急性腎損傷後的營養恢復
預防肌少症並延緩 AKI 向 CKD 進展

Post-AKI Nutritional Recovery
Preventing Sarcopenia and Slowing the AKI-to-CKD Transition

台灣營養學會 繼續教育委員會主任委員
台北醫學大學 保健營養學系助理教授
文林診所 營養師
陳淑子

Introduction

- **Post-AKI Nutritional requirement**
  - **Protein and Energy Requirements**
  - **Medical Nutrition Therapy**
- **Preventing Sarcopenia & slowing AKI to CKD**
  - **How to Prevent Muscle Wasting**
    - Energy Sources and Nutritional Requirements for Muscle
  - **How to Increase Muscle Mass**
    - Factors Affecting Muscle Protein Synthesis
    - Nutritional Supplementation During Exercise on Muscle Protein Synthesis

Post-AKI Nutritional requirement

- **Nutritional Care After Hospital Discharge for AKI**
  - Without appropriate post-AKI care, AKI may progress to AKD and subsequently to CKD
- **Principles of Nutritional Care**
  - Adequate protein and energy intake
    - Protein：0.8-1.2 g/kg
    - Energy：20-35 kcal/kg
  - Adequate fluid intake
    - 30-35 ml/kg
  - Avoid nephrotoxic medications
  - Prevent recurrent causes of AKI
  - Maintain optimal blood pressure and glycemic control
  - Smoking cessation

Principles for Sarcopenia Prevention
- Prevent muscle wasting
- Promote muscle gain

How to Prevent Muscle Wasting

- **Muscle as a Major Protein Reservoir in the Body**
  - **Except during growth, development, pregnancy, and wound healing, protein is not stored in the body**
    - Nitrogen balance
- **Nutritional Requirements of Muscle**

Adequate CHO & protein intake is essential to prevent muscle loss

  - **Carbohydrate is essential energy sources for muscle contraction**
    - Insufficient carbohydrate intake increases muscle protein breakdown.
      - ✓ Muscle protein is broken down for gluconeogenesis
  - **Insufficient protein intake for visceral protein synthesis**
    - Muscle protein is broken down
      - ✓ for the synthesis of plasma proteins, immune proteins, enzymes, hormones, and other essential proteins

如何增加 肌肉量

- 增加肌肉需要那些條件
  - 只有增加蛋白質不能增加肌肉量
    - 過多蛋白質會造成腎臟負擔
  - 運動時缺乏適當營養會造成肌肉減少
    - 肌肉耗損也會增加腎臟負擔
- 如何才能增加肌肉
  - 適當的運動+正確的飲食
- 運動種類的影響
  - 有氧運動 (耐力運動)
    - 走路、跑步、騎車、游泳
  - 阻力運動
    - 重量訓練、彈力帶訓練 (肌肉重量訓練)

運動 + 營養
才能增加肌肉

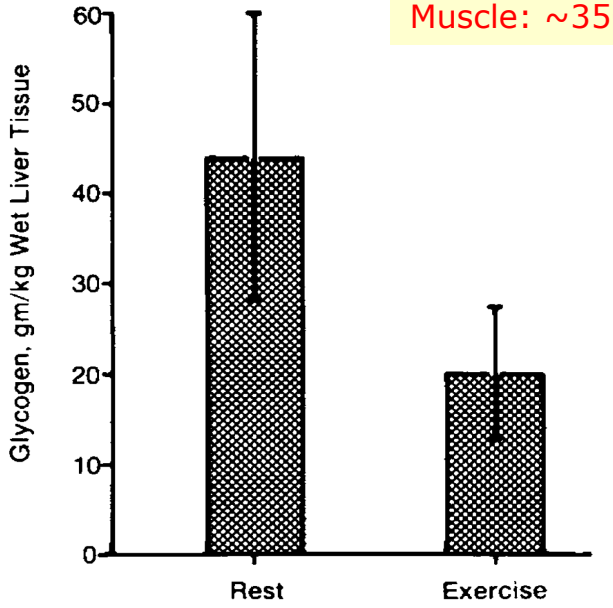
運動時要補充足夠的能量 肌肉才不會減少

- 肝醣(Glycogen)是運動時最主要的能量來源
  - 肝臟肝醣在運動後會降低
  - 肌肉肝醣在運動前30分鐘下降最快，約75分鐘用完
    - 供肌肉活動使用
    - 肝醣用完時，能量來自肌肉分解
  - 運動後回補肌肉肝醣，避免肌肉分解，才能燃燒脂肪

肝臟肝醣
主要功能:維持血糖
肌肉肝醣
供肌肉活動使用

Liver: ~100g
Muscle: ~350-700g

肝臟肝醣



肌肉肝醣

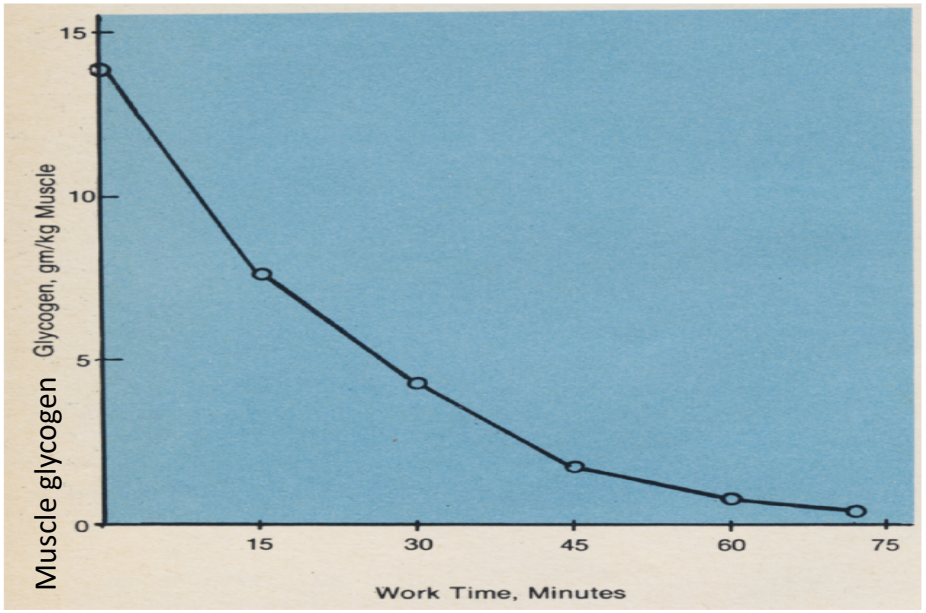


Fig 1.—Glycogen content in quadriceps muscle during intermittent bicycle work. Mean values from eight subjects.

運動後缺乏 碳水化合物 會造成肌肉減少

- 身體能量來源利用順序
  - 碳水化合物(肝醣、血糖)→蛋白質(肌肉)→脂肪
- 運動後補充 碳水化合物 肌肉才不會減少
  - 運動會導致肌肉發炎與血管損傷
    - 缺乏碳水化合物 會減少胰島素分泌
      - ✓肌肉蛋白質分解成能量使用-- 肌肉減少
      - ✓↓肌肉修補與恢復— 痠痛、感覺疲倦
  - 運動後補充
    - 含糖 + 蛋白質 的營養補充品
      - ✓利用肌肉發炎反應 增加肌肉
    - 能減少肌肉耗損且增加肌肉
    - 恢復疲勞

肌肉的能量來源
碳水化合物

AMPK
(Adenosine monophosphate-activated protein kinase)
肌肉運動後能量不足時會產生AMPK，增加蛋白質分解。
肌肉hold住後，增加脂肪分解。
AMPK 也會增加粒線體功能。

J Appl Physiol 109: 431–438, 2010 JAP 109:431-438 2010

Med Sci sports Exerc vol 44 pp682-691 2012

何種運動 增加肌肉的效果最好　　阻力運動

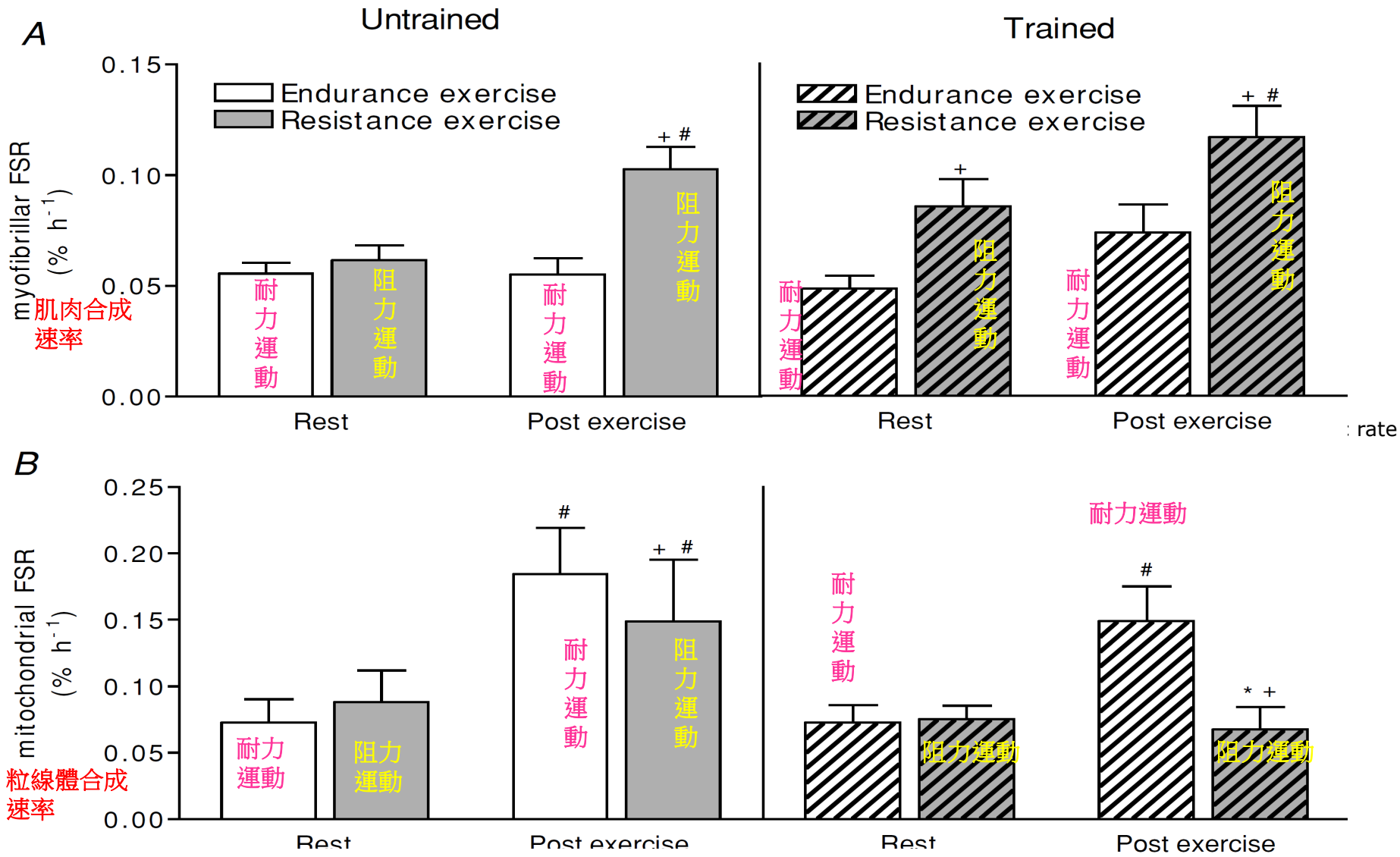


Figure 3. Myofibrillar (*A*) and mitochondrial enriched (*B*) FSR at rest and for the 4 h period after single-leg cycling (endurance) or single leg knee extension exercise (resistance) in the fed state
Values are means ± S.E.M. as percentage per hour. *Training effect: significantly different from untrained values with same leg at same time; +leg effect: significantly different from endurance values, same training state and at same time; #time effect: significantly different from values at rest with same leg at same time and from those with same training state, $P < 0.05$.

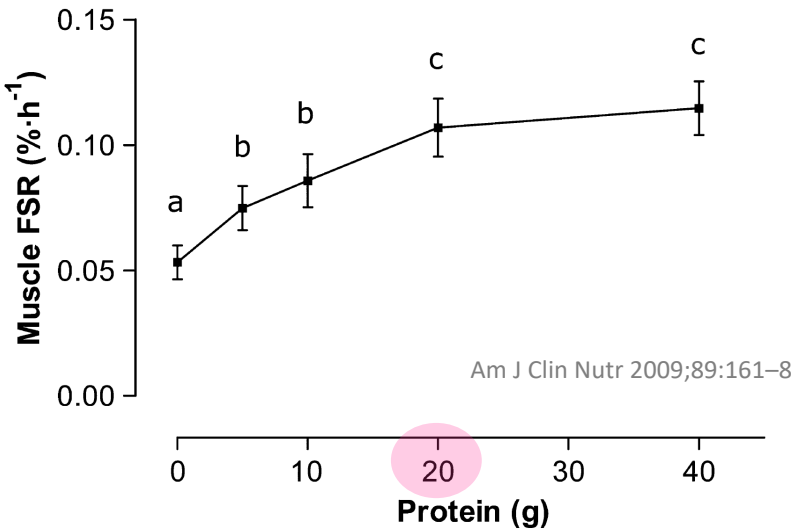
J Physiol 2008 Aug 1; 586(15):3701-17

改善肌少症

增加肌肉的營養策略

多吃 蛋白質 才能多增加 肌肉 嗎？

阻力運動後吃蛋白質增加肌肉的效果:
超過 20 g 就不再增加

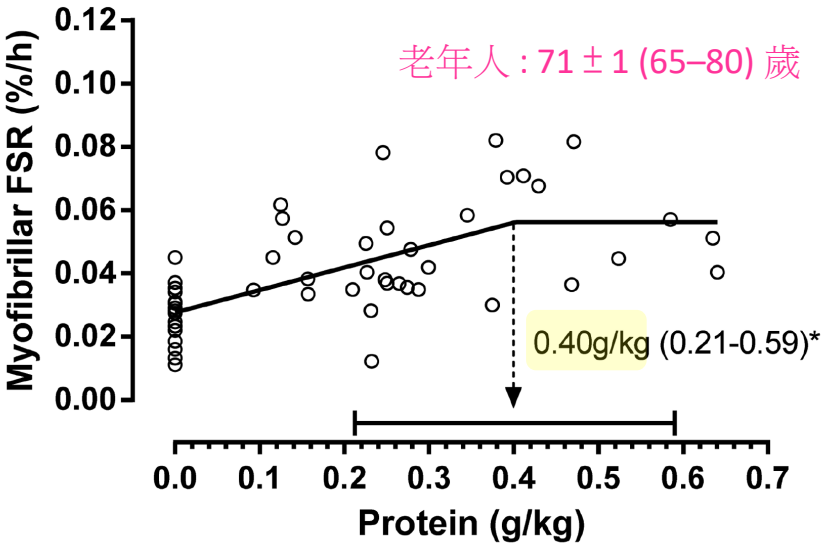


Am J Clin Nutr 2009;89:161–8

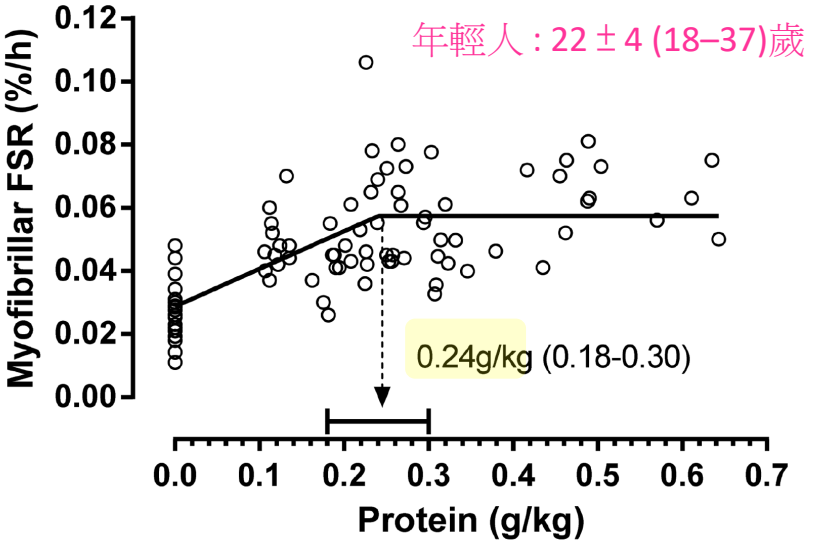
FIGURE 2. Mean (±SEM) mixed-muscle fractional protein synthesis (FSR) after resistance exercise in response to increasing amounts of dietary protein. Data were analyzed using a one-factor (protein) repeated-measures ANOVA to test for differences between conditions. Differences in means were analyzed using a Holm-Sidak post hoc test. Means with different letters are significantly different from each other ($P < 0.01$; $n = 6$).

＊沒有變成肌肉的蛋白質，
會分解產生尿毒素增加腎臟負擔。

A.



C.

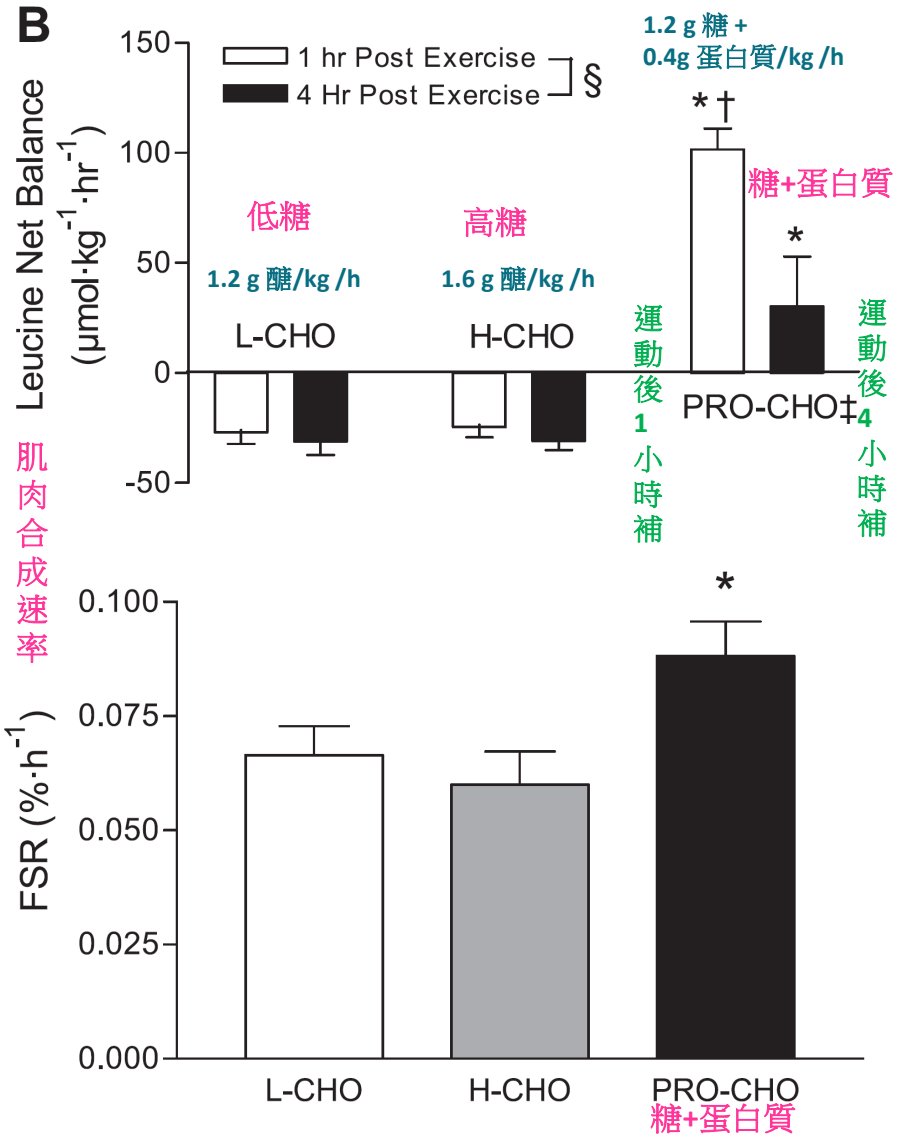


Biphase linear regression analyses of relative protein intake per kg bod mass (BM; panels **A** and **C**) and rested myofibrillar fractional synthetic rate (FSR) in healthy older (A) and younger (C) men. *p = .055 vs younger men.

增加肌肉量：
老人需要的蛋白質量比年輕人稍多

J Gerontol A Biol Sci Med Sci. 2015 January;70(1):57–62

運動後不需要大量蛋白質也可以增加肌肉量

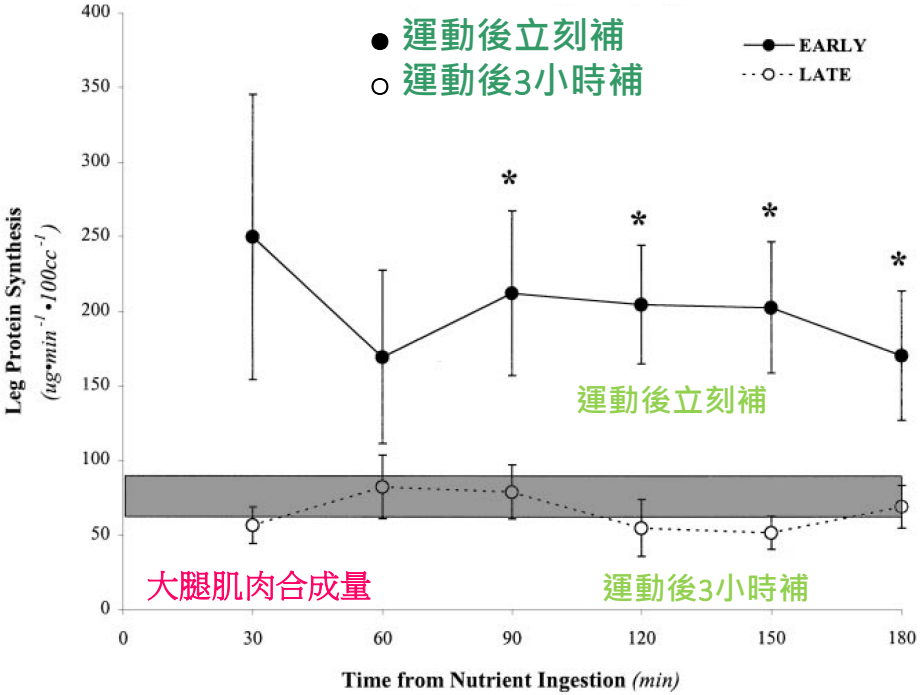


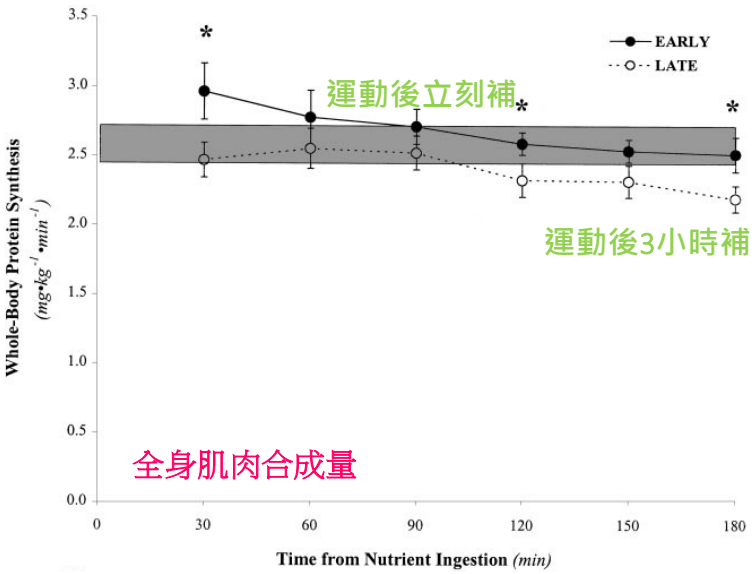
只要立即補充
醣類與蛋白質就可以增加較多肌肉量

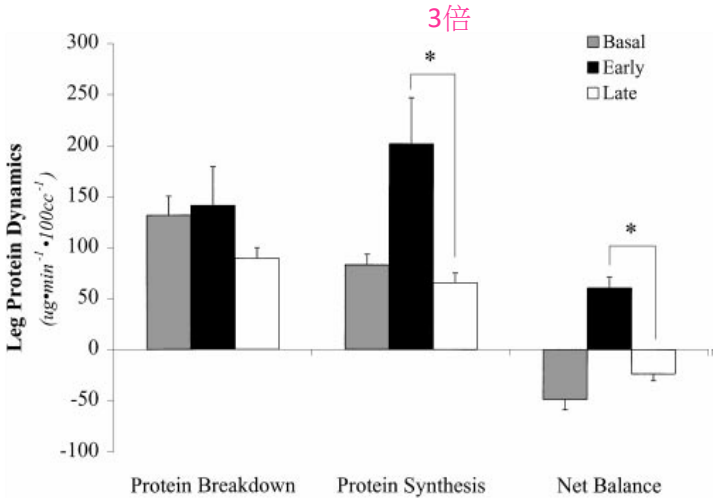
Fig. 3. Whole body **leucine net balance** during recovery from prolonged exercise while ingesting either 1.2 g CHO/kg /h (L-CHO), 1.6 g CHO/kg/ h (H-CHO), or 1.2 g CHO+0.4 g protein/kg/ h(PRO-CHO).
*P< 0.05 vs. other treatments at the same time point. †P<0.05 vs. 4 h in the same trial. ‡Main effect for treatment ,P< 0.05. §Main effect for time, P< 0.05.

Fig. 4. **Mixed muscle protein fractional synthetic rate (FSR)** during 4 h of recovery from prolonged exercise while ingesting either 1.2 g CHO/kg/ h (L-CHO), 1.6 g
CHO/kg/ h (H-CHO), or 1.2 g CHO+0.4 g protein/kg/ h (PRO-CHO).
*P < 0.05 vs. other treatments

要增加肌肉量:補充糖與蛋白質的時機很重要







＊運動後立刻補醣與蛋白質增加肌肉的效果最好

Fig. 7. Point-by-point timing of leg and whole body protein synthesis for 10 subjects given an oral nutrient supplement either immediately after exercise (EARLY) or 3 h postexercise (LATE). *Significantly different (P <0.05),

Fig. 4. Rates of leg protein dynamics for 10 subjects given an oral nutrient supplement either immediately after exercise (EARLY) or 3 h postexercise (LATE). *Significantly different (P<0.05)

運動後太晚進食 增肌效果差

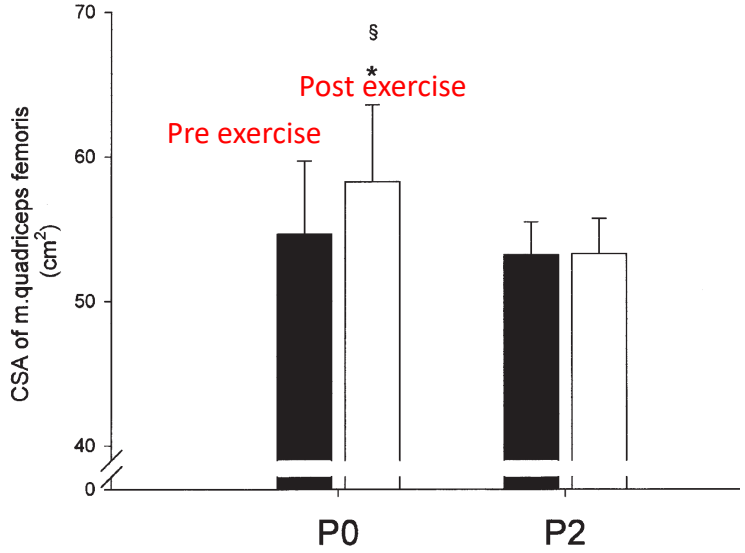
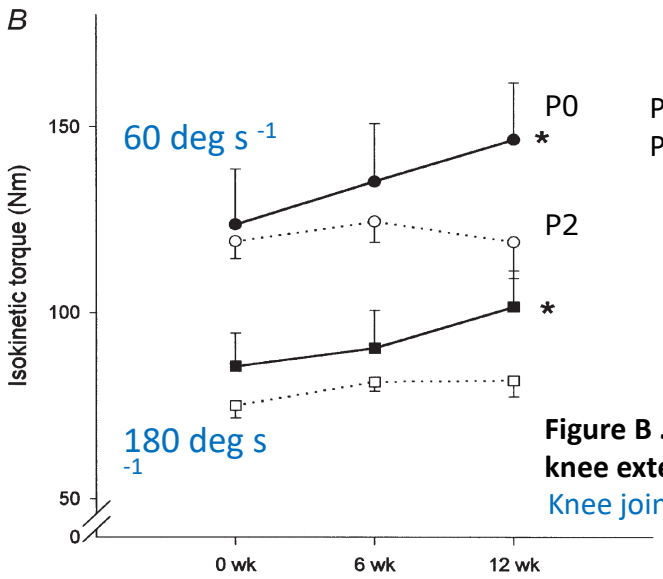


Figure 2. Cross-sectional area of m. quadriceps femoris (CSA-q.f.)



P0 : Immediately postexercise
P2: 2 h postexercise

Figure B . Strength measurements of knee extension
Knee joint angular velocity

Table 2. Distribution of MHC isoforms and fibre types

		P0		P2	
		Pre	Post	Pre	Post
MHC (%)	MHC-I	63 ± 5	57 ± 5*	63 ± 5	65 ± 4
	MHC-IIA	32 ± 4	38 ± 5*	30 ± 4	31 ± 4
	MHC-IIX	6 ± 2	5 ± 5	7 ± 2	4 ± 1*
Number (%)	Type 1	56 ± 6	51 ± 5	52 ± 4	60 ± 3
	Type 2a	29 ± 3	34 ± 4*	30 ± 4	29 ± 3
	Type 2b	15 ± 4	15 ± 2	18 ± 3	11 ± 1*
Area (%)	Type 1	62 ± 6	56 ± 6*	58 ± 5	65 ± 4
	Type 2a	28 ± 4	34 ± 5*	28 ± 4	27 ± 4
	Type 2b	10 ± 2	11 ± 2	14 ± 4	8 ± 1*

Data are presented as mean values ± S.E.M. for P0 ($n = 7$) and P2 ($n = 6$) before (Pre) and after (Post) a 12 week training period. * Significantly different from Pre ($P < 0.05$).

74 ± 1 years men
12 week resistance training
(3 times per week)
oral protein in liquid form
(10 g protein, 7 g carbohydrate, 3 g fat)

DEXA MRI muscle biopsy

Journal of Physiology (2001), 535.1, pp.301–311

美國糖尿病學會對糖尿病人運動前醣類補充建議

Table 1—Suggested carbohydrate intake or other actions based on blood glucose levels at the start of exercise

Pre-exercise blood glucose	Carbohydrate intake or other action
<90 mg/dL (<5.0 mmol/L) 運用前 需補充15-30克快速利用的糖 長時間中強度運動 0.5-1.0g/kg/h	• Ingest 15–30 g of fast-acting carbohydrate prior to the start of exercise, depending on the size of the individual and intended activity; some activities that are brief in duration (<30 min) or at a very high intensity (weight training, interval training, etc.) may not require any additional carbohydrate intake. • For prolonged activities at a moderate intensity, consume additional carbohydrate, as needed (0.5–1.0 g/kg body mass per h of exercise), based on blood glucose testing results.
90–150 mg/dL (5.0–8.3 mmol/L) 運用開始時需補糖 0.5-1.0g/kg/h	• Start consuming carbohydrate at the onset of most exercise (~0.5–1.0 g/kg body mass per h of exercise), depending on the type of exercise and the amount of active insulin.
150–250 mg/dL (8.3–13.9 mmol/L)	• Initiate exercise and delay consumption of carbohydrate until blood glucose levels are <150 mg/dL (<8.3 mmol/L). 可以不需先補充糖
250–350 mg/dL (13.9–19.4 mmol/L) 若有酮體 不建議運動	• Test for ketones. Do not perform any exercise if moderate-to-large amounts of ketones are present. • Initiate mild-to-moderate intensity exercise. Intense exercise should be delayed until glucose levels are <250 mg/dL because intense exercise may exaggerate the hyperglycemia.
≥350 mg/dL (≥19.4 mmol/L) 若有酮體 不建議運動 若無酮體 可於運動前調整胰島素後運動	• Test for ketones. Do not perform any exercise if moderate-to-large amounts of ketones are present. • If ketones are negative (or trace), consider conservative insulin correction (e.g., 50% correction) before exercise, depending on active insulin status. • Initiate mild-to-moderate exercise and avoid intense exercise until glucose levels decrease.

Adapted from Zaharieva and Riddell (88).

減少體脂肪的運動與營養補充

只有增加運動強度 不會增加脂肪燃燒比例

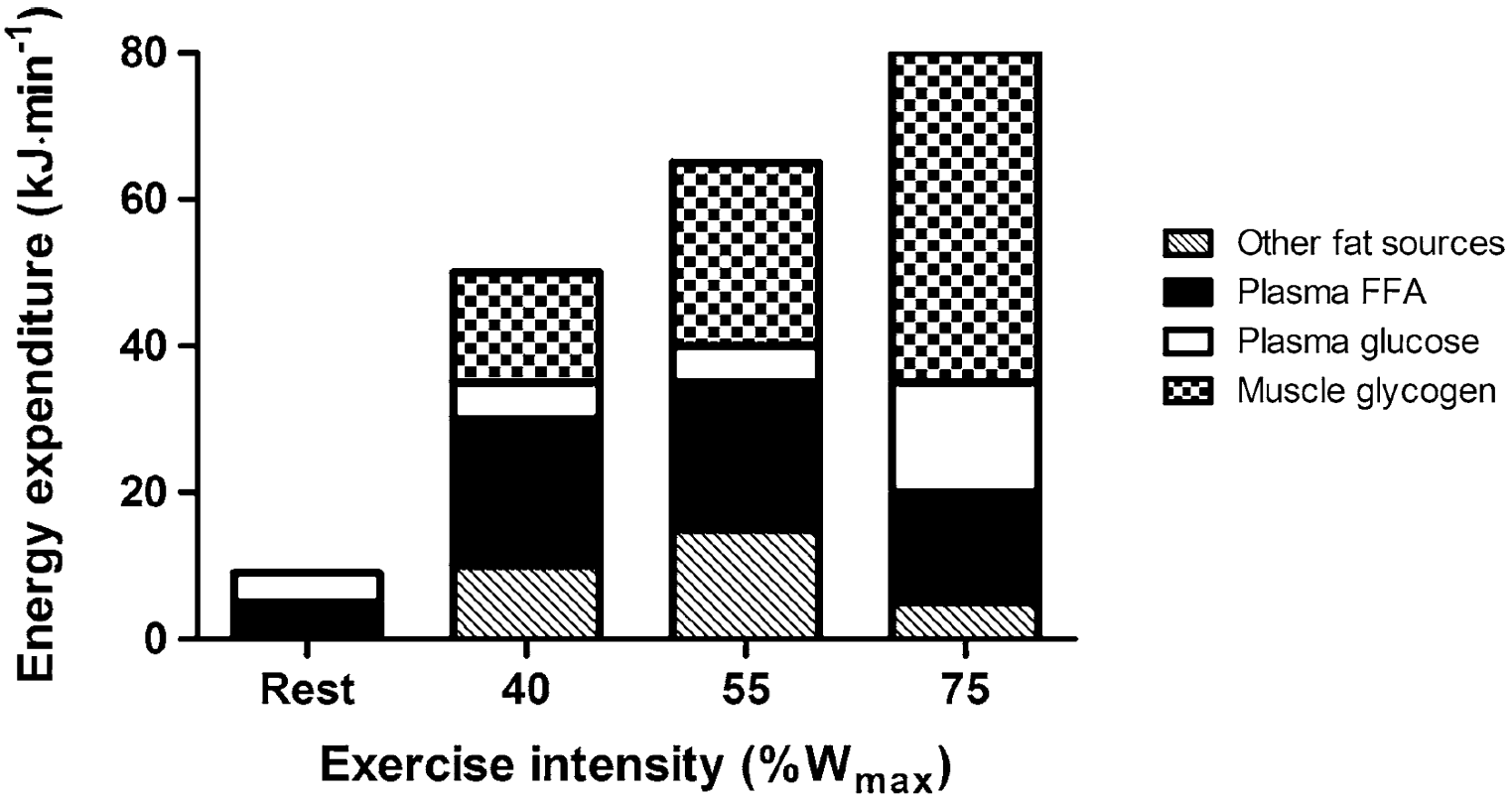


Fig. 1 Energy expenditure (expressed in kJ·min^{-1}) as a function of exercise intensity [expressed in percentage of maximal workload capacity (%W_{max})]. The relative contribution of plasma glucose, muscle glycogen, plasma free fatty acids (FFA) and other fat sources (sum of intramuscular plus lipoprotein-derived triglycerides) to energy expenditure are illustrated as described in the legend

Am J Physiol. 1993;265:E380–91

運動前,後補充碳水化合物與蛋白質才有增肌減脂效果

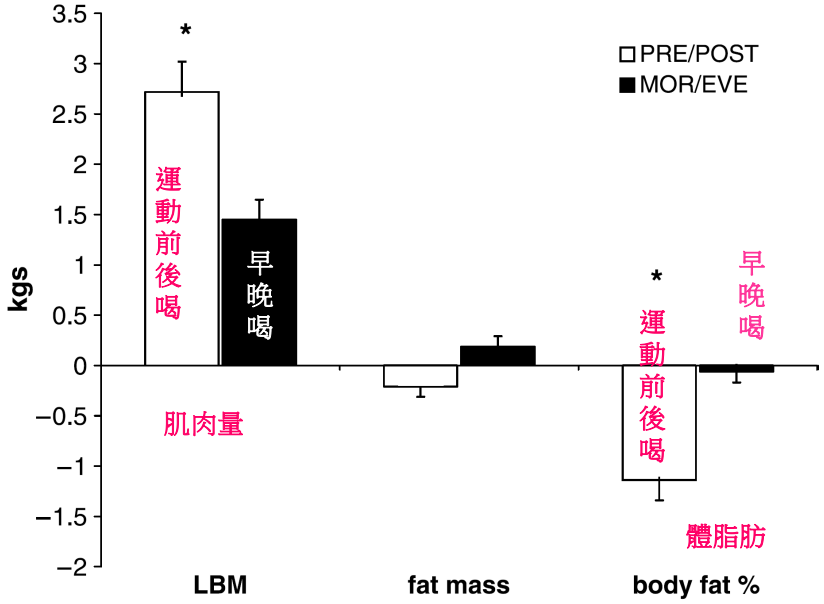


FIGURE 1—Body composition changes. * Greater change compared with MOR-EVE ($P < 0.05$).

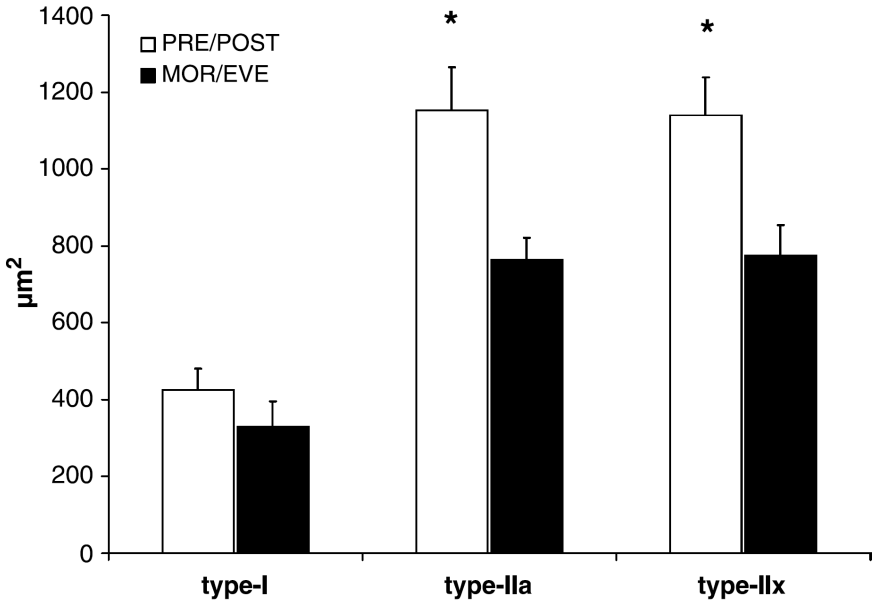


FIGURE 3—Changes in CSA (fiber types I, IIa, and IIx). * Greater change compared with MOR-EVE ($P < 0.05$).

PRE-POST : supplement before and after exercise
MOR-EVE : In the morning before breakfast and late evening before sleep

1 g/kg supplement
The supplement contained (per 100 g),
40 g of protein (from whey isolate),
43 g of carbohydrate (glucose),
7 g of creatine monohydrate

Med Sci Sports Exerc. 2006 Nov;38(11):1918-25.

高強度間歇性運動減少腹部脂肪效果較佳

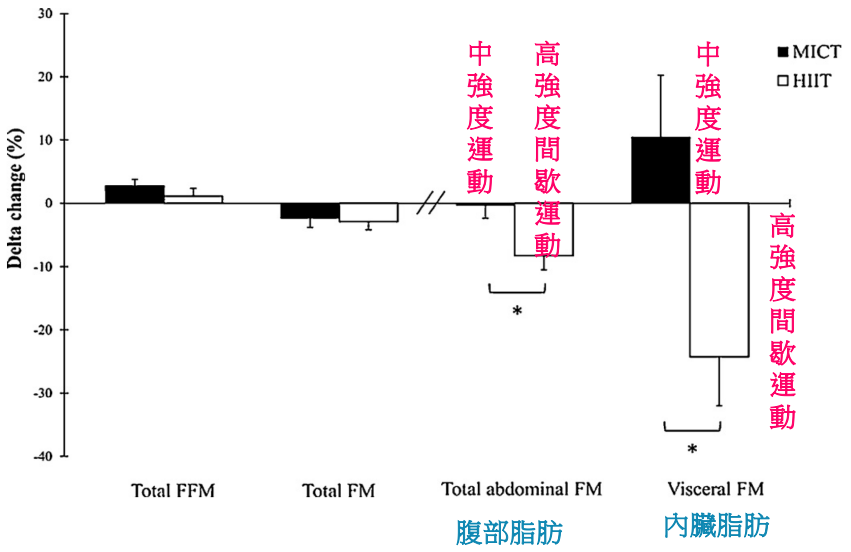


Fig. 2. Body composition changes [based on dual-energy X-ray absorptiometry (DEXA) imaging] between baseline and end of the 16-week exercise program with MICT ($n=8$) and HIIT ($n=8$). Data are means ± SEM. MICT: moderate-intensity continuous training; HIIT: high-intensity interval training; FFM: fat-free mass; FM: fat mass; delta change (%) = [(16 weeks − baseline/baseline) × 100]. $^{*}P \leq 0.05$ (MICT vs. HIIT groups).

High-intensity interval training reduces abdominal fat mass

postmenopausal women (61-80 y)
type 2 DM 14.5±2.1 ys
BMI > 25 kg/m²and ≤ 40 kg/m²
HIIT : 77–85% of max HR
MICT : 55–60% of max HR
16 weeks, 2days/week
HIIT: 20min (8s+12s)77-80% HR_{max}
MICT: 40min 55-60% THR

Diabetes & Metabolism 42 (2016) 433–441

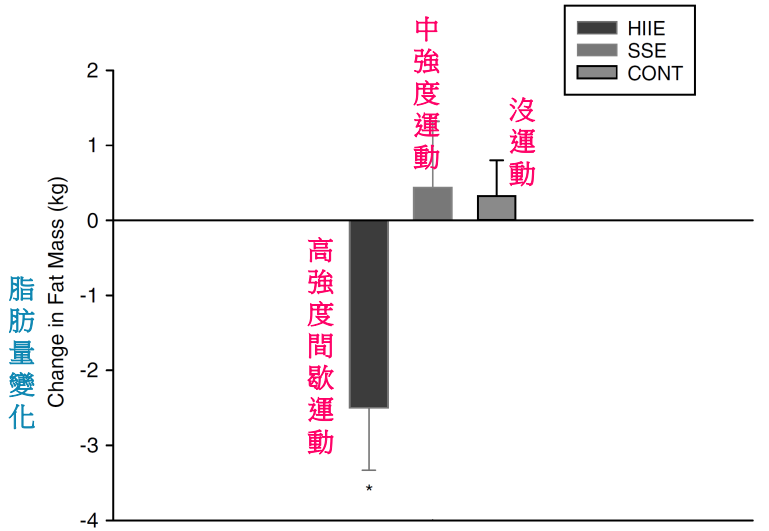


Figure 1 Total fat change for the high-intensity intermittent exercise (HIIE), steady-state exercise (SEE) and no exercise control groups. *Significantly different from control and SSE groups ($P<0.05$).

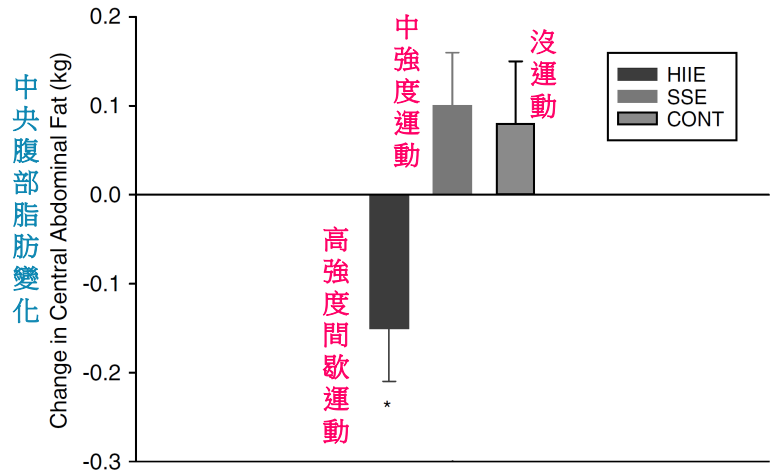


Figure 2 Central abdominal fat change for the high-intensity intermittent exercise (HIIE), steady-state exercise (SEE) and no exercise control groups. *Significantly different from control and SSE groups ($P<0.05$).

high-intensity intermittent exercise training on fat loss

BMI : 23.2±2.0
20.2 ± 2.0 y ♀
HIIE : 8 s of sprinting and 12 s of turning the pedals over slowly
SSE : 60% VO_2peak 10–20 min

International Journal of Obesity (2008) 32, 684–691

肌少症治療運動營養補充策略 整理

- 運動+正確的營養補充 才能增加肌肉
- 運動時缺乏糖類肌肉會耗損
  - 運動前15-30分鐘要攝取碳水化合物 (快速吸收的糖)
    - 100-150卡 ：視運動消耗的熱量而定
- 運動後立即攝食才能增加肌肉減少脂肪
  - 運動後攝取足夠碳水化合物(糖)才能避免肌肉耗損(快速吸收的糖)
    - 維持肌肉 才能強迫燃燒脂肪
  - 運動後立即攝取碳水化合物與蛋白質肌肉合成量最大
    - 不需要高蛋白質只要與糖一起吃， 就能有效增加肌肉量
    - 立刻補充(30分鐘內) ，增加肌肉最多，太晚補充效果差(>1小時)
    - 碳水化合物 : 蛋白質 = 3 : 1 至 4:1 (至少需2:1)
- 運動後太晚進食(>2hr)會導致肌肉耗損 脂肪增加
  - 肌肉耗損導致減重停滯期、脂肪累積

慢性腎臟病人 運用
運動前後可以喝全糖豆漿
100-150cc

THANK YOU FOR YOUR ATTENTION

To Cheer You up

散播幸福的種子就會長出 快樂小樹苗

搜尋 **FaceBook** 粉絲專頁
陳淑子營養
定期營養衛教資訊分享