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VITAMINS AND PHYSICAL FITNESS

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The purpose of the present experiment was to test whether, as the result of a deficiency in the average student's diet, the fitness of University students has diminished since the beginning of the war.

Procedure of Experiment

In two groups of students the effects of adding vitamin supplements to the diet of one group were studied. Certain anthropometric data, "physical efficiency tests," and the incidence of minor ailments were used as a basis of comparison of the two groups. The experiment was performed on 69 subjects over a period of 21 weeks (April 18 to Sept. 11, 1942). The subjects were 40 R.A.F. and 29 R.E. cadets attending a special short course at Manchester University. The cadets had only recently joined the Forces, were all about the same age (18-19), and had roughly the same social background; they lived in two of the University halls of residence, and had the ordinary undergraduate diet: breakfast and supper in hall and a midday meal in the refectory at the University.

Examination.—The subjects were first examined by A. A. H. and I. F. S. M. The examination consisted of the usual anthropometric data: height (standing and sitting), weight, chest girths ("normal," expiration, and inspiration), the distance between the iliac crests, and the bi-trochanteric diameter. In addition the following measurements were made:

(a) The resting heart rate (4 successive half-minute periods after the subject had rested in the recumbent position for 15 minutes), the standing heart rate (4 successive half-minute periods immediately after standing up); and the effect of exercise on the heart rate (measured 0-15 and 60-90 seconds after stepping on and off a 40-cm. box 15 times in 30 seconds).

(b) The resting vital capacity (the maximum expiration following a full inspiration, the expired air being collected in a Hutchinson bell spirometer: four attempts were allowed, and the maximum recorded); and the post-exercise vital capacity (measured 30 seconds and 90 seconds after 40 knee-bends in 1 minute).

(c) The R.A.F. breath-holding and endurance tests. The breath-holding test is the time in seconds during which the subject can hold his breath after a deep expiration followed by a full inspiration. In the endurance test the subject, with his nose clipped, expires deeply, and then, after a full inspiration, blows the column of mercury in a manometer steadily to a height of 40 mm. and maintains it at that level for as long as possible without breathing. The time during which the mercury column is sustained is measured in seconds, and the pulse rate for successive 5-second periods is noted during that time.

Vitamin Supplements.—The cadets were then divided into two groups. Group 1 (35 students) were given a daily vitamin supplement consisting of 6,000 units of vitamin A, 1,000 units of vitamin D, and 50 mg. of vitamin C, in the form of one "adexolin" capsule and one "celin" tablet daily. Group 2 (34 students), who acted as controls, received capsules of arachis oil and tablets containing citric acid, identical in

appearance with those given to group 1 but devoid of any vitamin content. Each group contained half the R.A.F. and half the R.E. cadets; care was also taken to see that the men examined by A. A. H. and I. F. S. M. were equally divided between the two groups.

History of Minor Ailments.—A fortnight's supply of capsules and tablets was issued to the cadets at a time. Each cadet was interviewed by one of us every fortnight, when he collected a fresh supply of vitamins, and a history was taken of any minor complaints during the previous two weeks, particular attention being paid to respiratory and gastro-intestinal upsets and to bleeding from the gums.

Re-examination and Change-over of Groups.—At the end of 10 weeks (June 25) the cadets were all re-examined, the same routine being used as in the first examination. At the same time the two groups were changed over: group 1 were now given control tablets and capsules, and group 2 vitamin tablets and capsules.

Final Examination.—The experiment was continued for a further 11 weeks (until Sept. 11), and the examination of the cadets was again repeated. Each cadet was examined on all three occasions by the same examiner. The cadets were not told whether they were on vitamin or control tablets, and did not know of the change-over of the two groups half-way through the experimental period. The examiners did not know which of the cadets were on vitamin supplements and which were on control.

Results

The detailed analysis of the various sets of measurements was made by Dr. G. L. Camm. In addition to considering the vitamin and control groups during each half of the experiment and over the whole experimental period, a separate sub-analysis was made of the behaviour of the R.A.F. and of the R.E. cadets. In brief the main observations are as follows:

1. Minor Complaints

The average number of days of minor respiratory and gastro-intestinal complaints per man was estimated. These included acute and chronic colds, loss of appetite, "indigestion," and, occasionally, nausea and vomiting. The minor nature of most of the complaints must be emphasized; they were "subclinical" in the sense that only in a small minority were the subjects ill enough to stop work. We would emphasize also that these figures are compiled from the histories given by the subjects. Only in a few instances did we verify their statements by examination. Very few cases of bleeding gums were reported, and these have been omitted from the calculations. Complaints during the first fortnight of the experiment, and during the first three weeks after changing over the groups, were also omitted, as it was considered that during these periods there was not enough time for any possible protective action of the vitamins to become apparent. It was found that over the other 16 weeks of the experiment the control group showed an

incidence of complaints 50% greater than the vitamin group. The total figures were: vitamin group, 671 days; control group, 1,015 days. The mean figures were: vitamin group, 9.7 days per man; control group, 14.9 days. Mean difference (vitamin—control): -5.2 ± 1.7 . The difference between the two groups is statistically significant.

2. Physical Examinations

The means of the various measurements made during the three examinations were calculated, and examined to see whether there were any significant differences between the vitamin and control groups. There was no significant difference in respect of the anthropometric measurements (heights, weight, chest girths, and pelvic measurements). Nor were any significant differences found on comparing the standing pulse rate, the pulse rate during the R.A.F. endurance test, the post-exercise pulse rate, or the post-exercise vital capacity in the two groups. On the other hand, in four of the measurements made, interesting differences were found between the vitamin and control groups. These measurements were (i) the resting vital capacity, (ii) the breath-holding time, (iii) the R.A.F. endurance test time, and (iv) the resting pulse rate.

Resting Vital Capacity.—At the beginning of the experiment the mean resting vital capacity was the same for the two groups. At the end of the first half of the experiment the vital capacity of both groups had increased, but much more so in group 1 (vitamin) than in group 2 (control). At the third examination the vital capacity of group 1 (now control) had diminished, and that of group 2 (now vitamin) had increased. At both examinations, therefore, the balance of improvement was in favour of the cadets who had been receiving vitamins for the previous 10 or 11 weeks. The differences between the vitamin and control groups are statistically significant. A separate sub-analysis of the R.A.F. and of the R.E. cadets also reveals a significant difference between the vitamin and control groups in both cases. The results are shown in Table I and Fig. 1.

FIG. 1.—Resting vital capacity.

FIG. 2.—Breath-holding time.

TABLE I.—Resting Vital Capacity in Litres

	1st Exam.	2nd Exam.	3rd Exam.
Group 1 ..	4.698	(vitamin) 4.826	(control) 4.740
Group 2 ..	4.694	(control) 4.727	(vitamin) 4.776
Whole period: Mean difference (vitamin—control) = $+0.119 \pm 0.022$			

Breath-holding Time.—The results resemble those of the vital capacity measurements. At the end of the first half of the experiment the increase in breath-holding time in group 1 (vitamins) was much greater than in group 2 (control). At the end of the experiment, following the change-over of the two groups, the average time for group 1 had decreased, while that for group 2 had increased. At each examination, therefore, the cadets on vitamins showed a greater improvement than those on control tablets. Statistical analysis revealed a definitely significant difference between the vitamin and control groups of the R.A.F. cadets and a just-significant difference between the combined groups.

The results are shown in Table II and Fig. 2.

TABLE II.—Breath-holding Time in Seconds

	1st Exam.	2nd Exam.	3rd Exam.
Group 1 ..	72.1	(vitamin) 91.0	(control) 85.4
Group 2 ..	78.2	(control) 88.4	(vitamin) 90.3
Difference (vitamin—control): $+8.6 \pm 3.7$ $+7.4 \pm 3.9$			
Mean difference over whole experimental period (vitamin—control) = $+8.0 \pm 2.7$			

Endurance Test.—An examination of the times during which the cadets could maintain a column of mercury at a height of 40 mm. by a steadily exerted expiration shows changes similar to those in the breath-holding times, but less marked in degree. In each half of the experiment the group then on vitamins increased its time more than the control group. The differences are statistically significant only for the R.E. cadets.

The results are shown in Table III and Fig. 3.

TABLE III.—Endurance Test Times in Seconds

	1st Exam.	2nd Exam.	3rd Exam.
Group 1 ..	55.3	(vitamin) 64.3	(control) 68.7
Group 2 ..	63.4	(control) 64.7	(vitamin) 71.3
Whole period: Mean difference (vitamin—control) = $+5.1 \pm 2.3$			
Mean difference for R.E. cadets = $+6.7 \pm 1.8$

FIG. 3.—Endurance test.

FIG. 4.—Resting heart rate.

Resting Heart Rate.—The changes in resting vital capacity and in the breath-holding and endurance test times—showing in each a greater improvement in the vitamin than in the control groups—were such as might have been expected, assuming that the extra vitamins had increased the “physical fitness” either by diminishing the incidence of minor illnesses or by some other mechanism. The changes in the resting heart rate, however, were unexpected, if one accepts the popular view that a slow heart rate is a sign of “physical fitness.” At the first examination the heart rates of both groups were practically the same. At the second examination the heart rates of both groups had diminished, but the slowing was more pronounced in the control than in the vitamin group. At the third examination it was found that the new control group showed a further diminution in heart rate, but the new vitamin group had increased in heart rate. The differences are statistically significant only in the R.E. cadets.

The results are shown in Table IV and Fig. 4.

TABLE IV.—Heart Rate at Rest, per Minute

	1st Exam.	2nd Exam.	3rd Exam.
Group 1 ..	75.1	(vitamin) 70.2	(control) 68.0
Group 2 ..	74.8	(control) 67.6	(vitamin) 68.5
Whole period: Mean difference (vitamin—control) = $+2.7 \pm 1.0$			
Mean difference for R.E. cadets = $+4.5 \pm 1.4$			

Discussion

The results of the experiment suggest that even during the summer months the diet of the students examined was sufficiently below the optimum level in respect of one or all of vitamins A, C, and D to produce a significantly greater amount of minor respiratory and gastro-intestinal upset than a similar diet supplemented with these vitamins. The greater improvement in resting vital capacity and in breath-holding and endurance times in cadets receiving vitamin supplements may be a reflection of this lessened susceptibility to minor infections, or may be due to some other action of the vitamins. The faster resting pulse rate in the cadets receiving vitamin supplements is difficult to explain.

The validity of these conclusions may be attacked on two grounds: first, that the number of subjects (69) was too small for an experiment upon nutrition and physical fitness; and, secondly, that the differences between the vitamin and control groups in vital capacity, etc., are not striking enough to warrant the drawing of any conclusions.

With regard to the second objection, Jokl, Cluver, Goedvolk, and de Jongh (1941), using a smaller group (32), found that repeated examinations of vital capacity and resting pulse rate showed mean figures varying only a matter of 20 to 30 c.cm. in the case of the vital capacity and fractions of one beat in the case of the pulse rate. All our variations are much greater than these.

The first objection (the paucity of numbers in the experimental group) is more valid. It is to some extent offset by the homogeneity of the group. All the cadets were of the same age, of the same social class, and during the experimental period were living under identical dietetic conditions. Another factor which increases the value of the observations is the striking manner in which the change over of vitamin and control groups half-way through the experiment in each case resulted in a reversal of the behaviour of the groups. This obviously increases the significance of the separate sets of observations, but no allowance for this was made in the computation of the results. The two halves of the experiment were treated separately, as if a second group of 69 students had been used for the second half. Had this actually been the case the differences obtained might well have been due to selection; but this can hardly be the true cause, since the same students were merely interchanged.

Despite these objections we feel that this report may be of value in drawing attention to a possible method of assessing the optimal rather than the minimal requirements of vitamins in the diet. A diet containing less than the optimum amount of a particular vitamin, while not producing a deficiency disease, may nevertheless give rise to a suboptimal physiological state which will only be revealed by the application of physiological tests such as we describe.

Summary

The effects of adding supplements of vitamins A, C, and D to the diet have been studied over a period of five months in 69 cadets living in university halls of residence at Manchester.

The cadets receiving vitamin supplements were less susceptible to minor respiratory and gastro-intestinal complaints than those receiving control tablets which contained no vitamins.

The group receiving vitamins showed a greater increase in resting vital capacity and in breath-holding and endurance times, and had a faster resting pulse rate than the control group.

We wish to express our thanks to Glaxo Laboratories Ltd. for facilitating the supply of vitamin and control tablets and capsules.

REFERENCE

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EFFECTS OF VITAMINS ON EXPERIMENTAL HYPERTHYROIDISM

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The problem of the relationship between thyroid hormone and vitamins is of great importance for the proper therapeutical application of these substances in several diseases and also for the treatment of hyperthyroidisms—in particular, Graves's disease. The existing literature on the subject is so large that economy of space unfortunately makes it impossible to review it here, but it will be reviewed elsewhere. At the same time it is most contradictory, apparently because the following facts have not been taken into consideration by some of the workers:

1. Vitamins are food factors; therefore thyroid hormone, the chief function of which is to increase the oxidation processes in the organism, increases the metabolism of the vitamins in a similar way to that, for example, of proteins, fats, and carbohydrates. Thus depletion of *vitamin A* in the organism of animals by thyroid hormone administration has been found by Abelin (1933), Parhon and Werner (1935), Sure and Buchanan (1937), and Mlinko (1938); a similar condition in hyperthyroid patients was indicated by Wohl and Feldman (1938). With regard to *vitamin B*, of especial importance are experiments by Himwich, Goldfarb, and Cowgill (1932), Hendricks (1933),

Cowgill and Palmieri (1933), Cowgill (1934), and Drill (1938), who showed that the requirement of vitamin B of an organism per unit of mass is proportional to the metabolism of that mass, and that thyroid hormone therefore greatly increases this requirement. The depletion of *vitamin C* from the animal organism by thyroxine has been recorded by Demole and Ippen (1935), Plaut and Bülow (1935), Mosonyi (1935), Nespor (1936), Sure and Theis (1938), and Thaddea (1938). Increase of metabolism due to any cause accordingly requires increased administration of vitamins: e.g., in the case of muscular work, Cowgill (1934) found this for vitamin B and Hamel (1937) for vitamin C.

2. Therefore when even non-toxic doses of thyroid hormone are given or mild hyperthyroidism is present without a corresponding increase in vitamin administration, a relative vitamin deficiency might develop with more or less pronounced symptoms of anorexia, partial starvation, and loss of body weight.

3. For these reasons it is difficult to draw definite conclusions as to the antagonistic effects of thyroid hormone and vitamins from the experiments of several previous workers who used, often deliberately, a diet deficient in, or containing only a minimal normal amount of, the vitamin investigated, or used toxic doses of thyroid hormone.

The effects produced by any substance differ greatly according to whether toxic or non-toxic doses are used. In toxicosis, non-specific, mostly destructive, changes occur which obscure the specific changes. This is true both for thyroxine and for vitamins.

Technique

Non-toxic Experiments.—All these facts were taken into consideration when planning our experiments (see Tables I and II), performed on rats kept on our usual diet. This diet is rich enough in all vitamins to ensure (this appears to be the best test) excellent breeding results. We have chosen as criteria for judgment of antagonism or co-operative activity the changes in body weight and weights of most of the organs, fat deposition, and histological structure of thyroid gland. We have used non-toxic doses both of thyroid hormone and of vitamins, but in the case of vitamins, except with vitamin D, they were much above the normal requirement, while with thyroid hormone they were large enough to produce specific and typical changes (Korenchevsky and Hall, 1941).

Experiments were performed on 121 male rats for investigation of the effects of vitamins B and C, and on 66 female rats for investigation of vitamins A and D. The final age of the rats averaged 150 days. Each experiment was repeated twice. Although the doses and, in the case of vitamin B complex, the numbers of vitamins B used were somewhat different in the first and second experiments, the results were similar. The data from both experiments were therefore pooled, and average figures only are given in Tables I and II.

TABLE I.—Effects of Non-toxic Hypervitaminosis A and D on the Means of Body Weight, Fat Deposition, and Actual Weights of Organs in Normal Female Rats and in Rats treated with Non-toxic Doses of Thyroid Hormones*

Organs	Co-V	Co+V	Thy-V	Thy+V
	Group 1	Group 2	Group 3	Group 4
Ovaries, mg.	68	68	87	84
Preputial glands, mg.	94	85	139	132
Adrenals, mg.	50	52	75	77
Thymus, g.	288	332	289	273
Liver, g.	7.05	7.03	9.57	9.64
Kidneys, g.	1.29	1.32	2.12	2.11
Spleen, mg.	729	674	1,002	1,226
Heart, mg.	714	712	1,028	1,036
Abdominal fat, g.	7.4	7.6	1.6	1.7
Final body weight, g.	196	195	188	186
Gain in body weight, g.	52	51	43	38
No. of rats in group	16	16	16	18

* In this and the following table "Co-V" denotes the group of control rats receiving no additional substances; "Co+V" the group of rats receiving an extra amount of vitamins; "Thy-V" the group of rats receiving thyroid hormone alone; "Thy+V" the group of rats receiving simultaneously thyroid hormone and an extra amount of vitamins.

No changes in weight of uterus, vagina, thyroid, hypophysis, and brain were obtained in this experiment.

The doses used were as follows: In the first experiment 85 mg. of desiccated thyroid in the form of a sweetened emulsion was given orally by pipette 3 times a week; and 0.6 mg. of thyroxine

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