémentations en fer → adaptation / performance



When physical performance was assessed post-BCT by using the 2-mile run time, there was no difference between the placebo and the iron-treated groups in volunteers who were iron-normal or ID at the start of BCT (**Figure 1**). However, in volunteers with IDA at the start of BCT, iron treatment had a beneficial effect because mean run time was 110 s faster ($P < 0.001$) at the end of BCT in the iron-treated as compared with the placebo-treated volunteers (1081 ± 125 s compared with 1191 ± 96 s).

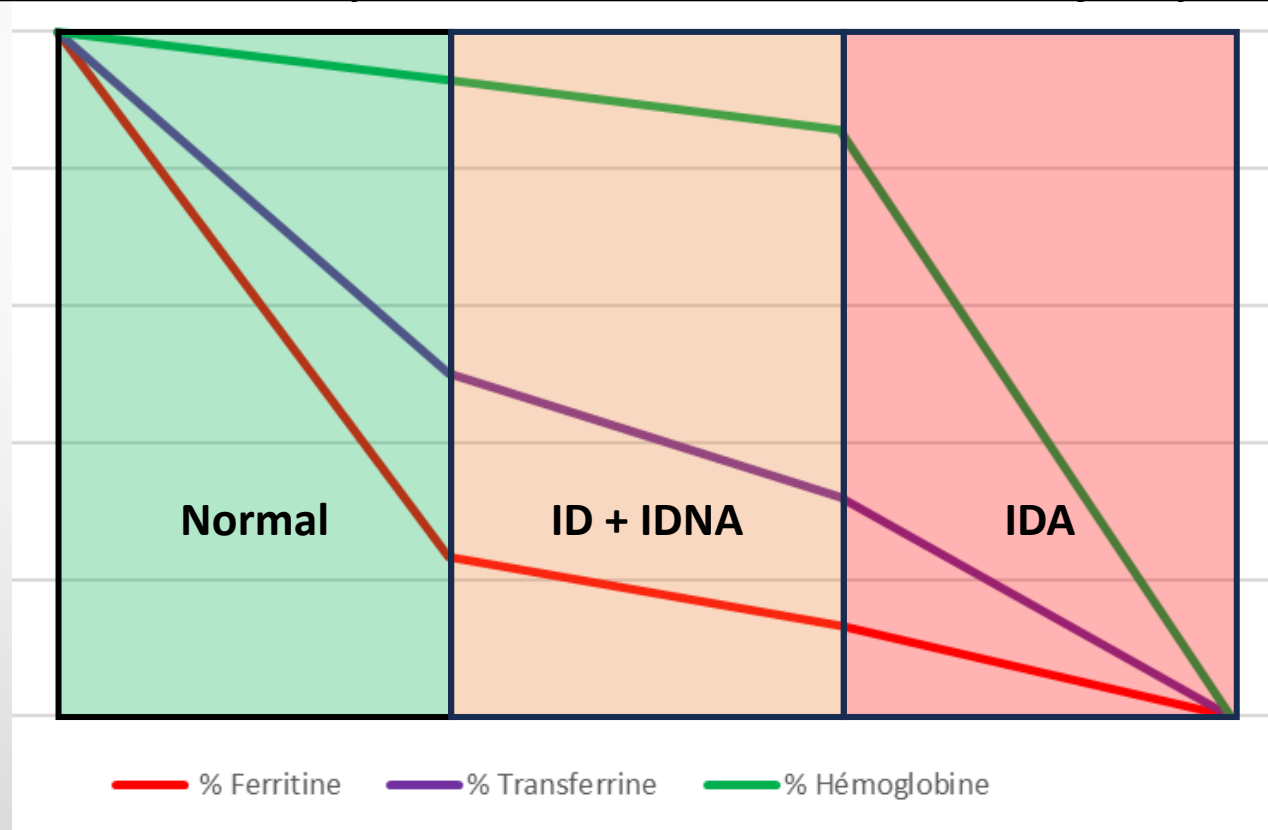
The BCT course resulted in a significant ($P < 0.05$) improvement in mood state as shown by effect of time on all subscales of the POMS questionnaire, as well as on the total score for both the placebo and iron-treated groups (**Table 4**).

J. P McClung et al. (2009)

Résumé

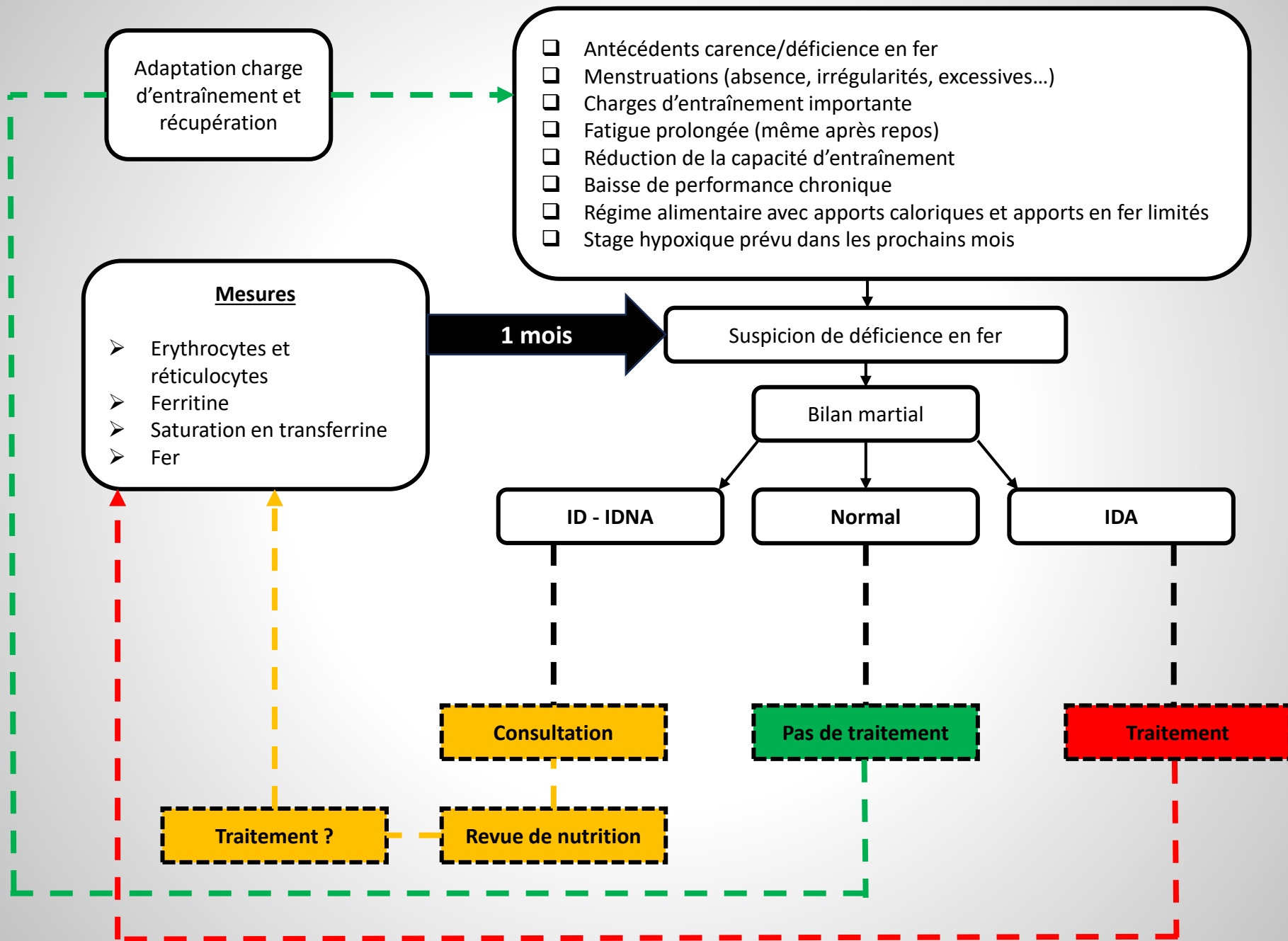
Statut martial	Normal	Déficient non anémié (stade 1 et 2)	Déficient anémié (stade 3)
Impact sur la santé	😊	😞	😞
Impact sur les adaptations	😊	😞	😞
Impact de la supplémentation sur le statut	-	😞	😊
Impact de la supplémentation sur les adaptations	-	😞	😊

Représentation schématique du statut martial et des données ferriques en UA



Arbre décisionnel - Supplémentation en fer

R
E
C
O
M
M
A
N
D
A
T
I
O
N
S



P
R
E
V
E
N
T
I
O
N
S

Revue de nutrition – IRONIC-FFQ

The content of iron in one serving of a size specified in the IRONIC-FFQ:

Group of products	Products	Serving size	Iron content/ serving (mg)
Meat	Liver (pork, beef, calf, poultry), pork kidney	100 g (palm of small hand)	13.3
	Other pork offal, poultry stomach	100 g (palm of small hand)	3.30
	Beef, calf, lamb, horse, goose, duck meat	100 g (palm of small hand)	2.60
	Pork meat	100 g (palm of small hand)	1.00
	Poultry meat	100 g (palm of small hand)	1.00
	Broth	250 g (1 glass)	0.25
Meat products	Blood pudding sausage	25 g (e.g. 1/2 of wiener, medium slice of ham, 5 slices of sausage)	4.22
	Other offal cold cuts	25 g (e.g. 1/2 of wiener, medium slice of ham, 5 slices of sausage)	1.35
	Loin cold cuts, ham, poultry sausages	25 g (e.g. 1/2 of wiener, medium slice of ham, 5 slices of sausage)	0.21
	Other sausages, wiener, smoked gammon, spam, pate, salami, brawn cold cut, bacon	25 g (e.g. 1/2 of wiener, medium slice of ham, 5 slices of sausage)	0.48
Eggs		50 g (1 egg)	1.10
Fish	Sardines	50 g (deck of cards)	1.07
	Other fish and fish products	50 g (deck of cards)	0.45
Dairy products	Milk and milk beverages (yoghurt, kefir, buttermilk, cream)	250 g (1 glass)	0.37
	Cottage cheese	50 g (1 thick slice, 2 tablespoons)	0.10
	Rennet and processed cheese	25 g (1 slice, 1 triangle serving)	0.15
Cereal products	White wheat and rye bread, bakery wares	35 g (1 slice, small roll)	0.37
	Dark bread, wholemeal, with grains, graham bread, pumpernickel bread	35 g (1 slice, small roll)	0.70
	Crispbread	10 g (1 slice)	0.40
	Wheat bran, wheat germs	10 g (1 spoon)	1.20
	Iron-fortified corn flakes and cereals	35 g (1 glass)	4.30
	Other cereal products (uncooked)	100 g (e.g. 1 glass of pasta or oatmeal, 1/2 glass of rice or groats)	2.70
Fruits	Fresh fruits	100 g (1 medium piece, 1 glass)	0.65
	Dried fruits	50 g (handful)	1.28
Vegetables	Dry legumes	100 g (1/2 of glass)	6.80
	Other vegetables	100 g (1 medium piece, 1 glass)	1.10
Potatoes		100 g (1 large piece)	0.50
Fats		10 g (1 spoon)	0.20
Nuts and seeds	Poppy, pumpkin and flaxseed	30 g (handful, 3 spoons of seeds)	3.78
	Other nuts and seeds	30 g (handful, 3 spoons of seeds)	1.28
Cocoa products	Cocoa	10 g (1 spoon)	1.07
	Chocolate	20 g (1/5 of bar)	0.41

Recommandations pratiques – Apports en fer

Fe²⁺

Héminique

Aliments riches en Fe²⁺:
Viande rouge - Poisson - Volaille

Grande biodisponibilité intestinale (15-45%)
Présent en plus faible quantité dans nos assiettes

2 types de fer

	Statut normal	Si Menstruations
Pertes en fer	0,8 - 0,9 mg/J	1,4 - 1,5 mg/J
Besoins en fer	8 – 10 mg/J	16 mg/J

Non héminique

Fe³⁺

Aliments riches en Fe³⁺:
Céréales - Légumes - Fruits - Légumineuses

Faible biodisponibilité intestinale (2-20%)
Présent en grande quantité dans nos assiettes = apport principal en fer

2

→ **Eviter d'inhiber l'absorption du fer intestinal**

Consommer le moins fréquemment possible :

- Aliments riches en **polyphénols = tanins** (thé, café, cacao, baies, raisins)
- Aliments riches en **phosphore** (<10mg/repas) (légumes et fruits secs, abats...)
- Aliments riches en **calcium** (<300 mg/jour) (lait, sardines, thym,...)

1

→ **Favoriser l'absorption intestinale du fer**

Privilégier l'association d'aliments riches en fer avec:

- Aliments riches en **vitamine C** (cassis, kiwi et fruits en général)
- Aliments riches en **citrate** (citron, orange, tomates)

3

→ **Eviter la concurrence d'absorption du fer**

Associer le moins fréquemment possible le fer avec:

- Aliments riches en **plomb** (bière, abats principalement)
- Aliments riches en **manganèse** (ananas, myrtille, thé, noix,...)
- Aliments riches en **zinc** (huîtres, fromage, chocolat)

Fenêtre d'absorption du fer

Table 1 Pre- and 3-h post-exercise hepcidin-25, pre- and immediately post-exercise interleukin-6, baseline serum ferritin, baseline Iron, and 25-km walk time for the entire study cohort (ALL) and for the median split by baseline serum ferritin; lower 50th percentile (LOW) and upper 50th percentile (HIGH). Data presented as mean \pm SD

	Hepcidin-25 (nM)		Interleukin-6 (pg/mL)		Baseline serum ferritin	Baseline serum iron	25-km walk time
	Pre-exercise	3-h post-exercise	Pre-exercise	Post-exercise	($\mu\text{g/L}$)	($\mu\text{mol/l}$)	(min)
ALL ($n = 24$)							
Mean	1.1	8.6 [†]	1.2	9.4 [†]	79.9	24.0	120.8
SD	1.0	5.3	1.1	4.6	28.1	8.2	8.0
LOW ($n = 12$)							
Mean	0.8*	6.0*	1.4	9.7	58.0*	21.6	117.7
SD	0.5	3.6	1.4	2.5	7.8	7.8	5.9
HIGH ($n = 12$)							
Mean	1.5	11.3	1.0	9.1	101.8	26.4	124.0
SD	1.2	5.4	0.5	6.1	23.4	8.2	8.8

* Indicates a significant difference from HIGH ($p < 0.05$)

[†] Indicates a significant difference from Pre-Exercise ($p < 0.05$)

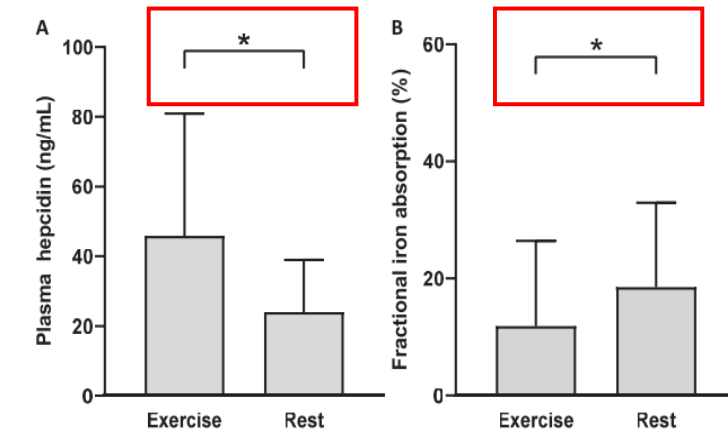


FIGURE 3 Plasma hepcidin (A) and fractional iron absorption (B) in trained female and male runners 3 h after a prolonged run and after rest. Log-transformed data were analyzed using paired t tests. Data are means \pm SDs. Two males were excluded from fractional iron absorption data for implausible absorption after exercise ($>70\%$). Inclusion of these participants did not change significance. *Significant difference ($P < 0.05$).

Table 2 Multiple regression analysis of baseline serum ferritin and serum iron levels, post-exercise interleukin-6, and the 25-km walk time, indicating the relationship to the 3-h post-exercise hepcidin-25 levels

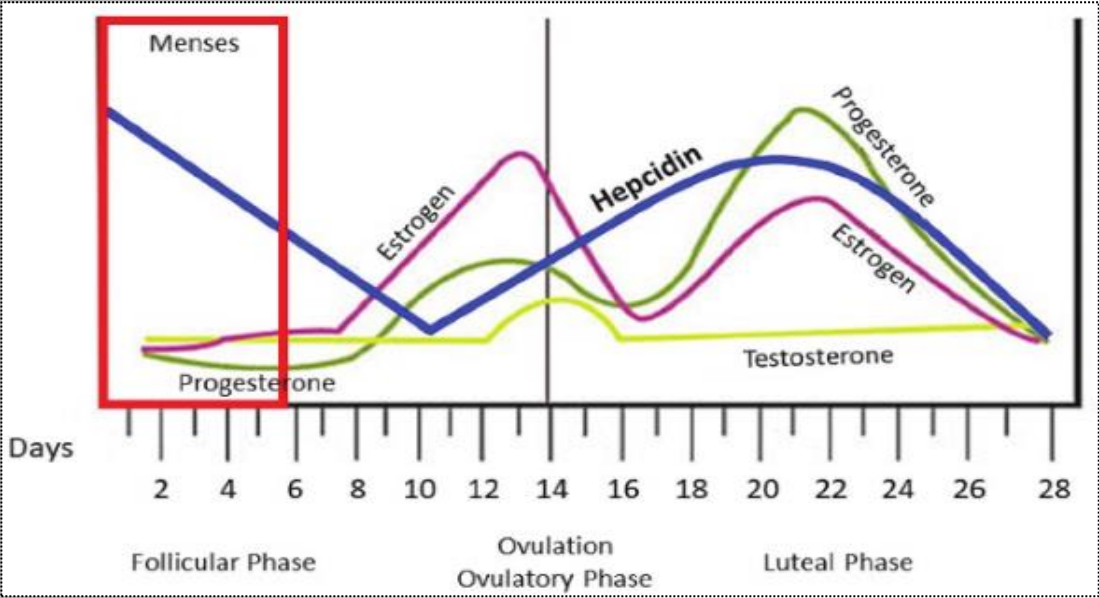
	Constant	Baseline serum ferritin ($\mu\text{g/L}$)	Baseline iron ($\mu\text{mol/l}$)	Post-exercise interleukin-6 (pg/mL)	25-km walk time (min)
β	-24.393	0.103	0.270	0.316	0.127
p value	0.019	0.0001	0.0002	0.028	0.130

Model significance (ANOVA) $p = 0.0001$; $r = 0.880$; $R^2 = 0.774$

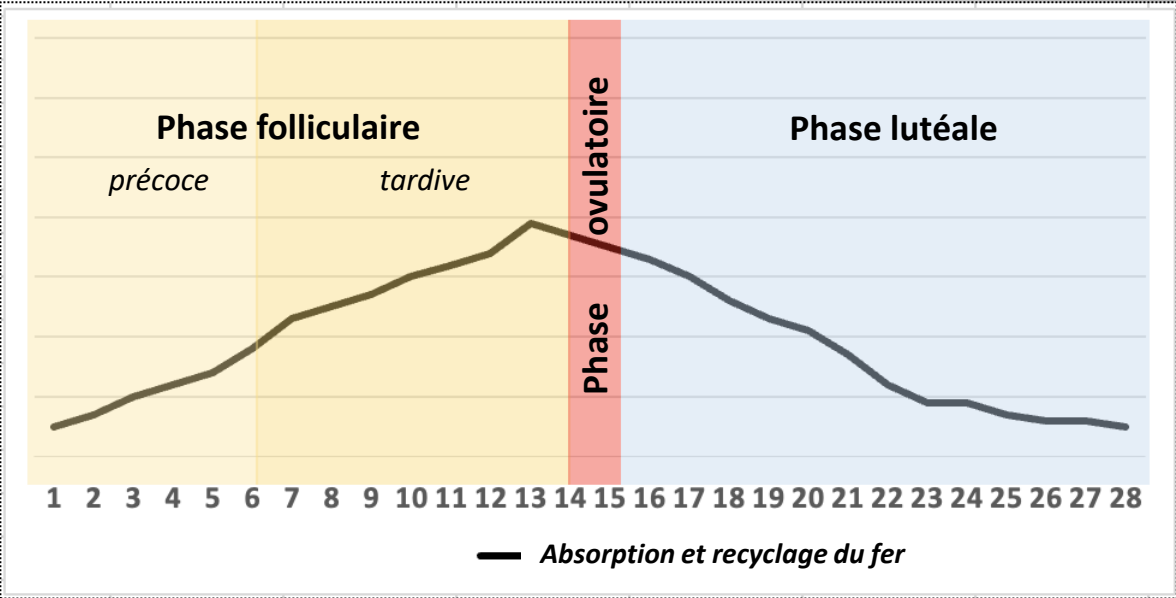
L'hepcidine pic 3h post-exercice (*statut martial normal*)

- Réflexion sur la fenêtre métabolique glucide-protéique classique post-exercice
- Mais l'apport ferrique alimentaire doit se faire sur des repas plus éloignés du pic hormonal d'hépcidine

Absorptions du fer et cycle menstruel



Représentation de l'absorption et du recyclage du fer au cours du cycle menstruel



Phase folliculaire précoce (0-5 j)	Déclin de l'activité hormonale régulatrice du fer et du sexe.	Absorption et recyclage du fer => corps féminin prêt à augmenter son absorption de fer.
Phase folliculaire tardive (6-14 j)	Augmentation progressive des œstrogènes maintenant une faible activité de l'hepcidine.	Absorption et recyclage accrue du fer dans les jours suivant les règles.
Phase ovulatoire (14 j)	Œstrogènes et pic de testostérone.	Absorption accrue de fer + érythropoïèse.
Phase lutéale (15-28 j)	Augmentation de la progestérone et des marqueurs inflammatoire corrélée à une augmentation de l'expression de l'hepcidine.	Activité de l'hepcidine +++ limitant ainsi l'utilisation du fer.

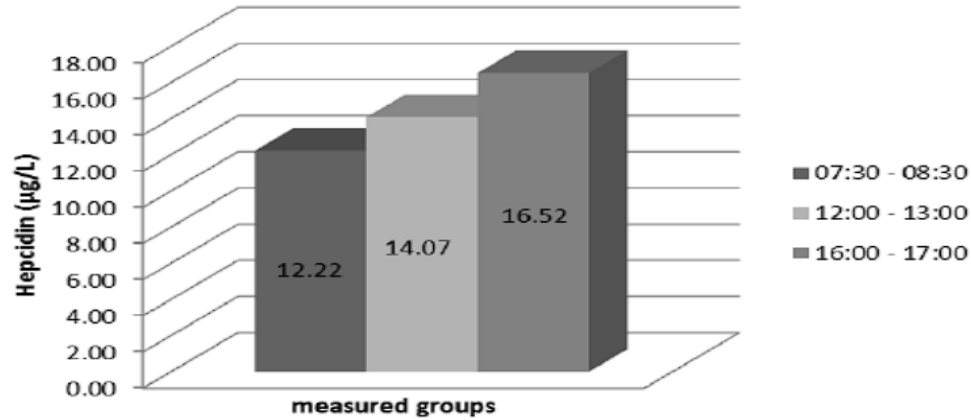
Par conséquent, la physiologie féminine serait plus réceptive et sensible au traitement nutritionnel et au supplément en fer dans la phase folliculaire

Absorptions du fer et rythme circadien

Étude réalisée sur des personnes en bonnes santé (femmes et hommes) :

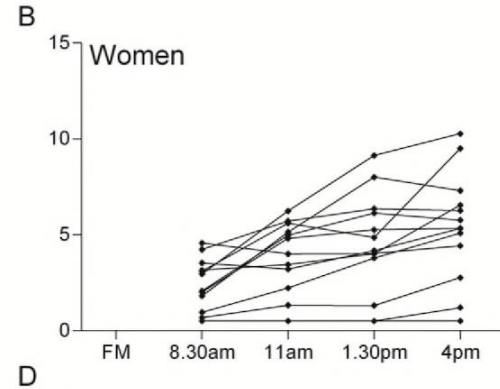
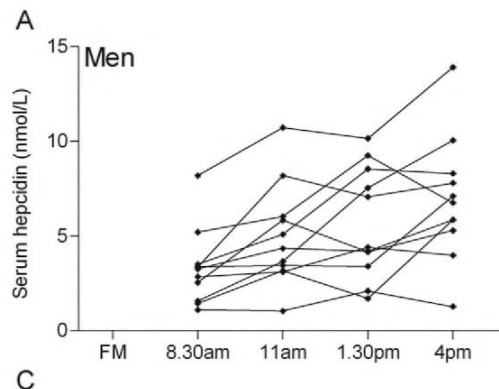
→ **Différence significative entre la valeur moyenne 07h30-08h30 et 16h00-17h00.**

→ **Pas de différences significatives entre 07h30-08h00 et 12h00-13h00.**



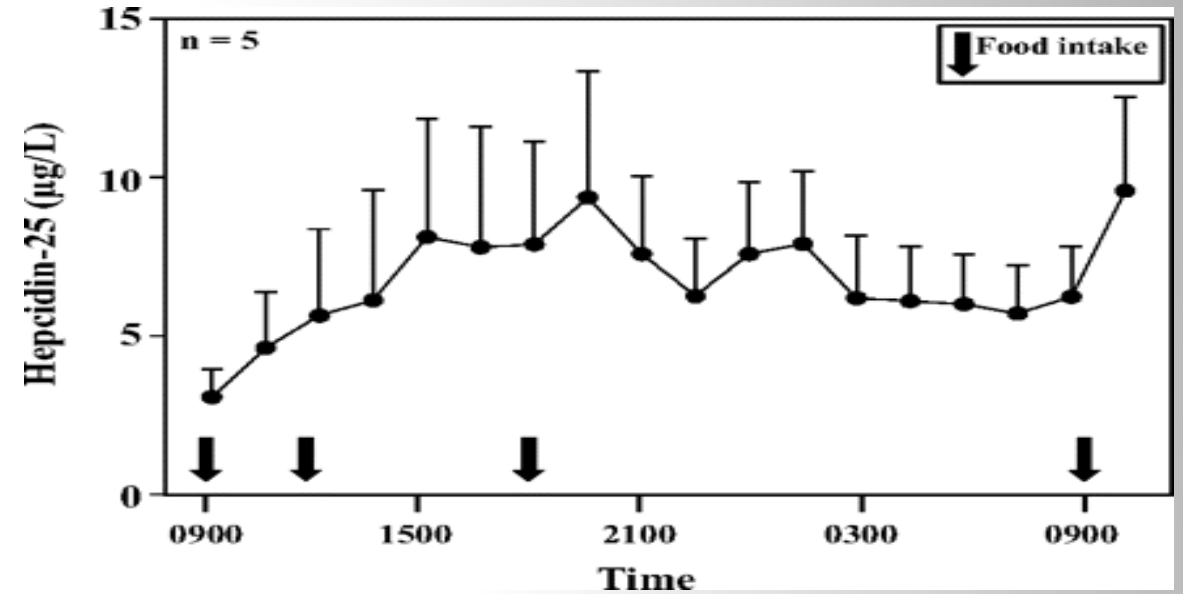
V. Manolov et al. (2015)

Les taux médians estimés d'hepcidine sérique étaient significativement différents entre tous les points de temps. Par conséquent, les **niveaux d'hepcidine sérique ont augmenté de manière significative tout au long de la journée.**



J.J.C. Kroot et al. (2009)

Les concentrations d'hepcidine 25 ont montré un rythme diurne, les concentrations étant les **plus faibles pendant les heures du matin, puis augmentant régulièrement tout au long de la journée avant de diminuer plus tard dans la soirée.**



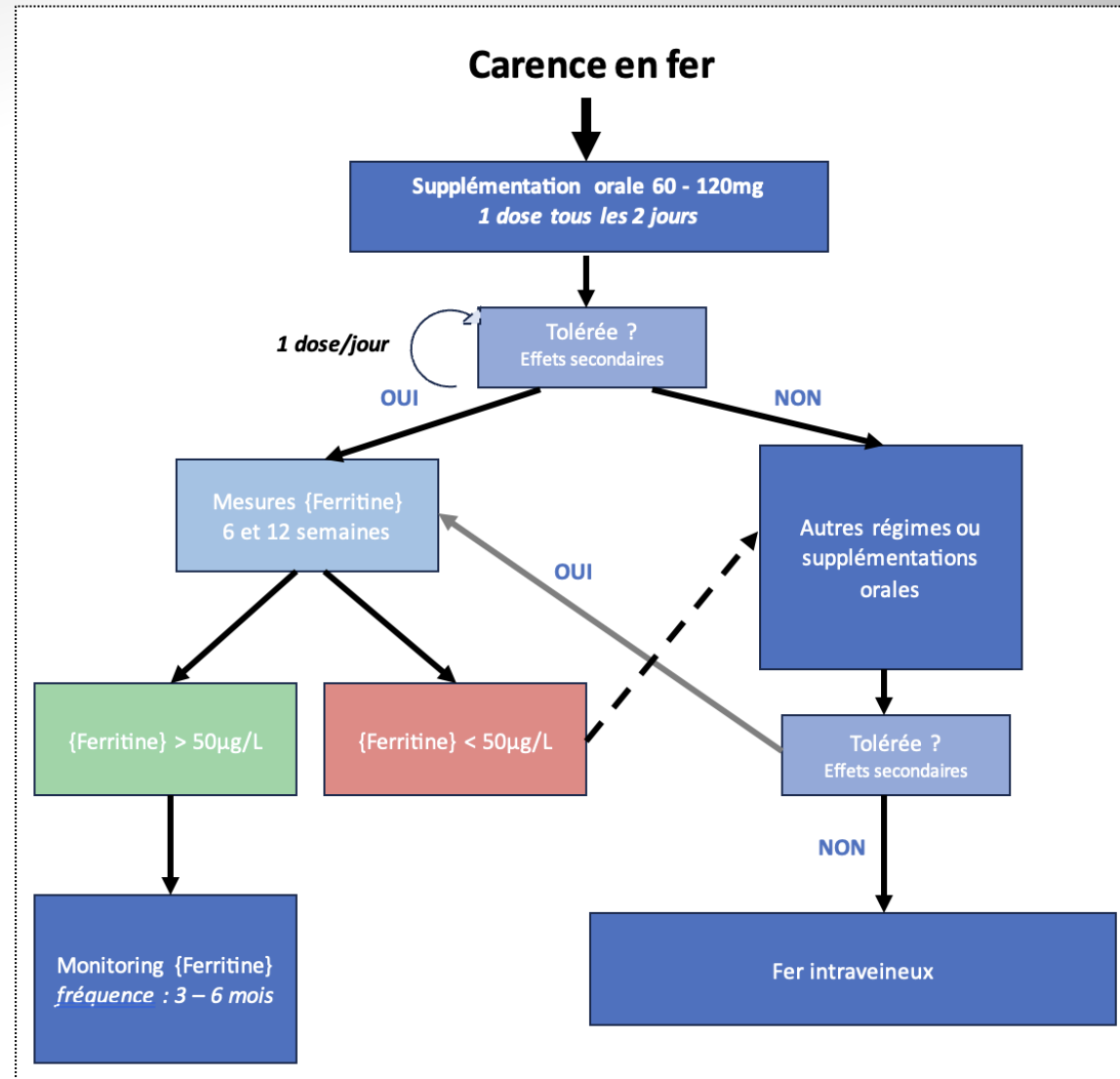
Troutt et al. (2012)

Par conséquent et de manière physiologique, notre athlète féminine serait plus réceptive et sensible à un apport nutritionnel ferrique et/ou à une supplémentation en fer dans la matinée → période durant laquelle, le taux d'hepcidine serait physiologiquement le plus faible !

Supplémentation orale - médicale

Supplémentations orales :

- ❖ Sels de Fer ferreux (*le + courant*)
- ❖ Complexe polysaccharide-fer
- ❖ Fer carbonyle
- ❖ Protéine de fer succinylate
- ❖ Chélastes d'acides aminés de fer



Le processus de supplémentation orale ou d'apport intraveineux en fer doit être décidé et encadré par un médecin

- Abbaspour, N., Hurrell, R., & Kelishadi, R. (2014). Review on iron and its importance for human health. *PubMed*, 19(2), 164-174. <https://pubmed.ncbi.nlm.nih.gov/24778671>
- Badenhorst, C. E., Goto, K., O'Brien, W. J., & Sims, S. T. (2021). Iron status in athletic females, a shift in perspective on an old paradigm. *Journal of Sports Sciences*, 39(14), 1565-1575. <https://doi.org/10.1080/02640414.2021.1885782>
- Barney, D. E., Ippolito, J., Berryman, C. E., & Hennigar, S. R. (2022). A prolonged bout of running increases hepcidin and decreases dietary iron absorption in trained female and male runners. *Journal of Nutrition*, 152(9), 2039-2047. <https://doi.org/10.1093/jn/nxac129>
- Besson, T., Macchi, R., Rossi, J., Morio, C., Kunimasa, Y., Nicol, C., Vercruyssen, F., & Millet, G. Y. (2022). Sex differences in endurance running. *Sports Medicine*, 52(6), 1235-1257. <https://doi.org/10.1007/s40279-022-01651-w>
- Coelho, A. R., Cardoso, G., Brito, M., Gomes, I. M. N., & Cascais, M. J. (2021). The female athlete Triad/Relative Energy Deficiency in Sports (RED-S). *Revista Brasileira de Ginecologia e Obstetrícia*, 43(05), 395-402. <https://doi.org/10.1055/s-0041-1730289>
- DellaValle, D. M., & Haas, J. D. (2014). Iron supplementation improves energetic efficiency in Iron-Depleted female rowers. *Medicine and Science in Sports and Exercise*, 46(6), 1204-1215. <https://doi.org/10.1249/mss.0000000000000208>
- Głąbska, D., Guzek, D., Ślęzak, J., & Włodarek, D. (2017). Assessing the validity and reproducibility of an iron dietary intake questionnaire conducted in a group of young Polish women. *Nutrients*, 9(3), 199. <https://doi.org/10.3390/nu9030199>
- Hinton, P. S., Giordano, C., Brownlie, T., & Haas, J. D. (2000). Iron supplementation improves endurance after training in iron-depleted, nonanemic women. *Journal of Applied Physiology*, 88(3), 1103-1111. <https://doi.org/10.1152/jappl.2000.88.3.1103>
- Kapoor, M. P., Sugita, M., Kawaguchi, M., Timm, D. H., Kawamura, A., Abe, A., & Ōkubo, T. (2023). Influence of iron supplementation on fatigue, mood states and sweating profiles of healthy non-anemic athletes during a training exercise : a double-blind, randomized, placebo-controlled, parallel-group study. *Contemporary Clinical Trials Communications*, 32, 101084. <https://doi.org/10.1016/j.conctc.2023.101084>
- Kroot, J. J., Kemna, E. H., Bansal, S. S., Busbridge, M., Campostrini, N., Girelli, D., Hider, R. C., Koliarakis, V., Mamalaki, A., Olbina, G., Tomosugi, N., Tselepis, C., Ward, D. G., Ganz, T., Hendriks, J. C., & Swinkels, D. W. (2009). Results of the first International Round Robin for the quantification of urinary and plasma hepcidin assays : Need for standardization. *Haematologica*, 94(12), 1748-1752. <https://doi.org/10.3324/haematol.2009.010322>

- Lainé, F., Angeli, A., Ropert, M., Jézéquel, C., Bardou-Jacquet, É., Deugnier, Y., Gissot, V., Lacut, K., Sacher-Huvelin, S., Lavenu, A., Laviolle, B., & Comets, E. (2015). Variations of hepcidin and iron-status parameters during the menstrual cycle in healthy women. *British Journal of Haematology*, 175(5), 980-982. <https://doi.org/10.1111/bjh.13906>
- Lo, J. O., Benson, A. E., Martens, K. L., Hedges, M. A., McMurry, H. S., DeLoughery, T. G., Aslan, J. E., & Shatzel, J. J. (2022). The role of oral iron in the treatment of adults with iron deficiency. *European Journal of Haematology*, 110(2), 123-130. <https://doi.org/10.1111/ejh.13892>
- Manolov, V., Velizarova, M., Atanasova, B., Vasilev, V., Lambreva, L., & Tzatchev, K. (2015). Preanalysis in serum hepcidin measurement. *Clinical Laboratory*, 61(05+06/2015). <https://doi.org/10.7754/clin.lab.2014.141114>
- McClung, J. P., Karl, J. P., Cable, S. J., Williams, K. W., Nindl, B. C., Young, A., & Lieberman, H. R. (2009). Randomized, double-blind, placebo-controlled trial of iron supplementation in female soldiers during military training : effects on iron status, physical performance, and mood. *The American Journal of Clinical Nutrition*, 90(1), 124-131. <https://doi.org/10.3945/ajcn.2009.27774>
- Mountjoy, M., Sundgot-Borgen, J., Burke, L. M., Carter, S., Constantini, N., Lebrun, C. M., Meyer, N. L., Sherman, R., Steffen, K., Budgett, R., Ljungqvist, A., & Ackerman, K. E. (2015). The IOC Relative Energy Deficiency in Sport Clinical Assessment Tool (RED-S CAT). *British Journal of Sports Medicine*, 49(21), 1354. <https://doi.org/10.1136/bjsports-2015-094873>
- Pal, S., Rishi, P., Pawaria, S., & Relayach, N. (2021). Prevalence of iron deficiency with or without anemia in female athletes - a review. *ResearchGate*. https://www.researchgate.net/publication/348756351_Prevalence_of_iron_deficiency_with_or_without_anemia_in_female_athletes_-_A_Review
- Peeling, P., Blee, T., Goodman, C., Dawson, B., Claydon, G., Beilby, J., & Prins, A. (2007). Effect of iron injections on Aerobic-Exercise performance of Iron-Depleted female athletes. *International Journal of Sport Nutrition and Exercise Metabolism*, 17(3), 221-231. <https://doi.org/10.1123/ijsnem.17.3.221>
- Peeling, P., McKay, A. K. A., Pyne, D. B., Guelfi, K. J., McCormick, R., Laarakkers, C. M., Swinkels, D. W., Garvican-Lewis, L. A., Ross, M. L., Sharma, A. P., Leckey, J. J., & Burke, L. M. (2017). Factors influencing the post-exercise Hepcidin-25 response in elite athletes. *European Journal of Applied Physiology*, 117(6), 1233-1239. <https://doi.org/10.1007/s00421-017-3611-3>
- Stoffel, N. U., Cercamondi, C. I., Brittenham, G. M., Zeder, C., Geurts-Moespot, A., Swinkels, D. W., Moretti, D., & Zimmermann, M. (2017). Iron absorption from oral iron supplements given on consecutive versus alternate days and as single morning doses versus twice-daily split dosing in iron-depleted women : two open-label, randomised controlled trials. *The Lancet Haematology*, 4(11), e524-e533. [https://doi.org/10.1016/s2352-3026\(17\)30182-5](https://doi.org/10.1016/s2352-3026(17)30182-5)
- Troutt, J. S., Rudling, M., Persson, L., Ståhle, L., Angelin, B., Butterfield, A., Schade, A. E., Cao, G., & Konrad, R. J. (2012). Circulating human hepcidin-25 concentrations display a diurnal rhythm, increase with prolonged fasting, and are reduced by growth hormone administration. *Clinical Chemistry*, 58(8), 1225-1232. <https://doi.org/10.1373/clinchem.2012.186866>