Aggressive behavioural syndrome is marked by restlessness, irritability, impulsivity and a proneness to violence. Constitutional factors including genetics and the effect of diseases and physical trauma are known to play a major role in determining the proneness to overaggressive behaviours. Dictum ‘you are what you eat’, emphasize the importance of nutritional factors impacting human behaviour. The Food ingestion influences the behaviour as it affects the formation of brain neurotransmitters and the possible consequences to brain function and behaviour (Beseler, 1999). Contribution of nutritional factors to anti-social and violent behaviour is less recognised and not properly addressed (Werbach, 1995). Although the role of malnutrition in the development of anti-social behaviour has gained some attention but research still places little weight on this topic (Fishbein, 2001; Rutter et al., 1998).

The present paper attempts to provide an overview of the nutritional components as risk factors for aggressive and anti-social behaviour. The studies on various aspects including, effect of early malnutrition on anti-social behaviour, specific nutrients associated with aggressive behaviour, and the effect of food additives on aggressive behaviour are reviewed with the aim to discuss the recent findings in the area which has attracted very little attention in India.

**Early Malnutrition and Aggressive Behaviour**

National Family Health Survey (2006-07) showed that 45% of Indian children are underweight. The recently published series on Maternal and Child Undernutrition in journal ‘The Lancet’, stated that India is home for an estimated population of 61 million stunted children. Indian children are twice as likely to be under nourished as those in Sub Saharan Africa (Black et al., 2008). It is
well established that malnourished children are more susceptible to disease, have low IQ and a reduced capacity to learn and are more susceptible to school dropouts. Under-nutrition is also associated with both short-term and longer term problems of both cognition and behaviour (Grantham-McGregor & Baker-Henningham, 2005).

Little is known about the role of malnutrition in contributing to the development of childhood externalizing behaviour (Fishbein & Pease, 1994; Rutter et al., 1998). Although deficiency in nutrition has been rarely studied in relation to externalizing behaviour, several studies have demonstrated the effects of related factors including food additives, hypoglycemia, and, more recently cholesterol on human behaviour (Kaplan et al., 1997; Raine, 1993; Rutter et al., 1998). Liu & Raine (2006) studied the influence of malnutrition on childhood externalizing behaviour and concluded that it is associated with both macro and micro nutrient deficiencies in both pre and post natal periods. They demonstrated that children with malnutrition signs at the age of three were more aggressive or hyperactive at the age of eight, had more externalizing problems at the age of eleven and had greater conduct disorder and excessive motor activity at the age of seventeen.

Insufficient food supply and mal-absorption of nutrients are fundamental risk factors for malnutrition. Malnutrition can predispose to psychopathology by reducing brain cell development, alterations of biochemical processes and increasing neurotoxicity. The behavioral outcome of this model includes both anti-social behaviour and schizophrenia spectrum disorders (Liu et al., 2007).

Micro Nutrients and Aggressive Behaviour

No single nutrient works in isolation from all other nutrients; a deficiency in one leads to sub optimal functioning of the other nutrients. Both Macro and micro nutrients influence the cognition and behaviour of children. Some of the nutrients that are known to markedly influence cognitive development and behaviour are described below.

Vitamins

Deficiencies of several vitamins are known to be associated with irritability. These include Niacin, Pantothenic acid, Thiamine, Vitamin B6 and Vitamin C. However, the classic vitamin deficiency diseases are rare, although marginal vitamin deficiencies due to inadequate intake appears to be fairly common. However, it is not very clear from the studies that how frequently overaggressive behaviours are a manifestation of marginal vitamin deficiencies. Thiamine is one of the most important vitamins found to be linked with neuro-functioning. Abnormalities of several neurotransmitters systems in the CNS have been recorded in thiamine deficiency (Butterworth, 1982; Witt, 1985). For example, acetylcholine synthesis markedly decreases in the brain of rat fed with a thiamine deficient diet, which may be linked with behavioural problems (Vorhus
et al., 1977). Lonsdale & Shamberger (1980), reported on twenty people eating “junk food” diets who were found to have biochemical evidence of marginal thiamine deficiency. Their subjects and particularly the adolescents were impulsive, highly irritable, aggressive and sensitive to criticism, their behaviour improved following thiamine supplementation concurrent with laboratory evidence of improved thiamine status, suggesting that marginal thiamine deficiency may have contributed to their aggressive behavioural syndrome. Eventually more controlled studies are required to provide clear evidence on importance of subclinical vitamin deficiencies on aggressive and anti-social behaviour.

Minerals

Iron and Zinc—Iron deficiency is most widespread nutritional deficiency in India. 79 per cent children in the age group of 6-35 months were reported to be anaemic (NFHS III, 2006-07). Iron-deficit anaemia is associated with general tiredness, lowered mood and an inability to concentrate and remember. There is increasing evidence that low iron status adversely influences psychological functioning that is believed to result from decreased activity of iron containing enzymes in the brain, in addition to reduced haemoglobin synthesis (Pollitt & Leibel, 1976). Deficiency of iron is known to interfere with proper brain function. Dopamine is a major neurotransmitter in the brain, iron is highly concentrated in the dopamine pathways and animal studies have shown that iron deficiency may cause learning deficits and consequent behavioural impairment by diminishing dopamine neurotransmission (Youdim et al., 1990). Iron is also needed as a co-factor for the enzymes which metabolize not only dopamine but also serotonin and norepinephrine, which also have a potent influence on behaviour.

Recent research suggests that iron deficiency can be an important contributor to the aggressive behavioural syndrome. Even in human beings, there is evidence that anti-social behaviour is related with iron deficiency anaemia (Rosen et al., 1985). Among adolescent males, iron deficiency has been shown to be directly associated with aggressive behaviour (Webb & Oski, 1974). Researchers have also implicated the zinc deficiency in aggression and violence (Arnold & DiSilvestro, 2005; Watts, 1990), but the role of zinc in brain functioning is poorly understood.

Magnesium—Rodent studies suggest that magnesium has a complex relationship with aggressive behaviours. Magnesium deficiency reduces offensive aggressive behaviour but increases defensive aggressive behaviour (Kantak, 1988). Lower levels of magnesium supplementation increase the number of attacks on intruders while higher levels have the opposite effect (Izenwasser et al., 1986).

In humans, magnesium deficiency, which enhances catecholamine secretion and sensitivity to stress, may promote aggressive behaviour. Increased
catecholamines, in turn, induce intracellular magnesium losses and, eventually, increased urinary losses of magnesium (Henrotte, 1986). It has been suggested that the Type A behaviour pattern, which is associated with chronic stress and aggressive behaviour may both cause and be caused by magnesium deficiency. Also, suicide attempts, which are violently aggressive acts against the self, have been correlated with lowered magnesium levels in the cerebrospinal fluid (Banki et al., 1985).

**Tryptophan**— Serotonin, a major neurotransmitter, has been found to play an important role in modulating aggressive behaviour. Impulsive, violent and suicidal behaviours have repeatedly been shown to be associated with a reduction in serotonergic activity in the central nervous system (Roy et al., 1988).

Tryptophan, an essential amino acid, is the dietary precursor to serotonin, and several lines of evidence have suggested that the amount of tryptophan in the diet closely relates to the aggressive behaviour. For example, rats given a diet almost lacking in tryptophan develop aggressive behaviour towards mice (Giammanco et al., 1990). These data suggest that tryptophan supplementation may be most effective in reducing aggression during times of stress. Another study conducted by Rott et al. (2006) showed that Tryptophan’s effects on behaviours and perceptions, while more marked in the men, were generally positive and accompanied by improved affect. Increasing serotonin in quarrelsome people may not only reduce behaviours associated with a predisposition to various mental and physical disorders and aggression but also enhance socially constructive behaviours and improve social perceptions.

**Essential Fatty Acids and Aggressive Behaviour**

The Essential Fatty Acids (EFAs) are LC-PUFAs (long chain polyunsaturated fatty acids) obtained exclusively through diet and they comprise 15–30% of the brain’s dry weight. Selected biochemical evidence suggests a potential role for n-3 long-chain PUFA (n-3PUFA) in the regulation of mood and behaviour. Though most research available is about investigating the role of n-3PUFA in depression, depressive illness and suicidal behaviour, few studies are also available examining the effect on anxiety and anxiety-related disorders, fatigue and fatigue-related disorders, aggression, hostility and anti-social behaviour, inattention, impulsivity and attention deficit hyperactivity disorder and schizophrenic disorders (Appleton, 2008). There is some data available on the effect of EFAs on psychopathic, aggressive and impulsive populations. In a carefully conducted RCT in young adult prisoners, a combination of -6 and -3 EFAs reduced offences by 26.3%, increasing to 35.1% if on supplementation for a minimum of 2 weeks ($P<0.01$). The greatest reduction occurred for the most serious incidents including violence. EFAs have proved beneficial also in stabilising aggression in a normal population of young university students at exam time compared with randomised controls and in a population of patients with borderline personality disorder treated for 8 weeks (Gesch et al., 2002).
Nutritional Correlates of Aggressive Behaviour

**Food Additives and Aggressive Behaviour**

A study conducted by Rowe & Rowe (1994) on 200 children concluded that behavioural changes in irritability, restlessness, and sleep disturbance are associated with the ingestion of tartrazine in some children. Benzoate preservative had adverse effects on the hyperactive behaviour of some children. The significant effects observed were an increase in the mean level of hyperactivity for the group. These findings are supported by another study by Bateman et al. (2004) which concluded that artificial food colouring and benzoate preservatives have an adverse effect on the behaviour of 3 year old children. Significant changes in children’s behaviour could be produced by the removal of colourings and additives from their diet and benefit would accrue to all children from such a change and not just for those already showing hyperactive behaviour or who are at risk of allergic reactions. A recent study conducted by McCann et al. (2007) demonstrated that artificial colours or a sodium benzoate preservative (or both) in the diet result in increased hyperactivity in 3-year-old and 8/9-year-old children in the general population.

**SUMMARY AND DISCUSSION**

The available literature provides evidence about the role of nutrition in aggressive and anti-social behaviour in humans. An early malnutrition could directly predispose extrenalising behaviour. However, the role of specific nutrients on aggressive behaviour, is still being investigated as several studies have suggested that presence or absence of micronutrients in food can lead to aggressive behaviour but there is a need for controlled follow-up studies to establish the specific role of each nutrient in aggression. The results of the case studies, open trials, observational studies and animal studies suggest that attention to nutritional factors may help in better management of aggressive behaviour. It can be concluded that there are possibilities that correct adjustments to diet can not only help to improve health state - or to help correct various illnesses generated by brain malfunctions - but also to enhance positive social behaviour of persons with a tendency towards violence and behavioural disorders.

**REFERENCES**


