THE IMPORTANCE OF VITAMINS AND MINERALS TO THE ENERGY CYCLE AND ONE'S OVERALL HEALTH AND WELL-BEING

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ABSTRACT

Doctors often see exhausted, sluggish, and low-energy patients. Vitamin and mineral deficiencies may cause these symptoms without an underlying sickness. Elderly and pregnant women are identified risk groups. We investigated if lesser-known groups were at risk. This research aims to identify risk groups for inadequate micronutrient intake, define the connections between micronutrients, energy metabolism, and wellbeing, and assess the efficacy of micronutrient supplementation in these groups. A research review found that young people, generally women, with busy lives, physical activity, and poor dietary choices or frequent dieting are at risk of insufficient micronutrient consumption. Micronutrient supplements may cure deficiencies if used long enough.

***KEY WORDS:** Vitamins; Minerals; Micronutrients; Micronutrient Supplementation; Energy Metabolism;*

Introduction

Every doctor has encountered a patient with lethargy, lack of energy, and weariness who cannot be diagnosed after a comprehensive examination and conventional laboratory tests. Without underlying sickness, might vitamin and mineral deficiencies cause these symptoms?

The biochemical pathways that produce cellular energy and the involvement of various vitamins and minerals as coenzymes and cofactors have been better understood since the second half of the 20th century. This research is based on the idea that micronutrient deficiencies might impair cellular energy generation, causing weariness and low energy. In the first part, we review the role of micronutrients in energy generation and discuss the impact of micronutrient deficit on energy and wellness. In the second segment, we examine whether doctors should recommend micronutrient supplements to patients with low energy and how they might assist.

This rating targets "healthy" busy people. Although athletes and sports performance are well-studied, they are briefly covered. The elderly, vitamin B12 and iron deficient, and other risk groups will also be eliminated.

Energy metabolism in the body

Food provides metabolic energy. Adenosine triphosphate, the body's energy storage molecule, stores energy in high-energy phosphate bonds via several catabolic routes (ATP). Cellular respiration converts energy into ATP (Fig. 1). The cell's power plants mitochondria perform most of this respiration. Other carbohydrates, lipids, and proteins may be converted to acetyl coenzyme A (CoA), enter the citric acid cycle (Krebs cycle), and be oxidized to create carbon dioxide and water. The body favours glucose for

ATP generation.

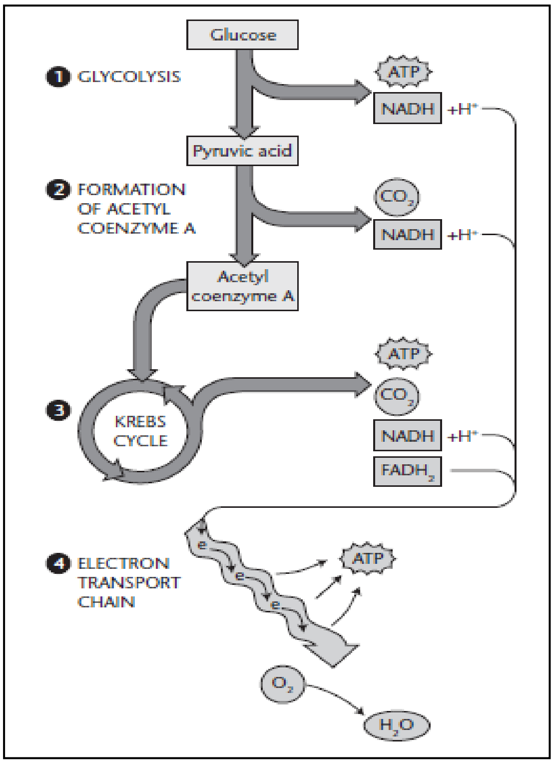

FIGURE 1: A simplified representation of cellular respiration with its four main steps.

ROLES OF MICRONUTRIENTS INENERGY METABOLISM

In order to transform dietary energy sources including carbs, lipids, and proteins into ATP, certain micronutrients work as coenzymes, cofactors, structural parts of enzymes and mitochondrial cytochromes, and active electron and proton transporters in the ATP-producing respiratory chain: Several chemicals impact the Krebs cycle and respiratory chain complexes I and II: 1,2 thiamine pyrophosphate (TPP; vitamin B1), CoA (containing pantothenic acid), flavin mononucleotide (FMN; derived from vitamin B2), flavin adenine dinucleotide (FAD), and nicotinamide adenine dinucleotide (NAD) are also part of the mitochondrial respiratory chain. Iron-sulfur (Fe-S) centers with two or four iron atoms function as electron transfer centers inside proteins.

Vitamins and energy metabolism are continuously studied. Depeint et al. showed that vitamins B6, B12, and folate maintain mitochondrial one-carbon transfer cycles by regulating mitochondrial enzymes. According to the same experts, any B vitamin deficiency inhibits mitochondria's energy metabolism.

Like B vitamins, minerals' energy metabolism effects are being studied. A recent research found that adequate magnesium, zinc, and chromium levels are needed for increased energy expenditure and task performance, and that magnesium and zinc supplements increase strength and muscle metabolism. In a subsequent investigation, magnesium shortage negatively affected cardiovascular function during sub-maximal work and increased energy needs. Lukaski has shown that reduced dietary zinc also impairs exercise-induced cardiorespiratory dysfunction. Table 1 summarizes current understanding of micronutrients' roles in energy metabolism.

Inadequate micronutrient intake

The serious consequences of profound vitamin deficiency have been recognized for more than a century. Mainly as a result of better general nutrition and of micronutrient supplementation in at-risk groups, the deficiency diseases, such as rickets, pellagra, scurvy and beriberi, are now relatively uncommon, at least in the developed world. But, within the past two decades, a number of investigators have re-introduced the concept of marginal micronutrient deficiency, first proposed by Pietrzik in 1985. This showed that, long before the clinical symptoms of deficiency appear, micronutrient deficiencies develop progressively through several sub-clinical stages.

TABLE 1:

Present state of knowledge with regard to the role(s) of individual micronutrients in energy metabolism7 – 10

Micronutrient	Function in energy metabolism
Vitamins	
Thiamine (B_1)	• Essential cofactor in the conversion of carbohydrates to energy.
	• Needed for normal muscle function, including the heart muscle.
	• Involved in oxidative carboxylation reactions, which also requiremanganese ions.
Riboflavin (B_2)	• As a cofactor in the mitochondrial respiratory chain, helps in the releaseof energy from foods.
	• Component of the main coenzymes FAD and FMN.
Nicotinic acid, niacin (B_3)	• As a cofactor in the mitochondrial respiratory chain, helps in the release of energy from foods.
	• Transformed into NAD and NADP, which play a key role in oxidation – reduction reactions in all cells.
Pyridoxine (B_6)	• Helps in the release of energy from foods.
	• Used as a cofactor by nearly 100 enzymatic reactions, mainly in proteinand amino acid metabolism.
Vitamin B_{12}	• Essential for metabolism of fats and carbohydrates and the synthesis ofproteins.
	• Interacts with folic acid metabolism.
Biotin	• As a cofactor, involved in metabolism of fatty acids, amino acids andutilization of B vitamins.
Pantothenic acid	• Plays an essential role in the Krebs cycle.
	• Component of coenzyme A.
Vitamin C (ascorbic acid)	• Essential for synthesis of carnitine (transports long-chain fatty acids into mitochondria) and the catecholamines, adrenaline and noradrenaline.
	• Ascorbic acid facilitates transport and uptake of non-haem iron at the mucosa, the reduction of folic acid intermediates, and the synthesis ofcortisol.
	• Potent antioxidant.
Folic acid	• Folates function as a family of cofactors that carry one-carbon (C1) units required for the synthesis of thymidylate, purines and methionine, and required for other methylation reactions.
	• Folate is essential for metabolic pathways involving cell growth, replication, survival of cells in culture.
	• Around 30 – 50% of cellular folates are located in the mitochondria.
Minerals	
Calcium	• Essential for the excitability of muscles and nerves.
	Activates a series of reactions including fatty acid oxidation, mitochondrial carrier for ATP (with magnesium), glucose-stimulated insulin

release.
Phosphorus • Structural component of nucleotide coenzymes; ATP contains phosphorus, as does creatine phosphate, another high-energy compound.
• ATP is involved in energy transformation and molecular activation.

TABLE 1 (continued):
Present state of knowledge with regard to the role(s) of individual micronutrients in energy metabolism7

Magnesium • Essential for the excitability of muscles and nerves.
• Cofactor in over 300 enzyme reactions, particularly those involving metabolism of food components.
• Required by all enzymatic reactions involving the energy storage molecule ATP.
Trace elements
Copper• Essential cofactor of cytochrome C oxidase, a component of the mitochondrial respiratory chain.
• Involved in iron metabolism.
Chromium (III) • Potentiates insulin action, thus promoting glucose uptake by the cells.
• Individuals who exercise strenuously have been reported to have higher urinary levels of chromium.
Iron • Essential part of haemoglobin for oxygen transport, of myoglobin for transporting and storing oxygen in the muscle and releasing it when needed during muscle contraction.
• Facilitates transfer of electrons in the respiratory chain and is thus important in ATP synthesis.
• Necessary for red blood cell formation and function.
Manganese • Cofactor of several enzymes involved in metabolism of carbohydrates and gluconeogenesis.
Zinc • Essential part of more than 100 enzymes, some of which are involved in energy metabolism.
FAD, flavin adenine dinucleotide; FMN, flavin mononucleotide; NAD, nicotinamide adenine dinucleotide; NADP, nicotinamide adenine dinucleotide phosphate; ATP, adenosine triphosphate.

Micronutrient Function in energy metabolism

An poor diet, malabsorption, or abnormal metabolism may cause micronutrient deficiencies. Most patients, whether in affluent or developing nations, have micronutrient status in phases 1 to 3. (Table 2).

A balanced diet should meet all micronutrient demands. Many people—even in wealthy nations—don't receive enough vitamins and minerals from their meals. Weight-reduction diets, poor and/or imbalanced nutrition, eating disorders, or demanding situations like strenuous exercise or mental or physical stress may lead to low micronutrient status in some demographic groups. Increased demands during development, pregnancy, nursing, the elderly, smokers, chronic drinkers, and those with specific underlying diseases may lead to vitamin and mineral deficiency. 14 – 17

Lifestyle concerns may put "healthy" people at danger.

TABLE 2:
The sub-clinical stages of marginal micronutrient deficiency13

Stage	Aetiology	Evidence
Stage 1	Depletion of vitamin stores (more for water-soluble than for fat-soluble vitamins).	Measurement of vitamin/mineral levels in rapid the blood or tissues.
Stage 2	Non-specific biochemical adaptation.	Decreased excretion of metabolites in the urine.
Stage 3	Secretion of micronutrient-dependant enzymes or hormones reduced.	First physical signs; lack of energy, malaise, loss of appetite, insomnia.
Stage 4	Reversible impairment of metabolic pathways and cellular function.	Morphological, metabolic or functional disturbances. More pronounced physiological changes.
Stage 5	Irreversible tissue damage.	Clinical signs of micronutrient deficiency.

Young to middle-aged people who work hard, have families, and suffer with time management are considered "lifestyle" cases. Lifestyle factors including rushed meals, poor food choices, chronic or sporadic dieting, and stress-related activities like smoking, drinking too much alcohol, and coffee enhance the risk of micronutrient deficiency in this population. Even moderate vitamin deficits may cause fatigue, reduced infection resistance, and cognitive decline. Recent study suggests that taking the proper quantity of a few vitamins is also important for long-term health including avoiding osteoporosis, heart disease, and cancer.

Contrary to common opinion, industrialized individuals are at danger of vitamin deficiency. The 1987–1988 Netherlands National Food Consumption Survey found low-thiamine, riboflavin, vitamin B6, and vitamin C intakes. According to a double-blind study, a regular diet may deplete thiamine, riboflavin, vitamins B6 and C after 8 weeks. Vitamin status worsened after 3 to 6 weeks due to a dip in blood vitamin concentrations, erythrocyte enzyme activity, stimulation tests, and urine vitamin excretion. This depletion study showed that mildly deficient thiamine, riboflavin, vitamin B6, and vitamin C induced decreased physical performance, even without vitamin-specific clinical symptoms. Vitamin B6 deficiency is a Dutch diet risk.

Vitamin and mineral consumption statistics were excellent, showing an average dietary and supplementary intake that was equal to or more than the regionally recommended daily amount (RDA) for each micronutrient. When food intake and stratified intake statistics were included, large portions of the population had intakes below the RDA.

- Low red blood cell folate (45.8%) and serum folate (18.4%) were common in the US population.
- In 1998, the US mandated folic acid fortification due to the health advantages of folate. Dutch data showed that 50% of a typical sample were not meeting folate needs. A recent study found 14.7% to 20.1% of rural and urban Turkish teenage girls lacking folic acid.
- In prosperous countries, vitamin D deficiency is rising. 36% of healthy people have low vitamin D levels, compared to 57% of American general practice patients and even more in Europe.

Individuals seldom consume enough magnesium. A recent US national survey found that a large majority of women don't get the recommended daily magnesium intake, which becomes worse as women approach menopause. The US Institute of Medicine advises 320 mg/day of magnesium, although women average 228 mg. This average magnesium intake level was determined using a 1-day food recall, thus it may be too high. Performance and activity may also be limited by magnesium. According to polls of athletes, some don't get enough magnesium. Using magnesium supplements may boost strength and exercise performance, according to several studies. It is unclear if these results are caused by a pharmacological response or magnesium deficit improvement.

TABLE 3:

The results of an extensive survey of the diets of adults aged 19 – 64 years in the UK24

Micronutrients		Men (%)	Women (%)
Vitamin B_1		12	**13**
Vitamin B_2		20	**28**
Vitamin B_6		6	**10**
Folate		11	**30**
Magnesium		50	**74**
Zinc		43	**45**
RDA, recommended daily allowance.			

Iron deficiency affects a large number of Europeans and Americans, particularly children, menstruating women, and pregnant women.

Low consumption of meat, particularly red meat, and high intake of zinc absorption inhibitors including phytate, certain dietary fibers, and calcium decrease zinc status. Many demographic groups in both developed and developing countries have low zinc consumption, resulting in poor zinc status. Zinc absorption inhibitors are more likely to cause the issue than dietary zinc deficiency. Zinc deficiency is more common in women, dieters, and seniors. Physically active adults often have low zinc intakes, especially those who do aerobic exercises.

Intense activity increases magnesium, iron, zinc, and chromium losses in sweat and urine.

Finally, the following may raise the risk of vitamin deficiency:

(i) Induced production of energy metabolism enzymes raises micronutrient cofactor demands.

(ii) Sweating and urine loss of minerals like magnesium and iron during exercise. Active people and athletes are known to have micronutrient deficiencies: B vitamins, vitamin C, iron; vitamin B2 in young women athletes;45 and vitamin B6 after marathon running.

(iii) Dieting, bad diet, and a rigorous lifestyle increase need. This is particularly true for active women who diet and make poor eating choices. Those ladies are at risk for B vitamin deficiency. Lifestyle-induced micronutrient insufficiency reduces performance and weariness.

(iv) While not addressed in this review, pregnant women and the elderly must be highlighted.

Consequences of inadequate micronutrient intake for physical well-being

Given the importance of micronutrients in energy metabolism, B vitamin deficiency and high B vitamin demands impact mitochondrial activity. Clinical investigations on micronutrient metabolism and physical performance are few. Research designs have not been extensive enough to draw solid findings because to cellular respiration's complexity and the body's ability to use other energy sources in emergencies. Nevertheless, poor folate, B12, and mineral consumption reduce endurance work performance.

Sports medicine and "women's health" research have examined the effects of restricted diets on physical performance. Long-term dieting to reduce weight is commonly feared by the medical and general press. A detailed examination of the health impacts of dieting in active women defines a "chronic dieter" as someone who "consistently and efficiently decreases calorie intake to maintain an average or below-average body weight".

The author notes that low-calorie eaters typically lack micronutrients including calcium, iron, magnesium, zinc, and B complex vitamins. These micronutrients "have a key role in energy production, haemoglobin synthesis, maintenance of bone health and strength, and an adequate immune function," making them essential for active people. Aesthetic or "thin-build" athletes like dancers, long-distance runners, and gymnasts may struggle if they diet often. Poor physical performance, especially if tied to employment demands, may have a devastating psychological effect on active females.

A Spanish study on vitamin status in healthy young women and calorie intake found comparable outcomes.

Only vitamins C, E, and retinol had normal or optimal blood levels in these young women who seemed healthy. Young women who eat low-energy meals are more likely to have mild vitamin deficiencies, the study found. Food restriction is linked to micronutrient deficiency, which may impair physical function.

Exercise may lower micronutrient levels, just as a vitamin deficiency does. Young women were given different amounts of riboflavin (vitamin B2) in a 10-week metabolic study. 43 20 to 50 minutes of exercise each day for six days a week lowered riboflavin levels, but raising dietary levels restored them. In a similar study, exercisers had lower riboflavin levels than non-exercisers.

Zinc deficiency affected physical performance in a recent double-blind, randomized, crossover experiment.

6 Following a 6-week washout, 14 young guys had a zinc-supplemented diet for 9 weeks. Zinc-deficient diets were provided for 9 weeks. Physiological tests, blood and feces analysis, were done during each feeding cycle to assess zinc levels. The authors found that low zinc intake impaired cardiorespiratory function and exercise-induced metabolic changes. The 1998 riboflavin DRI was based on metabolic research by the US Institute of Medicine. They concluded that although active adults may have larger demands, there was not enough data to measure them.

Exercise does induce a little loss of vitamin B6, according to several research. Vitamin B6 maintains plasma pyridoxal 5'-phosphate levels (PLP). After exertion, blood tests show vitamin B6 uptake as PLP levels rise fast. 48 B6-consuming subjects return to baseline 30–60 minutes after exercise. 48 Marathon runners lose 1 mg of vitamin B6, which is the adult DRI.

48 concluded that active people may need more thiamine, riboflavin, and vitamin B6 because activity stresses metabolic pathways that need them. As exercise worsens nutritional status in people with marginal vitamin intakes or body storage, those who restrict their calorie intake or eat poorly are more likely to have low

thiamine, riboflavin, and vitamin B6 levels. Speich et al. reviewed 1994–2000 studies on the effects of 16 minerals and trace elements on physical performance in 2001. Most of these minerals' physiological activities are unclear, even though some are involved in energy metabolism. This uncertainty suggests additional investigation. Although the long-term health repercussions of modest B vitamin deficiencies are unclear, understanding micronutrients and energy metabolism is even more important.

Micronutrient supplementation

Athletes typically take multivitamins/mineral supplements, urged by their coaches. Armstrong and Maresh42 reference Australian research suggesting that 30%–100% of players in various sports use supplements. The data suggests that micronutrient supplementation improves physical performance only when food consumption is inadequate. The most recent analysis found that vitamin and mineral supplementation did not increase performance in persons eating well. Yet, 'young females and those engaged in activities with weight categories or cosmetic components are prone to nutritional shortages since they limit food intake and particular micronutrient-rich foods'.

Do athletes' results apply to "regular" persons who exercise moderately? In a recent article, physically active young women with borderline vitamin status were shown to be at highest risk of micronutrient deficiencies due to persistent dieting. Manore and Lukaski discovered the same high-risk category from different perspectives: Lukaski found a "at risk" grouping of young women who controlled their diet, whereas Manore found a physically active subgroup of chronic dieters. Both authors suggested multivitamin/mineral supplementation for such women.

Lastly, the elderly are often undernourished. Food, micronutrient status, and supplementation have been researched in the elderly, although most studies have focused on the impact of deficiency on infection susceptibility and, more recently, cognitive performance. 18 Older adults often complain of fatigue, weakness, and oddly, loss of appetite. A recent research replicated prior pan-European results that 39% to 78% of senior adults had vitamin A, calcium, and iron intakes below the lowest European RDA. The link between micronutrient insufficiency and energy in this population merits additional investigation.

The research implies that poor micronutrient status may take several weeks to develop and several weeks to recover body storage. While data are limited, an experimental trial indicated that daily vitamin B6 treatment restored optimal blood levels in 6 weeks. This and multivitamin clinical data suggest a therapy term of at least 40 days.

Lichtenstein and Russell54 found good grounds to prescribe dietary supplements to some groups. Supplements are affordable and accurate. Supplements may help selected populations meet their nutritional demands if taken regularly.

Conclusion

Vitamins and minerals are essential to energy metabolism. B complex vitamins are required for mitochondrial function, and a deficiency of one of these vitamins may disrupt a whole metabolic pathway needed to convert food into energy. Energy creation requires various minerals and trace elements, but further study is required to determine their exact contribution.

Insufficient micronutrient consumption or higher demands may harm health, increase infection risk, and cause fatigue, lack of energy, and poor focus. Young to middle-aged individuals are also at risk of micronutrient deficiency, notably B vitamins. They are frequently energetic, physically demanding ladies with bad diets and frequent weight loss efforts.

For patients with chronic fatigue and no underlying illness, multivitamin–mineral supplementation is indicated due to the relevance of micronutrients for energy metabolism and the danger of micronutrient deficiency in otherwise healthy people. Supplements should be used for at least six weeks to have a visible influence on physical well-being.

References

1 *Groff JL, Gropper SS, Hunt SM: Advanced Nutrition and Metabolism, 2nd edn. St. Paul: West Publishing, 1995.*

2 *Depeint F, Bruce WR, Shangari N, et al: Mitochondrial function and toxicity: role of the B-vitamin family on mitochondrial energy metabolism. Chem Biol Interact 2006;* ***163:*** *94 – 112.*

3 *Depeint F, Bruce WR, Shangari N, et al: Mitochondrial function and toxicity: role of B vitamins on the one-carbon transfer pathways. Chem Biol Interact 2006;* ***163:*** *113 – 132.*

4 *Lukaski HC: Magnesium, zinc, and chromium nutriture and physical activity. Am J Clin Nutr 2000;* ***72(suppl):*** *585S – 593S.*

5 *Lukaski HC, Nielsen FH: Dietary magnesium depletion affects metabolic response during submaximal exercise in postmenopausal women. J Nutr 2002;* ***132:*** *930 – 935.*

6 *Lukaski HC: Low dietary zinc decreases erythrocyte carbonic anhydrase activities and impairs cardiorespiratory function in men during exercise. Am J Clin Nutr 2005;* ***81:*** *1045 – 1051.*

7 *Institute of Medicine: Dietary Reference Intakes for Calcium, Phosphorus, Magnesium, Vitamin D and Fluoride. Washington DC: National Academic Press, 1997.*

8 *Institute of Medicine: Dietary Reference Intakes for Thiamin, Riboflavin, Niacin, Vitamin* B_6*, Folate, Vitamin* B_{12}*, Pantothenic Acid, Biotin and Choline. Washington DC: National Academic Press, 1998.*

9 *Institute of Medicine: Dietary Reference Intakes for Vitamin C, Vitamin E, Selenium and Carotenoids. Washington DC: National Academic Press, 2000.*

10 *Institute of Medicine: Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium and Zinc. Washington DC: National Academic Press, 2001.*

11 *Brubacher GB: Assessment of vitamin status in pregnant women. In: Vitamins and Minerals in Pregnancy and Lactation (Berger H, ed). Nestle Nutrition Workshop Series, Vol 16. Vevey: Nestec / New York: Raven Press, 1988; pp 51 – 57.*

12 *Bässler KH: Definition und Relevanz subklinischer Vitaminmangelzustände. VitaMinSpur 1995;* ***10:*** *112 – 118.*

13 *Pietrzik K: Concept of borderline vitamin eficiencies. Int J Vitam Nutr Res Suppl 1985;* ***27:*** *61 – 73.*

14 *Baessler KH, Golly I, Loew D, et al (eds): Vitamin- Lexikon fuer Aerzte, Apotheker und Ernaehrungswissenschaftler, 3rd edn. Muenchen- Jena: Urban & Fischer, 2002.*

15 *Shankar AH: Nutritional modulation of immune function and infectious disease. In: Present Knowledge in Nutrition, 8th edn (Bowman BA, Russel RM, eds). Washington DC: ILSI Press, 2001; chapter 59, pp 686 – 700.*

16 *Meydani SN, Han SN: Nutrition regulation of the immune response: the case of vitamin E. In: Present Knowledge in Nutrition, 8th edn (Bowman BA, Russel RM, eds). Washington DC: ILSI Press, 2001; chapter 41, pp 449 – 462.*

17 *Rucker RB, Suttie JW, McCormick DB, et al (eds): Handbook of Vitamins, 3rd edn. New York: Marcel Dekker, 2001.*

18 *Huskisson E, Maggini S, Ruf M: The*

influence of micronutrients on cognitive function and performance. J Int Med Res 2007; ***35:*** *1 – 19.*

19 *Fairfield KM, Fletcher RH: Vitamins for chronic disease prevention in adults. JAMA 2002;* ***287:*** *3116 – 3126.*

20 *Fletcher RH, Fairfield KM: Vitamins for chronic disease prevention in adults. JAMA 2002;* ***287:*** *3127 – 3129.*