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Review Paper

Soft Drinks and Hard Facts: A Health Perspective

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Abstract: All living organisms including human beings in this biosphere are constantly exposed to a variety of xenobiotics. The enormous chemical load in the environment has been primarily through the modernization, industrialization and changes in lifestyle. The changing food habits to suit modern living pose a serious threat to a healthy life. Among others, consumption of soft drinks invariably forms a part of modern life. Mostly children and adolescents are the target groups vulnerable to frequent consumption, compromising the nutritious foods such as fruits, vegetables, milk and milk products. Logically, the quality of the soft drinks is determined by the type and quantity of chemicals present, including those present inherently in the water used for such preparations. The impact of soft drinks on human health has been a subject of in depth research. Consumption of soft drinks plays a major role in a variety of diseases like obesity, diabetes, dental and bone disorders and others, more so among children and adolescents. The toxic effects of soft drinks have gained much attention, due to the frequent scientific reports and media attention. The objective of this review is to provide a comprehensive scrutiny of the impact of soft drinks on health, as well as to suggest alternatives for a healthy life style.

Keywords: Non-alcoholic beverages, toxic chemicals, health hazards

INTRODUCTION

"An ounce of prevention is worth a pound of cure" is a well known proverb. Today, man is constantly exposed to a variety of toxic chemicals primarily due to changes in life style. The food we eat, the water we drink, the air we breathe, and the environment we live in are contaminated with toxic xenobiotics (man-made compounds) (Xavier *et al.*, 2004) Progressive globalization of the food supply and the increase in food intake, such as snacks, soft drinks and fast food, typically form a significant part of daily life (Fernandez San Juan, 2006). Eating habits and food consumption have a direct relation with obesity, diabetes, cancer, hypertension and coronary heart disease (Amas, 2006). Already the planet earth is alarmingly polluted due to modernization and industrialization, and to add to these woes, a healthy life style is also probably jeopardized through indiscriminate consumption of soft drinks. It is most appropriate to mention that an early intervention is the need of the hour to prevent the potential harms of indiscriminate consumption of soft drinks. The present review provides a comprehensive analysis on the impact of soft drinks on human health, and suggests alternatives for a healthy life style.

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Dental Health

A large number of conventional soft drinks cause dental enamel erosion (Jandt, 2006). Soft drink-induced demineralization of dental enamel has increased sharply over the last decades and is a major cause of tooth decay in the younger age group. During demineralization, calcium and phosphorus are mobilized from the enamel which eventually leads to collapse of the surface structure and loss of outermost layers of the enamel. The use of milk as a main liquid source for children is declining in many "advanced" societies, which is substituted with soft drinks, including carbonated beverages. Soft drinks have been suggested to cause damage to the teeth through acidogenicity and cariogenicity. Firstly, the low pH and high titratable acidity of some drinks may lead to the erosion of enamel surface. Secondly the sugars in drinks are metabolized by plaque microorganisms to generate organic acids that add to the process of demineralization, leading to dental caries (Sorvari and Rytoma, 1991). With the frequent consumption of acidic, sugar-rich soft drinks, children are at a higher risk of caries development (Tahmassebi *et al.*, 2006). Cola soft drinks which have pH of 2.74 cause highest change in the surface hardness of tooth, which is also true for sports drinks. However yogurt with the pH of 3.75 to 3.83 does not soften the enamel surface due to the presence of high concentrations of calcium and phosphate (Lussi *et al.*, 1993). Similarly 'Tom-Yum', a well known Thai hot and sour grass soup has been found to have no effect on the surface hardness of enamel (Wongkhantee *et al.*, 2006).

Obesity

Obesity is a serious public health problem world over, which is associated with high mortality and a major risk factor for cardiovascular diseases, diabetes mellitus, stroke, dyslipidemia, osteoarthritis and certain cancers (World Health Organization, 2000).

Trends in beverage consumption have changed during the past five decades. The proportion of persons of all ages consuming soft drinks, the portion sizes and the number of servings have all increased (Nielsen and Popkin, 2004). In the United States alone, the per capita consumption of soft drinks increased from 11 gallons/year to 49 gallons/year. Soft drink consumption in children has increased by 48% in 1998 compared to 1977 (French *et al.*, 2003). In the 70s most soft drinks were made with sucrose, while from 90s onwards this has been substituted with high-fructose corn syrup. All these put together may have serious effects by playing a critical role in the obesity epidemic (Bray *et al.*, 2004). A major concern about childhood obesity is that the condition is likely to continue in adulthood, with serious risks of related chronic disease conditions (Wright *et al.*, 2001).

The major dietary factors positively associated with the probability of developing childhood obesity include, increased consumption of soft drinks, fat, oils and sodium. The most frequently encountered barriers in the management of obesity include consumption of fast food and soft drinks (Perrin *et al.*, 2005). In children, inappropriate nutritional status can affect growth, development, as well as cause nutrition-related health problems (Baskin *et al.*, 2005).

Children, from the age of 5 years onwards spend considerable time at school. Schools play a critical role and have been considered ideal settings for primary prevention efforts aimed at supporting and promoting lifelong healthy eating (Ogden *et al.*, 2002). Generally school food environments mostly include energy-rich, low-nutrient foods and beverages (French *et al.*, 2003). Recent studies conducted in South Africa revealed that the majority of food purchases at schools were unhealthy, dominated by candies, chocolates, soft drinks (usually with high sugar content), French fries, and potato chips. Further, 22% of children did not have breakfast prior to school. Skipping breakfast may have a detrimental outcome on physiologic and scholastic achievements. In addition, a large percentage of students did not

bring healthy items from home. Consumption of low fat milk and dairy products, fruits and legumes is well known to be negatively associated with probabilities of being at risk for overweight. However, those from rural areas had a lower consumption of sugar and animal products and a higher consumption of legumes (Temple *et al.*, 2006). It is highly appropriate to mention the public opinion, that schools should offer students more healthy foods and eliminate low-nutrient food options such as candy and soft drinks (Kubik *et al.*, 2005). If initiated and scrupulously followed, this suggestion alone would have a significant contribution in the prevention of obesity.

Diabetes Mellitus

Globally, diabetes mellitus is a major health problem. It is characterized by high levels of blood glucose resulting from defects in insulin production, insulin action or both and can affect several body systems leading to heart diseases, stroke, blindness, renal and nervous system damage, limb amputations and dental diseases (American Diabetic Association, 2006). This problem is at an increasing trend, for instance, in the United States alone 20.8 million persons are suspected to suffer from diabetes mellitus and is reported to be the sixth leading cause of death (Bevan, 2006). Over the past 10-20 years, an alarming increase in the prevalence of diabetes has been reported world over (Fagot, 2000). Life style factors are responsible for world wide epidemic of overweight and obesity and have contributed to a dramatic increase in the prevalence of diabetes both in adults and children.

Many different pathologic processes can lead to the development of diabetes mellitus; however, most children and adolescents have type 1, while adults have mostly type 2 diabetes. Type 1 diabetes results from chronic, progressive T-cell mediated autoimmune destruction of the ≤-cells of pancreas, eventually leading to severe insulin deficiency (Atkinson and Eisenbarth, 2001). Type 2 diabetes manifests during the late 30s and early 40s placing the individuals at greater risk for major morbidity and mortality, especially during the most economically productive years of life. Further the newly diagnosed type 2 diabetic individuals are virtually overweight or obese. The resulting economic burden is enormous (Botero and Wolfsdorf, 2005).

Diet plays a significant major role in the management of diabetes, irrespective of the age group and the type of diabetes. The consumption of soft drinks which contain a high amount of free sugar, not only impairs the smooth control of blood sugar but also adds to other complications like overweight and obesity. Availability of calorie-dense fast foods or "junk foods", candy and sugar-soft drinks must be restricted in schools and other venues often visited by children. Otherwise, this may not only enhance the incidence of obesity but also contribute to the unsatisfactory control of diabetes in the community.

Hypocalcemia and Bone Density

Over the past 2 decades there has been an approximate 50% decrease in milk consumption among children and adolescents, with a corresponding increase in soft drink consumption. Soft drink consumption among children in the age group of 9-16 years has been found to be associated with an increased incidence of wrist and forearm fractures (Ma and Jones, 2004). Consumption of coffee, leading to an increased total intake of caffeine has been claimed to be associated with risk of osteoporotic fractures. A daily intake of 330 mg of caffeine, equivalent to 4 cups (600 ml) of coffee, or more may be associated with a modestly increased risk of osteoporotic fracture, especially in women with a low intake of calcium (Hallstrom *et al.*, 2006). The proposed mechanism(s) for the decrease in bone mineral density include the presence of phosphoric acid in soft drinks, which promotes bone resorption and/or certain other ingredients of beverages contributing to the increased excretion of calcium in urine. A high

phosphoric acid level is a source of exogenous phosphorus which causes hyperphosphatemia. The inhibition of 1±- hydroxylase resulting from hyperphosphatemia, causes diminished 1±, 25-dihydroxyvitamin D3 which leads to hypocalcemia. The phosphorus content of human milk is 14 mg per/dL. However, the phosphorus content in soft drinks ranges between 16.1 to 19.7 mg/dL, with virtually no calcium, which facilitates phosphorus absorption (Massey and Strang, 1982). Caffeine is frequently added to nonalcoholic proprietary drinks as part of the manufacturing process. Caffeine is known to increase urinary calcium excretion compared to caffeine-free drinks (Massey and Hollingbery, 1988).

These not only cause a reduction in bone density leading to increased incidence of fractures but also precipitate calcium-phosphorus complexes in soft tissues (Benabe and Maldonado, 1994), leading to diseases like renal stones. In addition, hypocalcaemia may cause seizures, subnormal intelligence, intestinal malabsorption and worsen congestive heart failure eventually leading to cardiac arrest (Carey, 1968). Caffeine has no intrinsic nutritional value, on the contrary it compromises the blood flow to brain, leading to anxiety, insomnia, paranoid features, frank psychosis and even lead to death in excess doses (Mathew and Wilson, 1985; Watson *et al.*, 2000; Parker, 1986). Caffeine concentrations in plasma above 15 mg/L can cause toxic symptoms while values above 800 mg/L are considered to be fatal (Riesselmann *et al.*, 1999). Excessive intake of caffeine by a mother during pregnancy may lead to fetal arrhythmias (Oei *et al.*, 1989). Menopausal women are inherently at a higher risk of osteoporosis and more vulnerable to fractures, which may be magnified with increased soft drinks consumption. Thus efforts at community health education towards reduced intake or avoidance of not only soft drinks but also caffeinated beverages, and a switch toward higher intake of fruit juices would elevate the overall health status.

The United States ranks first among the countries with higher soft drinks consumption, followed by Mexico (142 L/year per capita). It is distressing to know that, in Mexico some mothers have substituted soft drinks for milk to feed their infants. This phenomenon may be related to low educational and income levels in Mexico and to the fact that soft drink prices are three to five times lower compared to in the United States. Infants as well as children of school age who consume soft drinks, are at risk of hypocalcaemia. More than 50% of the students in a study practiced inappropriate food habits characterized by adding more salt to food, lower intake of dairy products, fruit and vegetables with a higher intake of soft drinks, butter and snacks (Cuce Nobre *et al.*, 2006). Thus irrespective of factors like education, per capita income, age and sex, there seem to be an increased tendency for soft drink consumption and the urgent need for deterrence of the same.

Cancer

Heavy consumption of soft drinks has also been implicated as one among the many risk factors for cancer. Changing life style, including the nutrition (soft drinks) at pubertal stage may be one of the factors for the development of breast cancer (Vandeloo *et al.*, 2007). Recent studies have shown that the consumption of soft drinks, and sweetened fruit soups are positively associated with a greater risk of pancreatic cancer (Larsson *et al.*, 2006). Though soft drink consumption has not been found to influence pancreatic cancer risk among men, consumption of sugar-sweetened soft drinks has been hypothesized to be associated with a modest but significant increase in risk among women who have an underlying degree of insulin resistance (Schernhammer *et al.*, 2005).

Other Important Health Effects

Urinary stone disease has been found to be associated with intake of phosphoric acid based soft drinks but not the citric acid ones (Shuster *et al.*, 1992). Soft drinks containing grapefruit juice and citrus fruit juice may lead to the formation of urinary stone. Still, citrus fruit juices could represent a natural alternative to potassium citrate in the management of nephrolithiasis, because they could be better tolerated and cost effective than pharmacological treatment. However, in order to obtain a beneficial effect in the prevention of calcium renal stones, reduced sugar content is desirable to avoid the increase of urinary calcium excretion due to the influence of sugar supplementation (Trinchieri *et al.*, 2002).

Soft drinks have also been implicated in the development of headache. Headache caused by drinking cold water is common in women having previous history of migraine (Mattson, 2001). The patients suffering from ice cream headache have experienced a type of headache, similar to migraine attacks, following consumption of hot or soft fuzzy drinks (Selekler and Komsuoglu, 005). Flying caps of the soft drink bottles and the glass fragments of the exploding bottles may cause eye injury (Avisar and Savir, 1978). Contamination of soft drinks with antibiotics (penicillin or penicillin like substances) may cause anaphylactic reaction in sensitive patients (Wicher and Reisman, 1980).

In Japan, teenagers have a tendency to consume excessive sweet carbonated soft drinks, instant noodles and power mill-polished rice, the latter readily inducing a relative thiamine deficiency. A sudden increase in thiamine requirement due to strenuous exercise has been suggested to result in overt beriberi heart disease (Kawai *et al.*, 1980). A particular brand of a soft drink produced in Nigeria containing bitter lemon was found to affect human sperm motility (Nwoha, 1992).

Reasons for Elevated Soft Drink Consumption

Cultural shift plays a major role in changing food habits. Acculturation, for example, is associated with change in dietary behavior within the Chinese-American population (Satia *et al.*, 2001). The accultured first-generation Chinese-Americans have increased their fat, sweet, and soft drink consumption (Lv and Cason, 2004). Generally Chinese-Americans have higher rates of chronic diseases such as diabetes, heart disease, and certain cancers than Asian-Chinese (Campbell *et al.*, 1998).

Television viewing is one of the major environmental factors influencing the food habits of young children and adolescents. There is an association with high television viewing rates and the less healthy food option, among adolescents with consequent increased risk for obesity (Vereecken *et al.*, 2006). Television advertisements directly affect children's eating habits and their food consumption. More than half of the foods advertised in the television are rich in fat and sugar. Children insist their parents buy them television advertised goods, thus affecting their healthy food consumption.

Movies are yet another major environmental influence, particularly with regard to the use of branded soft drinks by favorite artists, which have a tremendous influence over children and adolescents. A recent study conducted in the United States showed that the frequent appearance of branded soft drinks provide indirect evidence that product placement is a common practice for American produced films, exhibited in the US and other countries (Cassady *et al.*, 2006).

CHEMISTRY OF SOFT DRINKS

Sweeteners

Sodium and calcium cyclamates are additives widely used as non-nutritive sweeteners in many diet and medicinal products. They are no longer permitted as food additives in many

countries due to their conversion to cyclohexylamine, which is a strong carcinogen. However, they are still available in many countries as sweeteners (Llamas *et al.*, 2005). Aspartame (L-aspartyl-L-phenylalanine methyl ester) a sweetener, releases one molecule of methanol for each molecule consumed. The soft drinks sweetened with aspartame may release about 250 mg/ day of methanol upon consumption. The uncontrolled consumption of soft drinks sweetened with aspartame may lead to acute and chronic human methanol toxicity (Monte and Aspartame, 1984). Aspartame included in the soft drinks negatively influences the motivation to eat food. Human volunteers who consumed 1-2 cans of soft drinks with 234 to 470 mg equivalent of aspartame resulted in a prominent post-ingestive inhibitory action on appetite with consequent reduction in food intake. These effects of aspartame may be due to the release of cholecystokinin by phenylalanine, a constituent of aspartame (Rogers *et al.*, 2003; Black *et al.*, 1991).

Preservatives

Sulphur dioxide is widely used in food and drinks industries for its properties as a preservative. It can induce asthma when inhaled or ingested by sensitive subjects, even in high dilution. About one in nine asthmatics have asthma worsened by drinking soft drinks containing sulphur dioxide (Freedman, 1980). Sulphites, used extensively as preservatives in soft drinks, are also known to precipitate asthma attacks in susceptible children (Steinman and Weinberg, 1986).

Disinfectant

When chlorine is employed as a disinfectant, chlorinated organic compounds like 'trihalomethanes' are formed due to the interaction of chlorine with various organic substances in water. Epidemiological studies have demonstrated an association between cancer and high concentrations of trihalomethanes. Studies conducted to determine the quantity and quality of trihalomethanes in soft drinks showed that, the total trihalomethane concentration was higher in certain brands due to the presence of caramel (Abdel Rahman, 1982).

Food Colorants

Food colorants have been used to make the food more attractive and appetizing. Although the number of permitted food colorants was reduced for safety reasons, in recent years, many synthetic colorants are still widely used worldwide because of their low price, effectiveness and stability. Since many synthetic colorants are potentially toxic, the usage of colorants is strictly limited (Chen *et al.*, 1998).

Elements

Aluminum (Al) is widespread in water, soil and plants and consequently in the food chain. Al content in ground water may be increased by acid rain (Gerhardsson *et al.*, 1994). Further, soft drinks have a higher level of Al than fruit juices and drinking water. The quality of cans may also influence substantially the levels of this element in the beverages, during processing and preservation. Aluminum content in all soft drinks increases during storage as a result of dissolution, due to the presence of acidic substances (including orange, apple, lemon juice) and food additives like citric, acetic and tartaric acids (Seruga *et al.*, 1994; Jagannatha and Valeswara, 1995). The permitted level of dietary Al must not exceed 6 mg/day to avoid toxicity (Massey and Taylor, 1991). Elevated tissue levels of Al may lead to problems such as osteomalacia, neurodegenerative disorders like Alzheimer's disease and decreased renal function (Storey and Masters, 1995).

Fluoride has also been detected in soft drinks. The highest mean concentration of fluoride was found in juices and cola drinks. The fluorides ingested through the bottled drinks represent an important part of the total fluoride ingested by the population (Jimenez-Farfan *et al.*, 2004). Lead is another toxic metal

reported to be present in soft drinks (Boppel, 1973) adding to the problem of chronic toxicity.

Potable water, fruit juices and soft drinks are some of the most widespread beverages in the habitual diet, and they can contribute to chromium dietary intake. A study conducted in Spain showed that as much as 11.80 ºg/L of chromium was detected in potable water, 17.60 ºg/L in fruit juices, and 3.60 to 60.50 ºg/L in soft drinks (Garcia *et al.*, 1999). Health related problems due to consumption of soft drinks among different communities from time to time.

The Belgium Incident

In June 1999, secondary school pupils in Bornem, Belgium complained of abdominal discomfort, headache, nausea, malaise, respiratory distress, trembling and dizziness following consumption of a popular brand of soft drink. Immediately the Belgian health authorities banned the sale and consumption of all soft drinks from that company for several weeks. The outbreak not only involved schools children but a larger number of adults were also affected. The toxicological data that were made available later suggested that the cause of health complaints was due to contamination of the carbon dioxide in soft drinks by carbonyl sulfide, leading to a toxic by product, hydrogen sulfide (Nemery *et al.*, 2002).

The Irish Incident

The Irish government ordered an urgent investigation with reference to the effects of the so called "functional energy" or stimulant soft drinks, consequent to the death of a 18-year-old, following consumption of three cans of a particular stimulant soft drink. Though there were differing opinions regarding the cause of death, caffeine was the principal suspect (Birchard, 2000).

Social and Behavioral Problems

The Irish government drew the public's attention to the use or abuse of stimulant soft drinks which has one of the highest sales figures in the world. It is a popular mixer for vodka among young drinkers. There had been a rise in aggressive late-night violence. The situation was so alarming that senior doctors met the Prime minister and expressed their concern (Birchard, 2000). Another vital issue of recent concern is that there has been a high consumption of drinks containing natural products with stimulant properties among young adults. Although they might be harmless, overdoses or combination of these with other drinks could be harmful. It is of critical importance to screen stimulant soft drinks that are consumed in high quantity (Maria *et al.*, 2002).

Transition Towards Healthy Soft Drinks

There has been a paradigm shift in the perception of the soft drink manufacturing companies in recent times. The renaming of Australian Soft Drink Association (ASDA) to Australian Beverages (AB) Council Ltd, reflect a shift by companies to produce beverages consistent with trends of International kindred association. Alternative forms of soft drinks are introduced in the markets which have a high bioavailability of calcium, and nutrients similar to that of milk. These products are known as 'dairy soft drinks'. The lactose and the carbonation used in the production of the 'dairy soft drink' may also increase calcium absorption (Schroder *et al.*, 2005).

Dried fruits, especially figs are a convenient and superior source of important nutrients and antioxidants (Vinson *et al.*, 2005). Concerted research efforts should be devoted to developing soft drinks based on dry fruits and fruits with high nutritional value. The use of low calorie soft drinks based on herbal material enriched with vitamin C and iodine by patients with diabetes mellitus has resulted in the improvement of carbohydrate metabolism, apart from providing iodine and vitamin C (Maiurnikova *et al.*, 2000).

Despite the caffeine content, tea remains the most consumed drink in the world after

water, well ahead of coffee, beer, wine and carbonated drinks. Tea flavanoids, a potent source of antioxidants consistently lead to a significant increase in the antioxidant capacity of blood and also protects the DNA from oxidative damage (Rietveld and Wiseman, 2003).

Studies conducted among college students in the U.S. showed that, majority of them knew what constituted a healthy diet and the importance of exercise. Nutrition education and exercise information for optimal health need to be disseminated widely to all college students (Dennis *et al.*, 1995).

SUGGESTIONS

There has been an increasing trend in the sales and consumption of soft drinks world wide (De Guzman, 2004). Recent studies conducted in Saudi Arabia showed that carbonated soft drinks and fruit juices accounted for the largest proportion of total fluid intake by adolescents, to the detriment of nutritious milk (Bello and Al-Hammad, 2006). Parents and teachers should evince much concern about the nutritional health of children and the school food environment. Dietetic and other health professionals who work in school settings should engage parents and teachers in monitoring policies and practices that promote and support a healthful school food environment. The policies and practices should include, prohibition of the sale of low-nutrient food and beverages in school campus, provision of nutrient guidelines for food and beverages offered in vending machines and school stores and a ban on advertisement of food and beverages in the school settings (French *et al.*, 2003). Nutrition education among Eskimo teenagers has been shown to reduce soft drink consumption by 10% (Thiele and Boushey, 1989). Child nutrition advocates have called for a reduction in access to soft drinks in schools as an important step in optimizing a healthy environment. Soft drink manufacturers must acknowledge the problem of rising rates of overweight in children and work within their spheres of influence to limit access to soft drinks in schools (White *et al.*, 2004). Promoting the sale of milk and milk products including butter milk, yogurt in school stores and government sponsored promotion of the food stuffs in public places where people gather in large numbers such as bus and railway stations, amusement parks could also be undertaken. The influence of parental soft drink intake is stronger than peer influence, which reflects the responsibility of the parents. Parents should be aware that their eating behaviors, including their choice of beverage, may impact their children's eating habits. It is important that parents serve as positive role models, and their influence should be considered in designing interventions to promote healthful beverage choices by children.

Another strategy aimed at getting children to eat healthier foods at schools is to change the pricing structure of foods sold in school stores. A study conducted in the U.S showed that the price of fruits, carrots and salads was halved, resulting in a four-fold increase in sales of fruits, and a two-fold increase for carrot, and a slight increase for salads indicating such policies may redirect the food choices towards healthier food (French *et al.*, 1997).

Consideration should be given to developing public service announcements promoting healthful eating behaviors, such as choosing water and milk as beverages. In the context of obesity prevention and management, much attention should be given to encourage substitution of water and/or diet soft drinks for regular soft drinks (Grimm *et al.*, 2004).

In many countries there are no regulations for control of soft drink sales; however few countries that have experienced ill health effects due to soft drinks have their own regulations. For instance, Philippines, a country where malnutrition is an ominous health threat, has recently devised a plan that

would allow citizens to cash in on the country's "junk food diet" by taxing every liter bottle of carbonated soft drink sold.

Little research has been focused on the beneficial impacts of reduced soft drink intake. Concerted research directed towards promotion of positive impact of milk, butter milk, yogurt and other milk products *in lieu* of soft drinks, may prove fruitful. Such studies while indicating the way for healthy life, may also present an insight to the multinational companies to focus their attention towards development of health centered drinks.

In summary, all stake holders including the soft drink companies, Governments, parents and teachers should all play a concerted and critical role towards solving the problems related to soft drink consumption with the sole aim of "Prevention is better than cure".

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