

## Diet and Behaviour

### The Role of Omega-3 and Omega-6 fatty acids

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## A Rotten Way to Feed the Children

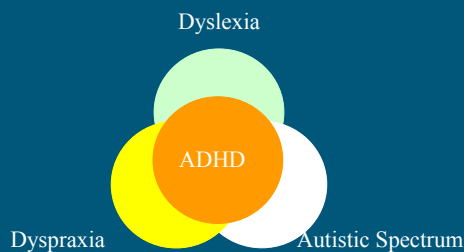
16 Apr 2004 - Times Educational Supplement  
By Stephanie Northern

“The physical risks to children from a nutritionally poor diet are now acknowledged, but the damage being done to their behaviour, learning abilities and mood is not.”



- The UK Government has been forced to pump £342 million into school behaviour improvement programmes.
- The WHO predicts a 50 per cent rise in child mental disorders by 2020.
- Dyslexia, hyperactivity, autism and related conditions all appear to be on the increase.

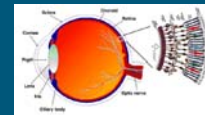
## Child Behaviour and Learning Difficulties – the Overlap



## Essential Nutrients and Vision

Omega-3 fatty acids from fish oils are absolutely essential to the visual system

- 30-50% of the retina should be made of the omega-3 DHA
- At the very first stage of visual processing, DHA deficiency can reduce retinal signalling by more than a thousand-fold
- Omega-3 deficiency is associated with poor night vision and other problems with visual, spatial and attentional processing.



## The role of Nutrition?

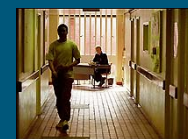
- **Appropriate nutrition is essential for:**
  - The growth and development of brains and bodies
  - Building, maintaining, fuelling and repairing every cell in every part of the brain and body
- **At least 39 essential nutrients must be provided by our food**
  - These include vitamins and minerals, essential amino acids, and **omega 3 and omega 6 fatty acids**
- **Many of these are lacking from modern diets**
- **Individual differences affect dietary requirements**
  - Specific nutrients may be needed in unusually high quantities
  - There may be allergies or intolerances to certain foods



## Nutrition in Young Offenders

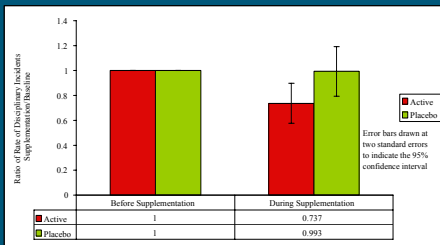
(Gesch et al, 2002, British Journal of Psychiatry)

- Randomised controlled trial of dietary treatment
- 231 young offenders imprisoned at a high-security unit in the UK took part
- Each received either a **multivitamin + fatty acid supplement**, or a matched placebo



Could diet help to reduce violence and cut crime?

**Results:** Rate of all Disciplinary Incidents - Intention to treat (ITT) N=231.



1133 offences: Active vs Placebo: -26.3 % ( $p < 0.027$ )  
 Supplementation for at least 2 weeks: Active vs Placebo: -34.0%  
 And for violent offences only: “ -37.0%

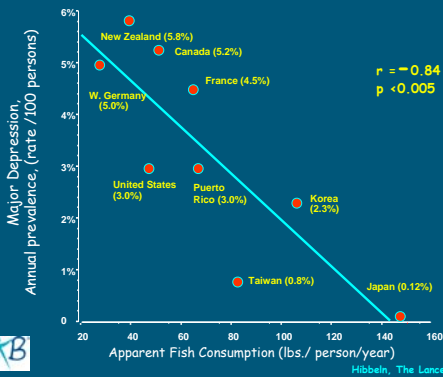
**Food and mood**

Depression also shows strong associations with diet

Omega-3 fatty acids (found in fish and seafood) seem to be a protective factor



**Fish Consumption and Major Depression Annual Prevalence by Country**



**WHO - Global Forum For Health**

Diseases accounting for the world burden of ill-health – the top seven as predicted for 2020

	1990	2020
• Coronary Heart Disease*	3.4	5.9
• Perinatal Conditions*	6.7	5.7
• Mental ill health*	3.7	5.7
• Cerebrovascular disease*	2.8	4.4
• Tuberculosis	2.8	3.1
• Lower respiratory infections	8.2	3.1
• Diarrhoeal disease	7.2	2.7

\* These have all been clearly related to diet – and specifically, to the amount and type of dietary fat

[www.globalforumhealth.org](http://www.globalforumhealth.org)



**The paradigm governing human nutrition last century was wrong**

The main emphasis has been on physical growth (and dietary protein)




**Human development is about the growth of the BRAIN, not the body**

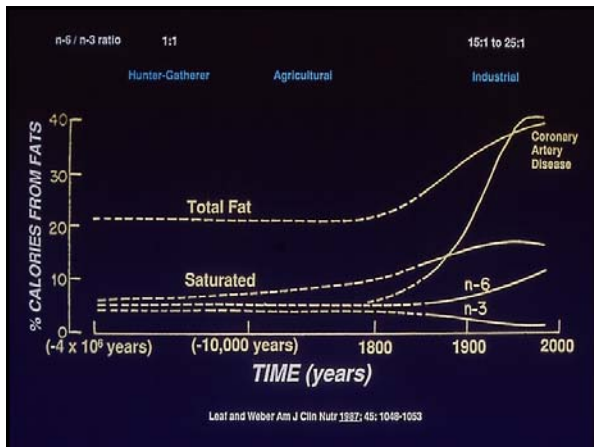


**The human brain is 60% FAT**  
and it really matters what kind!

Dietary advice has not been taking this into account



**Getting the Fats Right**

**Getting the Fats Wrong**



Margarines and commercially baked or fried foods usually contain high levels of hydrogenated and trans fats


These are artificially saturated and 'twisted' fats, which have

- no known nutritional benefits
- many health risks.




**Which fats really are essential?**

- **Essential Fatty Acids (EFA)**  
Two fatty acids are called 'essential', because humans can't make them – so they must come from the diet
  - **Linoleic acid (LA)** (omega-6)
  - **Alpha-linolenic acid (ALA)** (omega-3)
- **Highly Unsaturated Fatty Acids (HUFA)**  
These are the ones that the brain really needs. They aren't always called 'essential', because humans can synthesise them from the 'parent' EFAs.




Synthesis of Highly Unsaturated Fatty Acids (HUFA) from 'Essential' Fatty Acids (EFA)


	omega-6	omega-3
EFA	LA (Linoleic) 18:2	ALA (A-linolenic) 18:3
HUFA	GLA 18:3	18:4
	DGLA 20:3*	20:4
	AA (Arachidonic) 20:4*	EPA 20:5*
	Adrenic 22:4	DPA(n-3) 22:5
	DPA(n-6) 22:5	DHA 22:6



## Dietary Sources of Omega-6


**omega-6**


EFA	LA (Linoleic)	18:2	← Vegetable oils, nuts, seeds, grains
	GLA	18:3	←  Evening primrose oil
	DGLA	20:3*	
HUFA	AA (Arachidonic)	20:4	← Meat and dairy products (milk, yogurt, butter, cheese)
	Adrenic	22:4	
	DPA(n-6)	22:5	



## Dietary Sources of Omega-3

**omega-3**

	ALA ( $\alpha$ -linolenic)	18:3	← Green leafy vegetables, seaweed, & some nuts & seeds (flax, walnut)
		18:4	
		20:4	
HUFA	EPA	20:5*	←  Fish and seafood
	DPA(n-3)	22:5	
	DHA	22:6	



## Conversion of EFA to HUFA is poor, and is further blocked by:


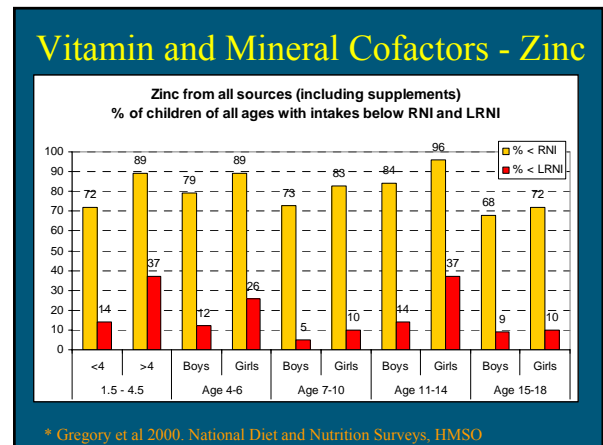
### Diet and Lifestyle

- Saturated fats
- Hydrogenated fats
- Trans fatty acids
- Lack of co-factors (*Zinc, magnesium, manganese, Vitamins B3, B6, C etc.*)
- 'Stress' hormones
- Viral infections

*NB: Excess alcohol & smoking: both destroy HUFA via oxidative stress*


### Constitutional factors

- Ageing
- Atopic eczema (& other allergies?)
- Diabetes
- Being male
  - Testosterone blocks conversion
  - Oestrogen helps to protect HUFA from breakdown
- Genetic predisposition to a spectrum of developmental and psychiatric disorders?

## What are fatty acids essential for?

- The structure of all cell membranes**
  - Omega-3 and omega-6 **increase** the flexibility of membranes, which is necessary for proper cell signalling
- Brain development**
  - Fatty acids make up around 20% of dry brain mass, and affect brain growth and connectivity
  - Supplementing infant formula with HUFA (found naturally in breastmilk) can improve visual and cognitive development
- Maintenance of optimal brain function throughout life**
  - Cell signalling depends on membrane fluidity
  - Omega-3 and omega-6 fatty acids and their derivatives have very powerful effects on many aspects of cell signalling.
  - The substances we make from them can profoundly affect **hormone balance, blood flow and immune system function**




## Functional fats and inflammation

Fatty acids and Prostaglandins (PG)

DGLA (20:3 omega-6)	PG 1	Anti-inflammatory
AA (20:4 omega-6)	PG 2	Pro-inflammatory
EPA (20:5 omega-3)	PG 3	Anti-inflammatory

- EPA (from fish oil) and DGLA (from evening primrose) have anti-inflammatory properties.
- Modern diets often lack these fatty acids, but are rich in AA (found in meat and dairy products), which can have pro-inflammatory effects.



## Fatty acid deficiency in disorders of behaviour learning and mood

What's the Direct Evidence?



## Evidence for fatty acid abnormalities in developmental conditions (1)

### Clinical signs of fatty acid deficiency

- Excessive thirst, frequent urination, rough dry skin & hair, soft or brittle nails, 'follicular keratosis' (hard dry 'bumpy' skin)
  - ADHD (*Colquhoun and Bunday 1981; Stevens et al, 1995, 1996*)
  - Dyslexia (*Baker, 1985; Richardson et al, 2000; Taylor et al, 2000*)
  - Autism (*Bell et al, 2000, Ross and Riordan, 2001*)



## Evidence for fatty acid abnormalities in developmental conditions (2)

### Blood biochemical studies

- Deficiencies of omega-3 / omega-6 fatty acids
  - ADHD (*Stevens et al, 1995, 1996 – but NB not 2003*)
  - Dyslexia (*Baker, 1985, Bell et al, 2004, Ross et al, 2004*)
  - Autism (*Bell et al, 2000, 2001; Vancassel et al 2001*)
- PLA2 enzyme abnormalities consistent with increased loss of omega-3 / omega-6 fatty acids
  - Dyslexia (*MacDonell et al, 2000*)
  - Autism (*Bell et al, 2003*)



## Can treatment with omega-3 fatty acids help?

Evidence from  
Randomised Controlled Trials



## Omega-3 for physical & mental health

- Randomised controlled trials have already shown that omega-3 (notably EPA) can be beneficial for:
  - Cardiovascular function
  - Inflammatory disorders
- And:
  - Schizophrenia (4/5 trials)
  - Bipolar disorder (manic depression) (2/3 trials)
  - Major depression (3/4 trials)
  - Borderline Personality Disorder (1/1 trial)
  - Reducing violence in Young Offenders\*

\* Active treatment also included vitamins, minerals and omega-6 fatty acids



## Omega-3 and Omega-6 for Children's Behaviour and Learning



## Randomised Controlled Trials of Fatty Acids for Child Behaviour and Learning

- Omega-6 fatty acids
  - Two small trials of evening primrose oil showed little or no benefit for ADHD (*Aman et al, 1987, Arnold et al, 1989*)
- Omega-3 fatty acids
  - Two RCTs found no benefits from treatment primarily or exclusively with DHA in ADHD (*Voigt, 2001, Hirayama et al, 2004*)
  - Three RCTs have shown significant benefits from fish oils providing both EPA and DHA (*Richardson & Puri, 2002; Stevens et al 2003; Richardson & Montgomery 2005*)



## Can HUFA treatment reduce ADHD symptoms in dyslexic children?

A randomised controlled trial

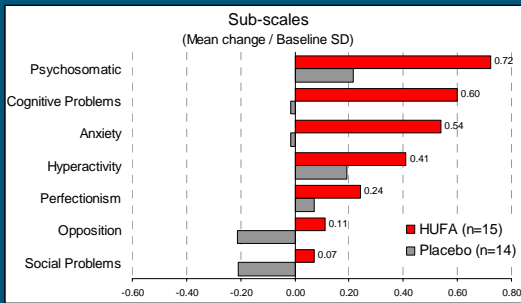
Richardson and Puri (2002) *Prog. Neuropsychopharm. Biol. Psychiat.* 26:233-9

School study: 41 children aged 8-11

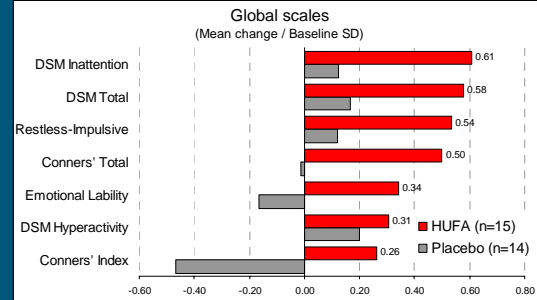
- All showed specific reading difficulties
- and
- All scored above population averages on parent ratings of ADHD symptoms (CPRS-L)



## Treatment effect sizes 0-3 months



## Treatment effect sizes 0-3 months



## EFA supplementation in children with inattention, hyperactivity and other disruptive behaviours

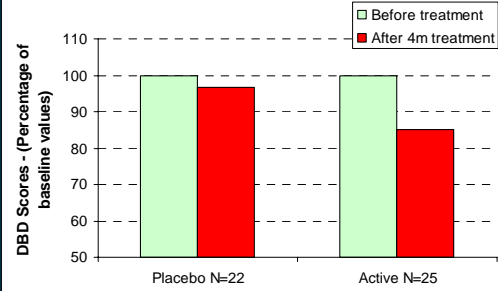
Stevens et al (2003) *Lipids*, 38(10) 1007-21

RCT involving 50 children aged 6-13

- All were under treatment for ADHD-type difficulties
- and
- Children were pre-selected for showing physical signs consistent with fatty acid deficiency

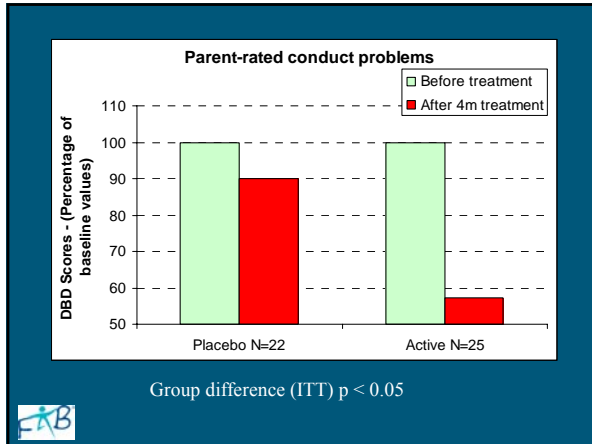


## Teacher-rated attention problems



Group difference (ITT)  $p < 0.03$





## THE OXFORD-DURHAM STUDY:

A randomised controlled trial of dietary supplementation with fatty acids in children with developmental coordination disorder.

Richardson AJ & Montgomery P. *Pediatrics*, 2005, 115:1360-6

117 underachieving children aged 5-12 years from mainstream schools

- All showed specific difficulties in **motor coordination** (DSM-IV DCD)
- 40% were behind expected achievement in **reading and spelling**
- Over 30% scored in the clinical range for **ADHD-type symptoms** (>2SD above population means)

## RESULTS - Overview

Fatty acid treatment vs placebo for 3 months

Intent-to treat analyses

- No significant differences for measures of motor function (NB - large placebo effect)
- Highly significant benefits for reading and spelling progress
- Highly significant reductions in ADHD symptoms

## Reading and Spelling

**Active treatment**

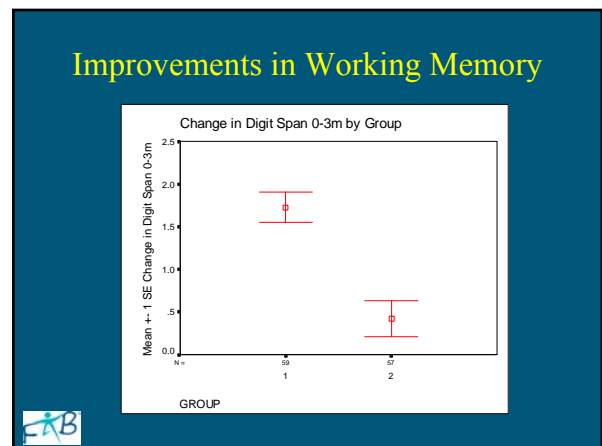
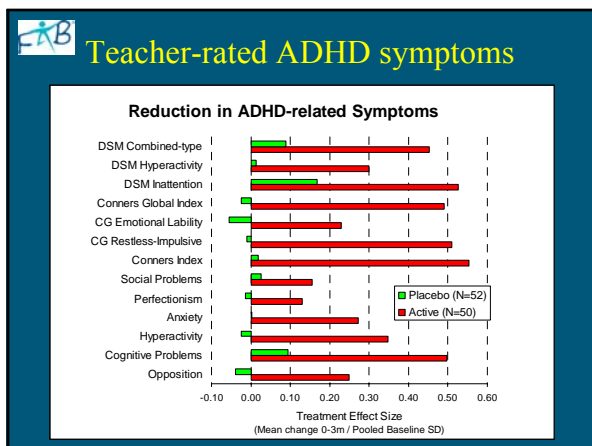
- Compared with expected progress for normal children, gains were **> 3 x normal rate for reading, > 2 x for spelling**

**Placebo**

- Gains were **1 x normal rate for reading, < 0.5 x for spelling**

**Group Differences**

- Reading  $p < 0.004$
- Spelling  $p < 0.001$



## Issues raised by these studies (1)

### Composition of Dietary Supplements

- Benefits for child behaviour and learning have been found from omega-3 HUFA but not omega-6.
- In successful studies, supplements have contained EPA. DHA alone has not shown any benefits for behaviour, learning and mood to date.
  - Supplements have all included some Vitamin E, which might have contributed to the benefits observed.
  - Supplements also contained a little evening primrose oil (omega-6), but studies of this alone have been negative

## Issues raised by these studies (2)

### Relevance to the general population

- Normal individual variations in attention, concentration and working memory do not differ qualitatively from those found in these conditions
  - Attention, concentration and behaviour problems were not extreme (and had not previously been identified) in two of these studies (Richardson & Puri, 2002; Richardson & Montgomery, 2003)
  - Difficulties with written language and memory were not extreme (and had not previously been identified) in one of these studies (Richardson & Montgomery, 2003)
- Studies of unselected children are now a priority

## Dietary need for Omega-3

- Scientific and medical experts recommend a daily intake of at least 500mg/day EPA+DHA\* simply to maintain cardiovascular health.  
*(ISSFAL Statement 2004; UK JHCI 2005)*
- In the UK, average daily intakes are more like 100-150mg
- Requirements for optimal brain function have not yet been investigated.

\*Conversion of ALA from vegetable sources is not always reliable

## Summary and conclusions

- Highly unsaturated omega-3 fatty acids are essential to brain development and function, but are often lacking from modern diets
- Controlled trials show that treatment with omega-3 (notably EPA) can:
  - reduce symptoms of depression, stress-aggression and related conditions in adults
  - improve attention and concentration, reduce disruptive behaviour, and boost reading and spelling progress in children with behaviour and learning difficulties
- Further studies involving general population samples are now clearly warranted.



## Further Information

Details of this and related research are available from the charity



Food And Behaviour Research

[www.fabresearch.org](http://www.fabresearch.org)