The electroencephalogram in veganism, vegetarianism, vitamin B₁₂ deficiency, and in controls

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The electroencephalogram (E.E.G.) is often abnormal in patients with pernicious anaemia. This abnormality is not related to age or to haemoglobin level and is reversible with vitamin B₁₂ therapy. In 76 cases of pernicious anaemia with abnormal E.E.G.s (Walton, Kiloh, Osselton, and Farrall, 1954) the changes in the E.E.G. were reversed in 60 (79%) by the administration of vitamin B₁₂, the improvement beginning in seven to 10 days and usually being complete in a month. Serum vitamin B₁₂ levels were not reported in that study, but the suggestion was made that the E.E.G. changes were due to a specific defect in cerebral metabolism. In another study (Smith, 1962) the E.E.G. was found to be abnormal in nine of 11 vegans, the abnormality being associated with low serum vitamin B₁₂ levels, the three most abnormal E.E.G.s being associated with values of 48, 80, and 90 $\mu\text{g./ml.}$ Vegans are extreme vegetarians who exclude not only meat but also dairy produce and eggs from their diet. Since it has become realized that vegans may develop neurological complications from dietary vitamin B₁₂ deficiency, many have supplemented their diet with a compound yeast extract or a milk substitute of vegetable origin which contains vitamin B₁₂.

In the present paper we report an investigation of 17 vegans. Their E.E.G.s were studied to see whether abnormalities were still present after low-content vitamin B₁₂ supplements. In a few of the vegans, E.E.G.s were repeated after intensive vitamin B₁₂ supplementation to try to detect reversal of abnormalities.

The reporting of the diffuse types of E.E.G. abnormality seen in metabolic disorders, particularly when these are mild, is apt to be highly subjective and subject to observer error, a bias likely to be increased when automatic frequency analysis is not available as was the case with our investigation. We therefore decided that the E.E.G. scoring should be done 'blind'. Furthermore, as about 10% of the population have diffuse non-specific deviations from a well-formed alpha rhythm in the E.E.G. we decided

to include control subjects so that any abnormalities in the vegans' E.E.G.s would have to differ significantly from the controls before they could be considered as possibly metabolic in origin. In addition, some vegetarians and some patients with vitamin B₁₂ and with folic acid deficiency were included in the expectation of forming a continuum of E.E.G. abnormality, ranging from the non-metabolic to the definitely metabolically abnormal types.

Another variable in the E.E.G. that we thought might intrude was the mild, diffuse, non-specific abnormality due to anxiety proneness (Ulett, Gleser, Winokur, and Lawler, 1953) or to general personality or constitutional differences (Hill, 1963). We therefore included a personality questionnaire to measure extroversion and neuroticism in the groups with the expectedly more normal E.E.G., namely, the controls, the vegetarians, and the vegans.

Personality and constitutional differences have been related to the type of body build (Kretschmer, 1951) so that we used a simple index calculated from the height and weight (Schrade, Boehle, and Biegler, 1960). Thinking that an error might be introduced in the body build index through the vegans being possibly underweight, we calculated an obesity index by relating the observed weight for height to standard values (Kemsley, Billewicz, and Thompson, 1962).

MATERIALS AND METHODS

CONTROL SUBJECTS The 18 meat-eating healthy controls were volunteers from the medical, nursing, and ancillary staff of Belmont Hospital. The sample was therefore biased in favour of the volunteer.

VEGANS AND VEGETARIANS Seventeen vegans and 10 vegetarians were prepared to have an E.E.G., serum vitamin B₁₂ and other blood investigations done, and to complete the personality questionnaire. This sample was likewise biased in favour of the volunteer.

PATIENTS WITH VITAMIN B₁₂ AND FOLIC ACID DEFICIENCY Ten patients with pernicious anaemia, some with cerebral

or neurological abnormalities, one patient with mixed vitamin B₁₂ and folic acid deficiency, and two with folic acid deficiency were referred before treatment was begun from the Kingston Hospital Pathological Laboratory. The E.E.G.s were done the day after the patients were referred to the laboratory to avoid delaying treatment.

REPEAT E.E.G.S AFTER TREATMENT AND AFTER ADDITIONAL VITAMIN B₁₂ SUPPLEMENTS The E.E.G.s were repeated at various times in five of the pernicious anaemia patients after they had had vitamin B₁₂ treatment, in one patient with folic acid deficiency after being treated for this, and in three of the vegans who had additional vitamin B₁₂ supplements. It was hoped that changes in the E.E.G.s due to lack of vitamin B₁₂ would begin to improve. It was not possible to arrange these follow-ups at the same time intervals.

VITAMIN B₁₂ SUPPLEMENTS Eleven of the 17 vegans had supplemented their diet with extra sources of vitamin B₁₂. In Table IV the compound yeast extract containing 1.5 µg. per ounce (28.35 g.) is designated +; the milk substitute of vegetable origin containing 2 µg. of vitamin B₁₂ per ounce (28.35 g.) ++; and repeated high oral dosage or injections of pure vitamin B₁₂ in the range 1,000-2,000 µg. for each dose is designated +++.

E.E.G.S All 58 subjects had a routine bipolar recording when either no drugs were being taken or were omitted at the time. No arrangements were made to take the E.E.G. in the fasting state or to pay attention to blood glucose levels. Three minutes of hyperventilation and rhythmic photic stimulation were included in the recording in addition to the routine resting record. In two of the pernicious anaemia patients it was not possible to carry out hyperventilation.

By obscuring the identity of the E.E.G.s and by randomly mixing up the records of all 58 subjects it was found possible to grade the E.E.G.s from those with normal 8-13 c/s alpha rhythm to those with high-voltage delta (3.5 c/s and under) seen in severe pernicious anaemia. When this was done, eight categories were formed (Table I). An additional half point was added for a further abnormality arising from hyperventilation or rhythmic photic stimulation, for more localized activity such as intermittent sharp waves, or for a record judged to be intermediate between two types. This half-point system also enabled the scoring to approximate to an interval scale and thus reduce error in calculation product-moment correlation coefficients.

Thus the valid objection that it is difficult to label as either normal or abnormal some of the milder generalized variants of the usual E.E.G. activity was met by scoring the records without any knowledge as to which group they belonged and without knowledge of age, vitamin B₁₂ or other measures.

HAEMATOLOGICAL INVESTIGATIONS Serum vitamin B₁₂ was measured by the *Lactobacillus leishmanii* method (Sewell, 1960) at the time the E.E.G.s were done. In a few of the vegans previous vitamin B₁₂ levels were known,

TABLE I

E.E.G. SCORES IN ORDER OF INCREASING ABNORMALITY¹

Score	Main E.E.G. Characteristics
1	Well-informed, abundant, regular, responsive alpha rhythm (8-13 c/s)
2	Sparse, slow alpha activity, mainly at 8 c/s, irregular in form, with poor responsiveness, with or without diffuse low voltage fast activity (14-30 c/s) in the background
3	Diffuse, sharp, high-amplitude fast activity with irregular slow alpha with or without focal sharp waves
4	Mainly regular alpha but theta waves (4-7 c/s) occasionally in the background.
5	Theta more evident, but alpha still prominent
6	Theta dominant, often of higher amplitude than 5, slow alpha (8 c/s) and ± irregular sharp fast background activity
7	Generalized theta, often of higher amplitude than 6, alpha absent
8	Mixed theta and delta activity (3.5 c/s and less)

¹An extra half point was given in each group for an additional abnormality evoked by overbreathing or rhythmic photic stimulation or for a record judged intermediate between two groups.

and in some folic acid estimations were done by the Waters and Mollin method (1961). The haemoglobin was estimated as a routine measure. Serum iron and serum cholesterol were also estimated in most of the vegans.

PERSONALITY QUESTIONNAIRE The short form of the Maudsley personality inventory was used (Eysenck, 1958, 1959) and was completed by the controls, vegetarians, and vegans, usually at the time the E.E.G. was taken. This questionnaire measures extroversion and neuroticism and we were more concerned that the anxiety-proneness associated sometimes with high neuroticism scores might introduce slight E.E.G. changes, which we could not allow for, than we were concerned with demonstrating personality differences between meat eaters and vegetarians and vegans. Clearly these groups differ already in personality as evinced by their choice of diet, and although the Maudsley personality scale is simple to use and has been well-validated, it is hardly a subtle or comprehensive measure of personality, and it was felt that measures of obsessional features or of eccentricity might show better delineation of the groups we studied. An additional factor that might produce high neuroticism scores is the alleged subclinical cerebral effect that may be associated with low serum vitamin B₁₂ values (Holmes, 1956; Smith, 1960; Hunter and Matthews, 1965) and we were interested to see whether the neuroticism scale would show this.

BODY-BUILD INDEX This index was calculated from the height and weight according to the formula, Burkhardt index = $\frac{\text{height in centimetres}^3}{\text{weight in kg.} \times 100}$.

The values given by this index were those used by Schrade, *et al.* (1960) to separate body types, values under 500 representing pyknic-endomorphs, between 500 and 700 for athletic-pyknic mesomorphs, from 700 to 900 for intermediate types, and over 900 for the asthenic-ectomorphic type.

OBESITY INDEX This index was the ratio of the observed

to the standard weight for height, multiplied by 100.

STATISTICAL ASSESSMENT The two-tailed *t* test was used to test between-group differences, the 5% level being required for significance. The correlation coefficient was used for within-group comparisons. Neither statistic was felt to be fully appropriate, particularly the *t* test where the variances differed significantly, but they were helpful in giving some estimate of sampling error. Scatter diagrams were used to exclude definitely curvilinear situations in all correlation cases. Unnecessary decimals were retained in some of the body-build indices (Tables II, III, IV) to assist ranking where significant differences were tested for by Wilcoxon's test. In this case the standard deviations were calculated from the mean range of subgroups of the observations.

RESULTS

Tables II, III, IV and V show the basic data for each

of the groups. Only the patient group shows a significantly greater mean age than all other groups (Table VI).

E.E.G.s As anticipated, the E.E.G.s of the vegans were slightly more abnormal than those of the controls or vegetarians (Table VIIa) but this abnormality was within the limits of sampling error. The same level of significance was reached between the vegan and control E.E.G.s when the E.E.G. scores were retained in categories, as when the E.E.G. scores were treated directly as a continuous scale of 1 to 8 points (Table VIIb). The E.E.G.s of the vitamin B₁₂-deficient patients were more abnormal than the three other groups and to a highly significant degree. The single correlation coefficient to reach statistical significance in the whole of the within-group comparisons was for the E.E.G. score

TABLE II

RESULTS IN 18 CONTROLS

Subject No.	Sex	Age	E.E.G. Score	Haemoglobin (g./100ml.)	Serum B ₁₂ (μg./ml.)	Burkhardt Index	Obesity Index	Extroversion	Neuroticism
1	F	67	6.5	10.80	170	569.0	104.0	30	10
2	M	37	1.5	14.16	230	898.0	111.5	35	0
3	F	59	5.0	15.32	250	766.8	79.1	20	7
4	F	48	2.0	13.88	265	899.7	99.7	20	8
5	F	22	1.0	12.55	300	757.0	100.8	39	8
6	F	34	5.0	13.85	300	846.0	92.3	34	9
7	M	49	2.0	14.45	315	621.0	113.8	36	0
8	M	68	4.0	13.45	320	768.0	101.3	15	38
9	M	69	5.0	14.32	330	748.0	90.5	14	17
10	F	22	4.0	13.43	350	618.9	127.0	16	30
11	M	49	1.0	13.72	350	730.0	100.6	18	2
12	F	51	3.5	13.10	350	722.0	98.0	22	11
13	M	28	5.0	12.80	375	915.0	89.4	24	8
14	F	46	2.0	13.90	375	611.0	103.0	26	18
15	F	49	1.0	12.10	375	731.0	83.7	16	20
16	F	20	1.0	12.70	395	741.0	105.3	41	11
17	M	34	1.0	15.77	400	907.5	92.5	32	6
18	F	39	2.0	13.85	425	694.6	100.0	31	18
Means		44	2.92	13.55	326.5	752.5	99.6	26.06	12.26

TABLE III

RESULTS IN 10 VEGETARIANS

Subject No.	Sex	Age	Years as Vegetarian	E.E.G. Score	Haemoglobin (g./100 ml.)	Serum Vitamin B ₁₂ at Time of E.E.G. (μg./ml.)	Burkhardt Index	Obesity Index	Extroversion Score	Neuroticism Score
1	M	21	20	2.0	14.45	125	783.0	93.5	12	24
2	F	44	2	5.0	11.82	160	765.0	96.5	37	20
3	M	48	2	1.5	12.85	175	825.0	90.3	25	18
4	M	38	38	1.0	15.48	185	775.0	108.0	19	20
5	M	72	72	5.0	14.15	185	768.0	98.7	24	20
6	M	24	7	2.0	13.28	230	771.0	93.4	18	15
7	M	69	57	2.0	13.00	250	775.8	94.0	8	29
8	F	53	2	5.0	12.55	260	808.0	81.5	34	2
9	F	19	7	3.0	—	—	740.5	99.4	28	34
10	F	43	20	1.0	11.97	—	810.0	70.7	27	4
Means		43.1	22.7	2.8	13.28	196.2	782.1	92.6	23.2	18.6
Sample size		(10)	(10)	(10)	(9)	(18)	(10)	(10)	(10)	(10)

TABLE IV

RESULTS IN 17 VEGANS

Subject No.	Sex	Age	Years as Vegetarian	Years as Vegan	Vitamin B ₁₂ Supplement ¹	E.E.G. Score	Serum Vitamin B ₁₂ at Time of E.E.G. (μg./ml.)	Means of Previous B ₁₂ Readings (g./100ml.)	Haemoglobin (g./100ml.)	Serum Iron (μg./100ml.)	Serum Cholesterol (mg./100ml.)	Folate (μg./ml.)	Burkhardt Index	Obesity Index	Extroversion
1	F	23	23	3.5	+	1	60	200(2) ^a	13.00	100	200	15.2	620.0	115.0	42
2	M	31	2	4.0	0	6.5	80	—	13.00	130	150	25.6	906.0	89.3	16
3	M	50	26	4.0	++	4	80	—	13.58	110	325	13.5	830.0	89.6	19
4	F	30	3	3.7	++	4	85	240(2)	13.73	30	175	24.2	1030.0	77.3	10
5	F	20	16	4.0	+	5	90	—	13.00	110	—	11.3	619.2	110.5	32
6	M	31	8	0.25	+	2	90	—	12.70	160	185	18.1	836.5	88.7	21
7	F	48	25	2.7	+	1.5	95	—	12.55	—	186	19.6	718.0	90.7	22
8	F	29	2	4.0	+	5.5	100	145(2)	12.55	97	180	17.0	763.0	103.0	35
9	F	37	0.5	7.0	0	1.5	210	—	11.68	130	160	—	723.0	113.4	25
10	F	32	0	2.6	+	5.0	315	—	13.14	71	200	—	777.0	88.8	25
11	F	64	—	21.0	+	6.5	320	—	12.55	136	300	27.2	867.0	78.3	28
12	M	38	3.0	3.0	+	5.5	350	—	13.73	136	154	13.4	768.0	101.0	36
13	F	50	6.0	0.25	0	6.5	350	—	11.25	50	200	—	685.0	92.5	13
14	F	55	10	5.0	+	5.0	380	200(2)	13.73	112	220	20.0	790.0	78.8	23
15	M	20	0	5.0	+++	6.0	450	295(1)	15.62	—	125	20.0	864.0	87.5	26
16	M	45	0	5.0	+++	2.0	450	—	14.45	140	160	—	931.0	86.7	27
17	M	29	1.0	1.0	++	1.0	575	—	14.74	124	116	—	560.0	127.8	16
Means (no. in sample)		37.2 (17)	7.9 (17)	4.5 (17)		4.0 (17)	240 (17)	216 (5)	13.23 (17)	109 (15)	190 (16)	18.8 (12)	781.6 (17)	95.2 (17)	24.5 (17)

¹Vitamin B₁₂ supplements are styled: + for a compound yeast extract containing 1.5 μg. vitamin B₁₂ to the ounce.
 ++ for a milk substitute of vegetable origin containing 2 μg. vitamin B₁₂ to the ounce.
 +++ for pure vitamin B₁₂ by injection or mouth just previous to time of this investigation.

^aNumbers in parenthesis refer to number of years over which readings were averaged.

TABLE V

RESULTS IN 13 PATIENTS IN VITAMIN B₁₂ AND FOLIC ACID DEFICIENCY GROUP

Subject No.	Sex	Age	E.E.G. Score	Serum B ₁₂ (μg./ml.)	Hb (g./100 ml.)	Clinical Type	Remarks
1	F	73	6.0	30	5.84	Pernicious anaemia	
2	F	78	6.5	30	5.84	Pernicious anaemia	
3	M	78	7.0	35	6.42	Pernicious anaemia	
4	M	48	5.0	40	5.25	Pernicious anaemia	
5	M	64	5.5	40	11.83	Pernicious anaemia	Also vegetarian
6	M	79	6.5	50	11.54	Pernicious anaemia	Previously vegetarian now vegan
7	F	75	8.0	60	10.95	Pernicious anaemia	And subacute combined degeneration of the cord
8	F	76	8.0	70	5.25	Pernicious anaemia	
9	M	31	6.5	90	5.84	Pernicious anaemia	
10	M	74	2.5	95	6.57	Pernicious anaemia	
11	F	19	3.5	90	7.00	Mixed vitamin B ₁₂ and folic acid deficiency	
						Serum folate 1.3 μg.	
Means	(11)	63.1	5.9	57.1	7.48		
12	F	68	5.5	330	8.32	Folic acid deficiency	
13	F	71	3.5	385	5.25	Folic acid deficiency	
						Serum folate 2.3 μg.	
Means	(2)	69.5	4.5	357.5	6.78		

TABLE VI
AGE COMPARISONS

Group	No. in Sample ¹	Mean Age	Median	Minimum-Maximum	Range	Standard Deviation	Percentage Aged 45 and over
Controls	18	44.0	47.0	20-69	49	15.7	55.6
Vegetarians	10	42.1	43.5	19-72	53	17.2	40.0
Vegans	17	35.1	32.0	20-64	44	12.8	35.3
Pernicious anaemia	10	67.6	74.5	31-79	48	15.9	90.0
<i>Differences</i>							
Controls-vegetarians		<i>t</i>	<i>df</i>	<i>P</i>			
Controls-vegans		0.29	26	n.s.			
Controls-pernicious anaemia		1.67	33	n.s.			
Vegans-pernicious anaemia		3.77	26	0.001			
		5.51	25	<0.001			

TABLE VII

(a) BETWEEN-GROUP DIFFERENCES

Measurement	No. in Sample ¹	Group Mean	Standard Deviation	Differences	<i>t</i>	<i>df</i>	<i>P</i>
<i>E.E.G. Scores</i>							
Controls	18	2.92	1.815	Controls-vegans	1.69	33	n.s.
Vegans	17	4.03	2.057				
Vegetarians	10	2.75	1.667	Controls-pernicious anaemia	4.46	27	0.001
Vitamin B ₁₂ deficiency	11	5.91	1.712				
Folic acid deficiency	2	4.5	1.412				
				Vegans-pernicious anaemia	2.62	26	0.02
				Controls-vegetarians	0.25	26	n.s.
				Vegans-vegetarians	1.8	25	n.s.
<i>Serum B₁₂ (μg./ml.)</i>							
Controls	18	326.5	65.8	Controls-vegans	1.99	23	n.s.
Vegans	17	240	167.8				
Vegetarians	8	194.2	46.58	Controls-pernicious anaemia	14.42	27	<0.001
Vitamin B ₁₂ deficiency	11	57.1	25.35				
Folic acid deficiency	2	357.5	38.9	Controls-vegetarians	5.9	24	<0.001
				Vegans-vegetarians	1.04	23	n.s.
<i>Extroversion Scores</i>							
Controls	18	26.06	8.87	Controls-vegans	0.55	33	n.s.
Vegans	17	24.46	8.52				
Vegetarians	10	23.2	9.13	Controls-vegetarians	0.8	26	n.s.
				Vegans-vegetarians	0.35	25	n.s.
<i>Neuroticism Scores</i>							
Controls	18	12.26	9.93	Controls-vegans	1.66	33	n.s.
Vegans	17	17.78	9.61				
Vegetarians	10	18.60	9.90	Controls-vegetarians	1.62	26	n.s.
				Vegans-vegetarians	0.21	25	n.s.

¹Variations are due to missing values in some instances.

TABLE VII

(b) E.E.G. SCORES OF CONTROL PATIENTS AND VEGANS CONSIDERED IN CATEGORIES

Group	E.E.G. Score Category			Total
	1 and 2 Points (Normal)	3 to 5 Points (Intermediate)	Over 5 Points (Abnormal)	
Controls	10	7	1	18
Vegans	6	5	6	17
Totals	16	12	7	35

$\chi^2 = 4.84$ $P = 0.1-0.05$ 2 d.f.

in the vegans related to length of time as a vegan (Table VIII) where r was positive and equal to 0.51 ($P = 0.05$).

In the follow-up E.E.G.s of treated patients (Table IX) four out of five pernicious anemia patients

showed both clinical and E.E.G. improvement, although case 2 remained confused; the two patients with folic acid deficiency did not show E.E.G. improvement. Neither of the three vegans showed any change in E.E.G. scores with added vitamin B₁₂ supplements, 2,000 μg. being given orally to the three subjects before the first repeat E.E.G., and 12 injections of 1,000 μg. being given to the two subjects before they had their third E.E.G. (Table X).

EXTROVERSION AND NEUROTICISM SCORES No significant between-group differences or within-group correlations were found. The suggestion that basic personality differences or low vitamin B₁₂ values might increase neuroticism was not found to be true in the vegans in this particular sample.

TABLE VIII

WITHIN-GROUP CORRELATION COEFFICIENTS			
Comparison	Sample Size	Correlation Coefficient	Significance
<i>Controls</i>			
E.E.G. score with age	18	0.39	n.s.
E.E.G. score with serum vitamin B ₁₂	18	—0.42	n.s.
E.E.G. score with extroversion	18	—0.29	n.s.
E.E.G. score with neuroticism	18	0.21	n.s.
<i>Vegetarians</i>			
E.E.G. score with age	10	0.42	n.s.
E.E.G. score with length of time vegetarian	10	0.14	n.s.
E.E.G. score and serum vitamin B ₁₂	8	0.12	n.s.
E.E.G. score with extroversion	10	0.59	n.s.
E.E.G. score with neuroticism	10	—0.09	n.s.
<i>Vegans</i>			
E.E.G. score with age	17	0.10	n.s.
E.E.G. score with length of time vegan	17	0.51	0.05
Serum vitamin B ₁₂ and length of time vegan	17	0.31	n.s.
Age and length of time vegan	17	—0.05	n.s.
E.E.G. score with serum vitamin B ₁₂	17	0.07	n.s.
E.E.G. score with extroversion	17	—0.07	n.s.
E.E.G. score with neuroticism	17	—0.33	n.s.
E.E.G. score with serum cholesterol	16	0.22	n.s.
E.E.G. score with serum iron	15	0.27	n.s.
E.E.G. score with serum folate	12	0.32	n.s.
E.E.G. score with years as vegan	17	0.29	n.s.
E.E.G. score with haemoglobin	17	0.11	n.s.
Years as vegan with serum cholesterol	16	0.49	n.s.
Years as vegan with serum iron	15	0.25	n.s.
Years as vegan with folate	12	0.53	n.s.
Years as vegan with haemoglobin	17	0.04	n.s.
<i>Vitamin B₁₂ Deficiency</i>			
E.E.G. score with age	11	0.42	n.s.
E.E.G. score with serum B ₁₂	11	—0.41	n.s.
<i>Combined Vitamin B₁₂ Deficiency and Folic Acid Deficiency Group</i>			
E.E.G. score with haemoglobin	13	0.22	n.s.

TABLE IX

EFFECT OF TREATMENT IN SIX CASES OF VITAMIN B₁₂ DEFICIENCY AND ONE OF FOLIC ACID DEFICIENCY

Case No.	Diagnosis	Clinical Condition at Follow-up	Pre-treatment E.E.G. Score	Follow-up E.E.G. Scores
2	Pernicious anaemia	Improved	6.5	4(14) ¹
3	Pernicious anaemia	Improved	7.0	5(8)
7	Pernicious anaemia	Improved	8.0	8(7) 4(403)
8	Pernicious anaemia	Improved	8.0	7.5(7) 7.5(459)
9	Pernicious anaemia	Much improved	6.5	7(227)
11	Mixed vitamin B ₁₂ and folic acid deficiency		3.5	4(220)
12	Folic acid deficiency		5.5	5.5(18)

¹Days elapsed at follow-up.

TABLE X

EFFECT OF VITAMIN B₁₂ SUPPLEMENTS ON THE FOLLOW-UP SCORES OF THREE VEGANS

Subject No.	First E.E.G. Score	Follow-up E.E.G. Scores
4	4	4(67) ¹ 4(382)
14	5	5(489)
15	6	6(182) 6.5(389)

¹Days elapsed after first E.E.G.

BODY-BUILD AND OBESITY INDEX The vegans and vegetarians were not notably underweight for their height when compared with the controls, and it may be taken that the Burkhardt indices are not invalidated by low body weight measures in the vegan and vegetarian groups. The Burkhardt indices do not differ significantly in the three groups (Tables XI and XII).

TABLE XI

BURKHARDT BODY-TYPE INDICES

	No. in Sample	Means	Standard Deviation from Range	Probability from Wilcoxon's Test
Controls	18	752.5	92.8	n.s.
Vegans	17	783.0	114.4	Controls-vegans n.s.
Vegetarians	10	782.0	20.4	Controls-vegetarians n.s. Vegans-vegetarians n.s.
<i>Obesity Index</i>				
Controls	18	99.6		
Vegans	17	95.2		
Vegetarians	10	92.6		

TABLE XII

BODY-TYPE DISTRIBUTIONS
REFERENCES

	Ectomorphs	Mesomorphs	Intermediate	Total
Controls	2	5	11	18
Vegans	3	4	10	17
Vegetarians	0	0	10	10
Totals	5	9	31	45

SERUM VITAMIN B₁₂ VALUES Eight of the 17 vegans showed vitamin B₁₂ levels which were within the pernicious anaemia range, although high values in other vegans raise the mean so that its value does not differ significantly from the controls. The variance however differs significantly from the controls (variance ratio test).

The serum vitamin B₁₂ values in the pernicious anaemia patients were significantly lower than the values in the other groups (Table VII).

CORRELATION FOR REMAINING HAEMATOLOGICAL AND SERUM FINDINGS IN THE VEGANS No significant correlations were found between either E.E.G. scores or years as vegan with serum cholesterol, serum, iron serum folate, and haemoglobin levels (Table VIII).

DISCUSSION

As expected, the patients with pernicious anaemia showed a greater mean E.E.G. abnormality and a lower average serum vitamin B₁₂ level than all other groups. Although the correlation coefficient comparing E.E.G. abnormality with serum vitamin B₁₂ level is uninformative because of the low variance of the vitamin B₁₂ level ($r = -0.41$, $P = \text{n.s.}$) in the pernicious anaemia patients, it is clear that most of the E.E.G. abnormality is in fact due to low serum vitamin B₁₂ levels because treatment with this substance reversed some of the E.E.G. abnormalities in this group. Although the average E.E.G. abnormality score in the vegans does not differ significantly in the statistical sense from the average E.E.G. score in the controls, the value is nevertheless more abnormal and falls between the controls and the pernicious anaemia group. The abnormality in the few vegan E.E.G.s which were repeated after heavy additional supplements of oral or injected vitamin B₁₂ does not appear to be improved by them. Furthermore, in spite of the large variance and low average serum vitamin B₁₂ level in the vegans, the correlation coefficient comparing serum vitamin B₁₂ level with E.E.G. abnormality is $+0.07$ and is not significant.

The vegetarians have a lower average serum vitamin B₁₂ level as a group than the controls, but the minimum value is $125 \mu\text{g./ml.}$, and this level exceeds eight of the 17 values in the vegans. Furthermore, the E.E.G.s of the vegetarians show very little abnormality.

We are left to explain why the abnormalities in the E.E.G.s of the vegans correlate positively, although weakly ($r = +0.51$, $P = 0.05$), with length of time as a vegan and yet not significantly with the age of the vegans. That previously low serum vitamin B₁₂ levels in the vegans may not be the whole explanation for their E.E.G. abnormalities is suggested by our finding that vegetarians have low serum vitamin B₁₂ levels, significantly lower than the controls ($t = 5.9$, $P = <0.001$) and yet they have normal E.E.G.s. We suggest, therefore, that, if the E.E.G. abnormalities in the vegans do not reflect the effect of previously low serum vitamin B₁₂ levels, they may be due to another as yet undefined dietary deficiency factor. If this were so, it would be expected that a minimal cerebral deficit might be reflected in raised neuroticism scores in the vegans, but this was not found. There may be a third explanation, namely, that the E.E.G. abnormalities are due to the cerebral effects of a metabolic readjustment to the vegan diet.

SUMMARY

The E.E.G.s in 17 vegans were compared with those

of 18 controls, 10 vegetarians, 11 patients with pernicious anaemia, and two with folic acid deficiency. The E.E.G. scoring was carried out blind.

Diffuse abnormalities were found in the vegans' E.E.G.s of a degree that is between that of the vegetarians and the pernicious anaemia patients, but unlike the abnormalities in the latter, the abnormalities in the vegans' E.E.G.s were not affected by high dosage vitamin B₁₂ supplements.

We suggest the following explanations for the diffuse abnormalities in the E.E.G.s in the vegans: that chronically low levels of serum vitamin B₁₂ have been causative; that a hitherto undefined deficiency factor is responsible, or that the changes represent a cerebral metabolic readjustment to the vegan diet. On present evidence, it is not possible to decide between these alternatives, but our finding that vegetarians also have a significantly lower serum vitamin B₁₂ level than controls and yet have normal E.E.G.s seems to throw doubt on serum vitamin B₁₂ levels being the sole explanation for E.E.G. abnormalities in the vegans.

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