

Can sugar cause addiction among humans?

A review to find out biologically plausible reasons.

INTRODUCTION

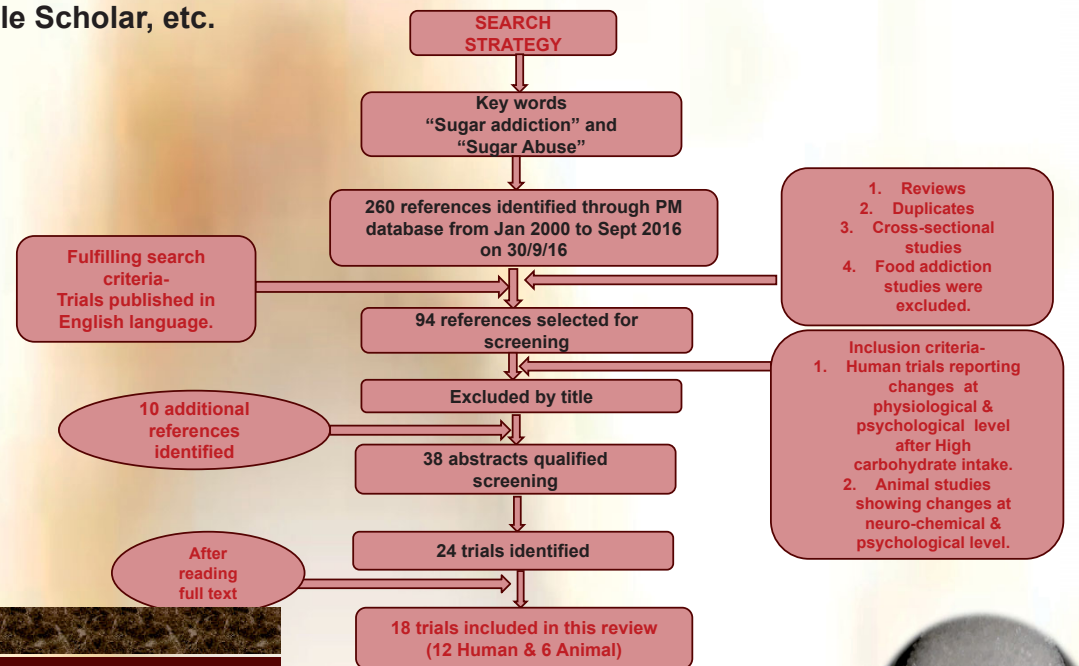
- Sugar is defined as a "A sweet crystalline substance obtained from various plants, especially sugar cane and sugar beet, consisting essentially of sucrose, and used as a sweetener in food and drink."¹
- Over the years, the dietary pattern has changed profoundly from consumption of cereals & pulses to highly palatable, rich-in-sugar products.²
- Research suggests that sugar can have systemic as well as dental effects.³
- In recent years, a new concept gaining attention is that highly palatable foods can cause addiction, which is commonly characterised by the following symptoms:⁴
 - Bingeing / intoxication,
 - Withdrawal,
 - Anticipation / craving,
 - Tolerance.
- Sugars are also considered to have addictive properties.⁵
- Moreover, factors like obesity, depression, anxiety, bipolar disorders, disturbed emotional status, people with low serotonin levels, and premenstrual disorders in women have been shown to make individuals susceptible to sugar addiction⁶
- So, there is a necessity to discover the plausible reasons; hence the present study was undertaken.

OBJECTIVES

- To discover evidence of the addiction potential of sugar in humans.
- To report the biologically and psychologically plausible reasons for sugar addiction.

MATERIAL & METHODS

- A systematic literature survey was carried out in electronic databases such as PubMed, Medline, Scopus, Embase, Science direct, the Cochrane database, Google Scholar, etc.



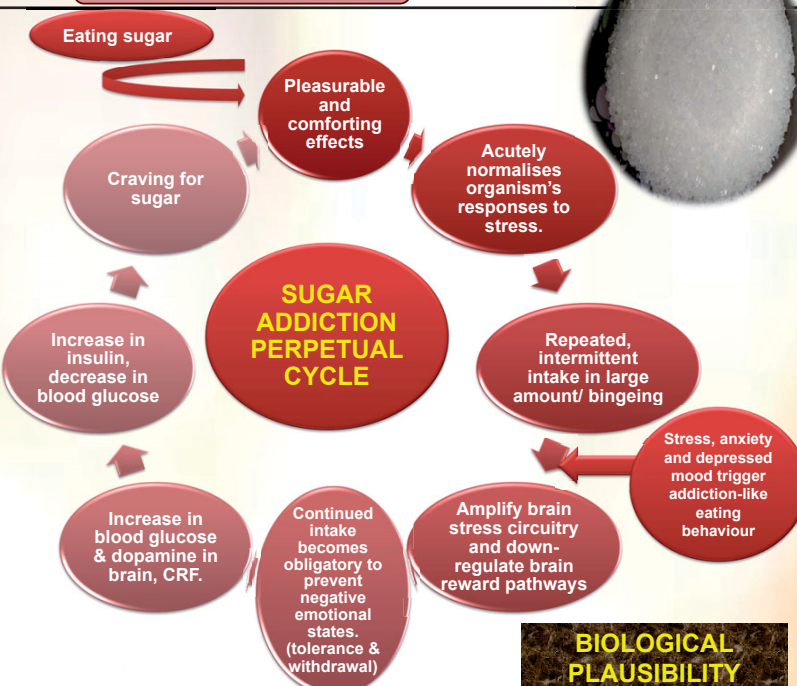
RESULTS

Table 1: Evidence for changes in the human body after sugar consumption

S.NO	AUTHOR	YEAR	SUBJECTS	INTERVENTION	FINDINGS
Physiological changes:					
1.	Raben <i>et al</i> ⁷	2002	41 adults 35 female 6 male	1 st gp- Sucrose 2 nd gp- Artificial sweetener	Total Energy intake, Sucrose consumption, BP, Body wt. - Sig. increase in sucrose gp (p<0.0001).
2.	Wurtman <i>et al</i> ⁸	2003	8 healthy adults 6 male 2 female	1 st gp- Carbohydrate rich 2 nd gp- Protein rich diet	Insulin-Carb gp > protein gp (p<0.05)
3.	Stanhope <i>et al</i> ⁹	2008	34 Healthy adults 18 male, 16 female	1 st gp- High fructose corn syrup 2 nd gp- Sucrose sweetened beverage	24-hr plasma profiles - Glucose, leptin, ghrelin, TG - NS(p>0.05) Insulin- Sucrose beverages > HFSC. (p<0.01)
4.	Teff <i>et al</i> ¹⁰	2009	17 obese 9 male 8 female	1 st gp- glucose 2 nd gp- Fructose sweetened beverage	24-hr plasma profiles - Glucose, leptin, ghrelin, TG & Insulin - Glucose gp > fructose gp (p<0.0001)
5.	Yu Z <i>et al</i> ¹¹	2013	138 adults	1 st gp- HFSC 2 nd gp- Sucrose	24-hr plasma profiles - Glucose, ghrelin - NS(p>0.05) Insulin, Leptin, TG- sig. high in Sucrose gp (p<0.05)
6.	Heden <i>et al</i> ¹²	2014	40 adolescents	1 st gp- Fructose 2 nd gp- Glucose beverage	Fasting level (12hr)- Glucose, Insulin, Lactate - NS(p>0.05)
Changes in Brain:					
1.	Lennerz <i>et al</i> ¹³	2013	Healthy overweight and obese young male, aged between 18 and 35 y.	1- High & 2- Low glycemic index meals	Cerebral blood flow in the right nucleus accumbens- greater after the high- than low-GI meal
2.	Stice <i>et al</i> ¹⁴	2013	106 healthy-weight adolescents	1- high-fat/high-sugar, 2- high-fat/low-sugar, 3-low-fat/high-sugar, 4- low-fat/low-sugar chocolate milkshake and 5- tasteless solution	High-fat/high-sugar milkshake (compared with the tasteless solution) intake elicited robust activity in the bilateral postcentral gyrus that extended into the insula and right Rolandic operculum.
Psychological changes:					
1.	Spring <i>et al</i> ¹⁵	2008	61 overweight women	1 st gp- balanced protein rich 2 nd gp- 100% Carbohydrate beverage	Beverage choice- Carbohydrate beverage consumption- Sig. increase (p<0.0001). Reduction in Dysphoria- Sig. reduction in Carb beverage gp (p<0.05).
2.	Lemmens <i>et al</i> ¹⁶	2011	38 adults 19male 19female	1 st gp- high Protein meal 2 nd gp- high carbohydrate meal	Test meal consumption- Wanting/liking of bread & drinks- sig decrease (p<0.001) in high carbohydrate gp.
3.	Lemmens <i>et al</i> ¹⁷	2011	27 normal weight (NW) 15 overweight adults (OW)	1 st gp- high Protein meal 2 nd gp- high Glucose meal Stress Vs rest condition	Test meal consumption- Wanting/liking of dessert & snacks- High Glucose gp > protein gp (p<0.001) Stress Vs rest condition- Wanting/liking- sig. increase in OW & Sig. decrease in NW (p<0.02).
5.	Lowdens <i>et al</i> ¹⁸	2014	65 overweight	1 st -10% Sucrose 2 nd -20% Sucrose 3 rd -10% Fructose 4 th -20% Fructose	Beverage consumption- Sig increase in both 20% gps than 10% gps (p<0.01). 20% fructose > 10% Sucrose (p<0.01).

Table 2: Evidence for changes in animals after sugar consumption

S.N O	AUTHOR	YEAR	SUBJECTS	INTERVENTION	FINDINGS (Physiological changes)
1.	Hajnal <i>et al</i> ¹⁹	2002	Rats	Sucrose gp Plain water gp	Dopamine release - sucrose gp > water gp (p<0.05).
2.	Avena <i>et al</i> ²⁰	2005	Rats	Sham feed gp Real feed gp (Sucrose water)	Sucrose consumption- Sham fed gp > real fed (p<0.01). Acetylcholine release- real fed gp > Sham fed (p<0.01).
3.	Lenoir <i>et al</i> ²¹	2007	Rats	Water with Saccharin Intravenous Cocaine	Preference - Saccharin gp > cocaine (p<0.01).
4.	Avena <i>et al</i> ²²	2008	Rats	Experimental gp- intermittent sugar+ chow Control gp- ad libitum chow	Dopamine release after 36 hrs- sig. less in experiment gp (p<0.05).
5.	Avena <i>et al</i> ²³	2008	Rats	Experimental gp- sucrose bingeing Control gp- ad libitum chow	Dopamine release - sucrose bingeing gp > control gp (p<0.001).
6.	Vendruscolo <i>et al</i> ²⁴	2010	Rats	Plain water gp Sucrose gp	Preference- Sucrose > water (p<0.0001).



DISCUSSION

- Sugar addiction represents a specific case of food addiction. A possible reason for its addictive properties may be because of the presence of a specific nutrient: i.e. Sucrose.²⁵
- This evidence is supported in the present review by various animal studies which showed that sucrose intake results in the production of neuro-chemical substances such as dopamine in the brains of these animals.^{19,22,23}
- Also, it was observed that the preference for Saccharin was greater than that shown by other addictive substances such as cocaine.²¹
- Human studies reported that the reason for the possibly addictive nature of sugar may be because of changes carried out by it at various levels in the body.
- In the brain** - It resulted in increased blood flow in the right nucleus accumbens, which plays a central role in reward and craving; high sugar intake also elicited robust activity in the bilateral postcentral gyrus that extended into the insula and right Rolandic operculum, which are known to be involved in reward, motivation, and oral somato-sensation.^{13,14}
- At a psychological level** - It resulted in an increase in liking or wanting a carbohydrate meal/beverage over protein meals.^{7,15-18}
- At a physiological level** - Insulin and glucose levels were significantly increased after sucrose intake, resulting in a craving for more sugar.⁸⁻¹¹
- The available evidence is limited because of difficulties comparing different types of rewards and psychological experiences in humans.

DENTAL PUBLIC HEALTH SIGNIFICANCE

- Evidence is available in the literature that suggests sugar addiction is related to an increased incidence of systemic diseases like obesity, various cardiovascular diseases, diabetes, hypertension, dementia, and dental problems such as dental caries in various parts of the world, which makes it a major public health problem.

CONCLUSIONS

- There is some evidence of sugar addiction among laboratory animal models, which gives biologically plausible answers, but these may not be applicable to humans.
- More research is necessary among human subjects to verify the status of sugar as addictive substance.

REFERENCES

- White JS. Straight talk about high-fructose corn syrup: what it is and what it ain't. *Am J Clin Nutr* 2008;88.
- Vasantha S, Vijayakshmi S and Kiran P. Review on impact of changing lifestyles on dietary pattern. *Int.J.Curr.Res.Aca.Rev.* 2015;3(6):135-47.
- George EW. Sugar, Cavities, Systemic Disease and Addiction? *J Oral Bio.* 2016; 3(2): 5.
- Koob GF, Zorrilla EP. Neurobiological mechanisms of addiction: focus on corticotropin-releasing factor. *Curr Opin Investig Drugs.* 2010;11(1):63-71.
- Avena NM, Rada P, Hoebel BG. Evidence for sugar addiction: Behavioral and neurochemical effects of intermittent, excessive sugar intake. *Neuroscience and Biobehavioral Reviews.* 2008;32:20-39.
- Panylak SL, Koob GF, Zorrilla EP. The dark side of food addiction. *Physiol Behav* 2011;104(1):149-56.
- Raben A, Vasiliadis TH, Mellier CA, and Astrup A. Sucrose compared with artificial sweeteners: different effects on ad libitum food intake and body weight after 10 wk of supplementation in overweight subjects. *Am J Clin Nutr* 2002;76:721-9.
- Wurtman RJ, Wurtman JJ, Regan MM, McDermott JM, Tsay RH, and Brew JJ. Effects of normal meals rich in carbohydrates or proteins on plasma tryptophan and tyrosine ratios. *Am J Clin Nutr* 2003;77:128-32.
- Stanhope KL, Griffen SC, Bair BR, Swarbrick MM, Keim NL, and Havel PJ. 24 Hour Endocrine and Metabolic Profiles Following Consumption of High Fructose Corn Syrup-, Sucrose-, Fructose-, and Glucose-Sweetened Beverages with Meals. *Am J Clin Nutr* 2008;87(5):1194-1203.
- Teff KL, Grudziak J, Townsend RR, Dunn TN, Grant RW, Adams SH, Keim NL, Cummings BP, Stanhope KL, Havel PJ. Endocrine and metabolic effects of consuming fructose- and glucose-sweetened beverages with meals in obese men and women: influence of insulin resistance on plasma triglyceride metabolism. *J Clin Endocrinol Metab.* 2009;94(5):1562-9.
- Yu Z, Lowndes J, Rippe J. High-fructose corn syrup and sucrose have equivalent effects on energy-regulating hormones at normal human consumption levels. *Nutr Res.* 2013;33(12):1043-52.
- Heden TD, Liu Y, Park YM, Nyhoff LM, Winn NC, and Kanaley JA. Moderate amounts of fructose- or glucose-sweetened beverages do not differentially alter metabolic health in male and female adolescents. *Am J Clin Nutr* 2014;100:798-805.
- Lennerz BS, Alsop DC, Holsen LM, Stern E, Rojas R, Ebbeling CB, Goldstein JM and Ludwig DS. Effects of dietary glycemic index on brain regions related to reward and craving in men. *Am J Clin Nutr* 2013;98:641-7.
- Stice E, Burger KS, and Yokum S. Relative ability of fat and sugar tastes to activate reward, gustatory, and somatosensory regions. *Am J Clin Nutr* 2013;98:1377-84.
- Spring B, Schneider K, Smith M, Kendzor D, Appelhans B, Hedeker D et al. Abuse potential of carbohydrates for overweight carbohydrate cravers. *Psychopharmacology (Berl).* 2008; 197(4): 637-47.
- Lemmens SG, Rutters F, Born JM, Westertrop-Plantenga MS. Stress augments food 'wanting' and energy intake in visceral overweight subjects in the absence of hunger. *Physiol Behav.* 2011;103(2):157-63.
- Hajnal A, Norgren R. Repeated access to sucrose augments dopamine turnover in the nucleus accumbens. *Neuroreport.* 2002;13(17):2213-6.
- Avena NM, Rada P, Moise N, Hoebel BG. Sucrose sham feeding on a binge schedule releases accumbens dopamine repeatedly and eliminates the acetylcholine satiety response. *Neuroscience.* 2006;139(3):813-20.
- Lenoir M, Serre F, Cantin L, Ahmed SH. Intense sweetness surpasses cocaine reward. *PLoS One.* 2007;2(8):e698.
- Avena NM, Rada P, Hoebel BG. Underweight rats have enhanced dopamine release and blunted acetylcholine response in the nucleus accumbens while bingeing on sucrose. *Neuroscience.* 2008;156(4):865-71.
- Avena NM, Bocarsly ME, Rada P, Kim A, Hoebel BG. After daily bingeing on a sucrose solution, food deprivation induces anxiety and accumbens dopamine/acetylcholine imbalance. *Physiol Behav.* 2008;94(3):309-15.
- Lowndes J, Simmett S, Pardo S, Nguyen VT, Malanson KJ, Yu Z et al. The Effect of Normally Consumed Amounts of Sucrose or High Fructose Corn Syrup on Lipid Profiles, Body Composition and Related Parameters in Overweight/Obese Subjects. *Nutrients* 2014;6:1128-44.
- Ahmed SH, Guillem K, Vandaele Y. Sugar addiction: pushing the drug-sugar analogy to the limit. *Curr Opin Clin Nutr Metab Care.* 2013;16(4):434-9.



AUTHORS: DR GEETA RANI & DR SANIL V.S
GUIDED BY: DR MANJUNATH BC & DR ADARSH KUMAR
 Department of Public Health Dentistry, PGIDS, PT. B.D SHARMA UHS, Rohtak
 International Sugar Symposium- "Is sugar the new tobacco?- Oral Health Perspectives" CDER, AIIMS

