Vitamin E and athletic performance

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Vitamin E has been of interest to sports people for many years, with reports of its dietary supplementation in the 1950s. In the last decade there has been a resurgence in the interest in the relationship between vitamin E and athletic performance and animal studies have demonstrated that endurance is reduced in vitamin E deficiency. Much of the recent research has centred around the antioxidant properties of vitamin E and it seems that these properties are in part responsible for the improvement of aerobic power of humans at medium to high altitude venues following supplementation of the vitamin. However, there have been no similar reports relating to sea-level performance. On the other hand, one recent study has indicated that supplementation of vitamin E to athletes consuming the recommended daily intake (RDI) elicited a reduction in indicators of muscle damage following an exercise bout. Furthermore, vitamin E is implicated in maintenance of both optimal immune function and optimal blood viscosity, both factors being important in athletes’ ability to train and compete, but it remains to be seen whether supplementation of the RDI has any beneficial effects. So, there seems little doubt that vitamin E deficiency will impair athletic performance and there is also some evidence that supplementation of vitamin E on top of the RDI may provide some advantage for the intensely training athlete, especially those training at altitude.

Introduction

A 1922 report identified a fat-soluble factor as preventing foetal resorption in animals fed a rancid lard diet. They named the factor tocopherol, ‘tocos’ meaning offstinging and ‘phoro’ to bring forth. This early experiment and later confirmation by others formed the basis for determination of the biological activity of the various tocopherols. The tocopherols were accepted as ‘vitamin E’ in 1925. The significance of foetal resorption clearly overshadowed the series of studies on the anti-oxidant properties of the tocopherols initiated by O’cott and Ewing and followed up by other workers through to the early ’60s. The profile of vitamin E enjoyed an upsurge when Cureton 1 and Cureton and Pohlsdorff 1 reported that vitamin E and wheat germ oil improved performance in training athletes and middle-aged subjects respectively. The momentum was maintained during the early ’60s when it was found that certain metabolites of α-tocopherol restored the fertility of vitamin E deficient rats 1.2.3.

There was considerable interest in the use of vitamin E at the Mexico City Olympic Games in 1968, supposedly to compensate for the effects of the reduced oxygen pressure. The latter interest probably arose through reports that vitamin E administration enhanced the survival of animals exposed to acute hypoxia 4.5. The general ergogenic implications of vitamin E supplementation were reinforced again some 20 years ago, by several animal studies in which induced vitamin E deficiency states resulted in decreased oxidative phosphorylation 4,6, decreased creatine phosphate activity 4,6,12 and decreased NAD/NADP succinate-cytochrome reductase activity and ATP production 12. These findings prompted the hypothesis that vitamin E acts to optimise orientation of cytochromes b and c for electron transport. Animal studies suggested that training induced the same type of muscle damage as vitamin E deficiency (Alkalai et al., 1984) and vitamin E deficient rats exhibited a 40% reduction in running endurance 14. The more recent findings that vitamin E is associated with maintenance of the structural and functional integrity of cell components 15.16, seems to provide a plausible explanation for the pro-oxidative metabolic effects associated with the vitamin. Clearly, if vitamin E deficiency induces lipid peroxidation of sarcoplasmic reticular vesicular suspensions, this will adversely affect the efficiency of the CA++ transport system and Ca++/ATPase activity 17, with resultant diminished muscular work capacity.

Consequently, research over the last decade relating vitamin E and exercise has targeted the antioxidant properties of vitamin E in relation to sparing of muscle fibre and red cell membrane during bouts of intense exercise. The exercise protocol used as the challenge has typically been metabolically stressful cycling or running, presumably to maximize production of reactive oxygen species and associated oxidative damage. However, some authors have hypothesized that vitamin E deficiency may be more detrimental in anaerobic exercise (such as downhill treadmill running or other exercise

Regional differences in coronary heart disease in Britain: do antioxidant nutrients provide the key?

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英國冠心病的地區差异

摘要

英國冠心病的死亡率有很大的地區差異，這不能用已建立的危險因素如血膽固醇鶏高或血壓來解釋。這些地區差異在很大範圍內可與另一個內部因互為相關，如飲食習慣、飲食中的蔬果和穀類的相對攝入、吸收和纖維素食品等。所有這些因素與血膽固醇和其它氧化脂質的相連系，由于低抗氧化作用和增加了血液的氧化力，這也是英國冠心病差異的基本機程。
Vitamin E supplementation and athletic performance

When considering the relationship of a nutrient with performance, there are, as usual with such studies, two separate questions that need to be addressed. The first is whether the nutrient is essential to the development of peak fitness or performance of the athlete. The second question is whether those athletes involved in strenuous training can benefit from the supplementation of the vitamin at levels higher than the RDI. Put another way, can an athlete consuming the RDI for vitamin E, with plasma vitamin E concentration between 5–10 mg/L, benefit from consuming a plasma concentration of 20 mg/L? As mentioned earlier, the first published study of vitamin E supplementation and athletic performance appeared in 1954 in the American Journal of Physiology and obviously excited coaches and athletes with a finding that supplementation improved laboratory cycling and running performances over training alone. Swimmers, in particular, responded to this research, but from what we can gather, a large proportion of other serious athletes took vitamin E as a supplement until the early to mid-70s. For the common use of vitamin E supplementation comes from Tolly Gathercole, Australian Institute of Sport swimming coach and former champion swimmer. He and his Australian athletes used to routinely take vitamin E tocopherol tablets during training and competition periods. Interestingly, during the 1956 Olympics Games, the coach Dr. Peter Thomas Cureton, author of the first study with athletes and vitamin E18, at which time Cureton took notes on each swimmer’s supplementation programme.

In the 70s five groups tried to reproduce the early findings but failed to detect any advantage of vitamin E supplementation19–22. None of these studies incorporated a placebo group, which would have been useful given the notable unreliability and lack of compliance in athletes involved in studies of this nature23.

Recently, there have been investigations of the effect of several months of multivitamin supplementation, which included vitamin E, on a variety of components of athletic performance12–14. Apart from some trends in one or two aspects of fitness, the authors were not able to support the hypothesis that vitamin E (or multivitamin supplementation) was responsible for the RDI, has any beneficial (or deleterious) effect on performance.

Two aspects of the latter studies are worth noting however. Firstly, plasma vitamin E levels did not rise after multivitamin supplementation, as these vitamins have been reported to mutually inhibit absorption24. Secondly, it has been explained as how elite athletes seek improvement in fractions of 1% - the design of performance studies may not be sufficient to detect these small improvements. Indeed, it has been estimated that more than 200 athletes may be needed in both treatment and placebo groups to detect a 10 second difference in 4 minute event25. Animals are easier to manage experimentally than humans, but we are, of course, faced with difficulties of interpretation of the findings of animal studies in relation to humans. Nevertheless, the endurance capacity of vitamin E deficient rats may, even when they are supplemented with vitamin C26. Further, the authors have demonstrated that the reduction in mitochondrial respiratory function and oxygen uptake in response to hypoxic stress may be improved by vitamin E supplementation27. Hence, the implication of the vitamin E studies at altitude for sea-level performance is that athletes utilize altitude training to seek improvements at sea level. Based on the data presented above, it may be speculated that if altitude-induced adaptations are beneficial for sea-level competition then these adaptations might also be enhanced through supplementation of vitamin E at altitude.

Vitamin E and performance modulators

There is a further relationship between studies of the effect of vitamin E and altitude on performance. For years, physiologists have been investigating the effect of medium altitude training (2000–2500m) on sea level athletic performance. For altitude training and vitamin E supplementation alike, numerous coaches and athletes claim it is beneficial despite the fact that scientifically controlled experiments have not borne this out28. The problems mentioned above of using absolute athletic performance as a criterion for a treatment’s effectiveness have been compounded by inherent difficulties when it comes to indicating effects on performance. It would then seem a more sensible approach to investigate specific mechanisms by which the activity controlled experiments have not borne this out46.

Vitamin E and muscle damage

Vitamin E is clearly an effective biological antioxidant, with the potential ability to protect cellular membranes from free radicals produced by the beta-carotene group29. Athletes’ training capacity is limited by their ability to recover between training sessions. Such limitations in recovery are due in part to muscle tissue damage, and associated general well-being and fatigue. Consequently,ler 29. It has been hypothesized that vitamin E, the antioxidant may have a beneficial role to play in this area. The Australian Institute of Sport has uncovered some interesting findings47. This double-blind, crossover, placebo controlled study, demonstrated that supplementation with vitamin E enhanced recovery from exercise. The results of this study have been replicated in other laboratories30.

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(b) Vitamin E and red cell damage

Reduced plasma ferritin concentrations can be a consequence of prolonged increased physical training, as indicated by the haematogard and haemoglobin levels25,26,48. Athletes’ training capacity is limited by their ability to recover between training sessions. Such limitations in recovery are due in part to muscle tissue damage, and associated general well-being and fatigue. Consequently, it has been hypothesized that vitamin E, the antioxidant may have a beneficial role to play in this area. The Australian Institute of Sport has uncovered some interesting findings47. This double-blind, crossover, placebo controlled study, demonstrated that supplementation with vitamin E enhanced recovery from exercise. The results of this study have been replicated in other laboratories30.

Vitamin E and endurance training

Vitamin E supplementation improved performances in conditions of chronic hypoxia. Apparently, reactive oxygen species are produced in greater quantities when metabolism and oxygen consumption are increased and in man the metabolic rate can be increased from 300 ml O2/min at rest to 6500 ml O2/min in endurance athletes. In addition, it seems that we may also be subjected to an increased stress response (acute stress syndrome) to hypoxic environments, given the better adaptations of vitamin E supplemented humans to physical exercise at altitude28. It has been postulated that the oxidative state of the intensely exercising person may also be viewed as ‘relative hypoxia’; hypoxia at the working tissue level because the demand for maximal power is not always met by the oxygen transport capacity and delivery of the circulation. This results in involvement of anaerobic glycolysis, and lactate accumulation in whole blood which will only be increased in intensely exercising athletes whilst pH drops below 7.0. Recent studies have demonstrated that the blood of even elite athletes can be progressively desaturated with oxygen at extremely high rates of power output2–4, so, if vitamin E supplementation at altitude, then it might be argued that it could also help intensively-exercising athletes at sea-level where muscle cells may also be under hypoxic stress. The implication of the vitamin E studies at altitude for sea-level performance is that athletes utilize altitude training to seek improvements at sea level. Based on the data presented above, it may be speculated that if altitude-induced adaptations are beneficial for sea-level competition then these adaptations might also be enhanced through supplementation of vitamin E at altitude.
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In the 1970s five groups tried to reproduce the early findings but failed to detect any advantage of vitamin E supplementation.23-26 None of these studies incorporated a pre-supplementation status, which would have been useful given the notable unreliability and lack of compliance in athletes involved in studies of this nature.27

Recently, there have been investigations of the effect of several months of multivitamin supplementation, which included vitamin E, on a variety of components of athletic performance.28-31 Apart from some trends in one or two aspects of fitness, the authors were not able to support the hypothesis that vitamin E (or multivitamin supplementation) would increase the RDI, has any beneficial (or deleterious) effect on performance.

Two aspects of the latter studies are worth noting, however. Firstly, plasma vitamin E levels did not rise above the RDI of vitamin/mineral supplementation.31 The authors suggested that absorption of vitamin E and A may have been impaired in the multivitamin preparations, as these vitamins have been reported to mutually inhibit absorption.22 Secondly, it has been explained that as elite athletes seek improvement in fractions of 1%32 - the design of performance studies are unlikely to detect these small improvements. Indeed, it has been estimated that more than 200 athletes may be needed in both treatment and placebo groups to detect a 10 second difference in a 4 minute event.33 Animals are easier to manage experimentally than humans, but we are, of course, faced with difficulties of interpretation of the findings of animal studies in relation to humans. Nevertheless, the endurance capacity of vitamin E deficient rats may, even when they are supplemented with vitamin C 21. Further, the authors have demonstrated that the reduction in endurance capacity of rats to mitochondrial activity in skeletal or heart muscle.

Vitamin E supplementation and performance at high altitudes

Three studies provide good evidence that vitamin E supplementation does improve performance at medium to high altitudes (2000-5000m). The potential of the data in this regard came from a study of a group of prominent long distance runners28 who received 300mg α-tocopherol daily for 4 days, significantly raising serum vitamin E concentrations. The experimental group was found to perform better than the control group in a race at 5000m altitude and the authors reported lower blood lactate accumulation in the supplemented group. A few years later, in a double blind cross-over design, it was demonstrated that 1200 IU/day vitamin E for 6 weeks improved the capacity for aerobic work at both 1524m and 4572m altitude significantly above baseline.42 Exercise training had no beneficial effect.32-34 More recently, there was an investigation of the aerobic fitness adaptations of mountaineers on the TransHimalaya Expedition in 1977.30,33 The mountaineers were given daily multivitamin capsules, one with vitamin E, the other without 2 x 200mg d-α-tocopherol per day. Anaerobic work (using the lactate accumulation in response to power output) were performed as the mountaineers proceeded on a 10 week expedition around 5000m. In contrast with the placebo group, improvements in fitness were demonstrated in the supplemented group. Furthermore, pentane exhalation, considered to be a measure of lipid peroxidation, was doubled in the 5 weeks in the vitamin group, but was unchanged in the placebo group.

These studies provide sound evidence that vitamin E supplementation improves performance and reduces the conditions of chronic hypoxia. Apparently, reactive oxygen species are produced in greater quantities when metabolic and oxygen consumption are increased. Consequently, it has been hypothesized that vitamin E is the antioxidant that may have a beneficial role to play.34

The Australian Institute of Sport has uncovered some interesting findings 44. This double blind, crossover, placebo controlled study, demonstrated that in a group of 13 runners with a 35% increase in VO2 max, the IU of α-tocopherol resulted in a significant increase in both plasma and red cell membrane concentrations of vitamin E. Individual response to a 40 minute run at 3m above sea level (very high altitude exercise) revealed that the supplemented runners had significantly lower blood creative kinase (CK) concentration compared to the unsupplemented runners. On the other hand, in a study of 11 male elite athletes. This premise is supported by findings of higher proportions of blood reticulocytes in athletes, indicating increased red cell turnover.43 The importance of vitamin E is indicated in the rat ischemia reperfusion test test: erythrocytes possess decreased ability to withstand osmotic stress from hydrogen peroxide when high levels in the blood are decreased. The test also implies another possible antioxidant role of vitamin E, in protection of the red cell membrane and potential reduction of capsular iron that is thought to be a factor in non-iron related disease. On the other hand, it may be argued that increased red cell turnover and a resulting younger population of cells is advantageous to the athlete given the more favourable physiological and rheological properties of younger red cells.39
(c) Vitamin E and endocrine activity

Of further interest in the Australian Institute of Sport study is the finding that the ratio of blood testosterone to estradiol increased during the 24 hours post-exercise and that the exercise was significantly higher in the supplemented group. The ratio has been utilized as an indication of recovery and exercise performance (as these hormones influence muscle anabolism/catabolism respectively). The physiological significance of this finding needs to be further investigated, but it does provide more evidence that vitamin E supplementation at multiples of the RDI may be of benefit to athletes. Also, through the enhanced testosterone concentrations, the relationship of vitamin E supplementation to the human reproductive system is hinted in humans, seven decades after the first findings of its influence on the reproductive process in laboratory animals.

(d) Vitamin D and blood viscosity

Blood viscosity is related not only to health, but performance in athletes. In another recent report from the current author's laboratory \(^1\) it was demonstrated that performance of elite rowers was best when their whole blood viscosity was lowest within the normal range. It is also of advantage to athletes involved in high level aerobic exercise to maximize their haematocrit, and accordingly their oxygen transport per unit volume of blood. This, however, will increase the haematocrit, the higher the blood viscosity, but vitamin E may help to optimize blood viscosity. For example, erythrocyte filtration through the capillary bed becomes compromised if vitamin E supplemented mountain climbers was unaccompanied under the hypertensive stress of a high altitude expedition, in contrast to a placebo group whose erythrocyte filterability fell significantly. Vitamin E administration is also effective in reducing platelet aggregation\(^2\), important to patients with thrombo-embolic disease, and with possible implications for athletes in optimizing whole blood viscosity, but as yet unstudied in this regard.

(1) Vitamin E and immune function

Studies concentrating on neutrophil function in athletes as well as untrained subjects indicate that, whilst moderate physical activity can enhance this ‘first line of defence’, intense and/or high volume training can depress neutrophil microbial capacity\(^3\). A variety of studies concerning various other aspects of immune function provide general support for this premise. Bearing in mind this constant threat to intensively training athletes, any method by which optimal immune function can be preserved will aid performance indirectly by facilitating illness-free training of higher quality and quantity.

Vitamin E supplementation has improved immune function in athletes. In fact, it has been suggested that the dietary vitamin E requirement of rats for optimal immune function is greater than that required to prevent experimentially enclosed muscle fibre and red cell damage. Vitamin E supplementation at multiples of the RDI has been postulated as a method of action is through inhibition by vitamin E of the synthesis of immunosuppressive prostaglandins from arachidonic acid.

Studies in humans also implicate vitamin E with immune function. The neutrophils observed after eccentric exercise was dampened in older people, but restored to a level similar to younger people after 48 days of supplementation at 400 IU/day\(^4\). No effect of vitamin E supplementation on blood monocytes was observed, but supplementation was observed in younger subjects. In another study of healthy adults aged 60 years and over, supplementation with 1200 mg/kg of vitamin E/day for 20 days in patients with certain indicators of immune function including a skin hypersensitivity test and response of lymphocytes to a T-cell mitogen antigen\(^5\).

Furthermore, vitamin E seems to have an immunomodulatory role, its influence on young people, particularly athletes, is unclear and warrants further investigation.

References

(c) Vitamin E and endurance activity

Of further interest in the Australian Institute of Sport study is the finding that the ratio of blood tocopherol concentrations (in mg/ml) to plasma free radical content in the muscle was significantly higher in the supplemented group. This ratio has been utilized as an indication of recovery from intense exercise (as these hormones influence muscle anabolism/catabolism respectively). The physiological significance of this finding needs to be further investigated, but it does provide more evidence that a high plasma free radical content at multiples of the RDI may be benefit to athletes. Also, through the enhanced testosterone concentrations, the relationship of vitamin E supplementation to the human reproductive system is hinted at in humans, seven decades after the first findings of its influence on the reproductive process in laboratory animals.

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References

Folate and neural tube defects

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The multifactorial aetiology of neural tube defects has stimulated many theories related to dietary factors in pregnancy. The results of the Medical Research Council Study confirm that folate has a protective effect if taken in the 3 months prior to conception and for the first trimester. The dosage recommended is 5mg daily for women at risk for spina bifida or anencephaly and 0.5mg daily for those at low risk. Dietary modification to include foods with high folate such as leafy green vegetables and wholemeal grain is not considered sufficient. Fortification of staple food items such as bread and cereals with folate is being considered in some countries. A comprehensive health education programme is essential, directed to women in the reproductive age group and to doctors involved in primary care, family planning and obstetric management. The incidence of neural tube defects could be reduced by 70% with the introduction of folate supplementation in all pregnancies.

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Malformations which result from defective closure of the neural tube are anencephaly, meningomyeleocele and encephalocele. Closure occurs in the third week of fetal development and proceeds in two directions—both cephalad and caudal. The general term, spinal dysraphism, is used to refer to open and closed defects, which can be induced experimentally. An alternative mechanism of rupture of the neural tube has been proposed, and this occurs at a slightly later stage in development. Anencephaly is absence of the cranial vault and brain and is incompatible with life.

Encephalocele is protrusion of the cranial contents and is associated with high perinatal mortality or severe physical and intellectual disability in survivors.

Meningomyeleocele is a cystic protrusion of the spinal cord and results in defective function of the cord below the level of the lesion with paraplegia and incontinence. Associated hydrocephalus causes specific learning disabilities. Survival rates are 50% past 6 months of life and the disability is so significant that there are criteria for selection for treatment.

Incidence rates for these abnormalities have varied throughout the ages. There are world-wide trends, and strange paraboles have been noted in seasonal peaks and sex ratios.

Perinatal mortality figures for New South Wales are available from 1958 to 1990 and show a downward trend which is partly due to decrease in incidence which has been observed world-wide, and partly to changes in diagnostic procedures which identify cases before 20 weeks of pregnancy, thus facilitating early termination which is not notified to Australian Bureau of Statistics. True incidence figures from multiple data sources are available from 1965 to 1990, and show a less marked downward trend.

Epidemiological studies have shown variations by race, country, area, social class, and parental occupation. Dietary factors have occasioned wide interest.

The aetiology of neural tube defects is said to be multifactorial, and is a genetic-environmenal interaction. A polygenic predisposition provides a background risk with a threshold effect which is exceeded by an environmental trigger.

The genetic component accounts for less than 10% of cases. 90% occur sporadically. There is a 5% recurrence risk after one affected case. Twin studies confirm 5% concordance rates.

Many environmental factors have been incriminated such as pesticides, heat waves, toxins, caffeine and a variety of dietary agents ranging from tannin in tea, through nitrates in meat preservatives to solanine in blightened potatoes.

Hibbard and Smithells suggested in 1965 that vitamins may play a role in the prevention of neural tube defects. This initial article was followed by a series of publications by Smithells et al. in 1976 and 1981. Laurence proposed that the active agent was folic acid in 1981. This suggestion was supported by the identification of high risk groups such as Aboriginal women, who are known to be folate deficient, women on folate antagonists such as septicin or aminopterin in pregnancy, and those with coeliac disease.

Due to criticism of the structure of the published studies, and uncertainty about the active component of vitamin supplements, the Medical Research Council Study was proposed and started in 1983. There were ethical objections to such a study on the grounds that withholding vitamins from women at risk of having a child with a neural tube defect was wrong. The lack of information about the efficacy of supplementation and possible harmful effects of the use of multivitamins was considered to outweigh these objections and the trial