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Adolescence: Does good nutrition = good behaviour?

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Abstract

Adolescence is often associated with exploring boundaries, rapid growth, hormones and pimples. A stable feature of this turbulent age is that these young people are highly over-represented in the criminal justice system. Adolescents account for disproportionate proportion of police-recorded crimes, and this seems to be a cross-cultural phenomenon. Furthermore, disaffected young people often have limited routine access to healthy foods and make poor food choices. These people form a large proportion of the prison population and there are concerns that insufficient attention is paid to their health. Hence their diet tends to be poor compared with international standards of dietary adequacy, which typically are set to protect the heart but not for optimal brain function. Thus, it has been posited that a poor diet may be a modifiable causal factor in antisocial behaviours. We tested what happened to the behaviour of violent young adult prisoners (18–21years) when nutrients missing from their diets were reinstated. We used food supplements as an analogue of a better diet because it provided the possibility of a placebo control. On a random basis, where neither the volunteers, prison staff nor researchers in the prison knew who was getting which type, 231 volunteers were given either placebo or real capsules containing broadly the daily requirements of vitamins, minerals and essential fatty acids. The number of proven offences committed by each prisoner was monitored before and while taking supplements. The result was that those who received the extra nutrients committed significantly (26.3%) fewer offences compared with placebos. Those consuming real supplements for at least 2 weeks committed 37% fewer (highly statistically significant) of the most serious offences, such as violence. These findings have been replicated by the Dutch Ministry of Justice; their double-blind study reported a 48% difference between groups. If these studies are widely replicated – and they need to be – we may have a simple and humane means to help reduce and prevent a significant proportion of violence and antisocial behaviour. This should also work in the community, because it is not about where you eat but what you eat. Indeed, criminal justice systems are often over-represented with ethnic minorities, but providing a more nutritious diet is never going to be discriminatory to these young people. The only risk is better health.

Keywords

Violence; nutrition; brain

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The nutritional ascent of man

No species can flourish without food and water. This global necessity highlights vast inequalities. Many of the world's population starve while at the same time we are witnessing an epidemic of obesity. Good nutrition is considered to be essential to our physical well-being. It is widely accepted as a major factor in the prevention of chronic disease. The tragic consequences of malnutrition include death, disability, and stunted mental and physical growth.[1] This may be the visible tip of an iceberg and, to extend that analogy further, it is the 90% that goes unseen below the water that is the most dangerous.

The impact of various changes in modern diets such as increased intakes of salt, saturated fats, and refined sugars is already apparent in global health. Yet it is curious that most of the authoritative reference works on diet and international dietary standards focus on health but hardly mention our brain, which is supposedly what sets us apart as a species. We can think of food as the part of the physical world we have to ingest in order to function physically, mentally and socially. The phospholipid structure of nerve membranes as well as the incorporation of trace elements in enzyme catalysts derives from evolutionary development around 600 million years ago in an aquatic environment.[2,3] Anthropological science has taught us how important nutrition was during the evolution of our brain,[4–6] which is exceptionally large for a terrestrial animal. This facilitated an enhanced capacity for adaptation and problem-solving.[7] The evolution of such a metabolically expensive organ is remarkable because in the adult it comprises only 2% of our body weight, yet consumes around 20% of available energy[8] and receives 12% of basal cardiac output to supply it.[9] It is thought that we became particularly effective at exploiting coastal and lakeside food resources, and that this occurred as recently 50,000 years ago.[10] It may have been this adaptation that facilitated our larger brain. If the anthropological perspective on our dietary origins is correct, it could be predicted that patterns of nutritional deficiencies seen nowadays would be related to our movement away from our historic coastal and lakeside food sources. It is noteworthy then that the most important nutrient deficiencies globally are nutrients that are typically richest in coastal food source such as iodine, iron, zinc, Vitamin A and omega-3 fatty acids.[11–14]

Our need for food security has shaped society from around 10,000 years ago when we began organizing our society. Thus began agricultural food production, which played an important role in shaping our present social structures and higher population densities.[7] Food plays a vital role in our social structures. Much of traditional family routine is based around meals. A mother's love, courtship, and friendship are often expressed through giving food. We incorporate food into medicine and our religious practices such as offerings to deities or sacrament. Yet for every social situation there will always be a biophysical analogy. Irrespective of what we eat, getting food into one's mouth will be socially mediated, but one's mouth is the gateway to the physical world. Crucially, our physiological responses to our diet are likely to be the most finite component of this equation, as they seem to be primarily derived from our evolution. What we consume is therefore an important determinant of our brain's operational environment. The availability of the unsaturated fatty acids, arachidonic acid (AA) and docosahexaenoic acid (DHA), from which our central nervous system is primarily constructed, is likely to have been a limiting factor in brain

size.[2,15] The derivatives phospholipase A2-arachidonic acid pathway and 20-hydroxyeicosatetraenoic acid may have a regulatory role in cerebral blood flow.[16] This blood flow carries the brain's energy supply, which may constitute a limiting factor to the brain's information-processing capacity.[17] Nutrients provide substrates for the neurotransmitters.[18,19] Our diet also interacts with our genome.[20,21] Furthermore, it has been shown that the maternal diet consumed prior to conception influences the sex of the foetus in humans, to help regulate the male/female balance,[22] and our physiology continues to adapt to our diet.[23] The body has a remarkable facility for regulation, but given even this cursory discussion of the role of diet in brain function, it would be remarkable if our diet had no effect on the brain.[24] However, this is not pharmacology; these effects will depend on the quality of the dietary baseline, and this varies both within society and by country.[25]

The dawn of dietary complacency

With the onset of industrialization from around 200 years ago, it seems, from the perspective of what we eat, that a miracle must have occurred, because irrespective of how much salt, saturated fat, vegetable oils, hydrogenated fats, and refined sugar such as fructose we added to our diet, we seemed to assume it had no implications for brain function. Can it really be assumed that what was crucial to the development our brain has no relevance now? Most recently, with the globalization of markets, we may have surrendered control of what we eat to the food industries, where food has become just another commodity. In the process, we seem to have forgotten that, like any other species, food and water are the physical basis for our survival. Thus, we seem to have made major changes to modern diets in a relatively short space of time with little or no systematic examination for potential impacts on brain function or behaviour. Hence, evidence of such impact is only emerging on a retrospective basis.

Because nutrition is fundamental for life and also the composition of our brains, its effects are likely to be pervasive. The health consequences of urban diets are already visible in the epidemic of obesity, but we are only beginning to appreciate them in brain chemistry, mental health, cognition and social behaviour. Crucially, these factors may act at a biochemical level and influence our behaviour without our knowledge.[26] We are likely to interpret behavioural problems in terms of what we can see, so it is feasible that on a societal scale the effects of poor diet are liable to be greatly amplified, as greater numbers of social interactions are subject to these hitherto unnoticed influences on our behaviour. Western industrialized dietary practices have been in operation for the last 200 years and are considered 'normal' nowadays, so any resultant behavioural effects could have shaped the current behavioural baseline.[24]

Taking account of the brain in the criminal justice

The classic criminal justice model assumes that behaviour is entirely a matter of free will. This assists the often difficult task of sentencing, but obviously one cannot exercise that free will without involving the brain. And since the brain is a physical organ, how can the brain function properly without an adequate nutrient supply? Straightforwardly, it cannot. Crime may often be described as brainless, but we should not take that literally. Indeed, if diet does

affect behaviour, then ‘free will’ may turn out to be more of matter of how it exercised through conscious choice or by direct influences on the brain.

Adolescents are currently estimated to commit around 23% of all police-recorded crime in England and Wales but account for less than 10% of the population.[27] There have been a number of influential longitudinal studies that have tried to identify the developmental correlates of delinquency.[28,29] One of the best know was the Cambridge Study of Delinquent Development that studied 411 boys from childhood to age 40, where 40% were convicted of at least one criminal offence by age 32. A small 6% subgroup of the cohort was responsible for around 50% of all the officially recorded crime.[30] These persistent recidivists tended to begin their criminal careers at the earliest ages. This observation led to the identification of two patterns of offending: (i) persistent life-course offenders, such as the 6% subgroup group identified in the Cambridge study; and (ii) late-onset offenders, whose criminal behaviour started during adolescence and desisted around early adulthood.[31,32] Early onset offenders have been differentiated from their late-onset peers by exhibiting heightened impulsivity,[33] neuropsychological and temperamental deficits[27] and structural brain abnormalities.[34] Men whose mothers had experienced severe prenatal nutritional deficiency during the first and/or second trimesters of pregnancy exhibited an increased risk for antisocial personality disorder (ASPD) (adjusted odds ratio 2.5; 95% confidence interval [CI], 1.5–4.2).[35] This raises the possibility that life-course offenders may have suffered from poor nutrition on a life-course basis, whereas the adolescent-onset offenders may have come under acute nutritional stress as their brain competes for nutrients during the adolescent growth spurt.[24]

Another element of this might be exposure to nutrient antagonists such as lead, which is a potent neurotoxin with life-course effects on behaviour.[36,37] It was routinely added to petrol until the late 1980s, when countries began to legislate for its removal. Nevin[38] has shown very strong statistical associations on a post hoc basis between childhood exposure to lead and subsequent crime rates over several decades in the USA, Britain, Canada, France, Australia, Finland, Italy, West Germany and New Zealand. This relationship has also been demonstrated prospectively,[38] and has been shown to reduce brain grey matter volume in the prefrontal cortex and anterior cingulate cortex that are responsible for executive functions, mood regulation, and decision-making.[40] These findings were more pronounced for males, suggesting that lead-related atrophic changes have a disparate impact across genders, which is consistent with crime trends. Lead also alters white matter via the expression of genes essential in myelin formation,[41] so its effects are heritable. But it should not be forgotten that the means of spreading lead around the world has been socially mediated, so what we may be appreciating is a feedback cycle between the more finite physiological factors and the more fluid social influences on behaviour.[42]

There are increasingly good reasons to believe that the health benefits of good nutrition extend into positive effects on our behaviour[43–48] and cognition.[49] A number of cross-sectional studies have identified inverse associations between the estimated nutritional quality of diets consumed and behavioural health in adults,[50,51] including prospective studies of behavioural problems[53] and with adolescents.[54,55] The relationship with antisocial behaviour is at present more limited, but growing. Two surveys of juveniles focused on

sugar-containing soft drinks; one found that juveniles who consumed more than four glasses a day had the poorest mental health and conduct problems,[56] and a significant correlation between sugar-containing soft drinks consumption and self-reported violence and carrying weapons was been reported in the other.[57] A limitation of these studies is that they are based on dietary estimates. Furthermore, many of the experimental studies using nutrients that might formally demonstrate effects relating to antisocial behaviour often rely on outcomes such as rating scales rather than counting actual events such as violence,[58,59] or use a diagnosis such as ASPD.[35] The relationship between antisocial behaviour and such measures is, however, less than clear when tested back to back under experimental conditions.[60] There are, however, examples of prospective studies that can distinguish rates of future violent offences based on glucose metabolism.[61]

Furthermore, it is increasingly accepted that disaffected young people have limited routine access to adequate nutrition and tend to make poor food choices[62,63] (see also Table 1).[64] Hence their intake of essential micronutrients tends to be low compared with the government's reference nutrient intakes (RNIs). The dietary recommendations are, however, set according to requirements of physical health, but correct levels of nutrients for optimal brain function have never been established and might be higher, or may require changes to the dietary composition.[24] Nutrients listed in Table 1 have been shown to adversely affect behaviour when insufficient quantities are consumed, and yet typically the UK will spend on average £55,000 per year placing these same children in custody[78] rather than ensuring they are properly nourished. These disaffected young people commit a large proportion of crime and constitute a sizable proportion of the prison population. Where, it is widely acknowledged that insufficient attention is paid to their health.[65,66] They frequently have no routine access to healthy food in the community, hence their intake of essential micronutrients tends to be low compared with the UK government's RNIs. Thus, it has been posited that a poor diet may be a modifiable causal factor in antisocial behaviours.

Experimental evidence

We therefore tested what happened to the behaviour of violent young adult prisoners (18–21 years) when nutrients missing from their diets were reinstated. We used food supplements as an analogue of a better diet because it provided the possibility of a placebo control. On a random basis, where neither the volunteers, prison staff nor researchers in the prison knew who was getting which type, 231 volunteers were given either placebo or real capsules containing broadly the daily requirements of vitamins, minerals and essential fatty acids. The number of proven offences committed by each prisoner was monitored before and while taking supplements. The result was that those who received the extra nutrients committed significantly (26.3%) (95%CI ± 18%) fewer offences compared with placebo ($p = 0.03$, two-tailed).[67] Those consuming active supplements for at least 2 weeks committed 37% ($p < 0.005$) fewer of the most serious offences such as violence. These findings have been replicated by the Dutch Ministry of Justice; their double-blind study reported a 48% difference between groups.[67]

If these studies are widely replicated – and they need to be – we may have a simple and humane means to help reduce and prevent a significant proportion of violence, antisocial

behaviour and suffering. Our study showed that simply ensuring prisoners consumed the UK government RNIs improved their behaviour significantly. An intriguing aspect of this is that the diets of the prisoner were typically better than those consumed by their disaffected counterparts in the community, but a significant effect was still observed. Conceivably, if this were rolled out to disadvantaged people consuming poor diets in the community at large, it might help to improve behaviour in society. There are already studies that suggest that providing a better diet to young children would prevent a significant proportion of antisocial behaviour.[68] Furthermore, ethnic minorities are often over-represented in criminal justice systems, but providing a more nutritious diet is never going to be discriminatory to these young people; their only risk is better health.

Discussion

Most of the social theories of antisocial behaviour are relatively weak predictors of behaviour. For instance, a meta-analysis found the predictive factors specified by social learning theory, such as parent behaviour and peer behaviour, were generally robust across cross-sectional and longitudinal studies, yet the overall effect was statistically insignificant.[69] However, early onset offenders have been differentiated from their late-onset peers by exhibiting heightened impulsivity,[33] neuropsychological and temperamental deficits[28] and structural brain abnormalities.[70] For instance a study of abnormal glucose metabolism explained prospectively 27% of the variation in subsequent violence over 8 years, suggesting factors involved in stimulating glycogen formation might be potential treatments for impulsive violent behaviour.[60] The blood supplies glucose to the brain, and it has been shown that acts of self-control deplete relatively large amounts of glucose in the brain.[71] This has led to suggestions that willpower may have physical origins in cerebral glucose metabolism.[72] Conceivably, what you have just eaten may turn out to be a better predictor of what you are about to do than what you have just done!

It is worth reflecting on how we have arrived at a situation where the criminal justice system largely ignores brain function when its role is to judge behaviour; we may describe crime as brainless, but we should not take that literally! Indeed, there is evidence that the judges themselves are also subject to such influences. It has been shown that the severity of their sentencing was strongly related to the length of time since their last refreshment break.[73] Similarly, why do the medical sciences seem to regard nutrition as a part of ‘alternative and complementary medicine’, when evidently the alternative to nutrition is death, and where, for instance, it can be deemed that the tomato sauce on a slice of pizza can be counted as a ‘serving of vegetables’ for federally sponsored school lunches, following lobbying from food manufacturers.[74] If we really are what we eat, then changing our diet will change us, and this extends to other areas such as intelligence and education.[75,76] Doubtless, some would argue that providing education about the importance of diet is an unwelcomed extension of the ‘Nanny State’, and that freedom of choice is being eroded. However, if the research on diet and behaviour was widely replicated, it would suggest our food choice is already affecting our behaviour via our physiology. Therefore, in reality is it more a matter of how our choice is being affected, rather than if it is being affected. This adds to the argument that Descartes was wrong to separate mind and body.[77]

Conclusion

Good nutrition is essential irrespective of race, age, legislative boundaries, whether you are in prison, or in a rich or developing country. It is a basic need that unites us all; hence it is not where you eat that is important, but what you eat. Humans are, after all, both social and physical beings – the hardware and software of life, so to speak. Nutrition can impact on both aspects and thus spans both nature and nurture. It should come as no surprise, therefore, that many vitamins, minerals, and essential fatty acids seem to promote positive health and behaviour; particularly those nutrients that modern dietary practices have rendered less available or those in excess. If nutrition was truly crucial for raising our ancestors to a new level of functioning, then let us rethink our present-day attitude to food. We need to develop our understanding of the dosage and range of nutrients required to positively impact on the human condition. It may be a recipe that goes beyond individual well-being; it may be a recipe for peace.

Acknowledgement

Turid Semb

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Table 1

Nutrient intakes from a sample of disadvantaged young people

Nutrient	Percentage who consumed adequate intakes
B12 Cobalamin	94%
B6 Pyridoxine	83%
B1 Thiamin	61%
B2 Riboflavin	33%
Iodine	33%
Folic acid	28%
Zinc	28%
Calcium	28%
Iron	22%
Magnesium	17%
Selenium	0%
Omega-3 from fish	0%

* See acknowledgement