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Intake of B vitamins in childhood and adult life in relation to psychological distress among women in a British birth cohort

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Abstract

Background—Lower levels of B vitamins (particularly folate, vitamin B_{12} and vitamin B_6) may be associated with psychological distress. Little is known about the impact of childhood nutrition on psychological distress in adult life.

Objective—We investigated whether prospectively measured childhood and adult dietary intakes of thiamin, riboflavin, niacin, folate, vitamin B_6 and vitamin B_{12} were related to the psychological distress of women in mid-age, taking into account socio-economic, behavioural and lifestyle factors.

Design—Prospective data were collected from a cohort of 636 British women followed up since their birth in 1946. Participants completed a 28-item, scaled version of the General Health Questionnaire (GHQ-28) to measure psychological distress at age 53 years. Dietary intakes in childhood (at age four) were determined by 24 h recall and in adulthood (at age 36, 43 and 53 years) by a 5 d food record.

Results—Low dietary vitamin B_{12} intake at age 53 was associated with higher psychological distress at that age. Women in the lowest third of vitamin B_{12} intake in adulthood had a higher GHQ-28 score compared with those in the highest third (percentage change, adjusted regression coefficient, 21 (95 % CI 3, 39)). There were no other significant associations between dietary B vitamin intake in childhood or adulthood and psychological distress in the cohort.

Conclusions—Overall, there is evidence that intake of vitamin B_{12} at age 53 is related to adult psychological distress but there is no evidence for the effects of other adult B vitamin intakes or childhood intakes on psychological distress.

Keywords

Mental health; General Health Questionnaire; Depression; Diet; Life-course nutrition; Vitamin B_{12}; B vitamins

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By 2020 depression will rank second in the global burden of disease, measured in terms of 'disability-adjusted life years'(1). In Britain the lifetime prevalence of major depressive disorder in women is estimated at around 10-20 % and through the reproductive years they are roughly twice as likely to experience depression as men(2).

Diet is modifiable and may impact on aspects of psychological distress, such as anxiety, depression, etc. In free-living populations, cross-sectional studies have found that low vitamin B_{12}, vitamin B_6 and folate status are risk factors for depression or psychological distress(3-8). In addition, deficiency or low levels of riboflavin, vitamin B_{12}, vitamin B_6 and folate have been reported in depressive patients(5,9-13). Furthermore, high vitamin B_{12} and folate status have been linked with a better response to antidepressants in patients with depression(12,14-16). Clinical studies also support the role of B vitamins in mental health. In a study of women taking a multi-vitamin supplement for 1 year, riboflavin and thiamin status were associated with improved mood(17). Vitamin B_6 supplementation has also been reported to improve both general mood and mood disturbances related to premenstrual syndrome in women(17,18).

In these studies, the effect of certain dietary components on psychological distress have been tested in cross-sectional(3-8) or in clinical trials(17,18) where the dose is additional to the normal dietary intake and higher than the recommended intake. Short-term studies are unable to examine the long-term and cumulative effects of nutrition over the whole life course. To date, little is known about the impact of childhood nutrition and long-term adult nutrition on adult depression or other aspects of adult psychological distress.

Potential biological mechanisms for the role of B vitamins in mental health involve deficits of serotonin and other neurotransmitters(19), syntheses of which are dependent on folate, vitamin B_{12} and vitamin B_6 as coenzymes in the one-carbon metabolism pathways(20,21). Hyperhomocysteinaemia has been shown to be associated with depression but it is still unclear whether this is primarily as a marker of disrupted one-carbon metabolism due to deficiencies of folate, vitamin B_{12} and B_6, or whether homocysteine has independent, detrimental effects(22), such as excitotoxic effects in the central nervous system(23).

The MRC National Survey of Health and Development (NSHD) is a population-based birth cohort study(24) that provides a unique opportunity to investigate whether prospectively measured childhood and adult nutrition is related to women's psychological distress at age 53. The present paper explores associations between the dietary intake of B vitamins (specifically thiamin, riboflavin, niacin, folate, vitamin B_6 and vitamin B_{12}), either in childhood or in adulthood, and the risk of high psychological distress in women in mid-life, while adjusting for socio-economic circumstances and lifestyle factors.

Methods

The MRC NSHD, also known as the 1946 British birth cohort, is a longitudinal study of health based on a social class-stratified, random sample of 5362 singleton births to married women in England, Scotland or Wales during the first week of March, 1946. The cohort has been followed up 20 times since their birth in 1946 until 1999 when they were aged 53 years(24). By that age, 6 % of the original cohort of women (*n* 2547) had died (*n* 154), 9 % were living abroad (*n* 232), 12 % had refused to participate (*n* 296) and 3 % could not be traced (*n* 87). In most respects, those interviewed at 53 years were still representative of the native-born population at that age(24). This analysis is based on the 636 women who provided both dietary data at all time points (ages 4, 36, 43 and 53 years) and a valid General Health Questionnaire (GHQ) score.

Outcome measure

At the age of 53, cohort members were asked to complete the 28-item scaled version of the GHQ (GHQ-28). This is a widely used validated instrument that measures psychological distress through a range of items, such as symptoms of anxiety, depression and somatic problems(25,26). The items covered are given in abbreviated form in the Appendix and the total GHQ score was calculated using standard procedures(25,26). The items were rated as either present or absent using the standard 0-0-1-1 coding of Likert responses. These were then summed to produce total scores ranging from 0 (lowest psychological distress) to 28 (highest psychological distress) and used in the analysis as a continuous variable. A total GHQ-28 score of greater than 4 has a sensitivity and specificity of over 84 % for detecting psychiatric disorders(27,28).

Dietary exposure

Dietary data were collected by local health visitors during home visits at age 4 years (in 1950) and by research nurses at ages 36, 43 and 53 years (in 1982, 1989 and 1999, respectively). At age 4 years, a 24 h recall of all meals was obtained at interview from the child's carer, usually the mother(29). At ages 36, 43 and 53 years, participants were asked to complete a 5 d food diary(30). All food and beverages consumed both at home and away from home were recorded in the diaries including brand names of food products, food preparation methods and recipes used. Participants were asked to record the amount eaten in household measures with guidance notes and photographs provided at the beginning of the diary to assist in the estimation of portion size(31).

Food and nutrient intakes were calculated using the inhouse software based on McCance and Widdowson's *The Composition of Foods* at MRC Human Nutrition Research in Cambridge(29,31-34). Period- and age-specific food portion sizes and nutrient databases were used(29,31). Detailed descriptions of the process of calculating food and nutrient intakes at each age are provided elsewhere(29-31,35). In order to ensure that the hypothesised effects in mental health were not confounded by total energy intake, intakes of the individual B vitamins were adjusted for energy intake using the nutrient density method calculated by dividing nutrient intake by total energy (per MJ)(36) and were categorised into thirds.

Covariates

Since differences in psychological distress across the various groups of nutrient intakes may be explained by other factors, the model included the following covariates: childhood socio-economic circumstances, adult social class and education, behavioural and lifestyle factors (alcohol, physical activity and smoking) and BMI.

Measures of childhood socio-economic circumstances were based on data collected when participants were aged 4 years. The following three measures were used: (i) father's occupational social class (I and II, III non-manual; III manual and IV and V); (ii) housing tenure (lived in council housing *v.* all other tenures); and (iii) overcrowding (two or more people per room *v.* others) (Registrar General 1961). Adult social class was based on women's own occupation (I and II, III non-manual; III manual and IV and V)(37). Highest educational qualifications attained by age 26 years were defined as follows: degree level (university degree or their training equivalents); advanced level ('A'-levels, usually attained at the age of 18 years, or their equivalents), ordinary qualifications ('O'-levels, usually attained at the age of 16 years, or their equivalents); and no qualifications.

Average alcohol consumption was obtained from the 5 d food diaries over the three adult time points and expressed as average daily consumption of alcoholic beverages in grams and

classified into thirds. Physical activity was defined at age 53 according to the self-reported frequency of participation in sport or vigorous activity during the previous 4 weeks (none, 1-4 times per month, more than 4 times per month). Smoking status at age 53 was categorised as non-smokers, past smokers and current smokers. Height and weight were measured according to standardised protocols and used to calculate BMI (weight in kg/height^2 in m^2). Due to low numbers in the underweight category (BMI<20·0 kg/m^2, *n* 37), women were classified according to their BMI as of underweight or healthy weight (<25·0 kg/m^2), overweight (25·1-30·0 kg/m^2) or obese (>30·0 kg/m^2).

Statistical analysis

The percentage of women meeting the reference nutrient intakes (RNI) value in childhood and adulthood was calculated using RNI values for the UK(38). ANOVA was used to identify associations between the GHQ-28 scores and intake of each of the B vitamins in childhood and adulthood. Univariate analyses (ANOVA or χ^2) were used to identify aspects of childhood socio-economic circumstances, adult social class and lifestyle variables that were associated with both psychological distress and dietary B vitamins, in order to establish their role as confounding variables. Variables that were associated with psychological distress (at the 10 % level) and dietary B vitamin intake were included in the multiple regression models to identify those who remained significant after mutual adjustment. Separate models were developed for each B vitamin as relevant. Adjusted betas and 95 % confidence intervals were estimated for psychological distress using multiple regression, with the highest third of each of the B vitamins intake chosen as the reference category.

The natural logarithm of psychological distress scores (×100) was calculated prior to analysis to reduce the right skewness of the distribution. Therefore the regression coefficients in these models can be interpreted in units of symmetric percentage differences in GHQ-28 scores between each third of the B vitamin and the reference category(39).

The possible influence of low-energy reporting on the relationships between B vitamin intake and psychological distress was investigated by repeating the analysis and including the ratio of energy intake to calculated basal metabolic rate (EI:BMR) in the statistical models(40).

Results

Responses to the GHQ-28 reveal that 25 % of women at age 53 years were in a psychologically distressed state, as indicated by a score greater than 4(27), and 9 % of the women had a GHQ-28 score of 10 or more (Table 1). A higher percentage of the participants were in non-manual occupations (class I, II and II non-manual) compared with their fathers (Table 1). When participants were 4-years old in 1950, the percentage meeting the 1991 RNI for B vitamins varied from as low as 6.4 % for niacin to almost all children (99.1 %) for vitamin B_{12} (Table 2). Slightly over a quarter of the children met the RNI for vitamin B_6 while around half of them met the RNI for thiamin. At least three-quarters of the children met the RNI for folate and riboflavin. During adulthood, over 90 % of the women met RNI for all the B vitamins with the exception of folate where only 72 % met the RNI (Table 2).

Two of the six B vitamins investigated in childhood were inversely associated with psychological distress. Women who were in the lowest third of childhood intake of thiamin and vitamin B_6 had higher adult psychological distress than those in the highest third of intakes (Table 3). However, these relationships disappeared when adjusted for the confounder smoking status in the case of thiamin, and father's social class in the case of vitamin B_6 (percentage difference, adjusted regression coefficient: for thiamine, 14 (95 % CI −2, 29) in lowest third of intake *v.* 11 (95 % CI −5, 27) in middle third of intake, $P = 0.2$; for

vitamin B_6, 7 (95 % CI −6, 20) in lowest third of intake *v.* −5(−13, 12) in highest third of intake, $P = 0{\cdot}4$).

Only intake of vitamin B_{12} at age 53 was significantly associated with psychological distress, with women in the lowest third of vitamin B_{12} intake having higher GHQ-28 scores than those in the highest third (Table 3). Of all socio-economic circumstances and lifestyle factors investigated, only BMI and physical activity were associated with the intake of dietary vitamin B_{12} (Table 4). The proportion of women who did not participate in any sport or vigorous activity was 10 % higher in the group with the lowest intake of vitamin B_{12}, whereas half of the women in the lowest third of dietary vitamin B_{12} intakes had healthy weight range (Table 4). The association between adult dietary vitamin B_{12} and GHQ-28 scores remained significant after adjusting for current BMI and physical activity (Table 5).

Discussion

Main findings

Of the six B vitamin hypotheses tested in this analysis, only low dietary vitamin B_{12} intake at age 53 was significantly associated with higher psychological distress at that age after adjustment for behavioural and lifestyle factors.

Comparisons of findings with other studies

This study provides limited support for the role of B vitamins in the maintenance of good mental health(41-43); no significant results were found for B_6 and folate, but lower intakes of vitamin B_{12} in adulthood were associated with higher psychological distress. In the American Women's Health and Ageing Study, elderly women with vitamin B_{12} deficiency (serum vitamin B_{12} <200 pg/ml) were more than twice as likely to be depressed as non-deficient subjects(4). In a study from Rotterdam, vitamin B_{12} deficiency (serum vitamin B_{12} <350 pg/ml) was significantly related to depression. Subjects with vitamin B_{12} deficiency were 70 % more likely to suffer from severe depression than those without(5). However, 95 % of the women in our study had vitamin B_{12} intakes above the RNI of 1.5 μg/d and therefore there were insufficient numbers to detect the effects of B_{12} intake below this level. The cross-sectional relationship observed between psychological distress and the intake of vitamin B_{12} at age 53, rather than intakes at earlier ages, could indicate that the low B_{12} intake may be the result of poorer mental health. It is also possible that this finding is the result of chance due to the number of dietary exposures investigated across four ages of the life course.

The lack of evidence reported here for an association between childhood or adulthood folate intake and psychological distress in women at age 53 is consistent with some other studies of the general population, where folate deficiency was not found to be related to depression in women or men in the community(3,4,44,45). However, other research has suggested that folate may be related to severe depression(46,47).

Explanation of findings

The lack of association between childhood B vitamins intake and psychological distress may be due to their low tracking into adulthood. The Spearman correlation coefficients between childhood and adulthood B vitamins intakes ranged from −0.008 (B_{12}) to 0.06 (B_6), indicating that dietary nutrient intake patterns have changed over time. As with most cohort studies, it is difficult to separate the changes in dietary habits during one's lifetime as being due to deliberate choices or in response to secular trends. Given the dietary restrictions that were in place in post-war Britain in the early 1950s(29) and the over 30-year time span

between the two different stages of life, it is not surprising that a poor correlation was found for all B vitamins.

It is also possible that most of the B vitamins intakes are not associated with mental health at the age of women in this study or that the range of intakes observed are not sufficient to make an association between the B vitamins intakes and psychological distress. It could also be possible that only some individuals with a certain genetic make-up may be sensitive to suboptimal vitamin B intake level (nutrigenetics) and that their number may be low in this study(48,49).

Alternatively, it is possible that the dietary intake assessment was not a sufficiently sensitive measure. However, our dietary assessment method has been shown to provide good measures of intake and associations with other health outcomes that have been identified(31,50-52).

Strengths and limitations

The prospective study design, length of follow-up and the measurement of a wide range of potential confounders are major strengths of our study. Psychological distress was measured by the GHQ, the most popular screening instrument for detecting psychiatric disorders in community samples(25). The prevalence of psychological distress among women in the study was comparable to other British studies(53). The study was also able to assess the impact of B vitamin intake after simultaneous consideration of a range of potential confounders measured prospectively across the life course.

It is well recognised that all dietary assessment methods suffer from limitations associated with measurement error. However, food diary methods are generally considered to provide good estimates of usual intake(29). While a 24 h recall is generally not considered to represent usual intake due to within-person variation, it is expected that this would be less relevant in the current cohort due to the nature of the time period in which the childhood data were collected when dietary habits would have been less varied(29). Previous studies of life-course nutrition and health have relied on adult recall of childhood intake(54) and prospective studies are less susceptible to dietary recall bias than retrospective studies(55). As the measurements of dietary exposure were collected prospectively, we would expect that any measurement error present would not be associated with later mental health status, and therefore is more likely to result in attenuation of the observed relationships rather than a strengthening of relationships(56). In addition, multiple assessments of dietary intake during adulthood were used rather than a single assessment, and period-specific food composition databases were used to calculate intakes allowing for real changes in food composition over time to be incorporated into the exposure measurement(29,31).

An important issue to consider with respect to dietary assessment is the presence of low-energy reporters (LERs). In the data from 1950, few (3 %) children were below the cut-off ratio of 0·9 that is considered plausible for a 1 d diet record(29). In adulthood at age 43, 25 % of the subjects were classified as LER (EI:BMR<1·05)(50). Despite this, in the current analyses, all statistical analyses were repeated with low-energy reporting included as a variable in the model and no differences were found.

Another limitation concerned the potential for bias due to women being excluded from the analysis where they had missing dietary data at any of the time points. However, there was no difference in the prevalence of psychological distress between women who provided dietary data during both childhood and adulthood and those who provided dietary data during childhood only (24·8%, *n* 636 *v.* 24·6%, *n* 761). Women who did not provide any dietary data had the highest prevalence of psychological distress (28·3%, *n* 53), therefore

excluding these women from the analysis would tend to attenuate rather than exaggerate the significance of nutritional relationships to health outcomes.

In summary, the present study found no evidence for long-term effects of B vitamin intakes on adult psychological distress. Only dietary vitamin B_{12} intake at age 53 was associated with mental health at the same age. None of the other B vitamins showed significant relationships with psychological distress. Use of biomarkers of vitamin B status such as red blood cell folate and plasma B_{12} measurements in prospective analyses may help to further evaluate the role of B vitamins in mental health. Future studies should also consider a total diet approach, to determine whether total diet is important in the protection of mental health as overall dietary patterns may be important predictors of health(57).

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Appendix A - Items included on the GHQ-28

GHQ01 ‘perfectly well and in good health’;

GHQ02 ‘in need of a good tonic’;

GHQ03 ‘run down and out of sorts’;

GHQ04 ‘felt that you are ill’;

GHQ05 ‘getting any pains in your head’;

GHQ06 ‘been getting a feeling of tightness or pressure in your head’;

GHQ07 ‘having hot or cold spells’;

GHQ08 ‘lost much sleep over worry’;

GHQ09 ‘had difficulty in stay asleep once off’;

GHQ10 ‘been managing to keep yourself busy and occupied’;

GHQ11 ‘been taking longer over the things you do’;

GHQ12 ‘felt on the whole you were doing things well ’;

GHQ13 ‘been satisfied with the way you’ve carried out your task’;

GHQ14 ‘felt that you are playing a useful part in things’;

GHQ15 ‘felt capable of making decisions about things’;

GHQ16 ‘felt constantly under strain’;

GHQ17 ‘been able to enjoy your normal day to day activities’;

GHQ18 ‘been getting edgy and bad tempered’;

GHQ19 ‘been getting scared or panicky for no good reason’;

GHQ20 ‘found everything getting on top of you’;

GHQ21 ‘been thinking of yourself as a worthless person’;

GHQ22 ‘felt that life is entirely hopeless’;

GHQ23 ‘been feeling nervous and strung up all the time’;

GHQ24 ‘felt that life isn’t worth living’;

GHQ25 ‘thought of the possibility that you might make away with yourself’;

GHQ26 ‘found at times you couldn’t do anything because your nerves were too bad’;

GHQ27 ‘found yourself wishing you were dead and away from it all’;

GHQ28 ‘found the idea of taking your own life kept coming into your mind’.

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Table 1

Characteristics of the sample (*n* 636)

	%*
GHQ-28 score at age 53	
>4	24·9
>10	9·4
Socio-economic indicators	
Father's occupational social class	
I and II	27·5
III non-manual	22·8
III manual	26·5
IV	19·2
V	4·4
Housing tenure	
Council housing	31·4
All other tenures	68·6
Overcrowding	
Two or more people/room	13·8
Less than two people/room	86·2
Adult social class	
I and II	39·7
III non-manual	38·0
III manual	6·5
IV	10·4
V	5·5
Educational attainment by age 26	
No qualifications	30·2
Ordinary qualifications	36·5
Advanced level	26·3
Degree level	7·0
Lifestyle factors	
Physical activity at age 53	
None	45·0
1-4 times/month	19·8
>4 times/month	35·1
Alcohol consumption (g), mean, SD	263, 269
Smoking status at age 53	
Non-smokers	54·3
Past smokers	29·4
Current smokers	16·3
BMI (kg/m^2)	
<25·0	44·0

	%*
25·1-30·0	35·1
>30·0	20·9

*Data are percentages unless otherwise stated.

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Table 2

Mean, standard deviation and median dietary B vitamin intake and percentage of subjects meeting the 1991 reference nutrient intakes (RNI) among 636 women *

	Childhood (1950)				Adulthood (average intake at age 36, 43 and 53 years)			
	Mean	sd	Median	% meeting RNI†	Mean	sd	Median	% meeting RNI‡
Energy (kJ)	6072	1425	6014		7608	1518	7558	
Energy (kcal)	1446	340	1432		1812	362	1797	
Thiamin (mg/d)	0·72	0·18	0·70	53·1	1·25	0·28	1·22	96·9
Thiamin (mg/MJ)	0·12	0·03	0·12		0·17	0·03	0·16	
Riboflavin (mg/d)	1·20	0·45	1·14	87·9	1·68	0·45	1·65	92·4
Riboflavin (mg/MJ)	0·20	0·08	0·19		0·23	0·05	0·22	
Niacin (mg/d)	7·31	2·24	6·95	6·4	17·48	3·79	17·17	90·6
Niacin (mg/MJ)	1·23	0·39	1·17		2·36	0·49	2·29	
Vitamin B_6 (mg/d)	0·83	0·29	0·79	28·1	1·59	0·34	1·56	89·4
Vitamin B_6 (mg/MJ)	0·14	0·04	0·13		0·21	0·04	0·21	
Folate (μg/d)	127·5	37·2	124·2	79·3	232·2	53·6	224·7	71·5
Folate (μg/MJ)	21·6	6·6	20·4		31·2	6·7	30·2	
Vitamin B_{12} (μg/d)	3·73	5·40	2·74	99·1	5·48	2·89	4·46	99·7
Vitamin B_{12} (μg/MJ)	0·64	1·00	0·46		0·74	0·40	0·61	

*Dietary intake was assessed by 24 h recall in childhood and by 5 d food diary in adulthood.

†RNI for 4-6-year-olds(38).

‡RNI for 19-50-year-olds(38).

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Table 3

Unadjusted percentage difference (95 % confidence intervals) in General Health Questionnaire scores (GHQ-28) at age 53 years by thirds of dietary vitamin B intake (per MJ) during childhood and adult life (*n* 636 women) *

	Childhood (at age 4)		Age 36		Age 43		Age 53	
	Regression coefficient (95% CI)	*P* value†	Regression coefficient (95% CI)	*P* value†	Regression coefficient (95% CI)	*P* value†	Regression coefficient (95% CI)	*P* value†
Thiamin		0·05		0·5		0·8		0·4
Low	22 (4, 40)		9 (−8, 27)		4 (−14, 22)		12 (−6, 30)	
Middle	16 (−2, 35)		0·2 (−18, 18)		−1 (−19, 17)		4 (−14, 22)	
High	Reference		Reference		Reference		Reference	
Riboflavin		0·8		0·5		0·6		0·4
Low	7 (−12, 26)		6 (−11, 24)		−5 (−23, 13)		11 (−7, 29)	
Middle	5 (−13, 23)		−5 (−23, 13)		16 (−2, 34)		12 (−6, 29)	
High	Reference		Reference		Reference		Reference	
Niacin		0·8		0·8		0·9		0·3
Low	1 (−18, 19)		7 (−11, 25)		3 (−15, 21)		14 (−4, 31)	
Middle	6 (−13, 24)		3 (−15, 21)		2 (−15, 20)		8 (−10, 26)	
High	Reference		Reference		Reference		Reference	
Vitamin B_6		0·04		0·5		0·8		0·4
Low	12 (−6, 31)		9 (−9, 27)		5 (−13, 22)		7 (−11, 24)	
Middle	−12 (−31, 6)		−1 (−18,17)		5 (−13, 23)		−6 (−23, 12)	
High	Reference		Reference		Reference		Reference	
Folate		0·5		0·9		0·9		0·1
Low	4 (−15, 22)		0·3 (−18, 18)		0·3 (−18, 18)		−4 (−22, 14)	
Middle	11 (−8, 29)		−1·0 (−19, 16)		−1 (−19, 16)		13 (−5, 31)	
High	Reference		Reference		Reference		Reference	
Vitamin B_{12}		0·8		0·3		0·6		0·009
Low	5 (−14, 24)		13 (−5, 31)		3 (−-15, 20)		15 (−3, 33)	
Middle	6 (−12, 24)		3 (−15, 21)		9 (−9, 27)		28 (10, 46)	
High	Reference		Reference		Reference		Reference	

*636 women provided both dietary data and a valid GHQ score.

†*P* value from regression analysis test for heterogeneity among the intake of dietary vitamin B group.

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Table 4

Socio-economic circumstances and lifestyle characteristics of survey members at age 53 years, by dietary vitamin B_{12} intake at 53 (*n* 636)

	Thirds of dietary vitamin B_{12} intake (μg/MJ)			
	Low	**Middle**	**High**	***P* value***
Vitamin B_{12} intake at age 53†				
(μg/day)	3·6, 1·1	5·1, 1·1	8·3, 4·4	
(μg/MJ)	0·46, 0·09	0·67, 0·06	1·16, 0·6	
Father's social class (% manual)	51·6	49·3	48·3	0·8
Own social class at age 53 (% manual)	18·2	25·5	23·9	0·2
Educational attainment ('O' levels or less)	65·6	68·3	64·1	0·9
Smoking status (% current smoker)	14·4	19·5	14·7	0·3
Highest third of alcohol intake (%)	31·7	36·8	35·2	0·7
Physical activity (% none)	48·3	50·2	38·7	0·004
BMI (% healthy weight range)	50·1	37·3	37·2	0·003

*χ^2 test of independence investigating the association between each sociodemographic and lifestyle factor and the intake of dietary vitamin B_{12}.

†Mean, SD.

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Table 5

Percentage difference (95 % confidence intervals) in General Health Questionnaire scores (GHQ-28) at age 53 years by thirds of dietary vitamin B_{12} intake (per MJ) at age 53, BMI and exercise level (*n* 665 women)

Covariates	Unadjusted	*P* value*	Adjusted for BMI only	*P* value*	Adjusted for BMI and exercise levels	*P* value*
Vitamin B_{12} intake at age 53 years		0·005		0·005		0·007
Low	18 (0·24, 36)		18 (−1, 36)		17 (−1, 35)	
Middle	30 (12, 48)		29 (11, 47)		29 (11, 47)	
High	Reference		Reference		Reference	
BMI at age 53		0·009		0·5		0·6
Overweight (25·1-30·0 kg/m^2)	4 (−8, 16)		−3 (−20, 14)		−4 (−21,13)	
Obese (>30·0 kg/m^2)	19 (7, 32)		9 (−11, 28)		7 (−13, 27)	
Underweight or healthy (25·0 kg/m^2)†	Reference		Reference		Reference	
Exercise level at age 53		0·005	-			0·4
None	18 (7, 29)				11 (−6, 27)	
1-4 times per month	7 (−8, 22)				3 (−18, 24)	
>4 times per month	Reference				Reference	

**P* value from regression analysis test for heterogeneity among the intake of dietary vitamin B group.

†Only one subject had BMI<20 kg/m2.