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Vitamin E, Exercise, and the Recovery from Physical Activity

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Abstract. A matched-pair trial under near double-blind conditions has tested the physiological effects of an 85-day-course of d-α tocopherol acid succinate (1200 I.U./day) in 20 university class swimmers. Valid comparisons were possible in 7 of the 10 pairs. These showed good initial matching of maximum oxygen intake, recovery curves, muscle strength and e.c.g. waveform. Despite a substantial yardage of swimming training ($\sim$20,000 yards/week), neither test nor control groups improved their aerobic power. However, both groups showed a reduction in the lactate component of the oxygen debt, with a faster pulse recovery curve. Muscle strengths tended to decline, the loss of handgrip strength being significant in the control group. No change of e.c.g. waveform was observed except a small increase of T wave height in the controls. It is concluded that the swimmers gained no advantage from the Vitamin E, although it could conceivably have helped maintain equality of status in the face of a slightly smaller weekly yardage than that of the control group.

Key words: Vitamin E — α Tocopherol — Ergogenic Aids — Swimming Training.

Related Literature

Several authors have suggested that Vitamin E (tocopherol) acts as an "ergogenic aid" to training and athletic performance, both in animals such as horses [4], and in man [3, 11, 12, 15, 16]. Postulated mechanisms of action have included a direct pro-oxidant effect of the tocopherol, as inferred from increased tolerance of low oxygen pressures [6, 8, 13][1], improvements of myocardial efficiency [25] and the development, dilation or preservation of capillaries in both skeletal and cardiac muscle [5, 7, 23].

Increased interest in the possible positive effects of Vitamin E has been generated by observations on animals deprived of tocopherol. In the rat, for example, a form of muscular dystrophy has developed [14, 25]

[1] The increased survival could equally reflect an anti-oxidant effect with a decrease of resting metabolism.

with weakness, fatty degeneration and fibrosis of the muscles. On the other hand, Consolazio *et al.* [2] reported that rats swimming to exhaustion 2 days/week for 6 weeks gained no benefit from octacosanol, wheat germ oil, or Vitamin E supplements.

The only clinical problems clearly linked to tocopherol deficiency have been anaemia and excessive haemolysis of red cells in certain rather specialized populations including premature infants [1], cases of Kwashikor [18], badly nourished Ugandan Africans [10] and astronauts subjected to restricted diet, restricted mobility, and high partial pressures of oxygen (Turner—unpublished report cited by Legge [9]). Thomas [24] found no gains when 30 athletes were put on a 5-week-course of α tocopherol acetate, and Sharman *et al.* [19] likewise found no response to a daily dose of 400 mg α tocopheryl acetate in a double-blind trial on 26 schoolboys.

It could be argued that negative responses have been based on too small a dose of Vitamin E. Russian investigators [17] claim that hard training produces a fall in blood and urine levels of Vitamin E and thus have set the daily requirements of athletes at 100 to 150 mg. Shute [22, 23], however, has suggested giving every sportsman 800 I.U. (660 mg) of α tocopherol/day, with doubling of the dosage prior to an important contest. In contrast, Prokop's positive findings [16] were based on a mere 50 mg given 1 h prior to exercise.

In view of continuing controversy regarding the possible value of Vitamin E to the athlete, it seems worth recording a study involving two small but closely matched groups of university competitive swimmers.

Methods

Subjects and Experimental Design. The subjects were 16 male swimmers, age (20.3 ± 1.6 years), height (182.6 ± 5.4 cm) and weight (79.7 ± 5.5 kg) being typical of performers at this level of competition. All were members of the university team.

The study commenced in October, when the swimmers began intensive training, and concluded some 3 months later. Measurements of maximum oxygen intake, recovery curves, muscle strength and electrocardiographic responses were made on each subject prior to and at the end of the trial. On the results of the initial tests, subjects were paired for maximum oxygen intake, body weight and swimming event, and the matched pairs were then allocated randomly to two groups arbitrarily designated AB and XY. Capsules were similarly designated, with the key (Vitamin E or placebo) held by the manufacturer until after completion of the experiment.

The trial was not completely double-blind, since one member of the laboratory staff knew the distribution of swimmers between the two groups, although he was unaware of the contents of the capsules. However, the coach was unaware of this distinction.

Vitamin Administration. A stable and non-toxic natural form of Vitamin E was used, namely d-α tocopheryl acid succinate. Individual capsules contained 400 I.U.[2].

[2] 1.21 I.U. of Vitamin E are equivalent to 1 mg of d-α tocopheryl acid succinate (N.F.).

Subjects were required to take 3 capsules/day, commencing 3 days after the initial testing, and continuing until the day before the final test; the total period of vitamin administration thus ranged from 78 to 92 days, with an average of 85 days.

The placebo was a lactose powder, identically encapsulated, but differing slightly from the test drug in texture, taste and solubility as shown by a post-trial taste test at which 10 of 11 subjects correctly identified the Vitamin E.

Blood levels of Vitamin E were not determined but subsequent questioning of the subjects established good compliance with instructions, pills being taken for an average of 81.6 of the 85.4 potential days. Despite requests to the contrary, 6 of the 16 athletes admitted attempting to determine the contents of their capsules. However, only 2 succeeded in breaking the code [31]; since the conclusion of the study was negative, this does not constitute a major objection to the experiment.

Treadmill Test. Oxygen consumption was measured by standard [20] open-circuit methodology (meteorological balloons, with paramagnetic analysis of oxygen concentrations and determination of CO_2 concentrations by infra-red spectroscopy) during rest (10 min), exercise, and recovery (15 min). An electrocardiograph permitted calculation of pulse rate (CM_5 lead) throughout.

Exercise consisted initially of a 9-min "warm-up" with three increasing 3-min treadmill loads (6 m.p.h. 2, 4, and 6 % slope); further increments of slope were made at 2 min intervals to exhaustion, usually reached in 15—17 min. During recovery the subject sat on a stool. A sample of arterialized capillary blood was taken for estimation of lactate concentration 2 min following activity [20]. A "curve-stripping" approach was used to divide recovery oxygen consumption readings into alactate and lactate components (Wright and Shephard, in preparation).

Muscle Strength. The force of handgrip was measured for both hands using a Stoelting dynamometer. A cable tensiometer system was used to test the force of forearm extension. The measurement was arranged to mimic the action of crawl swimming, the subject lying face downward on a rigid table, his upper arm extended laterally in the plane of the table, and the forearm pointing down towards the floor; the harness of the tensiometer cable was attached about the wrist, at 90° to the forearm.

Electrocardiographic Measurements. Voltages were recorded at the S-ST junction, at the ST-T point, and at the peak of the T wave. Results are averages of 6 to 8 representative cardiac cycles at each point in a given experiment, expressed as differences from the resting value for a given individual.

Statistical Methods. All data were treated by a matched pair technique, checking that no difference existed between test and control groups at the outset of the experiment, and testing whether differences developed over the course of treatment.

Results

1. Matching of the Groups

Twenty subjects initially volunteered to participate in the experiment. One was rejected because he was under the age of 18, and three ceased training for various reasons. Analysis of data is thus restricted to the 7 matched pairs that completed the experiment. Initial values for the 2 groups did not differ significantly with respect to any of the measured physiological criteria, although there were overall suggestions of rather smaller oxygen debt, lesser muscular force and faster pulse rate recovery in the test group AB than in the control group XY (Table 1).

Table 1. Initial matching of test and control groups; data limited to 7 pairs completing the experiment. Mean ± S.D. of results for initial tests. In no case was the initial difference between groups AB and XY statistically significant[a]

Variable	Test group (group AB)	Control group (group XY)
Maximum oxygen uptake (l/min STPD)	4.50 ± 0.29	4.48 ± 0.26
(ml/kg min)	57.4 ± 4.4	55.9 ± 5.1
Blood lactates 2 min after max effort ($n = 4$) (mg/100 ml)	139.2 ± 17.6	123.5 ± 29.7
Oxygen dept		
"Fast" component (1)	2.49 ± 0.41	2.64 ± 0.56
"Slow" component (1)	4.79 ± 1.24	5.21 ± 0.86
Heart rates (/min)		
Maximum exercise rate	198.0 ± 11.0	195.3 ± 6.6
Strength		
Right handgrip (kg)	53.8 ± 7.8	58.3 ± 4.4
Left handgrip (kg)	50.1 ± 5.9	57.1 ± 6.4
Forearm force (kg) ($n = 6$)	39.6 ± 8.4	42.3 ± 9.3

[a] For successful matching, the value of Δ, AB-XY should be non-significant.

2. *Physiological Responses to Training and Vitamin Dosage*

Both groups were initially quite well trained, as can be gauged from the maximum oxygen intake data. Despite a rigorous training schedule (average weekly swimming yardage 22,307 ± 7770 per subject in group XY and 18,842 ± 2050 in group AB)[3], there was no statistically significant change in maximum oxygen intake over the course of the 3-month training programme. However, both groups of subjects showed a reduction of maximum heart rate and the slow (lactate) component of the oxygen debt, with a substantial speeding of the recovery process (Table 2). Muscle strength tended to decline, the change of handgrip strength being statistically significant for group XY. The electrocardiogram showed no change of T wave, ST depression or junctional depression over the training period, with the exception of a small increase in T wave height in the 3rd min of exercise in the control group XY ($\Delta = 0.22 \pm 0.19$ mV, $P < 0.025$).

[3] The difference of yardage between groups reflects the less regular attendance in group AB. Individual members of both groups completed repetitions of their preferred distance at 85% of competitive speeds to a total of 4000 yards over a 1 to $1^1/_2$ h session.

Table 2. Significant changes in response to 85 days training. Results shown as difference from initial to final session

	Test group (AB)	Control group (XY)
Oxygen debt (slow component, 1.)	-0.8 ± 1.5	-1.3 ± 0.7^{c}
Strength		
Right handgrip (kg)	-2.5 ± 5.4	-2.5 ± 2.5^{b}
Left handgrip (kg)	-1.1 ± 3.1	-3.9 ± 3.4^{b}
Heart rate		
Maximum	-7.3 ± 8.8^{a}	-3.9 ± 8.0
Recovery		
0.5 min	-8.0 ± 7.9^{a}	-2.0 ± 8.8
1.0 min	-8.0 ± 11.1	-13.0 ± 18.0
1.5 min	-14.8 ± 8.4^{c}	-13.8 ± 15.8
2.5 min	-13.6 ± 7.9^{c}	-13.4 ± 15.7
3.5 min	-7.2 ± 5.4^{b}	-8.5 ± 14.7
5.0 min	-8.7 ± 9.2^{b}	-9.0 ± 10.0^{a}
15.0 min	-5.8 ± 8.8	-10.1 ± 7.1^{b}

^{a} $P < 0.1$; ^{b} $P < 0.05$; ^{c} $P < 0.01$.

Since both groups showed only small and rather similar training responses, the final condition of the matched pairs (Δ_2 AB — XY) was also statistically identical. No physiological advantage was gained by the test group (AB) relative to the control (XY) with the possible exception that equality of status was maintained in the face of a slightly smaller training yardage. None of 36 comparisons of resting exercise and recovery e.c.g. values showed any significant change in either group AB or group XY.

3. *Subjective Comments*

Twelve of the 16 subjects noted no unusual features of their subjective response to training; one (control) felt his improvement in condition less than expected, two thought their improvement greater than expectation and the 16th made no comment. Ten felt their competitive performance was at the expected level, two (one test and one control) believed it to be less than expected, two (both control) better than expected, and two were undecided. Rather significantly, the 3 best competitors of the season were from the control group. Thirteen of the 16 noticed no effect of the capsules upon appetite, digestion, mood, sleep, muscle soreness or other subjective complaints. One of the remaining subjects (control) could not get a complete night's sleep, one (test) complained of muscle soreness which required a longer recovery period, and the other (test) felt complacent, lacking his usual competitive drive.

Discussion

The present report provides no support for the view that Vitamin E will improve the exercise performance of the well-trained college level athlete; nor does it appear to influence tolerance of a demanding training schedule.

One possible criticism of our experiment is that no measurements of blood Vitamin E levels were obtained. Retrospective questioning established that a satisfactory proportion, some 95% of the intended dose, was in fact taken. To avoid conflict with iron therapy, some of the swimmers took the capsules at breakfast, and in the event that this was not a fatty meal, absorption may have been somewhat incomplete. Diet, also, was unrestricted, with the exception that food supplements such as wheat germ oil with a high content of Vitamin E were prohibited. Nevertheless, the dose of Vitamin E used was very large relative to some for which positive effects have been claimed.

Another possible criticism is that the subjects were initially quite well trained. Significant effects might have been observed with a more sedentary test population. Nevertheless, subjects from both experimental and control groups developed the types of response claimed for Vitamin E, including a reduction of oxygen debt immediately following maximal treadmill running to exhaustion, and a faster pulse recovery curve.

Since our subjects were tested only twice, it finally remains arguable that those receiving Vitamin E achieved a training effect faster, with the control subjects subsequently "catching up"; however, the swimming times of our subjects do not substantiate such a view.

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