

Influence of supplementary vitamins, minerals and essential fatty acids on the antisocial behaviour of young adult prisoners

Randomised, placebo-controlled trial

C. BERNARD GESCH, SEAN M. HAMMOND, SARAH E. HAMPSON, ANITA EVES and MARTIN J. CROWDER

Background There is evidence that offenders consume diets lacking in essential nutrients and this could adversely affect their behaviour.

Aims To test empirically if physiologically adequate intakes of vitamins, minerals and essential fatty acids cause a reduction in antisocial behaviour.

Method Experimental, double-blind, placebo-controlled, randomised trial of nutritional supplements on 231 young adult prisoners, comparing disciplinary offences before and during supplementation.

Results Compared with placebos, those receiving the active capsules committed an average of 26.3% (95% CI 8.3–44.33%) fewer offences ($P=0.03$, two-tailed). Compared to baseline, the effect on those taking active supplements for a minimum of 2 weeks ($n=172$) was an average 35.1% (95% CI 16.3–53.9%) reduction of offences ($P<0.001$, two-tailed), whereas placebos remained within standard error.

Conclusions Antisocial behaviour in prisons, including violence, are reduced by vitamins, minerals and essential fatty acids with similar implications for those eating poor diets in the community.

Declaration of interest The research was supported by a grant from the research charity Natural Justice (see Acknowledgements) and managed from the University of Surrey. Scotia Pharmaceuticals Ltd and Unigreg Ltd supplied nutritional supplements.

Most research into factors involved in antisocial behaviour investigates societal factors. This has produced important correlational evidence but does not demonstrate that such factors have causal relationships with antisocial behaviour, as this requires more rigorous experimental designs (Altman, 1991; Rutter, 1995). Such designs are difficult to achieve in sociological research, which leaves questions of volition, culpability, prevention and rehabilitation open, if cause and effect are more precisely understood. It is noteworthy that a Director of the US National Institute of Mental Health suggested that treatment programmes for offenders tend not to be rigorously evaluated: 'It's easy to fool yourselves about efficacy if you haven't done a proper clinical trial' (Marshall, 2000). It has, however, been suggested that deeper knowledge of the biology of antisocial behaviours will help interventions (Stone & Kelner, 2000).

Background

When Sinclair persuaded the wartime British government in 1942 to supplement the diet of all children with cod-liver oil and orange juice, he speculated that among other ills, poor diets could lead to antisocial behaviour. Since that time, evidence has grown to support this link (Moynahan, 1976; Virkkunen & Huttunen, 1982; Benton & Cook, 1991; Stevens *et al*, 1995, 1996; Hamazaki *et al*, 1996; Schoenthaler *et al*, 1997; Walsh *et al*, 1997; Hibbeln *et al*, 1998; Bjork *et al*, 1999; Golomb *et al*, 2000). If there is a causal relationship between micronutrient deficiencies and antisocial behaviour, then where such deficiencies exist supplementing the diet with appropriate nutrients should improve behaviour. With the approval of the Home Office, this was tested empirically. The study was approved by the University of Surrey Ethics Committee and conformed to the Declaration of Helsinki.

The findings have been subject to a 10-month Home Office review.

METHOD

Experimental study

Participation

Before recruitment, the purpose of the project was explained carefully to each participant. Participants had to be 18 years of age or over. Each volunteer recruited ($n=231$) signed an informed consent form, which was countersigned by a member of the prison staff. The trial had to conform to the normal operations of the institution where participants would leave for reasons such as parole or requirements of cell space. Thus, the analysis allowed for participation to vary from a minimum period of 2 weeks to 9 months in both baseline and supplementation periods. The average time spent on supplementation was 142 days for the placebo group and 142.62 for the active group. No individuals were withdrawn as a result of ill effects from supplementation. Participants were debriefed about their participation by written report.

Materials

It was agreed with the HM Prison Service and the Home Office to use nutritional supplements that were available 'over the counter.' Although improvements in dietary intakes of micronutrients could be achieved through diet, nutritional supplements provide a known quantity of micronutrients and allowed for the use of a double-blind, placebo-controlled design to test the hypothesis that supplementary vitamins, minerals and essential fatty acids would significantly reduce the rate of disciplinary incidents. An expert advisory group with no commercial interest in the outcome undertook the selection of nutritional supplements, based on formulation. The University of Surrey conducted assays to check manufacturing tolerance and assessed the match between active and placebo supplements. The vitamin/mineral supplement 'Forceval' is licensed for prescription purposes in the UK as a therapeutic adjunct where intake of vitamins and minerals is sub-optimal (UK product licence number PL 0528/5008R). It is formulated in line with European Economic Council Directive 90/496/EEC on international labelling for foodstuffs (24 September 1990) and the UK Dietary Reference Values for Food Energy and Nutrients for

the United Kingdom (Department of Health, 1991). Potency is presented in Table 1. A vegetable oil-based placebo with an identical opaque bi-coloured gelatine shell was employed.

Both omega-6 and omega-3 essential fatty acids have been found to be deficient among violent offenders (Corrigan *et al*, 1994). For this reason, an essential fatty acid supplement was also employed. 'Efamol Marine' provides omega-6 and omega-3 essential fatty acids without an obvious after-taste, a factor that could otherwise have compromised the blind. The daily dosage was four capsules providing 1260 mg linoleic acid, 160 mg gamma linolenic acid, 80 mg eicosa-pentaenoic acid and 44 mg docosa-hexaenoic acid. A vegetable oil-based placebo of identical colour and clear gelatine shell was used.

Measurements

Antisocial behaviour

Antisocial behaviours resulting in disciplinary action were adjudicated through Governor or minor reports. Governor reports adjudicate more serious incidents such as those involving violence and may involve loss of remission. Minor reports typically adjudicate on a failure to comply with requirements. The construction of the offence and the standard of proof 'beyond reasonable doubt' was the same for both types of report. Thus, Governor and minor reports proven in adjudication, over a specified time period, formed the measurement of antisocial behaviour. Before breaking the blind, Governor and minor reports were categorised into those occurring during the baseline or supplementation period for each participant.

Dietary intake

The dietary intake of the participants was assessed using 7-day food diaries. The nutrient content of each prisoner's diet was determined using a database based on McCance and Widdowson's *The Composition of Foods* (Holland *et al*, 1996). As all foods consumed by the prisoners originated in the prison, it was possible to devise a diary where the participants indicated which of the available choices they had eaten and how much (a quarter, a half, three-quarters portion, all or a second portion). Portion weights were determined from the serveries. They were asked to

Table 1 Vitamins and minerals in one 'Forceval' capsule

Nutrient	Potency	UK RNIs ²	EU RDAs	US DRIs ³
Vitamin A (μg) ¹	750	700	800	900
Vitamin D (μg)	10	–	5	5
Vitamin B1 (mg)	1.2	1	1.4	1.2
Vitamin B2 (mg)	1.6	1.3	1.6	1.3
Vitamin B6 (mg)	2	1.4	2	1.3
Vitamin B12 (μg)	3	1.5	1	2.4
Vitamin C (mg)	60	40	60	90
Vitamin E (mg)	10	–	10	15
Vitamin K1 (μg)	–	–	–	120
Biotin (μg)	100	–	150	30
Nicotinamide (mg)	18	17	18	16
Pantothenic acid (mg)	4	–	6	5
Folic acid (μg)	400	200	200	400
Calcium (mg)	100	700	800	1000
Iron (mg)	12	8.7	14	8
Copper (mg)	2	1.2	–	0.9
Magnesium (mg)	30	300	300	400
Zinc (mg)	15	9.5	15	11
Iodine (μg)	140	140	150	150
Manganese (mg)	3	–	–	2.3
Potassium (mg)	4	3500	–	–
Phosphorus (mg)	77	550	800	700
Selenium (μg)	50	75	–	55
Chromium (μg)	200	–	–	35
Molybdenum (μg)	250	–	–	45

RNI, reference nutrient intake; RDA, recommended daily allowance; DRI, daily recommended intake.

1. Retinol equivalent from intake of β -carotene.

2. UK RNI for 19 to 50-year-old males.

3. US RDA 19 to 30-year-old males. The values in italics have no US RDA and are defined as adequate intakes (AI). The figures in normal type are US RDAs.

report the number of items consumed, including spread on bread and milk and sugar in beverages. A list of food items (e.g. chocolate) that could be purchased from the prison shop was also included to record consumption. The quantity and type of all food consumed was entered into a computer package ('Superdiet') for each of the 7 days.

Psychological tests

The following psychological measures were employed: verbal ability and intelligence derived from the General Aptitude Test Battery (USES 1967) (Hammond, 1984); emotional control from the Emotional Control Questionnaire (Roger & Nesselhoever, 1987; Roger & Najarian, 1989); measurement of anger and aggression from the Survey Anger Scales (O'Rourke, 1994); self-reported health status from the Malaise Inventory (Rutter *et al*, 1970); and the Hospital Anxiety and

Depression Questionnaire (Zigmond & Snaith, 1983). The reliability and validity of these measures have been demonstrated previously (Bramley *et al*, 1988).

Procedures

Supplement distribution

Nutritional supplements were packed into blister packs containing one vitamin/mineral capsule and four essential fatty acid capsules. Blister packs contained either all active or all placebo supplements and were stamped with an 11-digit alphanumeric code during manufacture. To facilitate double-blind allocation, research staff were only provided with details of the respective alphanumeric code allocated for each participant. Each day, coded packs were labelled with the participant's name, cell and prison number, and as prison officers routinely locked inmates in their cell at lunchtime they also gave the packs to participants.

Compliance was monitored and logged through officers returning the used packs each day and routine cell searches. The log recorded if a participant's supplement packs were returned empty, full or at all. The HM Prison Service gave permission for the trial under the Declaration of Helsinki on the understanding that we provided active nutritional supplements for 3 months after the trial, so that all participants received benefit.

Randomisation

Participants initially entered the trial en-bloc at its commencement in September 1996. They underwent psychometric assessment and their baseline disciplinary records were obtained. A stratified randomisation was conducted on the population of participants in each of the four main wings of the institution, employing a random number generator to allocate to groups. Thus, each wing formed a stratum so that the placebo and active groups were matched in terms of disciplinary incidents and also progress in the prison regime. Participants that were recruited subsequently over the following 8 months were first grouped by their location (wing) and then randomly allocated to treatment conditions using a random number generator.

Statistical analysis

Disciplinary data were analysed using negative binomial (mixed Poisson) regression analysis (Lawless, 1987). This analysis was used because disciplinary incidents constitute a series of discrete events over time and the basic model for this is a Poisson process, which cannot have normal distribution. In a Poisson process, however, it is assumed that the average probability of a person committing an offence remains constant over time and is independent of previous outcomes. Because we knew some individuals were more prone to behaviour resulting in disciplinary incidents than others, we accounted for these variations in the individual rates of disciplinary incidents by modifying the Poisson distribution into to a negative binomial distribution. Goodness-of-fit tests confirmed that the rates of disciplinary incidents were indeed a good match with this predicted negative binomial (mixed Poisson) distribution, so we were able to use this distribution as the basis for our regression analysis. The regression was based on two main

parameters, λ and γ . The parameters λ_P and λ_A are the mean underlying rates of disciplinary offences per day in the institution for the placebo and active groups, respectively, and were used to compare baseline rates of offending. The parameter γ is the ratio of the underlying rates of disciplinary offences supplementation to baseline; γ_P and γ_A being the respective ratios for the placebo and active groups. The analysis controlled for those individuals who had no offences at baseline and took into account how long a person had been in the trial. Statistical power was calculated from a one-dimensional Wald test, where the deviation of the value of γ from its hypothesised value of unity (i.e. λ remains

unchanged) in the null hypothesis is compared to its standard error. The institution's population was typically 220 individuals. We estimated that we would recruit 75% of the population over 9 months. Taking all offences together, we estimated that statistical power for correctly rejecting the null hypothesis, with significance at the 1% level, would be 92%.

RESULTS

Experimental study

Compliance

Based on the daily log, the mean compliance rate for supplementation was

Table 2 Comparison of baseline dietary intakes

Nutrient	Placebo (n=55)	95% CI	Active (n=57)	95% CI
Energy source				
Energy (kJ)	10 363	11290.2–9435.8	10 335	11069.6–9600
Carbohydrate (g)	314.5	343.9–285.1	325	352–298
Fat (g)	108.5	119.2–97.8	104	110.8–97.2
Protein (g)	77.5	82.9–72.1	75.5	80.6–70.4
Fibre (g)	18.6	20.3–16.9	19.5	20.9–18.1
%E as carbohydrate	48.5	49.5–47.5	49.9	50.7–49.1
%E as fat	38.5	39.4–37.6	37.5	38.4–36.6
%E as protein	13	13.4–12.6	12.6	13–12.2
Vitamins				
A (μ g)	742.7	813.6–671.8	742	806.9–677.1
Thiamine (mg)	1.74	1.84–1.64	1.84	2.04–1.64
Riboflavin (mg)	2.1	2.4–1.8	2	2.5–1.5
Niacin (mg)	17.3	18.6–16	17.1	21.6–12.6
Folate (μ g)	253	272.7–233.3	273	301.3–244.7
B6 (μ g)	2.15	2.35–1.95	2.3	2.5–2.1
B12 (μ g)	4.6	5.1–4.1	4.2	4.7–3.7
C (mg)	81.4	97.3–65.5	98.7	119.3–78.1
D (μ g)	3.5	4–3	3.5	3.9–3.1
Minerals				
Calcium (mg)	1032	1159.6–904.4	1031	1154.4–907.6
Iron (mg)	12.9	13.9–11.9	13.1	14.1–12.1
Zinc (mg)	9.3	10–8.6	8.9	9.5–8.3
Magnesium (mg)	261	285.3–236.7	271	295.6–246.4
Phosphorus (mg)	1392	1519.8–1264.2	1357	1475.7–1238
Chloride (mg)	5354	5762–4946	5123	5441.2–4805
Sodium (mg)	3556	3844.3–3267.7	3431	3647.2–3215
Selenium (μ g)	43.9	47.8–40	45	48.9–41.1
Copper (mg)	1.1	1.2–1	1.1	1.2–1
Iodine (μ g)	124	140.2–107.8	123	138.6–107.4
Potassium (mg)	3083	3324.6–2841.4	3198	3472.4–2924

It should be noted that extensive warm holding of foods prior to service could result in significant losses of some vitamins. The actual quantity of vitamins consumed in these cases could therefore be substantially less than would be estimated through dietary analyses.

89.83% (95% CI 87.43–92.23%) for the placebo group and 90.67% (95% CI 88.47–92.87%) for the active group. The difference in compliance between groups was not statistically significant (normal deviate $z = -0.53$).

Adverse effects

The institution’s senior medical officer reported no adverse reactions to supplementation.

Dietary intake

Participants ($n=112$; 57 active, 55 placebo) completed a 7-day food diary. Table 2 shows the average nutrient intake of the active and placebo groups. No differences were considered clinically significant, so the groups were considered equivalent.

Psychometric assessment

There were no statistically significant differences between the active and placebo groups at baseline on any of the measures of intelligence, verbal ability, anger, anxiety, malaise and depression (Table 3).

Placebo effectiveness

At the end of the trial, participants were asked to complete and sign a form recording whether they thought they had received active or placebo supplements; a total of 97 did so (Table 4). The proportions of those that guessed correctly in the active and placebo groups were very similar and did not differ from that expected by chance ($\chi^2=1.26$; d.f.=1, NS).

Testing the null hypothesis

The null hypothesis, that there was no difference between the change of rates of disciplinary incidents during active and placebo supplementation (i.e where $\gamma_A = \gamma_P$), was first tested on an ‘intent-to-treat’ basis. Here all participants ($n=231$) recruited to the trial were analysed involving 532 Governor reports and 601 minor reports. Those who received the active capsules committed on average 11.8 infringements per 1000 person-days, a reduction of 26.3% (95% CI 8.3–44.3%) compared to those who received placebos. This difference between groups was statistically significant at $P < 0.03$ (two-tailed).

Table 3 Baseline psychometric scores

	Placebo (n=71)	95% CI	Active (n=66)	95% CI
Verbal IQ	97.23	99.4–95.1	97.63	99.8–95.4
Anxiety	18.07	18.8–17.4	18.04	18.7–17.3
Depression	16.43	17.0–15.8	16.37	16.9–15.9
Attitude towards anger	7.08	7.9–6.3	6.83	7.5–6.1
Expression of anger	6.09	6.8–5.4	6.1	6.8–5.4
Provocation to anger	7.27	8.3–6.2	7.32	8.3–6.4
Somatic anger	5.06	5.7–4.4	5.28	6.0–4.5
Duration of anger	4.95	5.7–4.2	4.57	5.2–4.0
Sensitivity	7.1	8.1–6.1	7.1	8.2–6.2
Victimisation	8.63	9.4–7.8	9.32	10.0–8.7
Assaultativeness	8.94	9.7–8.2	8.94	9.7–8.2
Consequences of anger	7.9	8.7–7.1	7.57	8.4–6.7
Anger control	6	6.7–5.3	6.82	7.5–6.1
Malaise	5.42	6.0–4.8	6.25	6.8–5.7

Actual effect of treatment on those treated

Intent-to-treat analysis is typically applied to test efficacy in the ‘real world’ where some people do not take their medication, so it assesses effects on the observed mixture of compliers and non-compliers. As a consequence, it is biased towards showing no effect compared with any effect that might occur in those actually receiving treatment (Korhonen *et al*, 2000). The intent-to-treat analysis above included 13 participants who prison staff reported did not take their capsules, 6 who were prescribed psychotropic medication and 40 that did not stay in the trial for 2 weeks, leaving 90 subjects who had received placebo and 82 who had received the active supplements (Fig. 1). In addition, the test used to reject the null hypothesis (i.e. $\gamma_A = \gamma_P$) makes no assumption that the two groups were matched at baseline in terms of rates of disciplinary incidents and as such it is a good test for efficacy but a conservative test of effect. Therefore, a more detailed analysis for the actual effect of treatment was undertaken on these 172 participants that were treated for a minimum of 2 weeks. In this analysis, each individual becomes his/her own control, and provided both groups are matched at baseline rates of offending, we can predict that the rates of disciplinary incidents for the placebo group will remain unchanged, whereas the rate should fall in the active group (i.e. where $\gamma_P = 1$, $\gamma_A < 1$).

The null hypothesis (that there was no difference between the change of rates of

Table 4 Accuracy of judgement on group allocation

	Judgement		
	Placebo	Active	Total
Actual			
Placebo	28	23	51
Active	26	20	46
Total	54	43	97

disciplinary incidents during active and placebo supplementation) was first retested with the 172 participants (now based on 338 Governor and 416 minor reports) and once again the disciplinary infringements of those that received active supplements fell significantly compared with those receiving placebo ($P < 0.03$, two-tailed). Because the null hypothesis can be rejected with the ‘treated’ 172 participants, average compliance was high (average 90.25%) and there were no significant differences between the groups in compliance or drop out for other reasons ($z = -0.53$), we investigated baseline rates of offending to ensure the groups were matched at baseline.

Based on 172 participants, the active and placebo groups were found to be equivalent in average rates of disciplinary incidents prior to supplementation. The parameters λ_P and λ_A are the average underlying rates of disciplinary incidents for the placebo group ($n=90$) and active group

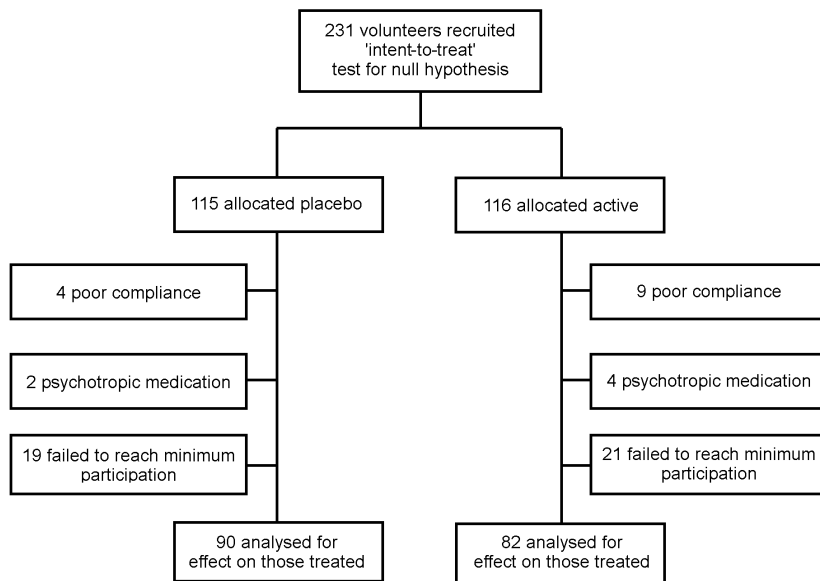


Fig. 1 Trial profile.

($n=82$), respectively. Based on 754 Governor and minor reports, λ_P and λ_A were 0.016, so both groups would commit on average 16 disciplinary incidents per thousand person-days. As an additional check, the minimum cut-off for length of participation was applied at 21 and 28 days (rather than 14 days) and consistent results were obtained.

The findings for this more specific test of the actual effect of treatment (i.e. where $\gamma_P=1$, $\gamma_A<1$), were that the active group showed a significant ($P<0.001$, two-tailed) average reduction in disciplinary incidents, this time from 16 to 10.4 incidents per thousand person-days, i.e. by 35.1% (95% CI 16.3–53.9%), whereas the placebo group reduced their rate of offending by only 6.7% (95% CI –15.3 to 28.7%) (negative figures in CI range indicate an increased rate of offending), which is again within the standard error ($P>0.1$, two-tailed). It should be noted that similar results are obtained when all participants ($n=231$) are included in this form of analysis.

The greatest reduction occurred for the most serious incidents (including violence) dealt with by Governor reports. Based on an analysis of 338 Governor reports, the active group achieved a significant ($P<0.005$, two-tailed) average reduction in Governor reports of 37% (95% CI 11.6–62.4%), whereas the placebo group reduced their Governor reports by only a non-significant ($P>0.1$, two-tailed) 10.1% (95% CI –16.9 to 37.1% (within standard error)).

Minor reports dealt with less serious incidents (there is a degree of overlap with Governor reports). Based on an analysis of 416 minor reports the placebo group again showed little reduction ($P>0.1$, two-tailed) 6.5% (95% CI –28.5 to 41.5 (within standard error)), whereas the active group showed a significant ($P<0.025$, two-tailed) reduction in minor reports of 33.3% (95% CI 0.9–65.7%) compared with baseline.

DISCUSSION

The experimental, placebo-controlled, double-blind methodology has demonstrated that supplementing prisoners' diets with physiological dosages of vitamins, minerals and essential fatty acids caused a reduction in antisocial behaviour to a remarkable degree. It is not advocated that nutrition is the only cause of antisocial behaviour but the difference in outcome between the active and placebo groups could not be explained by ethnic or social factors, as they were controlled for by the randomised design. If these findings are replicated, and they need to be, this nutritional approach to antisocial behaviour has the advantage that deficits in nutrition can be readily identified and remedied.

Limitations

Interpretation

It can be argued that behaviour in institutions is untypical and this will reduce the

extent to which these findings can be broadened in their interpretation. As a balance to this argument, the observed effect on behaviour is physiological and unlikely to be limited to prisons as there is no evidence that imprisonment affects the essentiality of these nutrients for human metabolism. Indeed, a greater effect could be predicted where baseline dietary intakes are worse. From experience, baseline dietary intakes among serious young offenders in the community are likely to be worse than in custody where regular meals are provided.

Statistical analysis

The analysis did not take account of the possibility that conducting such a project in a confined setting could influence the findings. It is likely, however, that interactions between the groups in a confined setting would weaken any observed effect because the active group could have influenced the atmosphere for the entire population. Hence, the findings could be an underestimate of the true effect size. With larger institutional studies it would be possible to test the frequencies of disciplinary offences involving two or more individuals for randomness between groups.

Biochemical measures

Further investigations should include assessments of nutritional status from blood before and during supplementation. Although blood analysis would have allowed correlations between behavioural and biochemical changes, we are confident from a considerable body of previous research (e.g. Blonk *et al*, 1990; Bunout *et al*, 2000) that the nutritional supplements would have raised the prisoners' vitamins, minerals and essential fatty acids by significant amounts. More recent research of violent and non-violent subjects has, for example, found omega-3 plasma essential fatty acids predicted levels of the metabolites of serotonin and dopamine taken from cerebrospinal fluid (Hibbeln *et al*, 1998). Findings such as these suggest that further improvements in behaviour could be achieved by providing a formulation with proportionally more omega-3 fatty acids.

Clinical implications

Re-assessment of risk factors

If these findings are replicated, a potential implication is that the dietary requirements for good health are also supportive of social behaviour. Indeed, like humans, food has both a physiological and social component. This suggests that food is an additional means to reduce antisocial behaviour but it also may improve our understanding of established risk factors. There is a great deal of research into factors that affect the behaviour of juveniles (Smith, 1995, Rutter *et al*, 1998), including for instance the breakdown of families (Heiss, 1995). However, one of the social functions of families is to provide food, it would be illuminating to investigate the extent to which diets are affected by such breakdowns.

Dietary education

Dietary analyses of the participants' food diaries showed that the diets provided for the prisoners were close to current UK dietary recommendations. We found, however, that some prisoners did not possess the most basic knowledge to choose a healthy diet; some had not heard of vitamins. Poor food choices by the prisoners typically resulted in lower nutrient intakes, most notably of minerals. Despite availability, a high percentage of our participants consumed on average less than the UK reference nutrient intakes (RNI) of selenium (97%), magnesium (74%), potassium (74%), iodine (73%) and zinc (66%). Although intakes below the RNI are not necessarily evidence of inadequate intake, most micronutrients were raised significantly in the active group by supplementation, suggesting the intervention could be welcomed on health grounds alone. It should come as no surprise therefore that the institution's medical staff observed no adverse reactions to supplementation and no individuals were withdrawn as a result of supplementation. The findings do suggest, however, a need to improve dietary education as well as providing more nourishing diets. Indeed, one early study (Schauss, 1978) conducted in the community claimed that such dietary education proved more effective at reducing recidivism than conventional probation programmes employed at that time.

CLINICAL IMPLICATIONS

- Dietary interventions should be considered when addressing antisocial behaviours.
- Without rigorous experimental designs, nutritional effects on antisocial behaviours may be subsumed within effects currently attributed to social risk factors.
- Dietary standards should be re-assessed to take account of behavioural effects.

LIMITATIONS

- Behavioural effects may be most apparent in those consuming the poorest diets.
- Reductions in antisocial behaviours attributed to nutrition may be underestimated due to interactions between groups in prison.
- Biochemical measures were not available and will be required in any replication to explore the utilisation of nutrients and also mediating mechanisms.

C. BERNARD GESCH, CQSW, University Laboratory of Physiology, University of Oxford, UK; SEAN M. HAMMOND, PhD, Department of Applied Psychology, University College Cork, Ireland; SARAH E. HAMPSON, PhD, Department of Psychology; ANITA EVES, PhD, School of Management Studies for the Service Sector, University of Surrey, UK; MARTIN J. CROWDER, PhD, Department of Mathematics, Imperial College, London, UK

Correspondence: C. Bernard Gesch, University Laboratory of Physiology, University of Oxford, Parks Road, Oxford OX1 3PT, UK

(First received 9 October 2001, final revision 25 February 2002, accepted 25 February 2002)

Current dietary standards

This research strongly suggests that the effect of diet on antisocial behaviour has been underestimated and more attention should be paid to offenders' diets. It should be noted, however, that the current dietary standards by which dietary adequacy are judged barely take behaviour into account. Thus, having demonstrated empirically an effect on antisocial behaviour, we are only at the start of understanding the potential of this intervention.

ACKNOWLEDGEMENTS

The research was conducted with the permission of the Home Office and HM Prison Service. It was supported by charitable donations to the charity Natural Justice by the Hayward Foundation, the AIM Foundation, the Wacker Foundation, the Wates Foundation, the Esmée Fairbairn Foundation, the Allen Lane Foundation, the Appeldore Trust, Hugh Cavendish Charitable Trust, the Sir Charles Jessel Charitable Trust, Larkhall Laboratories, Group 4 Prison Services Ltd and the Home Office.

Note: The research was conducted under the auspices of the charity Natural Justice with the

involvement of the Home Office throughout its development and evaluation. Donations to Natural Justice had no commercial undertakings whatsoever and were arranged during the chairmanship of the Right Reverend Bishop Montefiore and The Earl Kitchener. Although Larkhall Laboratories and Group 4 Prison Services Ltd both made modest donations to the work accounting for 3.5% of costs, the terms of their charitable donations were the same as grants from the grant-making trusts where no commercial arrangements were entered into whatsoever. In addition, the Home Office required that both supplement manufacturers provide letters stating that they would not seek commercial advantage from advertising the selection of their products other than being cited in the report of the findings. The Home Office subsequently made a modest contribution to Natural Justice when the findings were accepted.

REFERENCES

- Altman, D. G. (1991) *Practical Statistics for Medical Research*, p. 296. London: Chapman and Hall.
- Benton, D. & Cook, R. (1991) The impact of selenium supplementation on mood. *Biological Psychiatry*, **29**, 1092–1098.
- Bjork, J. M., Dougherty, D. M., Moeller, F. G., *et al* (1999) The effects of tryptophan depletion and loading

on laboratory aggression in men: time course and a food-restricted control. *Psychopharmacology* (Berl), **142**, 24–30.

Blonk, M. C., Bilo, H. J. G., Nauta, J. J. P., et al (1990) Dose-response effects of fish-oil supplementation in healthy volunteers. *American Journal of Clinical Nutrition*, **52**, 120–127.

Bramley, P. N., Easton, A. M. E., Morley, S., et al (1988) The differentiation of anxiety and depression by rating-scales. *Acta Psychiatrica Scandinavica*, **77**, 133–138.

Bunout, D., Garrido, A., Suazo, M., et al (2000) Effects of supplementation with folic acid and antioxidant vitamins on homocysteine levels and LDL oxidation in coronary patients. *Nutrition*, **16**, 107–110.

Corrigan, F. M., Gray, R., Strathdee, A., et al (1994) Fatty acid analysis of blood from violent offenders. *Journal of Forensic Psychiatry*, **5**, 83–92.

Department of Health (1991) *Dietary Reference Values for Food Energy and Nutrients for the United Kingdom. Report on Health and Social Subjects 41*. London: HMSO.

Golomb, B. A., Stattin, H. & Mednick, S. (2000) Low cholesterol and violent crime. *Journal of Psychiatric Research*, **34**, 301–309.

Hamazaki, T., Sawazaki, S., Itomura, M., et al (1996) The effects of docosahexaenoic acid on aggression in young adults. *Journal of Clinical Investigation*, **97**, 1129–1133.

Hammond, S. M. (1984) An investigation into the factor structure of the General Aptitude-Test Battery. *Journal of Occupational Psychology*, **57**, 43–48.

Heiss, L. E. (1995) Changing family patterns in Western Europe: opportunity and risk factors for adolescent development. In *Psychosocial Disorders in Young People. Time, Trends and their Causes* (eds M. Rutter & D. J. Smith), pp. 104–193. New York: John Wiley and Sons.

Hibbeln, J. R., Umhau, J. C., Linnoila, M., et al (1998) A replication study of violent and nonviolent subjects: cerebrospinal fluid metabolites of serotonin and dopamine are predicted by plasma essential fatty acids. *Biological Psychiatry*, **44**, 243–249.

Holland, B., Welch, A. A., Unwin, I. D., et al (1996) *McCance and Widdowson's The Composition of Foods. 5th Edition*. Cambridge: Royal Society of Chemistry & Ministry of Agriculture, Fisheries and Food.

Korhonen, P., Loeys, T., Goetghebeur, E., et al (2000) Vitamin A and infant mortality: beyond intention-to-treat in a randomized trial. *Lifetime Data Analysis*, **6**, 107–121.

Lawless, J. F. (1987) Negative binomial and mixed Poisson regression. *Canadian Journal of Statistics*, **15**, 209–225.

Marshal, E. (2000) The shots heard 'round the world'. *Science*, **289**, 570–574.

Moynahan, E. J. (1976) Zinc deficiency and disturbances of mood and visual behaviour. *Lancet*, **1**, 91.

O'Rourke, M. M. (1994) *Anger: Its Measurement and Implications for Treatment*. University of Surrey, UK (Doctoral thesis).

Roger, D. & Neshoever, W. (1987) The construction and preliminary validation of a scale for measuring emotional control. *Personality and Individual Differences*, **8**, 527–534.

— & Najarian, B. (1989) The construction and validation of a new scale for measuring emotion control. *Personality and Individual Differences*, **10**, 845–853.

Rutter, M. (1995) Causal concepts and their testing. In *Psychosocial Disorders in Young People. Time, Trends and their Causes* (eds M. Rutter & D. J. Smith), pp. 8–34. New York: John Wiley and Sons.

—, Tizard, J. & Whitmore, K. (1970) *Education, Health and Behaviour*. London: Longmans.

—, Giller, H. & Hagell, H. (1998) *Antisocial Behaviour by Young People*. Cambridge: Cambridge University Press.

Schauss, A. G. (1978) Differential outcomes among probationers comparing orthomolecular approaches to conventional casework/counselling. *Journal of Orthomolecular Psychiatry*, **8**, 158–168.

Schoenthaler, S. J., Amos, S., Doraz, W., et al (1997) The effect of randomised vitamin–mineral supplementation on violent and non-violent antisocial behavior among incarcerated juveniles. *Journal of Nutritional and Environmental Medicine*, **7**, 343–352.

Smith, D. J. (1995) Youth crime and conduct disorders: trends, patterns and causal explanations. In *Psychosocial Disorders in Young People. Time, Trends and their Causes* (eds M. Rutter & D. J. Smith), pp. 389–489. New York: John Wiley and Sons.

Stevens, L. J., Zentall, S. S., Deck, J. L., et al (1995) Essential fatty-acid metabolism in boys with attention-deficit hyperactivity disorder. *American Journal of Clinical Nutrition*, **62**, 761–768.

—, —, Abate, M. L., et al (1996) Omega 3 fatty acids in boys with behaviour, learning and health problems. *Physiology and Behaviour*, **59**, 915–920.

Stone, R. & Kelner, K. (2000) Violence: No silver bullet. *Science*, **289**, 569.

Virkkunen, M. & Huttunen, M. O. (1982) Evidence for abnormal glucose-tolerance test among violent offenders. *Neuropsychobiology*, **8**, 30–34.

Walsh, W. J., Isaacson, H. R., Rehman, F., et al (1997) Elevated blood copper/zinc ratios in assaultive young males. *Physiology and Behavior*, **62**, 327–329.

Zigmond, A. S. & Snaith, R. P. (1983) The hospital anxiety and depression scale. *Acta Psychiatrica Scandinavica*, **67**, 361–370.