ARTICLE

A fishy tale?

What impact does diet have on behaviour and intelligence? **David Benton** separates fact from myth

Large numbers of children receive food supplements with the implication that this will speed their long-term intellectual development, give them a short-term academic boost or cure aggressive or hyperactive tendencies. Some politicians, nutritional therapists and educationalists have introduced nutritional changes – so certain are they of the importance of diet.

Such an approach usually has some scientific basis, but have isolated studies been generalised to an inappropriate extent? Is the body of knowledge really sufficient to offer advice to the individual, or suggest public policy?

question

To what extent does diet influence a child's intellectual development and behaviour?

resources

www.childrensdisabilities.info/allergies/dietdevelopmentaldisorders.html

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What do Bertie Wooster, Alan Johnston MP and Lord Robert Winston have in common? They all believe that fish oil is good for the brain. In fact, many people share the view that diet both causes the behavioural problems of children and is a means of solving them. When asked which aspects of diets are most significant, the likely responses are additives, sugar and fish oils in their reincarnation as omega-3 and omega-6 fatty acids. To what extent are such views well-founded, rather than the product of media hype or opportunistic marketing?

Are you a fat-head?

You should not feel insulted if somebody calls you a fat-head – we all are. After adipose tissue, the brain is the organ richest in lipids, to the extent that they represent about 60 per cent of its dry weight and more specifically 80 per cent of nerve cells. The omega-3 fatty acid docosahexaenoic acid and the omega-6 fatty acid arachidonic acid play important roles in the structure of cell membranes. Unsaturated rather than saturated fatty acids are associated with a more 'fluid' membrane, such that communication from and to the cell is facilitated. Yet the body is not able to make these essential fatty acids: they must be supplied by the diet, with oily fish offering a major source.

Brain food?

The possibility that a limited supply of fatty acids may impact on child development has attracted increasing attention. The brain of a newborn is about 10 per cent of body weight, whereas in the adult it is only 2 per cent. The brain develops quickly in the last third of pregnancy and the first two years of life, placing great demands on the diet to supply the building blocks from which the brain is constructed. The concern is that an inadequate supply of fatty acids can adversely influence brain development.

The Avon Longitudinal Study, which for 15 years monitored a sample of children, found that a higher intake of seafood during pregnancy was associated at eight years of age with greater prosocial behaviour, better fine motor control and higher verbal intelligence (Hibbeln et al., 2007). The suggested mechanism was the intake of fatty acids that was related to the amount of fish eaten. There are many potentially confounding variables – for example fish consumption is greater in the more affluent and better educated – but the effects persisted when such confounding variables were considered.

More certain conclusions are offered by double-blind trials that compare infants fed with a cow's milk based formula that either has or has not been supplemented with fatty acids. Studies with term infants have found little evidence that fatty acid supplementation enhances cognitive functioning, although there is a beneficial effect on visual development in the first year of life. A review concluded that any effects were small, inconsistent and tended to occur at some ages but not others (Eilander et al., 2007).

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In older children fatty acid supplementation has been suggested to help various behavioural problems, although Benton (2007) was at the time unable to find a single study reporting a beneficial response in those with a clinical diagnosis of attention deficit hyperactivity disorder (ADHD). Isolated studies that considered children with dyslexia or dysphasia have reported improvements in hyperactive symptoms, although most of the children did not have a diagnosis of ADHD (Richardson, 2006). Such findings make it premature to offer advice. Interestingly, a meta-analysis of eight studies of the impact of omega-3 fatty acid supplements on hostility and aggression found a reduction in both children and adults (Benton, 2007). The positive findings in this area may reflect the use of similar supplements; all studies administered omega-3 fatty acids. In other areas the nature of the supplement has varied from study to study, both in terms of the nature of the fatty acids and the relative doses of different fatty acids. It is possible that significant findings may emerge when the nature of the supplement is considered.

The readiness to believe that diet plays a major role in the way children function led Alan Johnson, the then education secretary, to float the idea of giving fish oils to all schoolchildren. The idea was quickly knocked down when the Food Standards Agency, who pointed out that there was little supporting evidence (see box). Similarly the Advertising Standards Authority told Dairy Crest to remove St Ivel Advance milk adverts that implied the product could enhance children's learning ability. The 'Clever milk', containing omega-3, had been advertised by Lord Robert Winston.

Yet the idea that fish benefits the brain was promoted nearly a hundred years ago by the writer P.G. Wodehouse, when Bertie Wooster attributed the intellectual powers of his manservant Jeeves to the consumption of fish. The role played by essential fatty acids in the brain certainly makes the hypothesis plausible. However, the risk is that premature and excessive claims, with associated media hype, is producing a backlash such that they will be dismissed without being adequately researched.

The developing brain

There are higher levels of essential fatty acids in human rather than cow's milk, so it is interesting that there is a considerable literature that relates breastfeeding to better cognitive development (Anderson et al. 1999). However, as the better educated and more affluent are more likely to breastfeed it is difficult to conclude that any differences reflect diet.

Methodologically some of the best data have been obtained from the study of premature infants who are fed initially by tube. Premature children were randomly allocated to a traditional cow's milk based formula or one enriched with protein, vitamins and minerals. At 18 months, the enriched formula was associated with greater social and psycho-motor advancement (Lucas et al., 1990). At eight years of age boys, but not the girls, had significantly higher intelligence scores (Lucas et al., 1998). That the formula had been drunk on average for only four weeks shows the long-term significance of adequate nutrition during critical periods of brain development. Particularly convincing evidence comes from a brain-imaging study in which the size of the caudate nucleus was shown to be larger, and correlated with verbal intelligence, in the boys who had consumed the enriched formula (Isaacs et al., 2008). The caudate nucleus is thought to be play an important role in learning and memory.

Vitamins and minerals

Many people believe that their diet provides inadequate amounts of vitamins and minerals; supposedly due to the consumption of too many refined foods or as a consequence of modern farming methods. A British survey found that 32 per cent of boys up to 10 years of age, and 23 per cent of girls under seven, took vitamins and mineral supplements (Gregory & Lowe, 2000). Clearly there is a widespread concern about micronutrient deficiencies, but is it well founded?

In 1988 uninformed media reporting led to panic buying that emptied shops of vitamin and mineral supplements. A double-blind randomised trial had reported that vitamin/mineral supplementation improved the intelligence of children (Benton & Roberts, 1988). A review of studies in the subsequent 10 years found that 10 out of 13 studies reported a positive response in at least a subgroup of children (Benton, 2001).

The positive response had been found with non-verbal measures of intelligence, never with verbal. Non-verbal scores are said to measure fluid intelligence, reflecting biological potential. Verbal measures, in contrast, rely on crystallised intelligence – specific information and vocabulary. In the short term, supplementation would be predicted to

Durham trials

- September 2006: Durham County Council announce an initiative to give three million fatty acid supplements to 2000 children over eight months. They apparently believe the initiative 'could result in record GCSE pass levels next summer.'
- Although initially described as a trial, this was a misnomer. There was no placebo group or double-blind procedure.
- The Durham GCSE results were disappointing, and by February 2008 the county council said that it never suggested that this initiative would be used to draw conclusions about the effectiveness or otherwise of using fish oil to boost exam results.

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influence non-verbal scores – logically, micronutrients can influence biology but cannot improve vocabulary. A hypothesis is that in the longer term verbal measures would benefit if the biological potential is exploited by a stimulating environment.

Despite the promising results, there are no easy conclusions. We need large-scale trials that consider the composition of the supplement and the dietary styles of the children. We don't know which nutrients are important. There is no suggestion that all children respond. In fact it appears to be a minority: perhaps only the poorly nourished. Rather than the newspaper headline that claimed that vitamins increase intelligence, a more accurate summary would be that a poor diet may cause problems. Sadly those children most likely to benefit from supplementation may be those least likely to consume them. Those receiving the supplements may well in many instances not need them.

What about behaviour? Some double-blind studies have suggested a link between subclinical deficiencies of vitamins and minerals and behavioural consequences. A good example is a very well-designed study in which the disciplinary record of young offenders responded to supplementation. The greatest reduction occurred in more serious violent offences (Gesch et al., 2002). In this study it is unclear whether the response was to vitamins, minerals or fatty acids, although previous research suggests that all may be involved. These data replicated previous findings from the United States that did not include fatty acids in the supplement (Schoenthaler et al., 1997). The Dutch government was so impressed that it ran its own study, which, although not yet formally published, has been reported to have again found improved behaviour in prison.

Food intolerance

Although it is mainly self-diagnosed, millions avoid particular foods believing they suffer from food intolerance – the generic term used to include a range of mechanisms that generate adverse reactions. A food can be malabsorbed due to an enzyme deficiency; or naturally occurring chemicals in food, such as histamine and tyramine, can cause an adverse reaction. It has been estimated that an allergic reaction, one that involves the immune system, is involved in about 20 per cent of negative reactions to food. In some people the body treats some foods as if they are foreign proteins and generates antibodies in the same way it would react to bacterial infection. Common foods that may generate allergic response are nuts, shellfish and strawberries.

Millions avoid particular foods

Well-designed studies of food intolerance place children on a 'few foods' diet – those to which there is a low risk of adverse reaction. Foods are then added one by one, and if there is no response they are left as part of the menu. Finally foods to which an adverse reaction is found are tested under a double-blind procedure – pairs of meals are prepared, with and without the food item. When studies that had taken this approach were integrated using meta-analysis, food intolerance was shown to have a large influence on hyperactivity (Benton, 2007). The effect size was 0.8 of a standard deviation: that compares with a meta-analysis of studies of additives where the response was 0.2 of a standard deviation (Schab & Trinh, 2004).

The phenomenon can be illustrated by a study carried out in Great Ormond Street Hospital. The most common substances to which children responded were the artificial colourant tartrazine and the preservative sodium benzoate, a response that occurred in 79 per cent (Egger et al., 1985). However, no child was sensitive to these additives alone and it was not possible to single out additives, or particular foods, as a unique or universal problem. Cow's milk caused an adverse reaction in 64 per cent of children; other foods that were a frequent problem were chocolate (59 per cent), grapes (49 per cent), wheat (49 per cent), oranges (45 per cent), cow's cheese (40 per cent) and eggs (39 per cent). Although typically a child responded to a small range of foods, in total four dozen foods were demonstrated to be a problem for at least one child.

It should of course be remembered that these large responses were in children whose parents believed that they responded to diet. The finding cannot be generalised to all children, or even to those with ADHD whose parents do not suspect a role for diet. Unfortunately, short of subjecting a representative sample of children to an elimination diet, there is no means of knowing how frequently food intolerance occurs.

A study from Southampton University again drew attention to the impact of additives when they reported that children reacted to a cocktail of food additives irrespective of whether they had an allergic tendency or a history of behavioural problems (McCann et al., 2007). It is, however, unclear whether there was a response to all additives in the cocktail rather than a particular substance, or how

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important it was that a combination of substances was simultaneously consumed. The European Food Safety Authority considered the Southampton study and concluded that the effects were not consistent for different age groups and it was not possible to assess how widespread such sensitivity might be. In addition they were unclear if the small changes observed would interfere with schoolwork or other intellectual functioning. Although the findings were interesting, it is an isolated study and only a large body of evidence will allow a considered response.

As the Food Standards Agency funded the Southampton study, they have asked the food industry to identify which products contain the colouring used. The Food Standards Agency have asked manufacturers to voluntarily phase out the six additives by the end of 2009. However, as there are several thousand are several thousand additives it makes no sense to treat this as a homogeneous group. Each should be examined individually and excluded from the diet where the evidence supports such a response: you could, for example, make a case for excluding tartrazine. You should, however, consider every food in a similar manner. Studies of food intolerance have found that children respond in an idiosyncratic manner: for example Egger et al. (1985) reported that no child responded only to additives, rather they displaced in addition an adverse reaction to at least one food item. The picture was of a highly individual response such that general dietary advice would be inappropriate.

One response to such data is to suggest the use of only 'natural ingredients'. A report by Mintel on the soft drinks market stated that 'Any brand which could use the positioning claim "free from artificial flavours, colours and preservatives" would set itself apart and give reassurance'. In April 2007 the supermarket Sainsbury's removed artificial flavours and colours from its soft drinks and uses only 'natural' colours. The blue Smartie met with its end when artificial colourings were replaced with 'natural' substances – there was, at the time, no suitable alternative dye.

However, each of the many thousands of additives needs to be considered on its own merits. The vitamin C occurring naturally in fruit (ascorbic acid) is chemically identical to vitamin C manufactured in a factory. When the factory product is used as an additive for its anti-oxidant properties, it has a beneficial effect. Children are as likely or unlikely to respond to molecules produced by nature as in a chemistry laboratory – whether an additive is natural or artificial has no bearing on its safety. All novel substances need to be tested.

Sugar

Sucrose – table sugar – gets a particularly bad press. It is as if there is some sort of perverted logic that says that as sucrose is a source of energy (calories), when it is consumed this energy manifests itself as hyperactivity. Yet there can be few other food items whose behavioural consequences have been more studied than sucrose, and the conclusions are very clear. Meta-analyses of double-blind studies produce no evidence that it has an adverse influence on children (Wolraich et al., 1995).

The mechanisms by which sucrose could potentially influence behaviour have been considered (Benton, 2008). Although some children display intolerance to sucrose, it is no way near the top of the list of problem foods. Although there is evidence that a tendency to develop low levels of blood glucose is associated with irritability and violence, sucrose is not the predominant cause of swings in blood glucose levels. It is suggested that high sucrose consumption may decrease the intake of vitamins and minerals. However, micronutrient intake is more closely associated with total energy rather than sucrose intake; sucrose consumption has been shown repeatedly not to be associated with micronutrient deficiency.

Sucrose can be used to illustrate the importance of distinguishing genuine biological reactions to food from the psychological. It is not uncommon for people who are certain that they respond adversely to diet to find that when tested under double-blind conditions they fail to react. For example the behaviour of children whose parents believed they responded to sucrose was studied after the mother was told that the child had either drunk a sucrose-containing drink or one that was artificially sweetened (Hoover & Milich, 1994). In fact the drinks were identical – neither contained sucrose. However, when the mothers falsely believed that the drink contained sugar they rated their child as more hyperactive, exercised more control by being physically closer and were more likely to criticise. There is a risk that a child will be taught by the response of the parent to react adversely to food. The child will expect hyperactive behaviour to follow the eating of a food item, and will gain implicit permission to act in this way as it is not his or her fault.

Conclusion

Viewing behavioural problems as a reflection of diet may offer false hope to both child and parent as, although there is good evidence that diet can influence behaviour, we lack the information to give precise advice. There is a risk that taking an exclusively dietary approach will delay more effective treatment. Self-diagnosis is to be discouraged and professional advice should be obtained before concluding that there is a dietary problem.

Indeed, the ill-informed removal of food items from the menu can result in an unbalanced diet that generates additional problems. The nutritionist Vincent Marks coined the term 'Muesli belt malnutrition' to describe the effect on children of feeding a quirky diet that is falsely believed by the parents to be a healthy diet.

With additional research it is likely that there will still be no easy answers or general solutions; rather the picture will be one of individuality. There is a major need to be able to distinguish the occasional child who will benefit greatly from a change in diet.

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