R44-07

Reprinted from THE JOURNAL OF NUTRITION
Vol. 28, No. 4, October, 1944

EFFECTS OF VARIATIONS IN DIETARY PROTEIN ON THE PHYSICAL WELL BEING OF MEN DOING MANUAL WORK [1]

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(Received for publication May 27, 1944)

INTRODUCTION

The question of the effects of low and high protein diets has become an immediately practical one, not only because of the relative scarcity of high protein foods but also because of the greater difficulty in shipping them long distances. Previous work has shown clearly what was the minimum protein intake necessary to maintain nitrogen equilibrium (Reviews — Lusk, '31 and Terroine, '36) and that low levels are compatible with health in sedentary men. Although frequent statements are to be found that higher intakes are necessary for hard work, almost none of these is supported by experimental proof. In fact the most extensive experimental work, that of Chittenden ('04), reported increased vigor for hard working men when the protein intake was lowered to 50–60 gm.

In order to make the results of this work useful for direct practical application, the aim was to utilize normal young men in a natural environment carrying on their usual regime of work. For the same reason the diets were planned to include only items to be found in normal diets, and thus to avoid synthetic or laboratory foods which would not be encountered in practical dietary experience. The plan in one group of subjects was to restrict protein foods as much as possible within the above limitations; in another group of subjects to give the greatest possible excess of high protein foods. In a third group the individuals were to continue on their usual diet.

The conclusions from this work must be limited to results appearing within the time limit of the tests, namely 8 weeks of the modified diet.

[1] The work described in this paper was done under a contract, recommended by the Committee on Medical Research, between the Office of Scientific Research and Development and Harvard University.

Therefore, the practical implications must likewise be limited to apply to emergency modifications of diet lasting up to 2 months.

METHODS

The subjects were twenty-four volunteers from the personnel of a Civilian Public Service Camp, who continued on the work regime of the camp and ate their meals at special tables in the regular mess hall. At the start each subject was given a thorough physical examination, clinical laboratory examination of blood and urine and blood chemical estimation of NPN, protein and A/G Ratio. NPN was estimated by the method of Daly ('33); serum protein and urinary nitrogen by the Micro Kjeldahl method of Ma and Zuazaga ('42); and serum protein fractionation by the method of Howe ('21). Throughout the study frequent check-up physical examinations were held and the estimations of blood NPN and protein were repeated weekly along with a measurement of the nitrogen in a 24-hour specimen of urine. Assessment of physical fitness each week was by means of the so-called "Pack Test." In this test the subject, wearing a rucksack weighted to approximately $\frac{1}{3}$ his body weight stepped up onto a 16-inch platform and back down onto the floor once each 2 seconds (handrails at shoulder height were used as an aid). The stepping exercise was terminated at 5 minutes if the subject could carry on that long; after stopping, the pulse was counted for three periods: 1 to $1\frac{1}{2}$ min., 2 to $2\frac{1}{2}$ min. and 4 to $4\frac{1}{2}$ min. of the recovery period. From these data a numerical score was calculated as:

$$\frac{\text{duration exercise in seconds}}{2 \times (\text{Sum of pulse beats counted in the three periods})}$$

This test had been found previously to correlate with physical ability in athletes and to parallel improvements with training and deterioration accompanying proven inadequate diets. In order to have an additional index of recuperative powers, the test was administered twice on each occasion with only 15 minutes rest between the two.

The dietary test program consisted of three periods — 2 weeks preliminary control, 8 weeks of modified diet and 2 weeks of final control. The twenty-four subjects were divided in three groups of eight, each group including a rough cross section of the whole in respect to occupation and physical fitness. All groups ate the regular camp diet for the first 2 weeks and one of the groups of eight continued thus throughout. A second group, called the restricted protein group, changed their diet at the end of the first control period to one which allowed no meat,

cheese, eggs, nuts, legumes and only up to ½ cup of milk daily. Bread was the only other food allowed the restricted protein group which contained animal protein (milk); this was limited in amount to this group so that not more than 2½ gm. of milk protein was furnished daily in this form and not more than 5 gm. of animal protein in the entire daily diet (the other 2½ gm. or less in top milk on cereal). Unlimited amounts of low protein foods were furnished this group and they, like the other groups, were urged to fully satisfy their appetites. During the final control period this group was given a high protein diet.

The third group, called the high protein group, was furnished with large amounts of high protein foods and allowed only restricted amounts of low protein foods.

All groups were given daily 5 gm. of yeast extract [2] fortified with additional riboflavin to forestall any possibility of vitamin B deficiency. As will be noted from the above description, the dictates of taste were followed in so far as possible in this type of experiment. For measurements of the diet each mess table was furnished with a diet scales and standard ladles. All articles of food were furnished in standard portions of known weight or else the subjects weighed the portion eaten. Each subject had a special record book with a page for each day in which he noted the amounts of each article of food eaten during the day on one side of the sheet and the day's activities hour by hour on the other side. These books were kept in a rack in the dining room. The proper analytic figures for protein, fat and calories were entered in these books periodically by the dietitian staff. All items in the diet known to contain significant amounts of protein were analyzed at least once for protein during the experiments. Those subject to variation (e.g., bread, cereals) in cooking were analyzed each time they were on the menu. Our own analytic figures were supplemented with those of Bowes and Church ('40) for fat and calories and for the traces of protein in low protein foods. Whenever possible the manufacturer or baker was consulted to determine ingredients.

The work of the subjects included office work, kitchen work, laundry work, farming and forestry work (including work on trails, clearing forest ground and repair of roads). The daily caloric expenditure, depending on the subject's job ranged from 2400 to 5000 cal. with an average of approximately 3300.

[2] Standard Brands Co., Type 3. This amount of fortified yeast contained approximately 5 mg. thiamine, 1.5 mg. riboflavin and 10 mg. niacin.

RESULTS

I. Restricted protein group

The averages of daily protein intakes in this group of eight are shown in table 1 along with the caloric intakes, subjects' weights and their usual occupations. It will be seen that even with the severe restriction of high protein foods the daily protein intake was rarely below 50 gm. and averaged 53 gm. When the caloric intake was above 4000 cal. the protein was usually nearer 60 gm. Potato, bread and other cereal products were the chief sources of this protein; less than 5 gm. was of animal origin. Two subjects of this group terminated their experiment early, one because of an acute attack of recurrent appendicitis, the other because of transfer to another project.

The 24-hour urinary excretions of nitrogen were measured once a week and the results, expressed as grams of equivalent protein, are included in table 1. Since these figures are calculated from samples taken only once weekly whereas the figures for intake were obtained daily, exact agreement should not be expected. However, it can be seen that the urinary nitrogen figures furnish a rough check on the calculated intake, if the usual assumption of 1 gm. of stool nitrogen is made. If anything, the intake figures tend to be a little larger than the corrected urinary figure so it may be safely stated that the calculated mean daily intake figure of 53 gm. is perhaps too high.

In general all the subjects in this group believed they were getting enough food. It was their observation, however, especially those doing the heaviest work, that they became unusually hungry and felt a little weak late in the morning and late in the afternoon. There was an average weight loss during the 8-week period of 0.9 kg., a good part of which could be logically explained by the fact that several of the group started on a regime of much heavier outdoor work than was customary to them. A weight loss of similar magnitude was found in the group on the normal diet. One man who lost 2.8 kg. was obese and rather "flabby" at the start.

Aside from the experiences of late morning and afternoon hunger mentioned above, none of the subjects complained of unusual symptoms. They were able to carry on the work routine; no complaints by their work supervisors were ever made. The pack test data confirms the impression that they showed no deterioration. Table 2 summarizes these results on this group and those on the normal and high protein diets. In spite of some irregularities it will be seen that both groups improved slightly; a few individuals strikingly, undoubtedly

TABLE 1

Summary of caloric intakes, protein intakes and urinary nitrogen excretions expressed as "equivalent protein".

Diet	Individual	Occupation	Body weight	PRELIMINARY CONTROL PERIOD (DAILY)			EXPERIMENTAL PERIOD						FINAL CONTROL PERIOD (DAILY)		
							1st four weeks (Daily)			2nd four weeks (Daily)					
				Caloric intake [1]	Protein intake [1]	Protein metabolism [2]	Caloric intake [1]	Protein intake [1]	Protein metabolism [2]	Caloric intake [1]	Protein intake [1]	Protein metabolism [2]	Caloric intake [1]	Protein intake [1]	Protein metabolism [2]
			kg.		*gm.*	*gm.*		*gm.*	*gm.*		*gm.*	*gm.*		*gm.*	*gm.*
Normal diet	Co	Forestry	71.1	2830	100	..	3870	125	102	....	..	..	....	..	..
	H	Truckdriving	72.0	3140	110	108	3640	115	81	3240	108	91	3350	114	101
	K	Camp maintenance	75.6	2720	94	72	2830	101	80	2920	107	99	2960	97	77
	Lar	Kitchen	77.0	3080	123	..	2750	102	68	3460	131	71	2790	97	79
	M	Carpentry	72.3	3550	128	102	3460	107	92	3140	105	94	2970	92	104
	N	Kitchen	72.8	2460	81	85	2060	71	63	2280	76	61	....	..	..
	Su	Office	68.3	3590	126	104	3620	123	98	3130	108	80	3060	92	67
	Tr	Carpentry	73.8	3040	101	79	3150	106	75	3380	102	85	3190	95	54
		Average	72.9	3050	108	92	3170	106	82	3080	105	83	3050	98	80
Restricted protein	B	Truckdriving	85.0	3090	110	88	3300	55	42	3230	57	41	4440	189	128
	F	Kitchen	79.7	3240	103	100	3750	57	45	3800	53	40	4110	185	141
	G	Road repair	59.2	2770	75	58	3020	52	41	3230	52	36	3810	135	114
	J	Office	87.7	2900	83	67	3140	56	54	....	..	..	....	..	..
	R	Farming	69.7	3600	125	127	3750	57	66	4300	59	47	5600	274	207
	Sm	Road construction	85.9	3490	117	108	3470	57	51	....	..	..	....	..	..
	Ste	Kitchen	74.9	2800	92	96	2260	39	43	2950	43	34	3710	184	73
	Sto	Forestry	63.3	3500	122	99	3170	48	44	3350	50	41	4160	198	131
		Average	76.9	3180	103	93	3230	53	48	3480	53	40	4310	194	132
High protein	A	Office	69.6	2080	78	61	2330	96	83	2380	110	88	2340	88	69
	C	Farming	68.9	3660	142	120	3980	190	156	3980	189	179	3150	125	117
	D	Kitchen	107.0	2460	103	98	3290	139	128	3590	182	144	2750	100	123
	Li	Office	83.2	2980	97	75	3660	153	122	3770	159	115	3150	104	103
	Lo	Forestry	80.0	3810	126	112	4440	193	164	3810	172	163	3150	112	107
	Sa	Forestry	84.3	3410	114	..	3950	174	161	5010	254	153	3290	137	124
	Tu	Office	72.4	2980	108	104	3270	151	132	3820	176	135	2380	82	68
	W	Laundry	62.6	3240	114	98	4430	185	156	4090	175	159	3060	106	98
		Average	78.6	3080	110	95	3670	160	138	3810	177	142	2910	107	101

[1] Average values calculated from weights of food eaten and analytic figures (all days calculated).

[2] Average values from analysis for nitrogen of 24-hour urine, collected only once weekly (gm. nitrogen x 6.25 to obtain figure in gm. protein for comparison with intake).

due chiefly to the physical training from their active work regime. The irregularities of scores are in some cases due to changes in motivation on different days; in other cases to local disabilities arising from minor injuries. The relative scores on the two consecutive tests on the same day did not yield any additional information and are not reported in detail. It was an unexplained fact that the relationship of the second to the first score was largely characteristic of the individual: many dropped off slightly every time on the second score, a few markedly, while a few actually improved in every instance.

TABLE 2

Physical fitness as indicated by scores in "pack test".

DIET	SUBJECT	PRELIMINARY CONTROL PERIOD: WEEK		EXPERIMENTAL PERIOD: WEEK								FINAL CONTROL PERIOD: WEEK	
		1st	2nd	1st	2nd	3rd	4th	5th	6th	7th	8th	1st	2nd
Normal diet	Co	71	..	81	78	72	..	..	..	..	..	..	..
	H	105	..	92	99	110	110	102	103	113	102	108	106
	K	57	50	55	61	62	58	67	65	58	68	65	52
	Lar	31	..	52	40	37	81	79	88	86	68	89	69
	M	43	78	85	86	96	102	96	87	87	88	106	99
	N	70	58	53	47	39	31	48	53	52	61	..	..
	Su	46	82	77	81	77	73	83	85	86	73	86	91
	Tr	..	..	62	67	74	85	88	86	86	85	89	92
Average increase[1]					− 6	− 4	+ 1	+ 5	+ 6	+ 6	+ 3	+ 15	+ 9
Restricted protein	B	26	23	27	34	37	34	38	42	48	85	54	79
	F	68	77	84	80	77	82	95	91	95	84	89	87
	G	48	75	85	85	96	77	82	88	90	84	83	..
	J	30	45	53	48	30	44	..	..	..	..	..	..
	R	81	82	82	..	..	82	73	80	82	..	82	79
	Sm	56	58	79	..	87	85	90	..	..	..	..	..
	Ste	67	87	88	95	89	103	98	107	88	90	99	86
	Sto	92	93	111	102	97	93	96	101	111	101	106	98
Average increase[1]					− 1	− 2	− 1	+ 2	+ 6	+ 6	+ 10	+ 6	+ 7
High protein	A	71	69	73	68	77	70	84	83	79	84	83	80
	C	84	87	92	90	90	92	96	92	94	85	88	91
	D	32	37	52	35	48	47	54	62	55	38	50	53
	Li	69	..	83	94	87	80	84	78	86	79	93	87
	Lo	97	87	94	89	93	98	85	82	91	87	89	80
	Sa	109	88	..	100	..	107	104	108	111	108	105	134
	Tu	77	81	83	80	79	83	83	83	87	87	79	83
	W	25	..	25	23	33	27	25	43	37	34	35	46
Average increase[1]					− 4	+ 2	0	0	+ 3	+ 3	− 2	+ 1	+ 5

[1] These figures obtained by setting for each individual a standard score equal to the highest of his first three scores on the table, by calculating for each later score the difference from the standard, and then by averaging the individual differences for each week.

The blood chemical and hematological findings were completely negative. There was no trend toward a lowering of either albumin or total protein; the red blood count and hemoglobin remained essentially unchanged.[3]

In the case of this group the final control period had a special significance since the protein in the diet was raised to a high level at this time. No change in physical performance or chemical findings was evident aside from the increased amount of nitrogen in the urine. The subjective effect of the change was conditioned by the preferences of the men; two men, habitual lovers of meat, were much happier on the high protein diet; two men found the high protein diet actually distasteful, the remainder had no strong feelings one way or the other.

II. High protein group

Again in this group the changes due to alterations in diet were practically non-existent. The weekly averages of daily protein intake ranged from 157 to 192 gm. compared to 95 to 113 in the normal group (see table 1 for 4-week averages). The average in the high protein group was kept down by one subject, a sedentary, rather hypersensitive individual to whom "heavy food" was distasteful.

The less active men in this group tended to feel overfull and sleepy after meals. Not all this effect was necessarily due to the high protein per se. Among the available common foods high protein is associated with considerable fat. As a result the total caloric intake in this group tended to be higher than necessary. This is clearly shown in the weight figures which show an average gain of 1.0 kg. and a gain in one individual of over 5 kg. No other unusual symptoms were experienced.

The physical fitness tests showed a tendency to gradual improvement (table 2) as in the other groups, which is likewise explainable by training.

The urinary excretion of nitrogen expressed as equivalent protein in table 1 gives figures of 138 gm. and 142 gm. daily for the two 4-week periods. Although not exactly to be compared with the intake figures because of the less frequent measurements (see under Restricted Protein Group above), these figures confirm the high protein metabolism of this group but would require the assumption of rather high values of stool nitrogen (about 6 gm.) to be brought in line with the calculated intakes.

[3] Details of these measurements are omitted for the sake of brevity but will be furnished by the authors on request.

The only change in chemical findings [3] was a tendency to slightly higher NPN which is probably not very significant.

DISCUSSION

These studies fail to confirm Chittenden's conclusions that a restricted protein diet improves physical well being. His experiments had the advantage of being longer in duration but the disadvantage of having no parallel control subjects on their usual diet. His conclusion that there is no impairment of health by such a diet is completely supported.

It is apparent from these studies that to choose a low protein diet from commercial articles of diet is difficult, provided caloric balance is maintained. When sufficient calories are given for hard physical labor, a fairly respectable level of protein is automatically included.

Likewise it was found difficult to increase the protein level above 150 gm. using standard items of diet. To push beyond this without giving excessive calories, defatted foods such as buttermilk or skim milk would be necessary.

The conclusions from this study should not be extended beyond the conditions investigated. The protein needs during growth, illness and lactation are wholly outside the scope of this work. It is apparent only that for 2 months with normal men (such as laborers or soldiers) rather extreme variations in protein intake were without measurable effect either beneficial or harmful. The practical implications are that under emergency conditions a diet supplying about 50 gm. of protein, chiefly from potatoes and grain products, is not incompatible with the health of physically active young men.

SUMMARY AND CONCLUSIONS

1. Within 2 months no measurable influence either deleterious or beneficial could be observed on the physical vigor or efficiency of eight healthy young men subsisting on a diet adequate in calories but restricted in protein. The daily protein intake averaged 50 to 55 gm., very little of which was of animal origin.

2. Similarly no beneficial or harmful effect could be observed in 2 months on eight men subsisting on a diet providing 160 gm. or more of protein, mostly first class.

ACKNOWLEDGMENTS

This study was made possible only by the complete cooperation of the authorities and personnel of C. P. S. Camp no. 32 where it was held. The authorities concerned include both those of the Selective Service System and of the American Friends Service Committee. The camp personnel to whom we are indebted include not only the volunteer subjects, who added the hardships of the diet to a busy schedule, but also to various members of the maintenance personnel who assisted in many tasks connected with the experiments.

We are indebted to Dr. F. J. Stare and Dr. D. M. Hegsted of the Nutrition Department, Harvard Medical School for helpful suggestions on the choice and preparation of diets and for their loan of dietitians.

Various members of the U. S. Forestry Service sssisted us throughout by various courtesies.

We acknowledge substantial financial assistance from the Nutrition Foundation, Inc.

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