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Diet and Muscular Fatigue

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IT IS common knowledge that in order to do work one must eat. In total starvation muscular efficiency and work capacity fall continuously. Food is the source of the energy for work. We must admit, however, that our detailed knowledge of the function of many foods is scanty. Most everyone will agree that certain classes of foodstuffs—as glucose, amino acids, fatty acids, minerals, vitamins, and water—are absolutely necessary for normal metabolism. But what effect does maximal or minimal daily intake of the various dietary constituents have on the human's ability to do muscular work? Can one do more work or prevent the onset of muscular fatigue by following any special dietary regime?

Scientists have long known that carbohydrates—specifically glucose—play a major role in muscle metabolism. It was recognized that tiredness, fatigue, and, in extreme cases, even collapse occurred when the blood sugar was depleted. Men kept on a low carbohydrate diet soon exhibited increased muscular efficiency and ability to do hard physical work.[1] In experiments on the efficiency of industrial workers,[2, 3, 4, 5] it was found that when the blood sugar was low, the muscular efficiency—and consequently the output—of the workers decreased. When the blood sugar and muscular efficiency of the workers had fallen to fasting levels, as they were found to do within 3 hours after the last meal, the ingestion of 30 grams of glucose or 225 cc. of fruit juice raised the blood sugar 75 per cent and the muscular efficiency 25 per cent. From this evidence it appears justifiable to conclude that the total amount of work and the efficiency with which one can do it are decreased when the blood sugar falls below some optional value. There is, however, no evidence that in normal humans fatigue can be delayed or decreased by maintaining a superoptimal blood sugar level. One might, also, criticize the results of the experiments on the industrial workers on the basis that it has been shown[6] that almost anything one does to change the worker's routine will increase output.

The role of the fats and proteins in work and fatigue is not firmly established. When men were kept on a high fat diet they were less efficient and fatigued faster. However, this finding may have been related to the relatively lower carbohydrate intake. Pro-

* Superior figures refer to Bibliography at end of article.

tein intakes up to 500 grams per day have been investigated. The subjects were more efficient on the high protein diet than on the high fat diet, but were not as efficient as when the blood sugar was kept at high levels by giving carbohydrates.[3] Numerous papers have appeared on the value of a high glycine diet. Some of the investigators found that work output could be increased up to 200-300 per cent by a daily intake of 10 to 50 grams of glycine.[7, 8, 9] In other laboratories the beneficial effects of glycine could not be confirmed.[10, 11, 12] Consequently, it remains for the future to show the true importance of the amino acids in muscle metabolism.

Amphetamine sulfate (benzedrine) has been used rather widely to postpone the onset of fatigue and to lessen its symptoms. Research has, in part, justified its judicious use. It has been shown that 10 to 20 mg. of benzedrine sulfate given to patients complaining of chronic fatigue markedly improved 80 per cent of them. In a group of 80 normal people 62 per cent of those receiving the drug recorded subjective feelings of decreased fatigue and increased efficiency while only 16 per cent of those receiving placebos recorded any subjective help.[13] Benzedrine given 3½ hours before the end of the working day increased the flicker fusion frequency and decreased the sense of fatigue in a group of office and laboratory workers.[14] Doctor Ivy[15] has concluded that the diminution of the sense of fatigue by benzedrine was entirely a subjective phenomena. This might cast some doubt on the ability of benzedrine to influence true muscular fatigue.

The use of coffee, tea, and "cokes" to combat fatigue is a common practice. One might be tempted to think that the popular mid-morning coffee and afternoon tea habit might reflect something a bit more fundamental than accidental habit. Caffeine[16] has been shown to prolong the onset of fatigue and increase the total work output of an isolated frog muscle. In the normal non-coffee-drinking human it took from 0.5 to 1.0 gram of caffeine intravenously to produce any subjective or objective effect on fatigue.[17] With such high doses the recovery rate from fatiguing work and the total amount of work that could be done before complete fatigue were increased. If it takes about 1 gram of caffeine intravenously to be effective, it hardly seems logical that the average coffee drinker would get enough caffeine to have any alleviating effect on fatigue.

Of particular interest is the part played by the vitamins—especially ascorbic acid and thiamine—on muscle metabolism. There is no doubt that the vitamins are dietary essentials for maintaining normal muscular activity. The recognition that an increased intake of vitamins will increase the physical vigor of frank vitamin deficiency cases has given rise to the belief that a superabundance of these vitamins may produce supermen or at least help one in meeting physical strain. Research on isolated muscles has led a few investigators to believe that ascorbic acid and thiamine will increase the ability of a normal muscle to do work.[18, 19, 20, 21] Others, however, were unable to confirm the results.[22, 23]

Experimentally induced thiamine deficiency in human subjects has produced interesting results. When subjects were kept on a diet adequate in all respects except thiamine (.5 mg. or less per day) they developed clinical symptoms of thiamine deficiency including muscle soreness, weakness, and a decreased ability to do work.[24, 25, 26, 27, 28, 29] As the daily thiamine intake was progressively increased a level was attained where the clinical symptoms disappeared and the work capacity was increased. When still higher doses of thiamine were given to these subjects on intakes just sufficient to prevent deficiency symptoms, the amount of work the subject could do seemed to be further increased. Clinical symptoms disappeared on thiamine intakes of .5 mg. per 1,000 calories while maximal benefits were obtained with not more than 1 mg. of thiamine per 1,000 calories. Thiamine intakes of that order fall within the 1.2 to 2.3 mg. per day suggested by the Committee on Food and Nutrition of the National Research Council.[30] Food purchase surveys have shown that from 30 to 50 per cent of the American diets would fall into the subclinical deficiency class receiving less than 1 mg. thiamine per 1,000 calories.[31, 32] It would be expected then that a great many people should be helped physically by an extra thiamine intake. Addition of up to 15 mgs. per day of thiamine to uncontrolled human diets has been reported to improve such muscular performances as holding the breath, arm-holding, cycling, and football playing.[33, 34, 35] However, the results can be justly questioned because the experiments were poorly controlled.

Doctor Ancel Keys and the author[36, 37] have carefully investigated the possibility of increasing work ability by vitamin supercharging. The subjects were healthy normal enlisted men of the United States Army who were eating the regular garrison ration. Analysis of the ration showed it to be sufficient in all respects. The thiamine content was not less than 1.7 mgs. per day's ration. Increasing the daily vitamin intake by 17 mgs. of thiamine, 100 mgs. of nicotinic acid amide, 20 mgs. of calcium pantothenate, 10 mgs. of riboflavin, 100 mgs. of pyridoxine, and 200 mgs. of ascorbic acid over periods ranging from 5 to 6 weeks had no effect on the subjects' biochemical and physiological response to a set task of severe work. Each subject was on a control period which was identical to his experimental period except that he was given placebos identical in size, shape, and color to the vitamin tablets. In this way each subject served as his own control so that individual variations were eliminated. The variables measured to assess the effects of the vitamins were

pulse rate, heart size, stroke output of the heart, oxygen consumption, respiratory quotient, urinary nitrogen and ketone body excretion, blood glucose, blood lactate, hemoglobin, blood acetone, and 2-hour glucose tolerance curves. Except for a slight training effect none of the variables measured were significantly different during the control and the experimental periods. Only one subject expressed any subjective improvement and that happened when he was on the placebos.

The garrison ration contained the suggested optimal thiamine intake; consequently the experiments did not cover the subclinical thiamine deficiency levels which might, according to some other investigators, be benefited by increased thiamine intakes. We have now finished a series of experiments on normal active college men who have been kept on the suboptimal thiamine levels for periods ranging from 5 to 10 weeks. As with the soldiers each subject has served as his own control. The subjects ate only the basal diet. During half of each experimental period they received extra thiamine and during the other half they got placebos. Thiamine determinations were run on the diet every day and 24-hour urinary thiamine excretions were done each week. One-half day each week each subject was subjected to a standard routine severe muscular work. Complete blood chemistries were run before and after each work period. The results indicate that the ability to do the set task of work was the same when getting extra thiamine as when on the basal diet alone. No symptoms of deficiency were noted. These experiments indicate that thiamine intakes of more than .3 mg. per 1,000 calories of food consumed have no effect on the ability of a normal person to do severe muscular work.

SUMMARY

Although special benefits from special foods have often been suggested for normal humans, there is little evidence that the special benefits are actually obtained.

Extra supplies of vitamins have no influence on physical ability, resistance to fatigue, or the rate of recovery from severe muscular work.

The usual dietary constituents are essential for normal muscular activity and physical well-being. However, the optimal intakes of the various foods are not fully established. By following the recommendations of the Committee on Food and Nutrition of the National Research Council, basic food requirements for all normal needs would be amply fulfilled. Even though the recommendations may in some cases exceed the optimal requirements, it is comforting to know that the results of a superoptimal intake are nothing more serious than a waste of money.

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