Caffeine Update

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Caffeine – The World's Most Widely Used Drug
咖啡因 – 全世界廣泛地使用的藥物

- In US alone, about 4 out of 5 people drink, eat, or consume caffeinated substance every day.
- 在美國，約4/5人每日飲用、食用或使用含咖啡因的物品
- January 1st 2004, caffeine was removed from the WADA prohibited list
- 從2004年1月1日起，咖啡因從世界反興奮劑機構於從違禁藥物名冊剔除
- Caffeine now becomes popular ergogenic aid in competitive sports
- 咖啡因現成為運動員在比賽時常用的營養強力劑

Source of Caffeine
咖啡因的來源

- Chemically known as 1,3,7-trimethylxanthine
- 化學名稱為1,3,7三甲基黃嘌呤
- Natural stimulants found in tea leaves, coffee beans, cocoa beans, kola nuts and guarana
- 在茶葉、咖啡豆、可可豆、可樂樹的堅果及瓜拉拿藤找到的天然興奮劑
- Major dietary source: Coffee, tea, chocolate, cola, some sport supplements and energy drinks
- 主要的食物來源: 咖啡、茶、朱古力、可樂、某些運動補充劑及能量飲品

Caffeine Content

Foods 食品	Caffeine content (mg/250ml) 咖啡因含量 (毫克/250毫升)
Starbucks coffee 星巴克咖啡	250
Milk tea (HK style) 港式奶茶	93
Red Bull energy drink 紅牛能量飲品	80
Instant coffee 即溶咖啡	53 – 85
Tea 紅茶	50
Green tea 綠茶	30
Coke light 健怡可樂	32
Brewed coffee 調製咖啡	26 – 135
PowerBar® Gel – caffeinated (40g sachet)	25 - 50
Coca Cola & Coke zero可口可樂及Coke Zero	23
Tao-Ti green tea with honey 道地蜂蜜綠茶	21
Decaffeinated instant coffee 去咖啡因即溶咖啡	5
Nestle low fat chocolate milk 雀巢低脂朱古力奶	3

Source: Harland (2000), Consumer Apr 2003, Powerbar product, Wikipedia


1X CAFFEINE
STRAWBERRY BANANA
flavor
PowerBar
GEL
REFUEL
STEP 2
C2 MAX
higher-octane
carb blend
Speeds more energy
to muscles
Science at powerbar.com
ELECTROLYTES
of a sports drink


2X CAFFEINE
TANGERINE
flavor
PowerBar
GEL
REFUEL
STEP 2
C2 MAX
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of a sports drink

Caffeine and Exercise
咖啡因與運動

- 1 – 13mg/kg body weight (1 hour per-exercise) improve exercise performance (Jenkins et al 2008, Doherty & Smith 2004, Cox et al 2002)
- 每公斤體重1 – 13毫克咖啡因 (運動前一小時)提許升運動表現
- There is sound evidence that caffeine enhances performance over a range of exercise situations
- 許多研究指出咖啡因能提升不同類型運動的表現
  - Endurance events (> 60 min) 耐力運動 (60分鐘以上)
    - Hogervorst et al (2008), Cox et al (2002)
  - Prolonged high intensity events (20 – 60 min) 長時間高強度運動 (20 – 60分鐘)
    - McLellan and Bell (2004), Graham and Spriet (1995)
  - Short-term high intensity events (1 – 5 min) 短時間高強度運動 (1 – 5分鐘)
    - Anderson et al (2000), Bruce et al (2000)
  - Intermittent high intensity events (e.g. team sports) 間歇性高強度運動 (例如: 團體運動)
    - Stuart et al (2005)

Caffeine and Exercise
咖啡因與運動

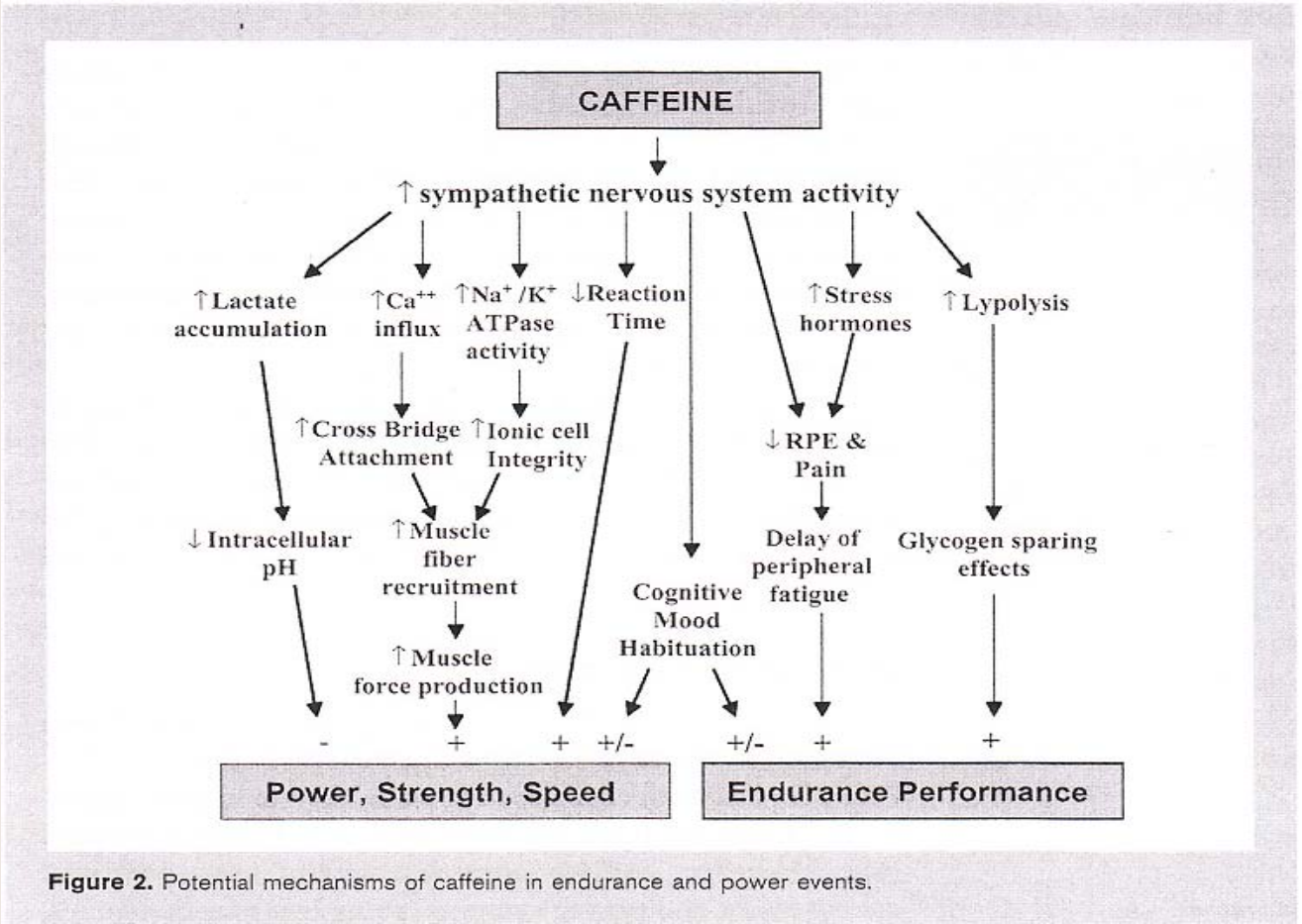


Figure 2. Potential mechanisms of caffeine in endurance and power events.

Sökmen et al (2008)

Effects of Caffeine on Psychological Factors
咖啡因與心理因素的關係

- Possible effects of caffeine on psychological functions
  - Increase mental alertness
  - Improve mood
  - Decrease tiredness
  - Decrease pain perception
  - Increase performance accuracy

- 咖啡因對心理的影響
  - 提神作用
  - 令心情愉快
  - 減低疲倦
  - 減少痛楚感覺
  - 提升準確性

Sökmen et al (2008)

Caffeine and Rate Perceived Exertion (RPE)
咖啡因與感覺盡力程度

- Doherty and Smith (2005)
- Meta-analysis study
- Aim
  - To quantify the effects of oral caffeine ingestion on RPE
  - To determine whether the perceptual response was related to exercise performance

- Doherty and Smith (2005)
- 薈萃分析
- 研究目的
  - 量化咖啡因攝取與感覺盡力程度關係
  - 確定感觀反應與運動表現的關係

Results
結果

Table 1. Chronological summary of the investigations included in the meta-analysis

First author	Year	*n*	Males	Females	Caffeine consumption	$\dot{V}O_{2max}$ (mL/kg/min)*	Caffeine abstinence (h)	Caffeine ingestion – exercise test (min)	Caffeine dosage (mg/kg)†	Exercise mode
Perkins	1975	14	0	14	NR	NR	24	30	4, 7, and 10	Cycling
Giles	1984	6	6	0	NR	67.9	24	60	5	Running
Butts	1985	15	0	15	NR	47.9	NR	60	4 and 5	Cycling
Casal	1985	9	9	0	NR	61.1	NR	60	6	Running
Tarnopolsky	1989	6	6	0	200 mg/d	63.3	15	60	6	Running
Fulco	1994	8	8	0	NR	50.4	48	60	4	Cycling
Alves	1995	8	8	0	"Low"	65.1	48	60	10	Cycling
MacIntosh	1995	11	7	4	<200 mg/d	NR	48	150	6	Swimming
Trice	1995	8	8	0	<300 mg/d	54.5	24	60	5	Cycling
Bell	1998	8	8	0	"Users"	47.0	24	90	5	Cycling
Denadai	1998	8	8	0	"Low"	NR	24	60	5	Cycling
Anderson	2000	8	0	8	Mixed	48.6	72	60	6 and 9	Rowing
Bruce	2000	8	8	0	NR	NR	72	60	6 and 9	Rowing
Bell	2002	8	5	3	<50 mg/d	50.7	12	60	5	Cycling
Bell	2002	13	10	3	>300 mg/d	51.2	12	60	5	Cycling
Collomp	2002	8	8	0	NR	54.4	168	60	6	Cycling
Cox	2002	12	12	0	150 mg/d	76.7	48	60	6	Cycling
Doherty	2002	14	14	0	130 mg/d	58.1	24	60	5	Running
Bell	2003	9	9	0	>300 mg/d	52.0	12	60	5	Cycling
Doherty	2004	11	11	0	185 mg/d	NR	24	60	5	Cycling
Birnbaum	2004	10	5	5	NR	51.0	240	60	7	Running

*Where $\dot{V}O_{2max}$ was reported in L/min, conversion to mL/kg/min was made using sample mean body mass.
†Where Amount of caffeine administered was reported as an absolute value (mg), conversion to mg/kg was made using sample mean body mass.
NR, data not reported.

Doherty and Smith (2005)

Results
結果

Table 2. Summary of RPE data obtained during constant rate exercise and following exhaustive exercise

First author	RPE scale	RPE during exercise						RPE following exhaustive exercise		
		Protocol (%$\dot{V}O_{2max}$ unless stated)	Total exercise time (min)	RPE interval (min)	*n* RPE scores	Mean RPE (%) Δ	Mean ES′ Δ	Mean RPE (%) Δ	Mean ES′ Δ	Performance (%) Δ
Perkins	1–20	GXT	3	1	3	−6.2	−0.21	2.2	0.14	−4.2
Perkins	1–20	GXT	3	1	3	−5.2	−0.16	−1.7	−0.11	−0.1
Perkins	1–20	GXT	3	1	3	−6.2	−0.21	3.0	0.20	−1.2
Giles	6–20	65	120	15	8	−8.5	−1.00	NA	NA	NA
Butts	6–20	75	NA	NA	NA	NA	NA	−1.5	−0.30	−14.4
Butts	6–20	75	NA	NA	NA	NA	NA	−1.0	−0.40	−3.1
Casal	6–20	75	45	15	3	−12.3	−2.37	NA	NA	NA
Tarnopolsky	0–10	70	90	15	6	−16.1	−0.34	NA	NA	NA
Fulco	6–20	85	10	10	3*	−7.2	−0.40	NA	NA	−4.5
Alves	6–20	80	~12.8	~12.8	1	−4.4	−0.48	NA	NA	−15.9
MacIntosh	6–20	3 × 100 m	NR	NR	1	−4.6	−0.45	−0.7	−0.06	−2.0
Trice	6–20	87.5	60	30	2	−5.8	−0.49	NA	NA	−26.5
Bell	0–10	85	10	5	2	−3.9	−0.17	7.1	0.43	−14.3
Denadai	6–20	BAT	10	10	1	−13.5	−0.14	−15.1	−1.04	−43.6
Denadai	6–20	AAT	10	10	1	−1.4	−0.01	2.3	0.17	3.8
Anderson	6–20	60 and 80†	10	4 and 6	1‡	2.8	0.19	−1.1	−0.15	−0.7
Anderson	6–20	60 and 80†	10	4 and 6	1‡	4.6	0.32	0.0	0.0	−1.3
Bruce	6–20	60 and 80†	10	4 and 6	1‡	−3.6	−0.14	0.0	0.0	−1.3
Bruce	6–20	60 and 80†	10	4 and 6	1‡	−8.0	−0.30	1.1	0.18	−1.0
Bell	6–20	50 and 80§	20	5	4	−0.6	−0.48	−1.6	−0.27	−35.1
Bell	6–20	50 and 80§	20	5	4	−3.0	−0.34	4.3	0.67	−24.4
Bell	6–20	50 and 80§	20	5	4	−2.1	−0.25	2.2	0.31	−36.6
Bell	6–20	50 and 80§	20	5	4	−4.8	−0.36	−1.6	−0.30	−17.6
Bell	6–20	50 and 80§	20	5	4	−5.9	−0.39	1.1	0.22	−21.1
Bell	6–20	50 and 80§	20	5	4	−0.9	−0.14	0.0	0.0	−4.3
Collomp	6–20	90	10	10	1	−3.1	−0.18	2.2	0.36	−2.2
Cox	6–20	70	120	20	6	−5.6	−0.46	NA	NA	−4.0
Doherty	6–20	125	2	0.5	4	−3.8	−0.22	NA	NA	−12.0
Bell¶	6–20	50 and 80§	20	5	4	−3.7	−0.45	NA	NA	−36.1
Doherty	6–20	70 and 80	12	6	2	−7.1	−0.91	NA	NA	NA
Doherty	6–20	100‖	2	0.5	4	−2.4	−0.19	NA	NA	−5.9
Birnbaum	6–20	70	30	10	3	−3.7	−0.21	NA	NA	NA
						-5.6±-5.3%		**0.01±4.2%**		**-11.2%**

*Included overall, local, and central RPE.
†% maximal heart rate.
‡Average of 4 and 6 min RPE.
§Five minutes at 50% followed by 15 min at 80% with RPE taken every 5 min.
¶Morning data only.
‖100% peak power output.
RPE, ratings of perceived exertion; GXT, graded exercise test; ES′, corrected effect size; NA, data not applicable; NR, data not reported; ↖, delta change; AAT, above anaerobic threshold; BAT, below anaerobic threshold.

Doherty and Smith (2005)

Possible Mechanisms of Caffeine Reduced RPE During Exercise
咖啡因減低運動期間感覺盡力程度的可能機制

- Exerts a direct influence on nervous system → affect both motor and sensory neurons (Kalmar & Cafarelli 2004, Tarnopolsky et al 2000)
- 咖啡因直接影響神經系統 →影響運動及感覺神經
- Improves the efficiency of respiratory system
  - Caffeine is known respiratory stimulant that augments ventilation under exercise conditions (D'Urzo et al 1990, Powers et al 1985)
    - Increase in alveolar ventilation (Brown et al 1991)
    - Enhance respiratory muscle endurance (Sunpinski et al 1986)
- 提高呼吸系統的效率
  - 在運動情況下，咖啡因可以增強換氣
    - 增加氣泡通氣量
    - 增強呼吸肌肉的耐力
- Enhances analgesia → changes in mood (Laska et al 1982)
- 提高止痛/麻醉感 → 情緒的改變

Caffeine and Endurance Performance
咖啡因與耐力表現

- 2 studies performed
  - Study A
    - To determine the timing of caffeine intake to endurance performance
    - To compare the effects of Coca-cola ingestion late in the last 30% of exercise against the conventional caffeine dose
  - Study B
    - To determine the separate effects of the caffeine content of Coca-cola and its higher carbohydrate concentration (11% Coca-cola vs 6% sports drink) and endurance performance

- 進行2個研究
  - 研究A
    - 測試咖啡因攝取時間與耐力表現
    - 在運動後期飲用可口可樂與傳統咖啡因攝取功效比較
  - 研究B
    - 測試可口可樂咖啡因及高碳水化合物與耐力表現的關係

Cox et al. (2002)

Methodology
方法

- Well-trained male cyclist
  - Study A: 12
    (VO_{2max}: 66.4±1.3 ml/kg/min)
  - Study B: 8
    (VO_{2max}: 71.2±2.2 ml/kg/min)
- Habitual caffeine daily intake: ~150mg
- No caffeine intake for 48 hours prior to experiment
- Standardized diet and no training 24 hours prior to experiment
- Standardized pre-trial breakfast (eaten in the lab)
- Keep food and activity records

- 久經訓練的男性單車手
- 研究A: 12
  (VO_{2max}: 66.4±1.3 ml/kg/min)
- 研究B: 8
  (VO_{2max}: 71.2±2.2 ml/kg/min)
- 慣常咖啡因每天攝取量: ~150毫克
- 測試前48小時嚴禁攝取咖啡因
- 測試前24小時劃一飲食 + 限制訓練
- 統一測試前的早餐 (在實驗室進食)
- 飲食及運動記錄

Cox et al. (2002)

Study A: Protocol
研究A: 測試方法

120 min cycling at 70% VO_{2max}

TT 7kJ/kg

120

BF

2gCHO/kg

	-60	0	20	40	60	80	100	120	
	*	* *	*	*	*	*	*		Testing
		*	*	*	*	*	*		Sports Drink
Pre	■	■	■	■	■	■	■		Sports Drink
During	■	■	■	■	■	■	■		Sports Drink
Placebo	■	■	■	■	■	■	■		Sports Drink
Coke							Coca Cola		Coca Cola

5ml/kg BW

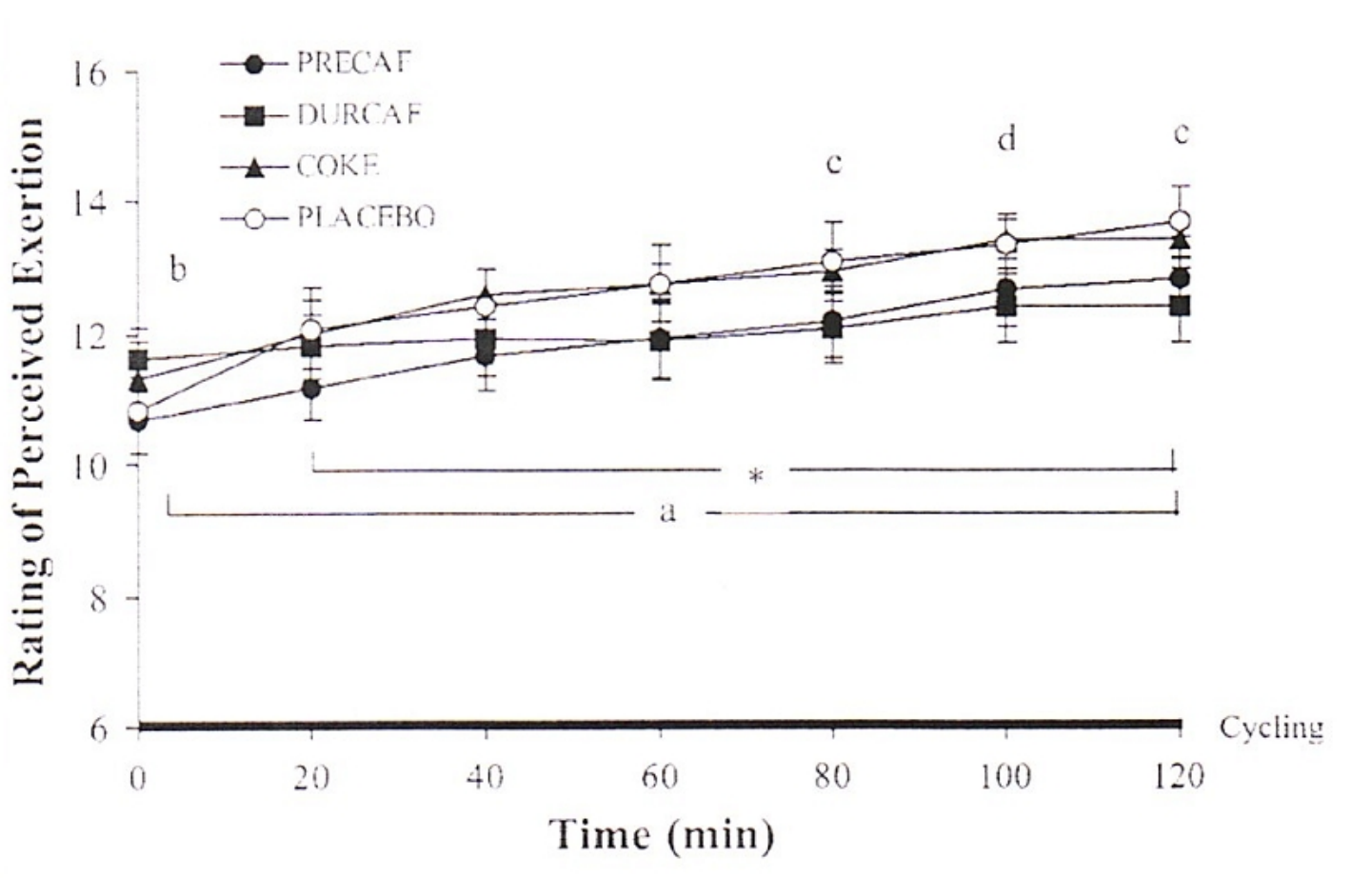
■ 1mg/kgbw caffeine 1毫克/公斤體重咖啡因

■ 6mg/kgbw caffeine 6毫克/公斤體重咖啡因

■ Placebo 安慰劑

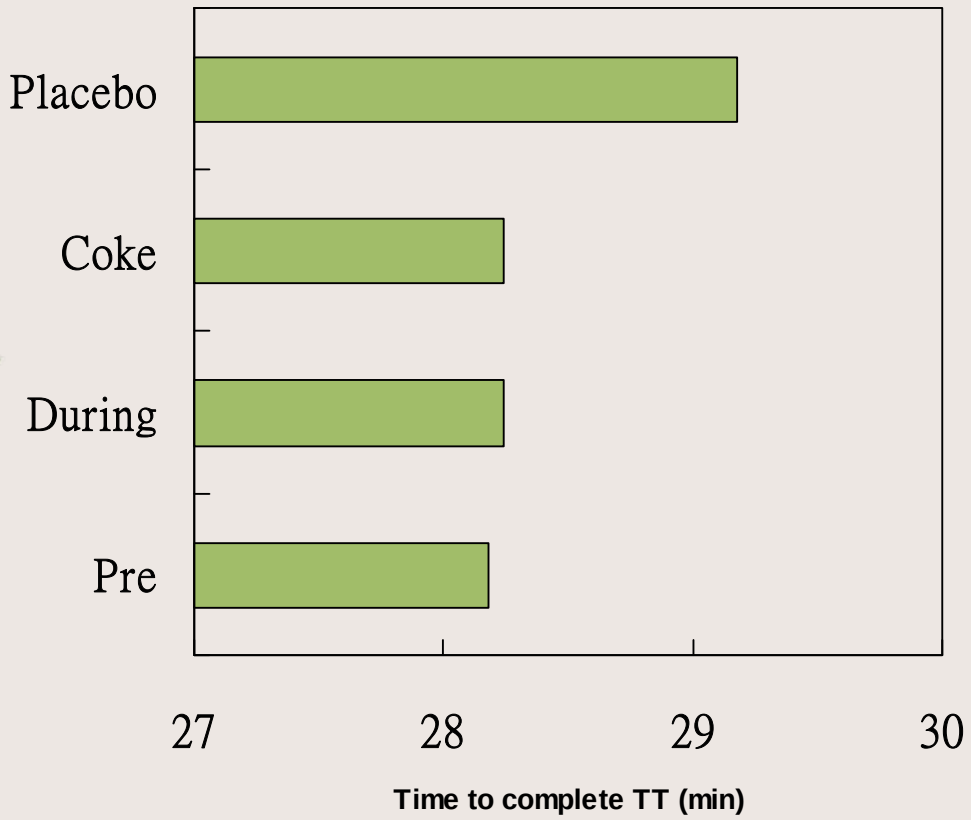
Cox et al. (2002)

Rating of Perceived Exertion
感覺盡力程度



Cox et al. (2002)

Time trial Performance
計時測試表現



Improvement

3.1% [-0.1 – 6.2%]

3.1% [-0.2 – 6.5%]

3.4% [0.2 – 6.5%]

Cox et al. (2002)

Study B: Protocol
研究 B: 測試方法

120		120 min cycling at 70% VO_{2max} Max							TT 7kJ/kg
BF									
2gCHO/kg	-60	0	20	40	60	80	100	120	
	*	* *	*	*	*	*	*		Testing
		*	*	*	*				Sports Drink

Decaf 6% CHO cola-flavored drink (Control)

Caf (13mg/100ml) 6% CHO cola-flavored drink (Caffeine)

Decaf 11% CHO cola-flavored drink (Extra CHO)

Caf (13mg/100ml) 11% CHO cola-flavored drink (Coke)

Control	Control			Control
Caffeine	Caffeine			Caffeine
Extra CHO	Extra CHO			Extra CHO
Coke	Coke			Coke

Cox et al. (2002)

Time Trial Performance
計時測試表現

Control	Caffeine
27:05±0:42 min	26:36±0:42 min 1.9% (-0.6 – 4.41%)
Extra CHO	Coke
26:55±0:43 min 0.6% (-1.8% - 3.1%)	26.15*±0:43 min 3.3% (0.8 – 5.9%)

Main effect of caffeine: 2.2% (0.5 – 3.8%) ($p<0.05$)

Main effect of additional CHO: 1.0% (-0.7 – 2.7%)

Cox et al. (2002)

Caffeine and Intermittent-Sprint Performance

- Schneiker et al. (2006)
- Aim of study
  - To determine the effect of ingestion of 6mg/kgbw caffeine on prolonged-duration, intermittent-sprint exercise
- 10 moderately trained, male team sports athletes

  (VO_{2max}: 56.5±8.0 ml/kg/min)
  - Football
  - Soccer
  - Hockey

- Schneiker et al. (2006)
- 研究目的
  - 測試攝取6毫克/公斤體重咖啡因對長時間，間歇性爆發運動的影響
- 10適度訓練的男性團隊運動員

  (VO_{2max}: 56.5±8.0 ml/kg/min)
  - 欖球
  - 足球
  - 曲棍球

Protocol
測試方法

- Before test
  - No alcohol and vigorous exercise 48 hours
  - No caffeine-containing products 48 hours
  - No food or beverages before arrival at the lab
- Standardize pre-test meal
  - 2g/kgBW of 100% glucose powder with 1L water 2.5-hour before the test
- Either ingest caffeine (6mg/kgBW) or placebo + 200ml water 1-hour before test
- Keep food and activity records

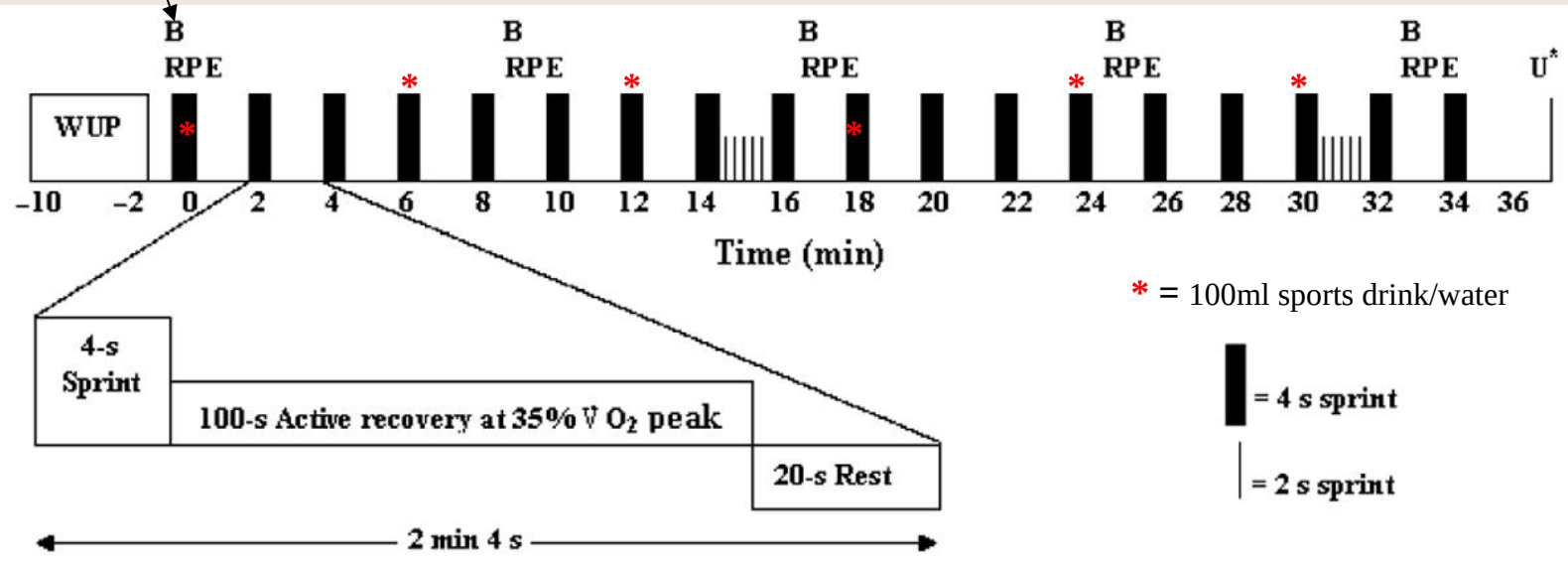
- 測試前
  - 48小時嚴禁酒精及劇烈運動
  - 48小時嚴禁含咖啡因產品
  - 到達實驗室前嚴禁飲食
- 劃一測試前的餐飲
  - 測試前2.5小時，2克/公斤體重 100%葡萄糖粉 + 1公升水
- 測試前1小時，攝取咖啡因(6毫克/公斤體重)或安慰劑
- 飲食及運動記錄

Schneiker et al. (2006)

Protocol
測試方法

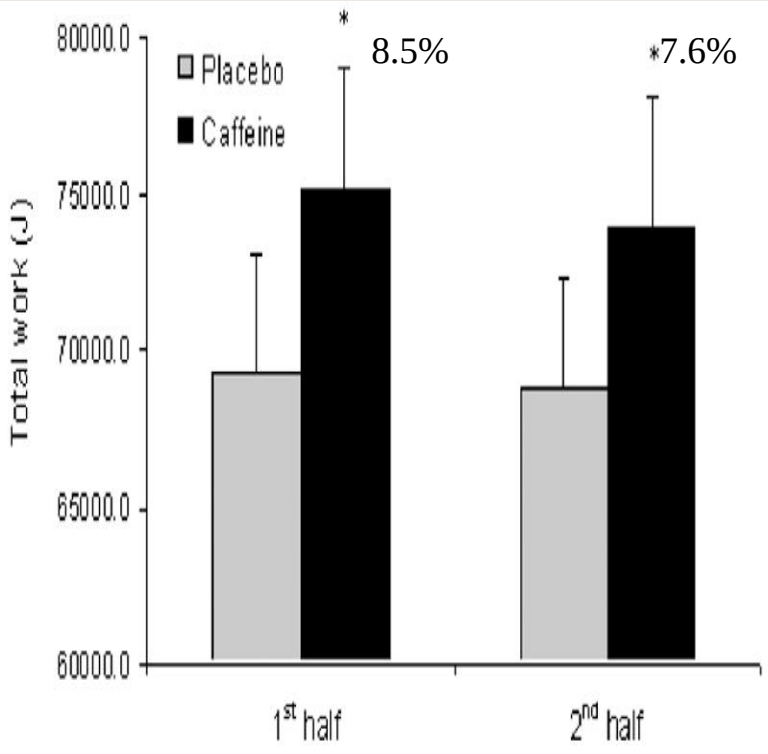
Blood sample

RPE measurement



Schneiker et al. (2006)

Results
結果

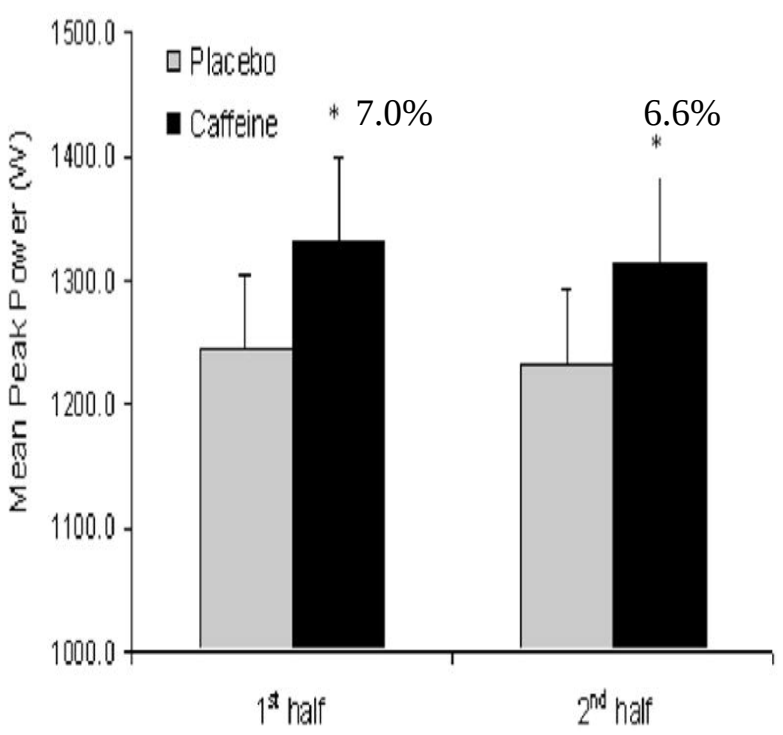


ES: 0.50 ES: 0.46

- Total amount of sprint work
  - Caffeine trial was significantly greater than placebo trial in both half of intermittent-sprint tests ($p<0.05$)
- 爆發力的總和
  - 服用咖啡因明顯比安慰劑多爆發力 ($p<0.05$)

Schneiker et al. (2006)

Results
結果



ES: 0.40 ES: 0.43

- Mean peak power
  - Caffeine trial was significantly greater than placebo trial in both half of intermittent-sprint tests ($p<0.05$)
- 平均最大爆發力
  - 服用咖啡因明顯比安慰劑高 ($p<0.05$)

Schneiker et al. (2006)

Caffeine and Muscle Glycogen Synthesis
咖啡因與肌醣合成

- Muscle glycogen accumulation following exhaustive exercise is enhanced by adequate intake of carbohydrate
- Studies demonstrated that coingestion of caffeine with carbohydrate had a positive effect on glucose uptake during and after exercise
(Yeo et al 2005, Battram et al 2004)

- 在劇烈運動後，迅速的肌醣儲存需要補充充足的碳水化合物
- 研究指出在運動期間或運動後攝取碳水化合物同時加入咖啡因有助葡萄糖吸收
(Yeo et al 2005, Battram et al 2004)

Is It True??
真的嗎??

- Pedersen et al (2008)
  - Measure the rate of muscle glycogen accumulation during recovery from exhaustive exercise when subjects ingested caffeine associated with a carbohydrate ingestion
  - 7 endurance-trained athletes
    - Cycling >250km/week
    - VO_{2max}: 71.2±2.2 ml/kg/min
    - Not habitual caffeine user

- Pedersen et al (2008)
  - 量度在消耗性運動後恢復期間攝取碳水化合物與咖啡因對肌醣儲存的速度
  - 7位耐力運動員
    - 踏單車 >250公里/星期
    - VO_{2max}: 71.2±2.2 ml/kg/min
    - 沒有慣常使用含咖啡因的產品

Protocol
測試方法

- Before the test
  - NO caffeine-containing substance for 48 hours
  - Exhaustive cycle exercise (16-hour prior to the test)
  - Low carbohydrate diet (evening meal before the test)
  - Keep food and activity records

- 測試前
  - 48小時嚴禁含咖啡因產品
  - 16小時進行衰竭性踏單車運動
  - 低碳水化合物餐 (在測試前一天的晚餐)
  - 飲食及運動記錄

Pedersen et al. (2008)

Protocol
測試方法

- 10 – 12 hours overnight fast
- 10 – 12 小時禁食

	70% VO_{2max} until volitional fatigue	4-recovery phase						
Minutes		0	30	60	90	120	180	240
Muscle biospy		*		*				*
Blood sample		*	*	*	*	*	*	*
4g CHO/kgBW (CHO)		*		*		*	*	
4g CHO/kgBW + 8mg/kg BW caffeine (CAFF)		*		*		*	*	

Pedersen et al. (2008)

Results
結果

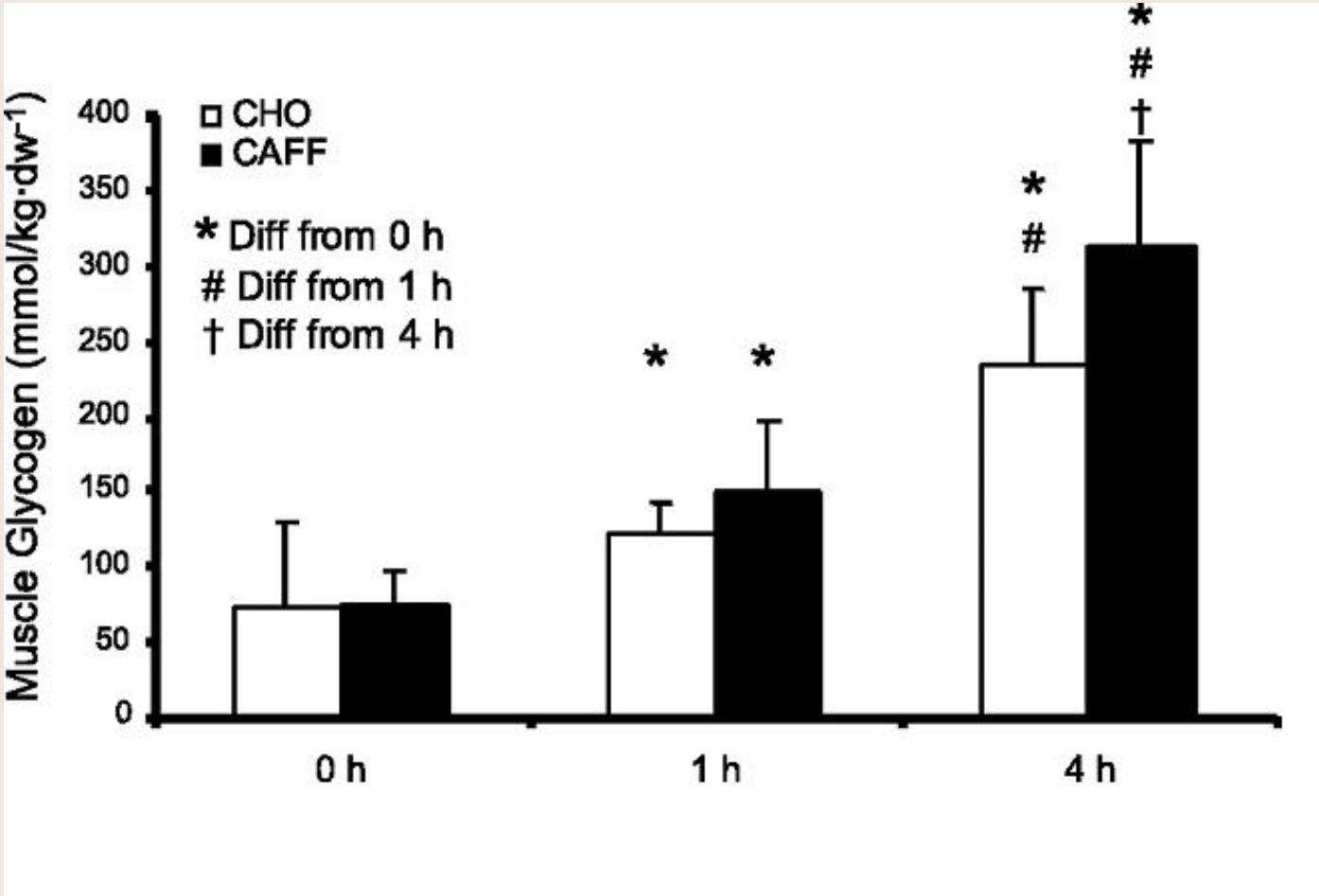
Table 1. *Blood glucose and plasma insulin concentrations at rest and after exercise*

	Rest	0 h	0.5 h	1 h	1.5 h	2 h	3 h	4 h
Glucose, mmol/l								
CHO	3.9±0.2	3.5±0.3	6.1±0.8[a,b]	5.9±0.8[a,b]	5.4±1.1[a,b]	5.7±1.2[a,b]	4.7±1.0[b,c,d,e]	4.6±0.6[b,c,d,e]
Caff	4.0±0.3	3.6±0.6	6.1±0.5[a,b]	6.3±0.8[a,b]	6.0±1.1[a,b,f]	5.6±1.4[a,b]	5.2±0.9[a,b,f]	5.2±0.9[a,b,f]
Insulin, μU/ml								
CHO	8.3±3.2	4.3±1.7	24.4±11.7	24.5±9.3	35.0±10.9[g,h]	34.0±15.7[g,h]	44.3±21.3[g,h]	36.8±24.5[g,h]
Caff	9.4±3.3	4.2±1.9	30.2±15.2[h]	29.2±7.8[h]	46.3±16.7[g,h]	46.0±20[g,h]	68.5±32.5[i]	46.9±30.4[g,h]

Values are means ± SD. During recovery subjects consumed 1 g carbohydrate/kg body mass (BM) (CHO) or 1 g carbohydrate/kg BM + 8 mg caffeine/kg BM (Caff). Glucose significant difference ($P < 0.05$): [a]vs. rest, [b]vs. 0 h, [c]vs. 0.5 h, [d]vs. 1 h, [e]vs. 2 h, [f]Caff vs. CHO. Insulin significant difference ($P < 0.05$): [g]vs. rest, [h]vs. 0 h, [i]vs. all.

Pedersen et al. (2008)

Results
結果



Pedersen et al. (2008)

Caffeine and Hydration
咖啡因與水份

- Dehydration impairs exercise performance (Oppliger and Bartok 2002)
- Caffeine is diuretic → increase urine production
- Some sport experts do not recommend athletes to choose caffeine-containing products before and during and exercise (Spriet 1995)
- ACSM (2007) stated that small dose (<180mg/day) is not likely increase daily urine output or cause dehydration

- 脫水可影響運動表現 (Oppliger and Bartok 2002)
- 咖啡因是利尿劑 → 增加尿液製造
- 一些運動專家建議運動前及期間避免選擇含咖啡因產品 (Spriet 1995)
- 美國運動醫學會(2007)提出小量的咖啡因(<180毫克/日)不會增加尿液排泄或引起脫水

Supportive Evidence
支持証據

- Wemple et al (1997)
- 6 healthy and active adults
  - 3 caffeine habitual users (~2 – 3 cups coffee/day)
  - 3 are not habitual users
- Aim of study:
  - To investigate the effects of caffeinated vs non-caffeinated sports drinks on urine production

- Wemple et al (1997)
- 6位健康及運動量高的成年人
  - 3位慣常使用咖啡因產品 (~2 – 3杯咖啡/日)
  - 3位非慣常使用咖啡因產品
- 研究目的:
  - 測試含咖啡因與不含咖啡因的運動飲品對尿液製造的影響

Protocol
測試方法

- 4 days prior to test
  - No caffeine containing products
- 3.5 – 4 hours prior to test
  - High carbohydrate liquid meal
    - 65% carbohydrate, 18% protein and 15% fat
    - 260kcal/236ml
  - 1 L of water

- 測試前4日
  - 嚴禁咖啡因產品
- 測試前3.5 – 4 小時
  - 高碳水化合物飲品
    - 65%碳水化合物、18%蛋白質、15%脂肪
    - 260千卡/236毫升
  - 1公升水

Wemple et al (1997)

Protocol
測試方法

- 4 different groups
  - Resting caffeine (RC)
  - Exercise caffeine (EC)
  - Resting placebo (RP)
  - Exercise placebo (EP)
- Caffeine dose
  - 25mg/dL → 8.7mg/kgBW

- 分成4組
  - 咖啡因-休息 (RC)
  - 咖啡因-運動 (EC)
  - 安慰劑-休息 (RP)
  - 安慰劑-運動 (EP)
- 咖啡因含量
  - 25mg/dL → 8.7mg/kgBW

Wemple et al (1997)

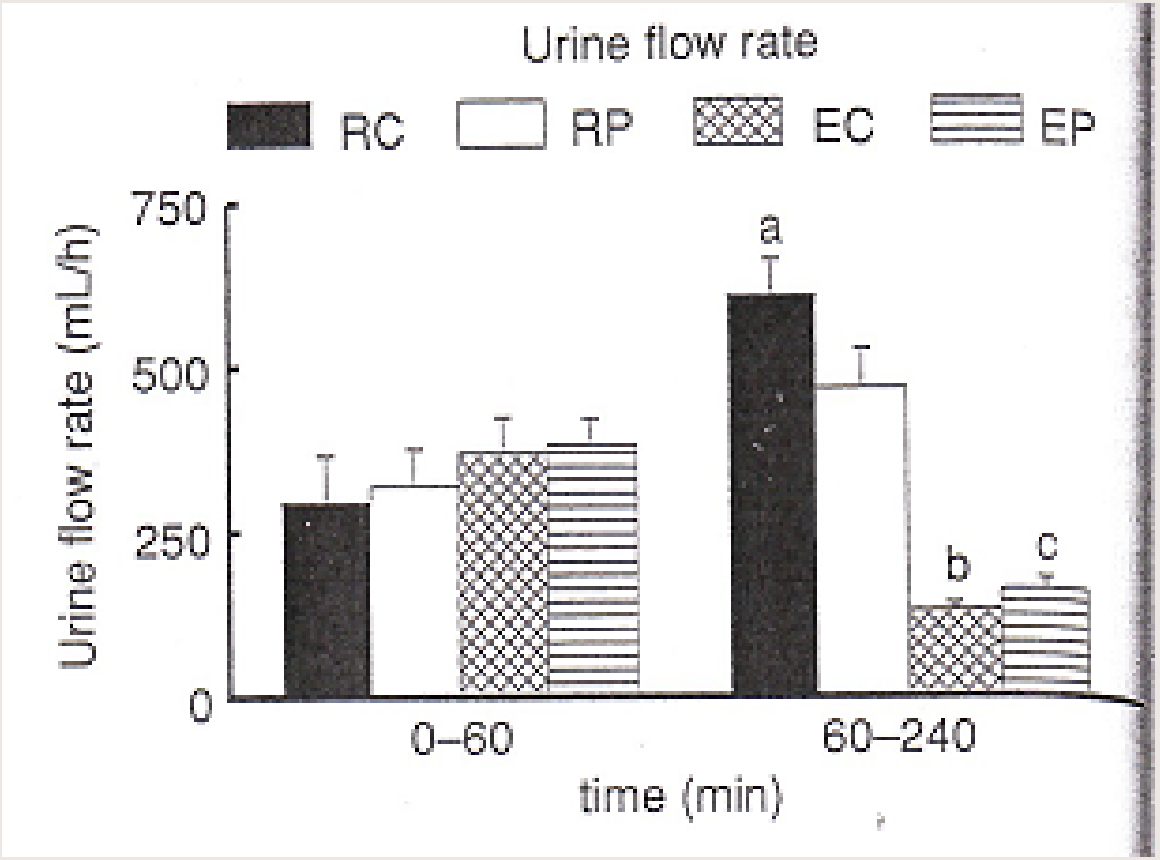
Protocol
測試方法

	Rest				60% VO_{2max} cycling x 180 minutes								
Minutes	0	20	40	60	80	100	120	140	160	180	200	220	240
Heart Rate	*			*	*	*	*	*	*	*	*	*	*
Rectal Temperature	*			*	*	*	*	*	*	*	*	*	*
Blood sample	*			*		*	*			*			*
Urine sample				*		*	*			*			*
Body weight					*	*	*	*	*	*	*	*	*
Sports drink intake* (8ml/kg BW)	*												
Sports drink intake* (3ml/kg BW)				*	*	*	*	*	*	*	*	*	

*** With or without caffeine (25mg/dL)**

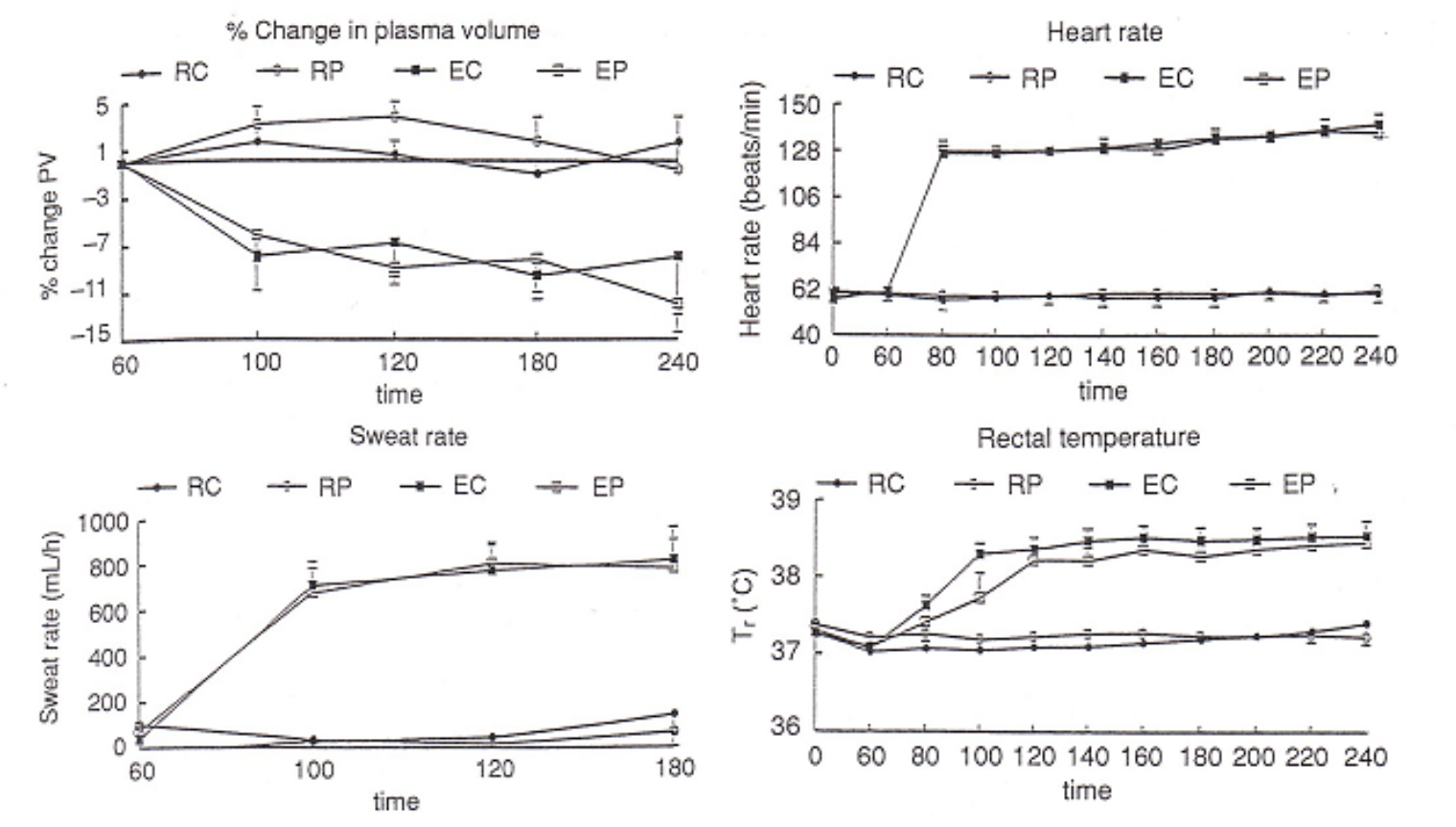
Wemple et al (1997)

Results
結果



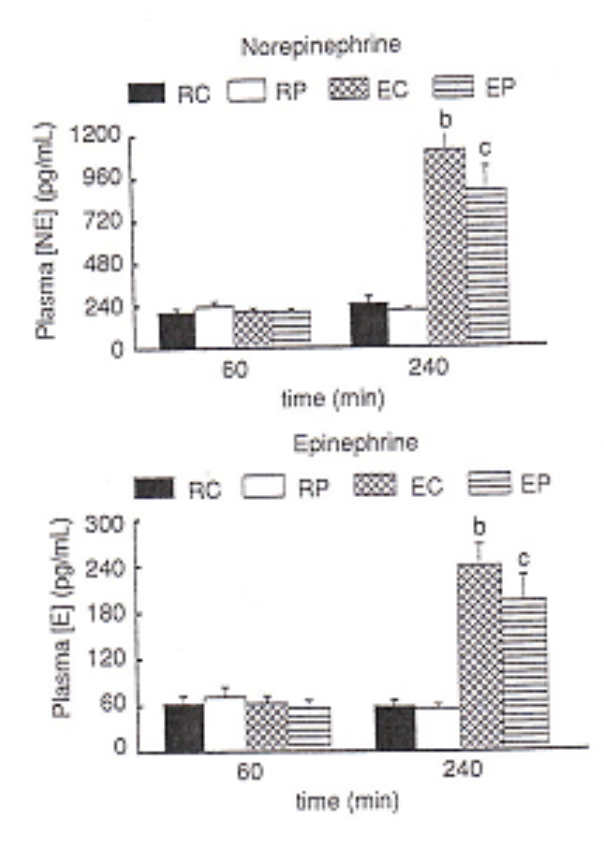
Wemple et al (1997)

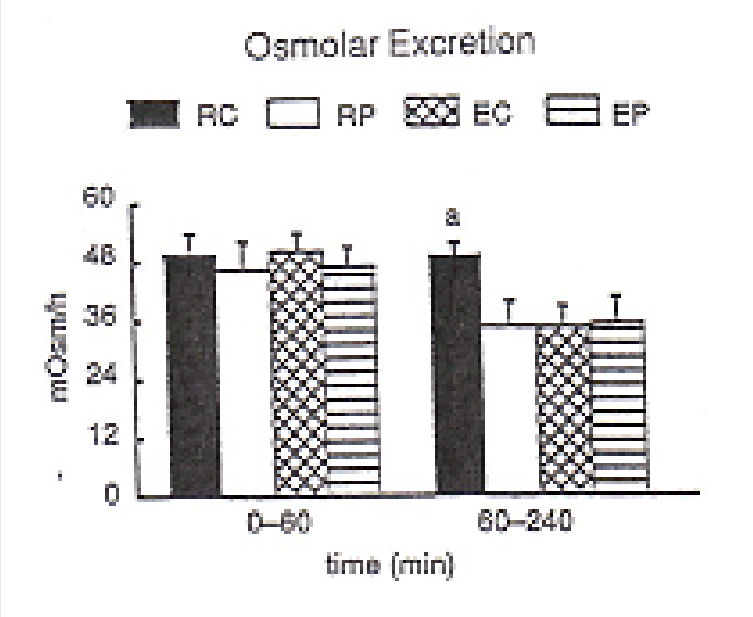
Results
結果



Wemple et al (1997)

Results
結果





Wemple et al (1997)

Supportive Evidence
支持証據

- Fiala et al 2004
  - 10 heat-acclimatized athletes
  - Habitual caffeine users
- Aim
  - To investigate hydration status of trained individuals using caffeine during 2-a-day practices across 3-day period

- Fiala et al 2004
  - 10位熱適應的運動員
  - 慣常使用咖啡因
- 目的
  - 了解在運動員在連續3天每天2節訓練使用咖啡因對水份補充的影響

Protocol
測試方法

- 2 groups
  - CAF: rehydrated with water during exercise and rehydrated with Coca Cola during all other time
  - CF: rehydrated water during exercise and rehydrated with caffeine-free Coca Cola during all other time

- 2組
  - CAF: 在運動期間飲用清水及期餘時間飲用可口可樂
  - CF:在運動期間飲用清水及期餘時間飲用不含咖啡因的可口可樂

Fiala et al. (2004)

Protocol
測試方法

- Laboratory data collection
  - Day 1 & 4
  - Body weight
  - Urine sample
  - Blood sample
  - Thirst sensation
    - 1 (not thirst) → 9 (thirst)

- 實驗室測試
  - 第1 & 4 日
  - 體重
  - 尿液
  - 血液
  - 口渴感覺
    - 1 (不口渴) → 9 (口渴)

Fiala et al. (2004)

Protocol
測試方法

Field data collection (Day 1 – 3)

Pre-AM Practice	Morning Practice	Post-AM Practice	Lunch 1-hour	Pre-PM Practice	Afternoon Practice	Post-PM Practice	Time on Own
ϑ ξ	40m soccer 40m ultimate Frisbee 40m modified rugby Water ad libitum	ϑ	Either: 1.Coca-cola 2.Caffeine-free Coca-cola ad libitum	ϑ	80m hike 40m flag football Water ad libitum	ϑ ξ	Either: 1.Coca-cola 2.Caffeine-free Coca-cola ad libitum

Remarks:

ϑ - Body weight, urine sample (USG, volume and urine color), RPE, thirst and thermal sensation (0 – unbearably cold, 8 – unbearably hot)

ξ- Environmental symptoms questionnaire (ESQ)

Avoid any high water content foods such as watermelon and soup during the trial

Avoid other caffeine-containing foods and beverages

Collect water and beverage consumption

Fiala et al. (2004)

Results
結果

Table 1 Field Variables for Pre-AM

Variable	Day 1		Day 2		Day 3	
	Caffeine	Caffeine-free	Caffeine	Caffeine-free	Caffeine	Caffeine-free
Body weight (kg)	68.6 ± 12.7	68.5 ± 12.6	68.5 ± 12.5	68.5 ± 12.5	68.6 ± 12.7	68.7 ± 12.4
ESQ	10 ± 6	11 ± 8	11 ± 7	10 ± 8	11 ± 9	13 ± 7
RPE	6 ± 0	7 ± 1	6 ± 0	6 ± 0	7 ± 1	7 ± 1
Thermal	4.0 ± 0.5	4.0 ± 0.5	4.0 ± 0.5	4.5 ± 0.5	3.5 ± 0.5	4.0 ± 0.5
Thirst	3.0 ± 1.0	4.0 ± 1.0	3.0 ± 1.0	3.0 ± 1.0	3.0 ± 1.0	3.0 ± 1.0
USG	1.017 ± 0.010	1.017 ± 0.009	1.023 ± 0.005	1.023 ± 0.006	1.021 ± 0.010	1.019 ± 0.008
Urine color	4 ± 2	3 ± 2	6 ± 1	6 ± 2	5 ± 2	5 ± 2

Note. Values are mean ± standard deviation.

Table 2 Field Variables for Post-AM

Variable	Day 1		Day 2		Day 3	
	Caffeine	Caffeine-free	Caffeine	Caffeine-free	Caffeine	Caffeine-free
Body weight (kg)	68.1 ± 12.4	68.2 ± 12.4	67.9 ± 12.1	68.2 ± 12.2	68.3 ± 12.5	68.3 ± 12.4
RPE	15 ± 1	15 ± 2	15 ± 1	15 ± 1	14 ± 3	16 ± 1
Thermal	5.5 ± 0.5	5.0 ± 1.0	5.0 ± 0.5	5.0 ± 1.0	5.0 ± 1.0	5.0 ± 1.0
Thirst	5.0 ± 2.0	5.0 ± 1.0	5.0 ± 1.0	4.0 ± 2.0	4.0 ± 2.0	4.0 ± 1.0
USG	1.019 ± 0.008	1.020 ± 0.008	1.020 ± 0.008	1.023 ± 0.007	1.021 ± 0.009	1.017 ± 0.010
Urine color	6 ± 2	6 ± 1	6 ± 2	6 ± 2	7 ± 1	5 ± 2

Note. Values are mean ± standard deviation.

Table 3 Field Variables for Pre-PM

Variable	Day 1		Day 2		Day 3	
	Caffeine	Caffeine-free	Caffeine	Caffeine-free	Caffeine	Caffeine-free
Body weight (kg)	68.8 ± 12.4	69.0 ± 12.4	68.8 ± 12.6	68.8 ± 12.3	68.8 ± 12.7	68.9 ± 12.4
RPE	7 ± 1	6 ± 1	7 ± 1	7 ± 1	6 ± 1	7 ± 1
Thermal	3.0 ± 1.0	3.5 ± 1.0	4.0 ± 1.0	4.5 ± 0.5	4.5 ± 1.0	5.0 ± 1.0
Thirst	2.0 ± 1.0	3.0 ± 1.0	2.0 ± 1.0	3.0 ± 1.0	4.5 ± 1.0	5.0 ± 0.5
USG	1.020 ± 0.009	1.022 ± 0.011	1.020 ± 0.009	1.028 ± 0.024	1.020 ± 0.012	1.021 ± 0.009
Urine color	5 ± 2	5 ± 2	5 ± 2	5 ± 3	5 ± 2	6 ± 2

Note. Values are mean ± standard deviation.

Table 4 Field Variables for Post-PM

Variable	Day 1		Day 2		Day 3	
	Caffeine	Caffeine-free	Caffeine	Caffeine-free	Caffeine	Caffeine-free
Body weight (kg)	68.7 ± 12.4	68.8 ± 12.4	68.5 ± 12.5	68.6 ± 12.3	68.2 ± 12.4	68.4 ± 12.5
ESQ	19 ± 9	15 ± 9	18 ± 9	16 ± 7	21 ± 12	22 ± 11
RPE	14 ± 1	13 ± 2	14 ± 1	14 ± 2	15 ± 1	14 ± 1
Thermal	4.0 ± 1.0	5.0 ± 0.5	5.0 ± 0.5	5.0 ± 0.5	5.5 ± 1.0	5.5 ± 1.0
Thirst	4.0 ± 1.5	3.5 ± 2.0	4.0 ± 1.5	3.5 ± 2.0	4.5 ± 1.5	4.0 ± 2.0
USG	1.015 ± 0.011	1.017 ± 0.011	1.016 ± 0.011	1.016 ± 0.011	1.017 ± 0.008	1.018 ± 0.010
Urine color	4 ± 2	4 ± 2	4 ± 3	4 ± 3	5 ± 2	5 ± 2

Note. Values are mean ± standard deviation.

Fiala et al. (2004)

Results
結果

Table 5 Laboratory Variables

Variable	Day 1		Day 4	
	Caffeine	Caffeine-free	Caffeine	Caffeine-free
Hematocrit (%)	45.5 ± 2.5	46.5 ± 2.0	42.5 ± 3.5	43.5 ± 3.0
Hemoglobin (g/dL)	14.17 ± 0.94	14.43 ± 0.97	13.47 ± 1.12	13.49 ± 1.11
Plasma osmolality (mOsmo/kg)	284 ± 6	284 ± 5	288 ± 5	287 ± 6
USG	1.018 ± 0.007	1.017 ± 0.007	1.024 ± 0.006	1.022 ± 0.006
Urine color	4 ± 2	5 ± 1	6 ± 1	6 ± 1
Urine osmolality (mOsmo/kg)	649 ± 322	633 ± 227	859 ± 219	778 ± 238
Thirst	4.0 ± 2.0	5.5 ± 1.5	6.5 ± 1.5	6.0 ± 2.0

Note. Values are mean ± standard deviation.

Fiala et al. (2004)

Results
結果

Table 7 Total Fluids Ingested and Produced, and Resultant Body Weight and Plasma Volume Changes for 3 Days

Fluid	Caffeine	Caffeine-free	*t*(9)	*P*
Soda	5.60 ± 1.54 L	5.39 ± 1.53 L	0.525	.612
Caffeine	741 ± 171 mg	0 ± 0 mg	13.685	.000
Water	6.26 ± 2.27 L	6.02 ± 1.78 L	1.295	.228
Total fluid	11.86 ± 1.83 L	11.41 ± 1.39 L	0.936	.374
Urine volume	5.08 ± 1.71 L	5.01 ± 2.47 L	0.173	.867
Urine percent[a]	43.7 ± 15.1%	44.2 ± 21.6%	–0.116	.910
Weight changes	–0.31 ± 0.76 kg	0.06 ± 0.26 kg	–1.830	.101
% change plasma volume	10.85 ± 10.61%	14.50 ± 9.15%	–1.618	.140

Note. Values for caffeine and caffeine-free are mean ± standard deviation.
[a]Urine percent = urine volume/total fluid × 100%.

Fiala et al. (2004)

Other Considerations: Tolerance and Withdrawal
考慮事項: 耐受性及戒斷

- Tolerance (i.e. diminished responsiveness) to caffeine resulted from repeated exposure
- 重複性的攝取咖啡因可致耐受性
- Lower caffeine doses are well tolerated by nonusers
- 低劑量的咖啡因可令非使用者容易接受
- 5 – 6 days to develop tolerance for nonusers
- 非使用者需要5 – 6天建立耐受性
- Start with a lower dose, ~1 – 2mg/kgBW, then gradually increase dose during the next few days
- 應從低劑量開始(約1 – 2毫克/公斤體重)，然後慢慢地增加
- Side effect: tremor, insomnia, anxiety, palpitation
- 副作用: 手震、失眠、焦慮、心悸、頭痛

Other Considerations: Tolerance and Withdrawal
考慮事項: 耐受性及戒斷

- Acute reduction of caffeine intake may cause withdrawal symptoms (e.g. decreased mental alertness, increased tiredness, degraded mood)
- 急性減少咖啡因攝取可引致戒斷症 (例如: 減低提神作用、增加疲倦、情緒下降)
- Reduce caffeine consumption at least 1 week before competition to avoid any withdrawal effects
- 應在比賽前一星期減少咖啡因攝取來避免戒斷症
- The dose should be gradually reduced over 3 – 4 days
- 需要3 – 4天將份量逐漸減少

Practical Applications
實際應用

- Source of caffeine
  - Caffeine capsule vs coffee
  - Results are inconsistent
    - Caffeine capsule had better effect than coffee (Graham et a1 1998)
    - No difference was found between caffeine capsule and coffee (McLellan & Bell 2004)
  - Cox et al 2002 showed that Coca-cola consumption toward the end of test enhance the performance
  - More studies are needed
- Inconsistent caffeine content in coffee
(Espresso: 25 – 214mg/serve; Desbrow et al 2007)

- 咖啡因來源
  - 咖啡因藥丸 vs 咖啡
  - 研究結果不一致
    - 咖啡因藥丸效果比咖啡好 (Graham et al 1998)
    - 咖啡因藥丸與咖啡沒有分別 (McLellan & Bell 2004)
  - Cox et al 2002指出在測試後段飲用可口可樂可提升表現
  - 需要多些研究
- 在咖啡裡沒有劃一的咖啡因含量
(特濃咖啡: 25 – 214毫克/份; Desbrow et al 2007)

Practical Applications
實際應用

- Timing of Intake
  - Peak blood level: 30 – 75 minutes after ingestion (Sökmen et al 2008)
  - Half-life: 4 – 6 hours
  - Bell & McLellan (2002) found that an increased time to exhaustion during exercise 1 and 3 hours after ingestion, but not after 6 hours or placebo trials
  - Recent studies also showed that intake of low dose of caffeine during exercise enhanced performance (Conway et al 2003, Cox et al 2002)

- 攝取時間
  - 血液最高含量: 進食後30 – 75分鐘 (Sökmen et al 2008)
  - 半衰期: 4 – 6小時
  - Bell & McLellan (2002) 指出進食咖啡因後1及3小時比進食後6小時或安慰劑可廷遲衰竭時間
  - 最近布有些研究指出在運動期間進食低劑量的咖啡因可增加運動表現 (Conway et al 2003, Cox et al 2002)

Practical Applications
實際應用

- Caffeine Dose
  - 1 – 13mg/kgBW (Roti et al 2006, Yeomans et al 2002, Graham et al 1991, Pasman et al 1995)
  - High dose of caffeine intake (9 – 13mg/kgBW) can result in dizziness, headache, nervousness, insomnia → decrease performance (Quinlan et al 1997, Graham et al 1995)
  - No evidence of dose-response relationship
- Recommend: 1 – 3 mg/kg

- 使用劑量
  - 1 – 13毫克/公斤體重(Roti et al 2006, Yeomans et al 2002, Graham et al 1991, Pasman et al 1995)
  - 高劑量的咖啡因攝取(9 – 13毫克/公斤體重)可導致頭暈、頭痛、緊張、失眠→減低表現 (Quinlan et al 1997, Graham et al 1995)
  - 沒有証明指出劑量-反應之關係
- 建議: 1 – 3毫升/公斤體重

Conclusion
總結

- Sound evidence suggested that caffeine supplement could enhance exercise performance
- Moderate caffeine intake will not induce diuresis
- Modest levels of intake 1 – 3 mg/kgBW) showed beneficial effects
- Different response to people – should try before use in competition
- Beware of side effects for non-users

- 許多研究指出咖啡因有助提高運動表現
- 適量的咖啡因不會利尿
- 適當的攝取(1 – 3毫克/公斤體重)可以提升表現
- 不同人有不同反應 – 在比賽前應試清楚
- 非經常使用咖啡因者要留意副作用

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