Effects of Nutritional Supplements on Aggression, Rule-Breaking, and Psychopathology Among Young Adult Prisoners

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In an earlier study, improvement of dietary status with food supplements led to a reduction in antisocial behavior among prisoners. Based on these earlier findings, a study of the effects of food supplements on aggression, rule-breaking, and psychopathology was conducted among young Dutch prisoners. Two hundred and twenty-one young adult prisoners (mean age = 21.0, range 18–25 years) received nutritional supplements containing vitamins, minerals, and essential fatty acids or placebos, over a period of 1–3 months. As in the earlier (British) study, reported incidents were significantly reduced ($P = .017$, one-tailed) in the active condition ($n = 115$), as compared with placebo ($n = 106$). Other assessments, however, revealed no significant reductions in aggressiveness or psychiatric symptoms. As the incidents reported concerned aggressive and rule-breaking behavior as observed by the prison staff, the results are considered to be promising. However, as no significant improvements were found in a number of other (self-reported) outcome measures, the results should be interpreted with caution. Aggr. Behav. 36:117–126, 2010. © 2009 Wiley-Liss, Inc.

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INTRODUCTION

In the last three decades, evidence seems to be mounting that dietary status and (deviant) behavior are associated. Ecological data and correlational studies, for instance, suggested associations between dietary habits such as fish consumption on the one hand, and psychiatric disorders [Noaghiul and Hibbeln, 2002; Peet, 2004], developmental disorders [Hibbeln et al., 2007], and aggression and criminal behavior [Hibbeln, 2001; Hibbeln et al., 2006] on the other. Fish contains high levels of the essential ω-3 fatty acids, eicosapentaenoic acid (epa), and docosahexanoenic acid (dha), which are assumed to be involved in all kinds of brain mechanisms [Hornstra, 2003; Horrobin, 1998]. Deficiencies of several other micronutrients, such as zinc and magnesium, have also been linked to impaired brain development and cognitive dysfunction [Sandstead et al., 2000], and with attention deficit disorder with hyperactivity [Hamakazi et al., 1996; Mousain-Bosc et al., 2006; Toren et al., 1996].

The mechanisms underlying potential associations between nutrition and behavior, however, are not yet clearly established. Although a clear comprehensive theory is lacking, several findings do offer some clues on the plausibility of dietary interventions. Epidemiological research, for instance, shows that major changes in dietary patterns over time have taken place, especially in industrialized world during the last century [Cordain et al., 2005; Crawford et al., 1999; Muskiet, 2005; Simopoulos, 1999]. These changes resulted in (micro)nutrient intakes that are significantly lower than in the ancient, Palaeolithic diet. Indeed, some ecological

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studies show correlations between diet and behavioral outcomes [Christensen and Christensen, 1988; Hibbeln, 2001; Peet, 2004], including criminal behavior [Hibbeln, 2001]. A major limitation of epidemiological studies is, however, the impossibility of making causal inferences. For this reason, the findings mentioned above must be judged with caution and experimental confirmation is needed.

Developmental studies also suggest that poor nutritional status in early development can lead to behavioral consequences. On the basis of a meta study, Cordain et al. [2005] concluded, for instance, that breastfeeding is superior over bottle feeding as far as cognitive development is concerned, and Horwood and Fergusson [1998] suggested lower school dropout in breastfed children. It can be hypothesized that nutritional deficiencies effecting brain development have potential detrimental effects later in adult life.

Furthermore, the importance of sufficient availability of essential fatty acids is stressed by many researchers in this respect [Hornstra, 2003], but other deficiencies may play a role as well. Neugebauer et al. [1999] demonstrated a high prevalence of antisocial personality disorder in a cohort that suffered severe (macro)malnutrition during gestation at the end of WW II in The Netherlands. In a highly pragmatic trial, Raine et al. [2003] showed that malnourished young children in Mauritius are at risk of antisocial and delinquent behavior later in life. His research also indicated that this tendency may be prevented by providing extra meals within the framework of an enrichment program. Although the study of Raine et al. suggests that antisocial and criminal behavior to a certain extent might be preventable, the question remains whether the effects of poor nutrition in early life are still reversible at a higher age, or at least can be influenced, and whether an improved nutritional status at higher ages results in less antisocial and criminal behavior. There are some indications that this is the case; Schoenthaler et al. [1996] reported the effectiveness of extra vitamins and minerals (resulting in less violent and nonviolent incidents in the institution). But he also demonstrated that subjects with deficient micronutrient blood levels seemed to have benefited the most from these additions. So the effects of poor nutritional status could at least be diminished. The study was one in a longer series of (positive) studies with incarcerated offenders, but it was the first study indicating the beneficial effect of food supplements with offenders suffering from objectively measured deficiencies. Deficiencies in (young) offenders are further suggested by Eves and Gesch [2003], who showed that young prisoners make poor diet choices in spite of the fact that the meals served were sufficiently nutritious. Gesch [in Bohannon, 2009] emphasizes the importance of balance in restoring dietary status. This makes the use of multiple vitamins, minerals, and essential fatty acids plausible.

A review of Schachter et al. [2005] shows that these potentially causal relationships between ω-3 fatty acids and mental health nowadays are being tested in a growing number of randomized controlled trials. Several of these trials suggested efficacy of ω-3 fatty acids—particularly epa—in selected patient samples [Appleton et al., 2006; Arvindakshan et al., 2003; Buydens-Branchey and Branchey, 2008; Emsley et al., 2002; Peet, 2003; Stoll et al., 1999; Van Strater and Bouvy, 2007; Zanarini and Frankenburg, 2003]. The body of evidence, however, is still limited. Trials conducted so far are often small in size, and considerable heterogeneity has been demonstrated in meta analyses [Appleton et al., 2006]. Apart from that, trial outcomes are sometimes conflicting [Fenton et al., 2001; Hamakazi et al., 1998; Schachter et al., 2005]. The same applies—a fortiori—to trials with micronutrients such as zinc and magnesium, even though the first results of studies with these minerals were promising as well [Akhondzadeh et al., 2004; Bilici et al., 2004; Mousain-Bosc et al., 2006].

In most studies mentioned above, single nutrients or a limited number of nutrients were the objects of study. Another approach is based on the assumption that dietary deficiencies, in general, have negative effects on behavior. These effects might be overcome by supplying a broad spectrum of micronutrients [Gesch et al., 2002; Schoenthaler et al., 1996; Walsh et al., 2004]. As early as the late 1970s, Schoenthaler investigated this principle in several studies with adult and juvenile offenders, and reported striking reductions in aggressive incidents and rule-violating behavior. Not without reason, however, Schoenthaler has been criticized for his unorthodox study designs and methodology, especially in his earlier work [Benton, 2007; Schoenthaler, 1983a,b]. Substantial improvements with multiple micronutrients were also reported by Walsh et al. [2004] in a case series study. All patients included in that study had histories of poor conventional treatment responses (e.g. medication interventions, behavior therapy, counseling). Although Walsh et al. reported that aggressive behavior (e.g. assaults, destructive behavior) was eliminated in more than half of the patients, it should be noted that no control subjects were included in this case series study.

In a well-designed, placebo-controlled study [see Cowen, 2003] among 231 young adult offenders, Gesch et al. [2002] found a (net) reduction of 26% of incident reports in supplemented prisoners compared with control subjects. The objective of this study was to investigate whether these findings could be replicated in The Netherlands among a comparable group of young adult offenders by means of a randomized, double-blind, placebo controlled trial.

METHODS

Subjects

The study was approved by the Dutch medical ethical committee for mental health-care institutions on November 11, 2005. Participants were enrolled in the trial after having provided written informed consent. The participants were male adult offenders, aged between 18 and 25, who were incarcerated in eight Dutch prisons. A relatively high number of prisoners who were initially enrolled in the study, however, could not be included in the analyses for various reasons. To be included, subjects had to swallow the capsules for at least one month (with a maximum of three months). To be more precise, 105 (32%) dropped out, often for practical reasons, such as early release from prison or transference to another and nonparticipating institution, whereas 221 (68%) completed the study. In the results section, potential differences between those who completed the trial and drop-outs at baseline will be briefly addressed.

Intervention

The intervention consisted of daily supplementation with vitamins, minerals, the ω-3 fatty acids, epa and dha, and the ω-6 fatty acid γ-linolenic acid (gla). These supplements, eight capsules in total, were offered during warm meals at lunchtime under watch and ward of prison staff. Lunchtime was chosen to minimize possible side effects, such as nausea and belching.

Two supplement capsules contained 25 vitamins and minerals (Table I), with potencies close to national and several international standards. The other capsules contained several fatty acids (Table II).

Although the amounts of vitamins and minerals in this study resembled those used in the earlier British study of Gesch et al. [2002], a few adjustments had been made. In the British study, a compact, over-the-counter vitamins/minerals supplement was used,

whereas in this study, two slightly more voluminous capsules were applied, allowing the use of highly resorbable organic metal compounds. The extra volume enabled the researchers to apply substantially more magnesium, which potentially is a behavior modifying agent [Mousain-Bosc et al., 2006]. Apart from that, here were differences in amounts of vitamin D (10 vs. 5 μg in this study), phosphorus (slightly different amounts in both studies) and β-carotene (not mentioned in the British study).

To date, recommended daily intakes of fatty acids—long chain ω-3 fatty acids, in particular—vary considerably. These recommendations are mainly based on current insights into cardiovascular health protection. For this study, a dose was chosen, in accordance with the recent research data [see ISSFAL, 2004; Schachter et al., 2005]. These data were not available in the design phase of the British study, resulting in lower amounts of ω-3 fatty acids in that study. Furthermore, linoleic acid was omitted in this study because of its abundance in the Dutch diet [Kruizinga et al., 2007].

The placebo content was composed of starch (vitamins–minerals placebo) and a mixture of saturated and (poly)unsaturated fatty acids, reflecting the fat and oil composition of Western European diet (fatty acid placebo).

Procedure

Before supplementation, the subjects were asked to complete a number of questionnaires. It concerned the Dutch version of the Aggression Questionnaire [AQ; Meesters et al., 1996; Morren and Meesters, 2002], the General Health Questionnaire-28 [GHQ-28; Koeter and Ormel, 1991], and the Symptom CheckList-90 [SCL-90; Arrindell and Ettema, 1986]. Prison staff also rated the level of hostile and aggressive behavior at baseline by means of the Social Dysfunction and Aggression Scale [SDAS; Wistedt et al., 1990].

After these pre-intervention assessments, participants were randomly allocated and started swallowing nutritional supplements or placebos under prison staff supervision. The administration of supplements or placebos was meant to be continued for 3 months. To be included in the analyses, a minimum period of administration of one month (30 days) was required [i.e. on average, the 221 participants used the capsules for 75.9 days (SD = 19.7), with no significant difference between the active and placebo condition; $t(219) = 1.4$, $P = .16$]. The participants received a small financial

TABLE I. Supplements: Vitamins, Antioxidants, Minerals Per Two Capsules

Nutrient	Form (present study only)	Potency Present study	Potency Gesch et al. [2002]	ADH (NL)	RNIs (UK)	RDAs (EU)	DRIs (US)
Vitamin A (μg)	Retinol acetate	**750**	750	1,000	700	800	900
β-Carotene (μg)	Natural β-carotene	**125**	–	–	–	–	–
Vitamin B1 (mg)	Thiamine	**1.2**	1.2	1.1	1	1.4	1.2
Vitamin B2 (mg)	Riboflavine	**1.6**	1.6	1.5	1.3	1.6	1.3
Vitamin B3 (mg)	Nicotinamide	**18**	18	17	17	18	16
Vitamin B5 (mg)	Calciumpantothenate	**4**	4	5	–	6	5
Vitamin B6 (mg)	Pyridoxal-5-phosphate	**2**	2	1.3	1.4	2	1.3
Vitamin B11 (μg)	Folic acid	**400**	400	300	200	200	400
Vitamin B12 (μg)	Cyanocobalamine	**3**	3	2.8	1.5	1	2.4
Biotin (μg)	–	**100**	100	–	–	150	30
Vitamin C (mg)	Ascorbic acid	**60**	60	70	40	60	90
Vitamin D3 (μg)	Cholecalciferol	**5**	10	2.5[a]	–	5	5
Vitamin E (mg)	D-Alfa-tocoferyl acetate	**10**	10	11.8[b]	–	10	15
Calcium (mg)	Tricalcium phosphate	**100**	100	1,000	700	800	1,000
Magnesium (mg)	Magnesium citrate	**100**	30	300–350	300	300	400
Phosphorus (mg)	Tricalcium phosphate	**52**	77	700–1,400	550	800	700
Zinc (mg)	Zinc citrate	**15**	15	7–10	9.5	15	11
Iron (mg)	Ferro fumerate	**12**	12	9[c]	8.7	14	8
Manganese (mg)	Manganese gluconate	**3**	3	–	–	–	2.3
Copper (mg)	Copper gluconate	**2**	2	1.5–3.5	1.2	–	0.9
Potassium (mg)	Potassium chloride	**4**	4	–	3,500	–	–
Iodine (μg)	Potassium iodide	**140**	140	100	140	150	150
Selenium (μg)	Sodium selenite	**50**	50	50–150	75	–	55
Chromium (μg)	Chromium chloride	**200**	200	–	–	–	35
Molybdenum (μg)	Sodium molybdate	**250**	250	–	–	–	45

ADH [aanbevolen dagelijkese hoeveelheid], recommended daily allowance, 19–50-year-old males; RNI, reference nutrient intake, 19–50-year-old males; RDA, recommended daily allowance, no age statement; DRI, daily recommended intake 19–30-year-old males.
[a]5 μg in cases of insufficient sun exposure.
[b]19- to 22-year-old 13 μg.
[c]19- to 22-year-old 11 mg.

TABLE II. Supplements: Fatty Acids Per Four Capsules Fish Oil and Two Capsules Evening Primrose Oil

Fatty acid	Potency Present study[a]	Potency Gesch et al. [2002][b]	Recommended intake Gezondheidsraad [Dutch Health Council, 2006]	Recommended intake European Food Safety Authority [EFSA, 2009]
Docosahexanoenic acid (dha) (mg)	**400**	44	450	250
Eicosapentaenoic acid (epa) (mg)	**400**	80		
γ-Linolenic acid (gla) (mg)	**100**	160	–	–
Linoleic acid (mg)	–	1,260	Approximately 5,000 (2 energy %)	10,000

[a]Four capsules containing fish oil; two capsules containing evening primrose oil; 30 mg vitamin E (5 mg/capsule).
[b]Four capsules.

compensation for their cooperation. The capsules had been blinded by means of four digit codes which had been randomly assigned to either supplements or placebos. Participants, staff members, as well as researchers were blind for these codes. As a check on the blinding of the capsules, a number of participants ($n = 55$) was asked 24 hr after the first administration whether they thought they received either supplements or placebos.

After the intervention period, aforementioned instruments (AQ, SDAS, GHQ-28, and SCL-90) were completed again. A subgroup of prisoners was asked again, at this point in time, whether they believed they had swallowed supplements or

placebos. Furthermore, all recorded incidents for the participating prisoners were gathered concerning the one month period before the intervention started (baseline), as well as for the period that the capsules were swallowed. The incidents were gathered from reports the ward staff in the prisons make about aggressive and rule-breaking behavior. These reports, in general, are about aggressive or disruptive behavior or incidents involving the possession or use of drugs (e.g. possession of illicit substances or having tested positive on a drug screening test). In this study, both the total number of incidents reported before and after the intervention (regardless of the type of the reported incidents), and the number of incidents reported after exclusion of alcohol and drug related incidents were analyzed.

Only after all the information was obtained and entered into a SPSS file, were the codes of the supplements unblinded.

Statistical Analyses

Differences between the experimental and control group on the various outcome measures (AQ, SDAS, reported rates of incidents, GHQ-28, and SCL-90) were tested by means of ANOVA ("repeated measures" in SPSS 15.0). For outcome measures with non-normal (skewed to right) distributions with relatively high numbers of zero scores (i.e. SDAS scores and rates of incidents), nonparametric Mann–Whitney U tests were performed. In order to make the incident data comparable between inmates who stayed in the trial for the full 3 months vs. those who had to stop earlier, incident numbers were converted into rates per 1,000 prison days. As was done in the earlier study of Gesch et al. [2002], negative binomial regression analyses were performed on these incident rates, because of the highly specific distribution of such incident variables [Gesch et al., 2002]. These negative binomial regression analyses were performed with STATA v9.

In line with the overall hypothesis that nutritional supplements would reduce aggressive and hostile behavior, α was set at .05, one-tailed. P-values below .1 will be mentioned as being trends.

RESULTS

Sample Characteristics

At enrolment, the average age of the 221 prisoners completing this study was 21.0 years (SD = 1.5; range from 18 to 25 years). These participants were distributed over eight Dutch prison sites. After unblinding the codes, 115 of these 221 prisoners (52%) had received nutritional supplements, whereas 106 prisoners (48%) were administered placebos. The distribution of supplements and placebos over the eight sites was in line with what could be expected on the basis of chance [$\chi^2(7) = 9.2$, $P = .24$].

As mentioned earlier in the methods section, a number of participants ($n = 55$) were asked 24 hr after the first administration whether they thought they received either supplements or placebos. At that point in time, the participants were not able to provide correct answers above chance level [$\chi^2(1) = 0.02$, $P = .89$; 51% gave a "wrong" answer]. At the end of the intervention period, this question was posed again to a subsample, and it should be noted that the number of participants giving the "wrong" answer was substantially decreased [$\chi^2(1) = 22.3$, $P < .001$; 25% gave the wrong answer]. This finding suggests that as the study progressed, more participants, one way or the other, were able to "guess" correctly whether they were swallowing supplements or placebos.

The 221 completers were compared on a number of characteristics (i.e. age, pre-intervention AQ, SDAS, GHQ-28, and SCL-90 scores) to the 105 prisoners who could not complete the study. No significant differences between completers and dropouts were found on these variables [i.e., $t(319) = 1.2$, $P = .22$, two-tailed; $t(223) = 1.0$, $P = .32$, two-tailed; $t(290) = 0.21$, $P = .84$, two-tailed; $t(321) = 0.65$, $P = .52$, two-tailed; $t(324) = 0.96$, $P = .34$, two-tailed, respectively). The distributions of completers vs. dropouts, however, did not turn out to be evenly spread over the eight participating institutions [$\chi^2(7) = 23.8$, $P < .005$], which suggests that participants in certain institutions were more likely to complete the study than in other ones. Taken together, the absence of other differences between those who completed the study and those who dropped out does not make it likely that the initial randomization was substantially affected by the relatively high drop out rate.

Following this, it was investigated whether differences at baseline existed between the participants who swallowed supplements ($n = 115$) vs. those who received placebos during the study ($n = 106$). No significant differences on any of the baseline assessments were found between the active and the placebo condition, in terms of their average age [$t(219) = 1.1$, $P = .29$, two-tailed]; AQ total scores ($t[219] = 0.29$, $P = .78$, two-tailed); SDAS scores [Mann–Whitney $U = 5012.5$, $P = .25$]; incident

TABLE III. Correlations Between the Outcome Measures

	AQ total scores	SCL-90 total scores	GHQ-28 total scores	SDAS total scores
SCL-90 total score	**.47***			
GHQ-28 total score	**.45***	**.82***		
SDAS total score	**.34***	**.23***	**.28***	
Incident ratio per 1,000 prison days	.05	.02	.08	**.38***
Incident ratio per 1,000 prison days, alcohol, and drugs incidents excluded	.08	−.04	.04	**.41***

*$P < .05$, two-tailed.

ratios per 1,000 prison days at baseline [Mann–Whitney $U = 5882.5$, $P = .53$; two-tailed]; incident ratios per 1,000 prison days when excluding alcohol and drugs-related incidents [Mann–Whitney $U = 5,980.5$, $P = .71$, two-tailed]; GHQ-28 total scores [$t(219) = 1.2$, $P = .24$, two-tailed]; and SCL-90 total scores [$t(219) = 1.2$, $P = .25$, two-tailed].

To gain insight into how the various outcome measures were interrelated, a correlation matrix was made. In Table III, the resulting correlations are presented. The table shows several significant associations, with the SDAS being the only scale that was significantly associated with all other measures.

With the apparently equal starting positions of the experimental and placebo group in mind, changes in aggressive and hostile behavior (i.e. AQ, SDAS, and incident data), as well as changes in well-being (i.e. GHQ-28 and SCL-90 scores), is presented below.

Effects of the Nutritional Supplements on Aggression and Hostility

The mean AQ score for the 221 participants at baseline was 80.1 (SD = 18.9). Figure 1 (left), depicts self-reported aggressiveness and hostility as measured with the AQ before and after the intervention. The reduction of AQ scores over time was 4.6 points in the supplement group compared with 1.8 points in the group receiving placebos. This trend of a higher reduction in the experimental condition did, however, not reach significance when compared with the control group [$F(1, 210) = 1.8$, $P = .091$; one-tailed]. Figure 1 (right) also depicts the development of aggression scores, as it was rated by the prison staff on the SDAS, both before and after the intervention. At baseline, the mean SDAS score for all participants was 5.1 (SD = 6.3). No significant difference was found in the development of
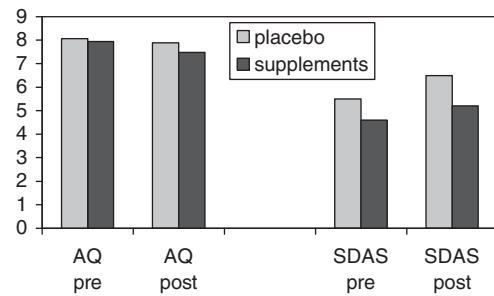
Fig. 1. Development of AQ scores (divided by 10) and SDAS scores. Supplements vs. placebo condition.
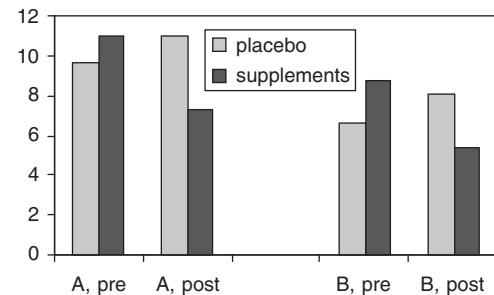
Fig. 2. Development of incident ratios (incidents per 1,000 cell days). Supplements vs. placebo condition. A: all incidents; B: all incidents minus alcohol and drugs infringements.

aggressive and hostile behavior of the experimental group vs. the control group [Mann–Whitney $U = 4652.0$, $P = .23$, one-tailed].

Figure 2 (left) presents the development of the number of incidents of aggression and other rule-breaking (e.g. alcohol or drug abuse). At baseline, the mean incident rate was 11.0 incidents per 1,000 prison days in the supplement condition, and 9.7 per 1,000 prison days in the placebo condition. In line with the earlier study of Gesch et al. [2002], the changes in the numbers of incidents before and after the intervention were tested by means of negative binomial regression analyses. These analyses take into account the highly skewed, non-normal distribution of such incident data (e.g. many subjects were not involved in incidents, a small group of prisoners was involved in multiple incidents, etc.). Apart from that Mann–Whitney U tests were performed.

The negative binomial regression results indicate that the total number of reported incidents was reduced for the group receiving nutritional supplements in comparison with the placebo group (IRR[1] = .600[2]; $P = .017$, one-tailed). The Mann–Whitney U test results were in line with this finding that the number of

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[1]IRR = Incident Rate Ratio.
[2]95% CI: 0.37–0.96.

incidents was lower for the supplemented prisoners compared with control subjects [Mann–Whitney $U = 5,314.5$, $P = .036$, one-tailed].

The same tests were performed on the incident ratios in case alcohol or drug-related violations of prison rules were excluded (i.e. possession or use of illegal substances in prison). These results are also presented in Figure 2 (right). Again, a significant reduction was found in the number of reported incidents involving prisoners who took supplements as compared with prisoners who received placebos (IRR = .602[3]; $P = .020$, one-tailed), after exclusion of the alcohol and drugs-related rule-breaking. In this case, the Mann–Whitney U test results did, however, not reach significance, although a trend toward improvement was observed (Mann–Whitney $U = 5,432.0$, $P = .055$, one-tailed).

Below, the results of the nutritional intervention on the psychological well-being of the prisoners as measured with the GHQ-28 and the SCL-90 are addressed.

Effects of Nutritional Suppletion on Psychological Well-Being

The mean GHQ-28 score of the 221 participants at baseline was 24.4 (SD = 14.1). In Figure 3 (left), the development of GHQ-28 scores pre- and post-intervention is presented for both the experimental and the control group. The graph suggests a trend that prisoners on nutritional supplements experienced more improvement in well-being than the control subjects, as lower scores on the GHQ-28 represent more well-being. The observed difference between the groups, however, was not significant [$F(1, 214) = 2.2$, $P = .069$; one-tailed].

Figure 3 also depicts the development of SCL-90 scores during pre- and post-intervention periods. At baseline, the mean SCL-90 score for the entire sample was 146.2 (SD = 46.8). As can be seen in Figure 3, the development toward improvement (i.e. lower scores on the SCL-90 represent less psychiatric complaints) as time progresses was highly similar in the experimental vs. the control group [$F(1, 211) = 0.25$, $P = .31$; one-tailed].

DISCUSSION

In this study, a significant reduction ($P = .017$, one-tailed) was found in the number of reported incidents of prisoners who received nutritional supplements, as compared with prisoners taking
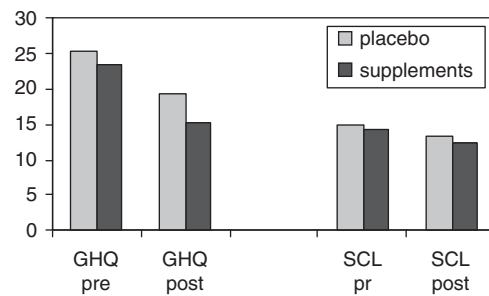
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[3]95% CI: 0.37–0.98.

Fig. 3. Development of GHQ-28 scores and SCL-90 scores (divided by 10). Supplements vs. placebo condition.

placebos. When expressed in proportional differences, the decrease on this measure was impressive, with a reduction of 34% in the experimental group against a 14% increase in the control group. This difference was significant, in spite of the relatively low base rate of reported incidents in this study (i.e. 11.0 incidents per 1,000 prison days in the supplement condition, and 9.7 per 1,000 prison days in the placebo condition in this study, compared with 16 incidents per 1,000 prison days in the British study of Gesch et al. [2002]).

At the same time, however, no significant differences were found on other measurements (i.e. AQ, SDAS, SCL-90, and GHQ-28). Therefore, when considering these findings as a whole, a firm conclusion that the supplements reduced aggressive and disruptive behavior cannot be drawn. Yet, the results in terms of a substantial reduction in reported incidents seem promising, as this outcome measure in particular may have practical relevance. These incidents concern documented accounts of observed behavior that is perceived as disruptive or dangerous by the prison staff and that is in violation of prison rules. In many cases, the reported incidents led to measures or sanctions imposed on the prisoner. Because of this, this outcome measure may be a more "concrete" outcome measure than self-reports of the prisoners", for instance, feelings of hostility on the AQ.

On the other hand, on the other assessment about observed aggressive and disruptive behavior (i.e. SDAS) which was completed by the staff, no change was detected. These SDAS scores were obtained at the beginning and at the end of the study, and it concerns an assessment of behavior as seen during the week previous to completion. This may have made this measurement to be a more limited "snapshot" of behavior in these two particular weeks. It can be argued that the baseline measure was biased by a (temporary) atmosphere of cooperation between staff and inmates during

inclusion. On the other hand, it should be noted that these SDAS scores were found to be significantly associated with all of the other outcome measures.

On all self-report measures (i.e. AQ, SCL-90, and GHQ-28), no significant improvements in the experimental condition were seen when compared with the placebo group. On the AQ and GHQ-28, trends (nonsignificant) ($P < .1$) toward improvement were seen, but the proportional differences cannot be regarded to be impressive, as was the case with the changes in incident rates. For this reason, the conclusion seems justified that the supplemented prisoners themselves did not experience marked differences in feelings of hostility and well-being in comparison with control subjects.

One limitation of this study needs to be addressed, in particular, when trying to interpret the results. Participants were asked to "guess" which condition they were in. The subjects were not able to do so 24 hr after the first administration of the capsules. This indicates that the nutritional supplements were not identifiable directly by their taste or smell. At the end of this study, however, significantly more participants than could be expected on the basis of chance gave the "correct" answer. Perhaps, this was the result of effects experienced by the prisoners (or a lack of effects in case of placebos) but, nevertheless, this does mean a partial breaking of the blind occurred. No information is available as to whether this "knowledge" may possibly have spread to the prison staff who reported the incidents.

To summarize, the prospect of influencing aggression and rule-breaking behavior with nutrients in moderate doses is important enough to warrant further research. This is particularly true as adequate supplementation may also have beneficial effects on mental health and cognitive functioning [Benton, 2001; Hibbeln, 2001; Richardson, 2004]. This study, however, did not confirm this association, except for some marginal trends in this direction. Yet, as the found decrease in the outcome measure—reported incidents and rule-breaking—is in line with the earlier British prison study of Gesch et al. [2002], we feel that further research on the association between dietary status and violent behavior is warranted.

There are several issues that could be addressed in future studies. The hypothesis of deficiency (or multiple deficiencies) could be tested further by detailed monitoring of dietary intake, and by determining levels of (micro)nutrients in blood samples. Note that many of the criminal subjects in the current sample may have had a better dietary status during their imprisonment, when compared

with their living conditions outside, especially in cases when severe drug and alcohol addiction was connected to their criminal conduct. Although prison food certainly does not have a good reputation [Eves and Gesch, 2003; Gesch et al., 2002], the provision of regular meals in the prison may have masked potential effects of supplementation on aggressiveness and well-being to a certain extent. That no information was gathered in this study about the nutritional status and diets of the participants before the intervention, clearly limits the possibilities to interpret the results. Collecting such information, or assessing the levels of (micro)-nutrients in blood samples at baseline, may provide more specific insight into which potential nutritional deficits might be prevalent among incarcerated criminal subjects. In this way, the question whether improvement in nutritional status—as measured in blood samples—is associated with less aggressive and antisocial behavior, could be more adequately addressed.

To further study the effects of the nutritional status on violence and crime, other groups could also be targeted, preferably (outpatient) populations with high base rates of incidents. Certain offender categories, such as perpetrators of domestic violence, as well as populations of psychiatric patients with severe aggression management problems could also be considered.

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