



以上資料由運動員及科研事務科轄下的運動營養部提供，只供參考。

歡迎轉載以上資料，惟事先須得本院許可；轉載時亦須鳴謝本院。

如有查詢，請致電26816277與
運動科學部聯絡。

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For enquiry, please contact: Sports Science
Department. Tel: 2681 6277.



香港體育學院有限公司
Hong Kong Sports Institute Limited

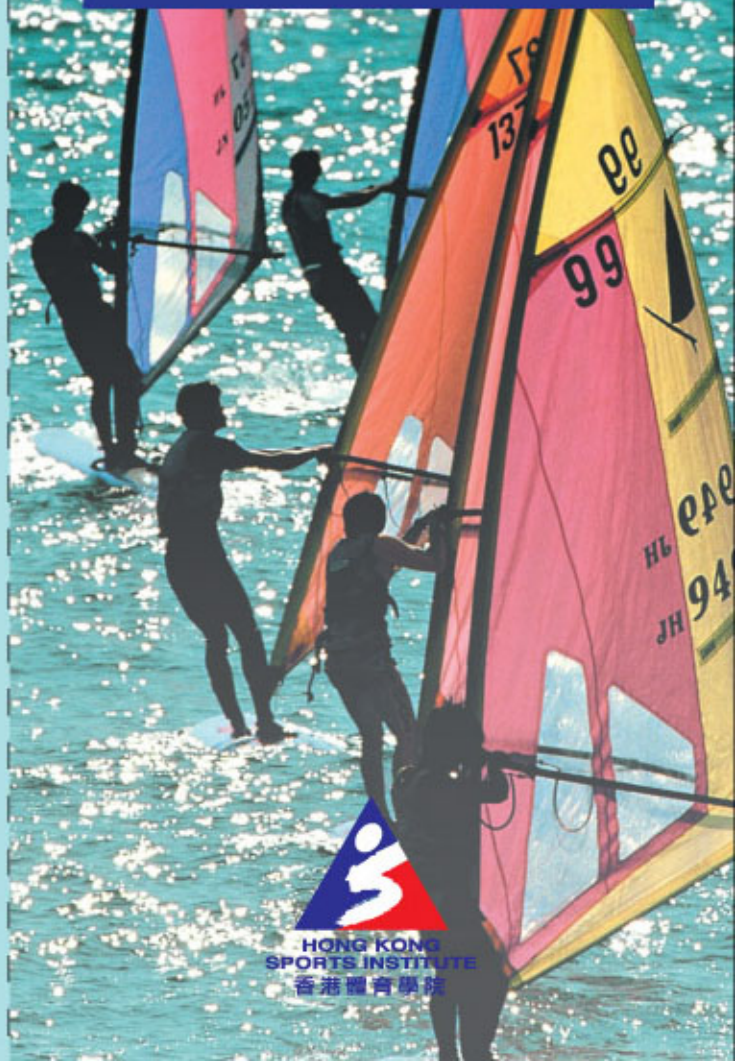
香港新界沙田源禾路25號香港體育學院
Hong Kong Sports Institute, 25 Yuen Wo Road,
Shatin, N.T., Hong Kong

電話 Tel: (852) 2681 6888 圖文傳真 Fax: (852) 2681 6330
網址 Website: <http://www.hksi.org.hk>

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免疫力與營養 Immunity and Nutrition



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前言

恆常運動能改善體質。然而，長時間的劇烈運動和高強度的訓練會抑壓免疫功能，從而增加一些感染的機會，例如上呼吸道感染（URTI）。運動所致的免疫系統失調主要是由於壓力荷爾蒙，例如：腎上腺素和皮質醇引起免疫力的抑制。近期的研究指出碳水化合物、蛋白質及一些維他命和礦物質對維持免疫功能扮演重要的角色（Gleeson et al 2004, Venkartaman and Pendergast 2002）。

碳水化合物

充足的碳水化合物有助改善運動表現及預防免疫系統失調。葡萄糖是免疫細胞主要燃料之一。近期的研究指出運動員在進食低碳水化合物餐而同時進行長時間運動的數天後，壓力荷爾蒙（例如：腎上腺素和皮質醇）和炎症細胞因子（例如：IL-6、IL-1ra 和 IL-10）會明顯增加（Mitchell et al 1998, Bishop et al 2001）。研究亦顯示在長時間的運動期間飲用含碳水化合物飲品（每小時30 - 60克碳水化合物）可減輕免疫抑制（Gleeson et al 2004）。因此，運動員應在運動前、中、後攝取充足的碳水化合物。定期的生化監察可反映運動員日常飲食中是否攝取足夠的碳水化合物。當運動員飲食中缺乏碳水化合物或進食過量的蛋白質會令血尿素上升。



Introduction

Regular physical activity can improve fitness but strenuous bouts of prolonged exercise and heavy training are associated with depressed immunity and increased risk of certain types of infection such as upper respiratory tract infections (URTI). The cause of this exercise-induced immune dysfunction is mostly due to immunosuppressive actions of stress hormones such as adrenaline and cortisol. Recent studies have shown that carbohydrate, protein and certain vitamins and minerals play a role in maintaining immune functions (Gleeson et al 2004, Venkartaman and Pendergast 2002).

Carbohydrate

Adequate carbohydrate helps to improve exercise performance and prevents immune dysfunction. Glucose is one of the critical fuels for immune cells. Recent studies (Mitchell et al 1998, Bishop et al 2001) showed that after several days of prolonged exercise with low carbohydrate diet, the levels of stress hormones (e.g. adrenaline and cortisol) and inflammatory cytokines (IL-6, IL-1ra and IL-10) were markedly increased. Studies have also stated that the consumption of carbohydrate (CHO) containing beverages (30 - 60g CHO/hour) during prolonged exercise can alleviate some immunosuppressive effects (Gleeson et al 2004). Therefore, athletes should have adequate CHO intake before, during and after exercise. Regular biochemistry monitoring may indicate whether athletes have adequate CHO intake in their daily diet. Athletes with inadequate CHO or excessive protein intake will have elevated blood urea level.



運動員碳水化合物需求指引

(資料來源：澳洲體育學院)

情況	碳水化合物建議攝取量
每天少於60至90分鐘運動或低強度運動	每天每公斤體重5至7克
每天90至120分鐘運動	每天每公斤體重7至10克
每天6至8小時	每天每公斤體重10至12克或以上
運動前的飲食	運動前1至4小時進食每公斤體重1至4克
超過1小時的訓練或比賽	每小時60克
訓練後或進行多天比賽，特別是兩節訓練之間少於8小時，需要快速恢復	運動後恢復初期（0至4小時）每小時進食每公斤體重1 - 1.5克及在24小時內合共進食每公斤體重6 - 10克

如何增加碳水化合物的攝取

- 每天的正餐及小食中加入碳水化合物豐富的食物，例如：飯、粉麵、麵包、水果、根莖類蔬菜（蕃薯、薯仔、南瓜）及低脂奶品類。
- 運動期間，使用碳水化合物為主的小食，例如：能量棒、糖漿或運動飲品。
- 在簡單的食物加入碳水化合物豐富的食物，例如：在方包塗上果醬或在乳酪中加入水果便可增加碳水化合物的攝取量。
- 飲食建議可參考附件I及II。



Guidelines of CHO requirement for athletes

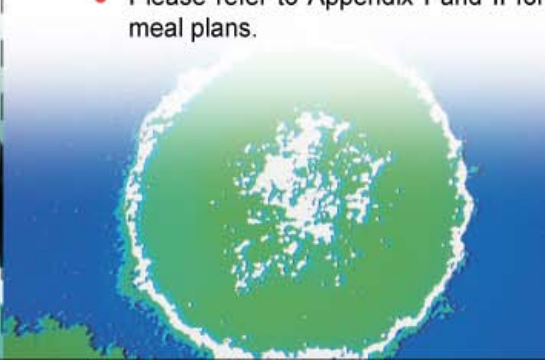
(Source: Australian Institute of Sport)

Situation	Recommended CHO Intake
<60 – 90 minutes/day or low intensity exercise	5 – 7 g/kg BW/day
90 – 120 minutes/day	7 – 10 g/kg BW/day
6 – 8 hours/day	10 – 12 or above g/kg BW/day
Pre-event meal	1 – 4 g/kg BW 1 – 4 hours before event
During training sessions and competition events >1 hour	60 g/hour
Rapid recovery after training session or multi-days competition, especially for training session intervals of <8 hours	1 – 1.5 g/kg body weight for every hour in the early stage (0 – 4 hours) of recovery after exercise, contributing to a total of 6 – 10 g/kg BW over 24 hours

*BW = body weight

How To Increase CHO Intake

- Include CHO-rich foods such as rice, pasta, breads, fruits, starchy vegetables (yam, potato, pumpkin) and low fat dairy products in every meal and snack.
- During exercise, have a CHO-based snack such as energy bar, carbohydrate gel or sports drink.
- Adding CHO rich foods on plain foods such as spreading jam on breads and adding fruits in yoghurt can increase carbohydrate intake.
- Please refer to Appendix I and II for sample meal plans.



蛋白質

由於許多免疫細胞，例如：免疫球蛋白、急性期蛋白和細胞激素都是由蛋白質構成，所以蛋白質在身體的免疫系統扮演重要的角色。蛋白質攝取不足會削弱免疫系統，特別是T-細胞功能，從而增加受感染的機會（Venkatraman & Pendergast 2002）。需要節食控制體重或素食的運動員會較容易缺乏蛋白質。這些運動員可定期測試血液前蛋白濃度監察營養狀況（理想值：15 – 35mg/dL）。發炎和服用避孕藥可導致血液前蛋白濃度下降。因此，判斷前蛋白水平時需特別注意。

運動員蛋白質需求指引

（資料來源：澳洲體育學院）

情況	蛋白質每天建議攝取量
靜態生活模式的男性和女性	每公斤體重0.8 – 1.0克
精英耐力運動員	每公斤體重1.6克
中強度練習的耐力運動員†	每公斤體重1.2克
康樂型耐力運動員‡	每公斤體重0.8 – 1.0克
力量運動	每公斤體重1.4 – 1.7克
抗阻力性運動員（訓練初期）	每公斤體重1.5 – 1.7克
抗阻力性運動員（穩定階段）	每公斤體重1.0 – 1.2克
女性運動員	約男性運動員攝取量的85%

† 每星期運動4 – 5次，每次45 – 60分鐘

‡ 每星期運動4 – 5次，每次30分鐘，運動強度 <55%VO₂max

Protein

Protein plays a crucial role in immunity as many immune cells, such as immunoglobins, acute phase protein and cytokines, are made up of protein. Inadequate protein intake impairs immunity particularly to the T-cell system, resulting in increased incidence of infections (Venkatraman and Pendergast 2002). Athletes who restrict food intake for weight loss or practice vegetarianism are at a higher risk of protein deficiency. Such athletes should regularly measure blood pre-albumin level to monitor nutrition status (Reference range: 15 – 35mg/dL). Inflammation and oral contraceptives will lower pre-albumin level and thus special attention is required when interpreting the result.

Guidelines of protein requirement for athletes

(Source: Australian Institute of Sport)

Situation	Recommended Daily Protein Intake
Sedentary men and women	0.8 – 1.0 g/kg BW
Elite male endurance athletes	1.6 g/kg BW
Moderate-intensity endurance athletes†	1.2 g/kg BW
Recreational endurance athletes‡	0.8 – 1.0 g/kg BW
Power sports	1.4 – 1.7 g/kg BW
Resistance athletes (early stage training)	1.5 – 1.7 g/kg BW
Resistance athletes (steady stage training)	1.0 – 1.2 g/kg BW
Female athletes	15% less than male athletes

† Exercising 4 – 5 times per week for 45 – 60 minutes

‡ Exercising 4 – 5 times per week for 30 minutes at VO₂max <55%



維他命和礦物質

要維持正常的免疫功能，必須充分地攝取一些微量營養素，包括維他命A、C、E、B6、B12、葉酸、鋅、鐵、鎂、錳、硒和銅（Gleeson et al 2004）。運動員日常應進食不同類型的食物以確保得到充足的維他命和礦物質。素食或需要控制飲食的運動員較容易缺乏某些與免疫系統有關的微量營養素例如鋅、鐵及維他命B12。在這情況，他們或需服用綜合維他命及礦物質補充劑作補充。

維他命C

維他命C是一種水溶性維他命及構成白血球的其中一種成份。一份研究指出超級馬拉松運動員在比賽前3星期每天服用600毫克維他命C比服用安慰劑運動員減少比賽後患上URTI的機會（Peters et al 1993）。水果及蔬菜，例如：木瓜、橙、奇異果及西蘭花都含有豐富的維他命C。每天建議攝取量為100毫克（中國居民膳食營養素參考攝量 2000）。

不同食物的維他命C含量（資料來源：美國農業部）

食物	份量	維他命C含量（毫克）
木瓜	1個（中型）	188
鮮橙汁	1杯	124
西蘭花，熟	1杯	101
奇異果	1個（中型）	71
橙	1個（中型）	70

鋅

鋅是身體200多種酵素的輔助因子，而當中某些酵素在免疫系統中扮演重要角色。鋅會從尿液及汗液中流失，而運動過程中會加劇流失。運動員應在日常飲食中進食含豐富鋅的食物，例如：貝殼類、紅肉、全穀麥片、乾豆及堅果。每天建議攝取量是15毫克（男性）和11.5毫克（女性）（中國居民膳食營養素參考攝量 2000）。

Vitamins and Minerals

Adequate intake of some micronutrients including vitamin A, C, E, B6, B12, folic acid along with zinc, iron, magnesium, manganese, selenium and copper are essential for normal immune function (Gleeson et al 2004). In order to get sufficient vitamins and minerals, athletes should consume a variety of foods. Athletes, who are vegetarian or on energy-restricted diet, are at risk of certain micronutrient deficiencies related to immunity such as zinc, iron, and vitamin B12. In this case, supplementation of vitamins and minerals may be necessary to ensure adequate nutrient intakes.

Vitamin C

Vitamin C is a water-soluble vitamin and also a component of white blood cells. A study showed ultramarathon runners, who took 600mg vitamin C daily for 3 weeks before the race, reduced the risk of developing URTI after the race comparing with the controls (Peters et al 1993). Fruits and vegetables such as papaya, orange, kiwi fruit and broccoli are good sources of vitamin C. The recommended daily intake of vitamin C is 100mg (China DRI 2000).

Vitamin C Content in Foods (Source: USDA)

Foods	Portion	Vitamin C content (mg)
Papaya	1 medium	188
Fresh orange juice	1 cup	124
Broccoli, cooked	1 cup	101
Kiwi fruit	1 medium	71
Orange	1 medium	70

Zinc

Zinc is a cofactor of over 200 enzymes and some of these enzymes play a role in the immune system. Zinc is lost from urine and sweat and these losses are increased by exercise. Athletes should include zinc-rich foods such as shellfish, red meat, whole grain cereals, dried beans and nuts in their daily diet. The recommended daily intake of zinc is 15mg (male) and 11.5mg (female) (China DRI 2000).

不同食物的鋅含量 (資料來源：美國農業部)

食物	份量	鋅含量 (毫克)
牛肉·熟	100克	5.3
花生·烘	100克	3.3
核桃	100克	3.1
蜆·熟	100克	2.7
早餐穀物類	100克	0.3 – 6.8

雖然暫時沒有確實的證據指出服用維他命C和鋅補充劑可以預防感染，但是一些研究指維他命C和鋅補充劑可以紓緩感染的症狀及縮短受感染的時間 (McElroy and Miller 2002, Peters et al 1993)。運動員如想服用補充劑，最好先諮詢運動營養師。

運動員需要特大劑量的維他命和礦物質嗎？

雖然維他命和礦物質攝取不足會增加受感染的風險，但是過量攝取亦會影響免疫功能，甚至危害健康。例如：一項研究指運動員在鐵人耐力賽前2個月連續每天服用600毫克的維他命E (中國居民膳食營養素參考攝量建議每天14毫克)，氧化壓力和炎症細胞因子反應比服用安慰劑的人為高 (Gleeson et al 2004)。服食過量的維他命A會損害免疫功能及增加患維他命A中毒症的風險 (Gleeson et al 2004)。服食過量的鋅，例如：連續6星期每天服用300毫克 (中國居民膳食營養素參考攝量建議每天最高攝取量37 – 45毫克) 亦會損害免疫系統 (Venkatraman and Pendergast 2002)。

Zinc Content in Foods (Source: USDA)

Foods	Portion	Zinc content (mg)
Beef, cooked	100 gram	5.3
Peanuts, roasted	100 gram	3.3
Walnuts	100 gram	3.1
Clams, cooked	100 gram	2.7
Breakfast cereals	100 gram	0.3 – 6.8

Although the evidence of using vitamin C and zinc supplement to prevent infections is inconclusive, there are some indications that vitamin C and zinc can reduce the severity and duration of infections (McElroy and Miller 2002, Peters et al 1993). Athletes who wish to use the supplement should consult with Sport Nutritionist before use.

Are megadoses of vitamins and minerals needed for athletes?

Although inadequate intake of vitamins and minerals may increase susceptibility to infections, excessive intake of vitamins and minerals can impair immune function and have other harmful effects. For example, a study showed that athletes supplemented with 600mg vitamin E per day (China DRI 14mg/day) for 2 months before an Ironman triathlon event resulted in elevated oxidative stress and inflammatory cytokine responses compared with placebo (Gleeson et al 2004). Megadoses of vitamin A may also impair immune function and increase the risk of vitamin A toxicity (Gleeson et al 2004). Megadoses of zinc, for example, 300mg per day for 6 weeks (China Upper Limit 37 – 45mg/day) have detrimental effects on the immune system (Venkatraman and Pendergast 2002).

監察免疫系統

定期驗血不但可以監察運動員的身體狀況，而且可以及早發現運動員受感染的徵象。以下一些血液指標可以監察運動員免疫系統的情況 (Gleeson 2006)。

血液指標	描述	參考值
白血球	<ul style="list-style-type: none"> ● 監測身體有沒有受感染 ● 運動員未完全恢復或受感染可導致白血球數量上升 	4.0 – 11.0 K/uL
嗜中性白血球	<ul style="list-style-type: none"> ● 抵抗病原體(引起疾病的微生物)的第一道防線 ● 急性細菌感染可令嗜中性白血球數量上升 	0.5 – 7.5 K/uL
淋巴細胞	<ul style="list-style-type: none"> ● 製造抗體以抵抗病原體 ● 淋巴細胞數量上升反映身體正受感染 	1.5 – 4.9 K/uL
單核細胞	<ul style="list-style-type: none"> ● 控制免疫系統反應及抵抗病原體，包括細菌和病毒 ● 長時間受感染可引致單核細胞數量上升 	0.2 – 0.8 K/uL
嗜酸性細胞	<ul style="list-style-type: none"> ● 對過敏症作出反應 ● 發生過敏症可引致嗜酸性細胞數量上升 	0 – 0.4 K/uL
唾液免疫球蛋白A	<ul style="list-style-type: none"> ● 抵抗可引致上呼吸道感染的病原體 ● 低水平唾液免疫球蛋白A可增加上呼吸道感染的風險 	建議在正常和大量訓練時檢測唾液免疫球蛋白A，從而建立運動員個人的數值，用來監察患上上呼吸道感染的風險

Monitoring Immune System Status

Regular blood test can be used to monitor athlete's health status and to give an indication of an individual's susceptibility to infection. There are some blood parameters that can be used to monitor an athlete's immune system status (Gleeson 2006).

Parameters	Description	Reference range
White blood cells	<ul style="list-style-type: none"> ● Surveying the body for infection ● A high level of white blood cell count represents that the athlete has not recovered properly from a training session or an infection is present 	4.0 – 11.0 K/uL
Neutrophils	<ul style="list-style-type: none"> ● A first line of defense against invading pathogens (microorganisms causing illness) ● An elevated neutrophil count is usually indicative of an acute bacterial infection 	0.5 – 7.5 K/uL
Lymphocytes	<ul style="list-style-type: none"> ● Producing antibodies against invading pathogens ● An increased in lymphocyte count is usually a sign of infection 	1.5 – 4.9 K/uL
Monocytes	<ul style="list-style-type: none"> ● Controlling immune responses and killing pathogens, including bacteria and virus ● An elevated monocyte count tends to be indicative of a chronic infection 	0.2 – 0.8 K/uL
Eosinophils	<ul style="list-style-type: none"> ● Involving in reactions to allergies ● An elevated eosinophil count indicates the presence of allergic condition 	0 – 0.4 K/uL
Salivary Immunoglobulins A (Salivary IgA)	<ul style="list-style-type: none"> ● Defense against pathogens that cause URTI ● A low level of salivary IgA is associated with increased risk of URTI 	Suggest regular monitoring of salivary IgA during normal and heavy training periods and to establish personal ranges for the assessment of the risk of URTI.

總結

許多研究已經指出攝取足夠的碳水化合物、蛋白質及一些維他命和礦物質可維持正常的免疫系統功能。運動員應在日常飲食中包含不同類型的食物，以確保攝取足夠的營養素。運動員若不能在飲食中攝取足夠的營養素便需要服用補充劑作補充。儘管如此，運動員亦應注意過量攝取維他命和礦物質（例如：維他命A和鋅）能影響免疫系統功能。除了充足的營養外，適當地控制訓練量及心理壓力、保持個人衛生和確保得到充足的休息是維持健康免疫系統所必須的。

附件 I

一位體重70公斤成年精英男性運動員的飲食建議（每天90 – 120分鐘的運動）

早餐	蔬菜4 安士	晚餐
脫脂奶1杯	香蕉1隻	白飯3碗
粟米片1杯	果汁2杯	牛肉4安士
麵包1片	下午茶	蔬菜4安士
果占1茶匙	麵包2片	果汁1杯
午餐	果醬1茶匙	橙1個
白飯3碗	加鈣豆漿 1杯	宵夜
雞肉3.5安士		蕃薯糖水1碗

營養分析		參考攝量
能量	3516千卡	
碳水化合物	593克 (8.5克/公斤體重)	490至700克 (7至10克/公斤體重)
蛋白質	115克 (1.6克/公斤體重)	112克 (1.6克/公斤體重)
脂肪	76克	
維他命C	124毫克	100毫克
鋅	15毫克	15毫克
鈣	997毫克	800 – 1000毫克

Conclusion

Numerous studies have shown that adequate intakes of carbohydrate, protein and certain vitamins and minerals can maintain normal immune function. Athletes should include different types of food in their daily diet to ensure adequate nutrient intakes. Supplementation is necessary for athletes who cannot meet nutrient needs from their diets. However, athletes should be aware that over-consumption of certain vitamins and minerals (e.g. vitamin A and zinc) can be detrimental to the immune system. Besides adequate nutrient intakes, managing physical training loads and psychological stress, maintaining good personal hygiene and ensuring adequate rest are essential to maintain proper functioning of the immune system.

Appendix I

Sample meal plan for a 70 kg elite male athlete
(Exercise: 90 – 120 min/day)

Breakfast	Afternoon Tea
Skimmed milk 1 cup	Bread 2 slices
Corn flakes 1 cup	Jam 1 teaspoon
Bread 1 slice	Calcium fortified soy milk 1 cup
Jam 1 teaspoon	Dinner
Lunch	Rice 3 bowls
Rice 3 bowls	Beef 4 oz
Chicken 3.5 oz	Vegetable 4 oz
Vegetables 4 oz	Fruit juice 1 cup
Banana 1 each	Orange 1 each
Fruit juice 2 cups	Evening snack
	Sweet potato sweet soup 1 bowl

Nutrient analysis		Recommended Intake
Energy	3516 kcal	
Carbohydrate	593 g (8.5 g/kg BW)	490-700 g (7-10 g/kg BW)
Protein	115 g (1.6 g/kg BW)	112 g (1.6 g/kg BW)
Fat	76 g	
Vitamin C	124 mg	100 mg
Zinc	15 mg	15 mg
Calcium	997 mg	800 – 1000mg

附件II

一位體重55公斤成年精英女性運動員的飲食建議 (每天90 – 120分鐘的運動)

早餐	雞肉2安士	晚餐
脫脂奶1杯	蔬菜4安士	白飯1½碗
粟米片1½杯	香蕉1隻	牛肉3安士
麵包1片	下午茶	蔬菜4安士
果占1茶匙	裸麥條1條	橙1個
午餐	(約35克)	宵夜
白飯1½碗	果汁1杯	果汁1杯
		低脂乳酪1杯 (約150克)

營養分析

能量	2408千卡	參考攝量
碳水化合物	408克 (7.4克/公斤體重)	385至550克 (7至10克/公斤體重)
蛋白質	77克 (1.4克/公斤體重)	77克 (1.4克/公斤體重)
脂肪	52克	
維他命C	124毫克	100毫克
鋅	12毫克	11.5毫克
鈣	894毫克	800 – 1000毫克

Appendix II

Sample meal plan for a 55 kg elite female athlete (Exercise: 90 – 120 min/day)

Breakfast

Skimmed milk 1 cup
Corn flakes 1½ cups
Bread 1 slice
Jam 1 teaspoon

Lunch

Rice 1½ bowls
Chicken 2 oz
Vegetables 4 oz
Banana 1 each

Afternoon Tea

Cereal bar 1 bar (35 g)
Fruit juice 1 cup

Dinner

Rice 1½ bowls
Beef 3 oz

Vegetable 4 oz
Orange 1 each

Evening snack

Fruit juice 1 cup
Low fat yoghurt 1 tub (150g)

Nutrient analysis

Energy	2408 kcal	Recommended Intake
Carbohydrate	408 g (7.4 g/kg BW)	385 – 550 g (7 – 10 g/kg BW)
Protein	77 g (1.4 g/kg BW)	77 g (1.4 g/kg BW)
Fat	52 g	
Vitamin C	124 mg	100 mg
Zinc	12 mg	11.5 mg
Calcium	894 mg	800 – 1000 mg

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