KWAŚNIAK, Ksenia, MAGIERSKA, Agata, FORYŚ, Angelika, MIŁEK, Magdalena, BANACH, Mariola, ŚLUSARCZYK , Monika, STAWSKA, Weronika, NIEMCZYK, Anna, KMIOTEK, Weronika and KOTOWICZ, Zuzanna. The effects of sugar addiction on health and the importance of exercise. Quality in Sport. 2024;19:50908. eISSN 2450-3118.
https://dx.doi.org/10.12775/QS.2024.19.50908
https://apcz.umk.pl/QS/article/view/50908

The journal has had 20 points in Ministry of Higher Education and Science of Poland parametric evaluation. Annex to the announcement of the Minister of Higher Education and Science of 05.01.2024. No. 32553. Has a Journal's Unique Identifier: 201398. Scientific disciplines assigned: Economics and finance (Field of social sciences); Management and Quality Sciences (Field of social sciences).
Punkty Ministerialne z 2019 - aktualny rok 20 punktów. Załącznik do komunikatu Ministra Szkolnictwa Wyższego i Nauki z dnia 05.01.2024 r. Lp. 32553. Posiada Unikatowy Identyfikator Czasopisma: 201398. Przypisane dyscypliny naukowe: Ekonomia i finanse (Dziedzina nauk społecznych); Nauki o zarządzaniu i jakości (Dziedzina nauk społecznych).

The authors declare that there is no conflict of interests regarding the publication of this paper.
Received: 02.04.2024. Revised: 05.05.2024. Accepted: 29.05.2024. Published: 05.06.2024.

The effects of sugar addiction on health and the importance of exercise

Ksenia Kwaśniak, Agata Magierska, Angelika Foryś, Magdalena Miłek, Mariola Banach, Monika Ślusarczyk, Weronika Stawska, Anna Niemczyk, Weronika Kmiotek, Zuzanna Kotowicz

Ksenia Kwaśniak
Clinical Regional Hospital No. 2 named after St. Hedwig of Anjou in Rzeszów Lwowska Street 60, 35-301 Rzeszów
ksenia.f@vp.pl
ORCID: https://orcid.org/0009-0000-8826-4884

Agata Magierska
Clinical Regional Hospital No. 2 named after St. Hedwig of Anjou in Rzeszów Lwowska Street 60, 35-301 Rzeszów
magierskaagata01@gmail.com
ORCID: https://orcid.org/0009-0005-4150-0495

Angelika Foryś
Ludwik Rydygier Specialist Hospital, Złota Jesień 1 Street, 31-826 Kraków
forys.angelika@gmail.com
ORCID: https://orcid.org/0009-0006-6631-8179

Magdalena Miłek
University Clinical Hospital in Opole, 26 Wincentego Witosa Avenue, 45-401 Opole
milekmagdalena2@gmail.com
ORCID: https://orcid.org/0009-0006-1355-3386

Mariola Banach
Praski Hospital, 67 Solidarności Avenue, 03-401 Warszawa
mariolabanach01@gmail.com
ORCID: https://orcid.org/0009-0004-0295-7348

Monika Ślusarczyk
Ludwik Rydygier Specialist Hospital, Złota Jesień 1 Street, 31-826 Kraków
monslu97@gmail.com
ORCID: https://orcid.org/0009-0008-4765-7081

Weronika Stawska
University Clinical Hospital in Opole, 26 Wincentego Witosa Avenue, 45-401 Opole
weronikastawska98@gmail.com
ORCID: https://orcid.org/0009-0002-8916-2585

Anna Niemczyk
GMW Gynaecological and Obstetric Diagnostic Centre Partnership M. Tomala & W. Niemczyk & G. Głąb, ul. Juliana Tuwima 1, 45-551 Opole
anna.niemczyk00@gmail.com
ORCID: https://orcid.org/0009-0001-3608-6112

Weronika Kmiotek
Clinical Regional Hospital No. 2 named after St. Hedwig of Anjou in Rzeszów Lwowska Street 60, 35-301 Rzeszów
weronika55.12@o2.pl
ORCID: https://orcid.org/0009-0009-7699-0585

Zuzanna Kotowicz
Voivodeship Clinical Hospital No.2 in Rzeszów
St. Lwowska 60, 35-301 Rzeszów
kotowiczzuzia@gmail.com
ORCID: https://orcid.org/0009-0009-5711-3229

Abstract

Introduction and purpose: Sugar is the primary energy substrate for the brain. Consuming sweet products releases dopamine, which activates the reward system. In this aspect, excessive consumption of sugar is similar to drug use and leads to many health risks. The aim of the study is to systematize information on sugar addiction, highlight the need for preventive measures and create treatment algorithms covering areas such as psychotherapy, pharmacotherapy and the positive impact of physical activity.

Materials and metods: A literature search was conducted using the medical databases PubMed and Google Scholar. Articles were retrieved in English, employing the key words: "sugar addiction", "sweet taste", „sugar diabetes" and „sugar sport" in appropriate configurations. The analysis encompassed data from 34 scientific references published between 2007 and 2024.

Conclusions: Many factors contribute to sugar addiction. It is a self-perpetuating cycle, as obese and sugar addicts need more sugar to feel satisfied. At the same time, sugar negatively affects body weight, behavior, mood, cardiovascular, nervous, digestive systems. Which is why steps should be taken to increase public understanding and awareness of the mechanism of sugar addiction and its risks.

Key words: sugar addiction, sweet taste, sugar diabetes, sugar sport

Introduction:

The World Health Organization advised that adults with a normal BMI should limit their daily intake of "free sugar" to 25 grams, which is less than 10 kg of sugar/person/year. [1]

While according to the Central Statistical Office data, in 2017 the annual sugar consumption in Poland was 44.5 kg per capita and this was the highest value observed in 2008-2017. [2]

The significant increase in global sugar consumption, particularly through sugar-sweetened beverages, has led to concerns about its impact on health. The link between high sugar intake and obesity and metabolic issues is well-establishe. Moreover, research results indicate that physically active people best control their energy balance via the appetite centres in the brain, which indicates a possible beneficial effect of sport on addiction. [33] At the same time there

is less understanding of how sugar may affect other health aspects such as cognition, learned behavior [3], depression [4], cancer [12] and gut micro biota [19].

Concerns about excessive sugar consumption and its effects on health are amplified by the fact that there are disturbing studies about how addictive sugar is. They discuss the addictive effects of sugar and the sweet taste itself compared to the effects of addictive substances. [5, 6, 11]

1. Food addiction

The definition of "addiction" denotes a psychological reliance, indicating a mental or cognitive issue rather than solely a physical condition. It is frequently interchanged with the term "dependence". Drug dependence is defined by compulsive and often uncontrollable actions that take priority over other tasks and escalate with frequent exposure. [7] The term of „food addiction" frequently centers on the excessive consumption of foods mainly with sweet tastes. It is suggested that sugar and sweet flavors can trigger neural and behavioral reactions similar to those seen with addictive substances (dopamine release in the brain's reward center). [6, 8, 13]

The criteria used to diagnose addiction can be categorized into three phases: bingeing, sensitization and tolerance. [7]

To binge is characterized by an increase in consumption after a period of abstaining or being deprived. This heightened intake through binging can be influenced by sensitization and tolerance to the sensory aspects of a substance, which develop with repeated exposure. Sensitization involves becoming more responsive to a impuls that is frequently encountered, while tolerance involves a progressive drop in reactivity, requiring more of the substance to achieve the same result. These factors play a role in the strong, immediate rewarding effects of addictive substances and are significant in the early stages of addiction as they can lead to increased consumption. Researchers have purposed rat models for studying drug addiction to investigate sugar dependence. [7]

In studies on rats, it has been shown that even with unlimited access, these animals tend to self-administer drugs in repetitive episodes. Similar behavioral results have been observed with sugar. Rats with restricted access to sugar tend to overeat sugar at the onset of access and consume larger, fewer meals of sugar compared to rats with continuous access. [6] In addition, periods of food restriction have been shown to increase drug consumption and cause neuroadaptations in the brain's reward system. [13, 14] Restricting access to sugar can lead to binge-like behavior similar to those present in compulsive drug users. [7]

Moreover, there were experiment with rats, they are confronted with a decision to either self-administer cocaine or choose an alternative reward like appetitive foods, sweetened water or

social interaction with another rat. The results consistently reveal that the majority of rats choose the drug-free reward over cocaine, methamphetamine or heroin. One theory suggests that cocaine may have a slower impact on dopamine levels compared to the rewarding effects of food (sweeteneded water), even when cocaine is quickly injected intravenously. [11] The addictive effect of sugar on rats is so strong that they are able to endure extreme heat and colf for it in order to get it. [13, 14] However, despite many attempts, it has not been possible to completely explain why rats prefer other rewards that are not drugs. [11]

2. Brain and dopamine

Studies highlight the similarities between consuming large amounts of sugar and addictive drugs in terms of their effects on the brain. They mention how sugar can lead to a continuous rise in dopamine levels, similar to addictive substances like morphine and nicotine, rather than the usual gradual decrease seen with natural rewards. [12, 13, 14] What's more when sugar is removed from the diet it can cause withdrawal symptoms similar to opiates such as teeth chattering, anxiety and aggression. [8, 9] There are studies demonstrate that sugar withdrawal symptoms can differ significantly depending on a person's age, the time of day and menstrual cycle [10].

Additionally, sources point out that long-term consumption of sugar can lead to changes in dopamine receptor expression, particularly a decrease in dopamine D2 receptor expression, similar to what is seen in drug addiction. Furthermore obese people have lower dopamine sensitivity in the nucleus accumbens and decreased dopamine D2 receptor expression. Which leads to a situation when chronic sugar consumption may lower dopamine D2 receptor expression and as a result people who are obese may consume excessive amounts of sugary foods as a result of a lack of dopamine. These findings suggest that there may be a connection between sugar consumption and addictive behaviors in terms of brain chemistry. [8, 9]

By knowing the mechanism of sugar addiction, it is possible to search for effective therapies. For example, the impact of physical activity is being studiem. Excessive sugar intake can change the brain's reward system, which can lead to a dependence on sugar. However, this cycle can be broken by engaging in physical activity, which can boost levels of neurotrophic factor (BDNF) and improve the dopaminergic system. [32]

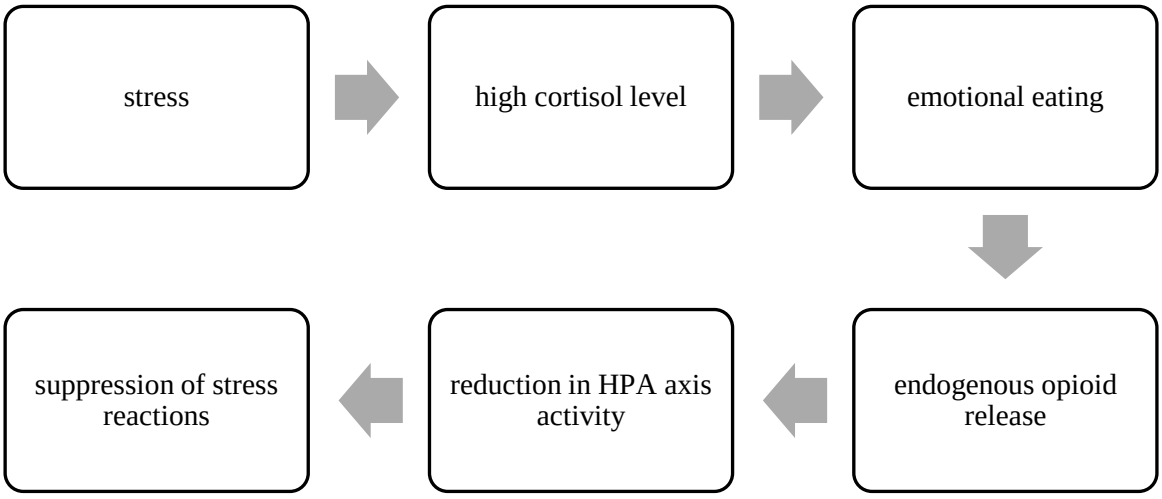
3. The impact of stress on sugar consumption

Nowadays, fight against stress is a significant public health task. [15, 16] Emotional eating is often associated with stress, which is regulated in part by the hypothalamic-pituitary-adrenal (HPA) axis. Sugar can lower HPA activity, triggering hormones that reduce stress, but also increase appetite for comfort foods, fueling the cycle of emotional eating. [14]

At the same time, stress is associated with increased levels of cortisol, which affects appetite management. Cortisol can decrease the brain's response to leptin, which stops leptin from signaling feelings of fullness. In contrast, the dopaminergic system encourages the release ghrelin and neuropeptide Y, leading to cravings for high-calorie foods even when not hungry.

Analysing these links, one can see the interconnectedness of eating in response to stress with the brain reward system and addiction to food (highly palatable, usually high in sugar). [21] (Figure 1)

Figure 1. Emotional eating



Frequent activation of the brain's reward system from stress or indulging in tasty foods can lead to compulsive overeating. Cortisol can affect how rewarding food seems, disrupting the balance of hormones like leptin and insulin. Chronic stress may lead to increased eating and fat storage. [15, 21] However, other actions leading to lower cortisol levels are possible. Ten studies have shown that physical activity is effective in decreasing cortisol levels, which may prove to be a useful finding in developing treatments for food (sugar) addiction. [34]

4. Sugar forms

Global sugar consumption has tripled over the past five decades, in part due to the widespread addition of sugars to highly processed foods. [14] Sugar is typically added into food through ingredients such as honey, sucrose, high-fructose corn syrup (HFCS), agave or maple syrup, all of which are usually composed of equal parts fructose and glucose. However, according to a

study conducted in Los Angeles in which soft drinks were analysed, a fructose content of 65% was found. This variation could be significant, as fructose seems to elicit a stronger sense of reward and has a higher level of toxicity compared to glucose. [10].

In addition, fructose consumption is associated with other risks. It is believed that fructose may increase the risk of cardiometabolic problems due to the way it is processed in the liver. Furthermore, fructose has been found to increase the production of uric acid in the liver. This can lead to gout, as well as hypertension, Type 2 diabetes, and cardiovascular disease, as hyperuricemia is a precursor to these conditions. Hyperuricemia may also play a role in the connection between consuming sugary beverages and hypertension, potentially by causing kidney issues, endothelial dysfunction and mobilization the renin-angiotensin system. [12] Moreover chronic consumption of fructose leads to elevated insulin levels and high triglycerides, preventing the hormone leptin from reaching the brain and reducing its ability to regulate dopamine signaling, leading to tolerance and withdrawal in both animals and humans. Additionally, fructose does not decrease levels of the hunger hormone ghrelin, which can contribute to excessive eating regardless of actual energy requirements. Comparing fructose to glucose, it appears that fructose, like sucrose, poses a higher risk for binge eating, suggesting that the fructose molecule itself plays a key role in triggering both pleasure and addictive behaviors. [10]

5. Sugarfree sweeteners

Artificial sweeteners were developed as an alternative to caloric sweeteners. They allow you to recreate a sweet taste without any sugar. [22] Replacing calorie sweeteners with non-calorie sweeteners such as acesulfame-K, aspartame, saccharin, sucralose, taumatin, cyclamate, neotame and advantame may lower the energy density of foods and drinks, but it may not necessarily lead to metabolic benefits or improved health. Instead, frequent intake of non-calorie sweeteners could potentially increase sweet-taste cravings and addiction by disrupting the brain's post-ingestive food reward system. [17] When sweet taste is not associated with energy, it can weaken conditioned responses to sweet taste over time, affecting the body's ability to sense and utilize energy, impacting feelings of fullness and energy utilization. [8]

Research has shown that non-calorie sweeteners, such as sucralose, elicit different responses in the brain compared to calorie sugars. Sucralose may require additional incentives to achieve the same rewarding effect as sucrose [8, 17], and sweet taste from both nourishing and non-nourishing sweeteners has been found to exceeds rewards from drugs like cocaine and nicotine in rats, leading to intense food-seeking urge. This suggests that sweet taste itself may involved

in reward and craving, potentially leading to alterations in homeostatic control and increased intake of sugar sweetened foods. [9]

Human imaging studies have shown that sucrose, but not saccharose, can decrease stress-related cortisol levels and activate the hippocampus, while habitual intake of artificially sweetened beverages decreases amygdala activation, indicating a disconnect between stimulus and reward. [17] Epidemiological studies have linked artificial sweetener consumption with increased BMI, although some intervention studies have not found a direct increase in caloric or sugar consumption after artificial sweetener intake. [9]

Artificial sweeteners have also been shown to impact sweet-taste receptors and alter the release of certain substances like ghrelin, glucagon-like peptide-1 (GLP-1) and YY peptide, which can influence blood glucose levels. [23, 24]

In conclusion, artificial sweeteners May stimulate the reward system, potentially playing a role in food addiction. Therefore, artificial sweeteners may not be a suitable substitute for sugar. [23, 24] However, further research is needed to fully understand their impact on overconsumption, tolerance, cross-sensitization and withdrawal.[9, 17]

6. Effects of sugar

The impact of sugar on obesity, metabolic syndrome, Diabetes type 2, cardiovascular disease is well-known. But it is important to keep in mind that sugar affects many other aspects of health. [12, 14]

6.1.Gut microbiota

Research has shown that consistent eating habits over time can affect the variety of bacteria in the gut and can lead to alterations in the regulation of energy balance in the brain. Consuming too much sugar can overwhelm the small intestine's ability to absorb it, leading to an abundance of nutrients for bacteria to thrive. This can result in a decrease variety of beneficial microbial [19] and lead to an increase in Bacillus fragilis and Prevotella, which in turn can harm the lining of the intestines. [25]

6.2.Cancer

Consuming sugary drinks can increase the risk of developing certain types of cancer due to increased body fat and metabolic disruptions. While there is limited and conflicting evidence, studies have shown associations between sugary drink intake and breast, colorectal, prostate and pancreatic cancers [30]. However, there were no significant links found between sugary drink intake and bladder or renal cell cancers. [12]

The meta-analysis included several studies that showed an association between consumption of sugary drinks and cancer risk. The NutriNet-Santé study showed a positive association with general cancer risk and breast cancer, particularly premenopausal breast cancer. The Melbourne Collaborative Cohort Study and the Seguimiento Universidad de Navarra (SUN) cohort also showed an association sugary drinks with breast cancer and colorectal cancer. However, the Framingham Offspring Cohort study found no association between consumption of sugary drinks and cancer, except in a subgroup with central obesity. The evidence regarding consumption of sugary drinks and pancreatic cancer is unclear. [12]

6.3.Cognitive functions

Glucose, as sugar, is the main fuel for cognitive activities. The study performed in Malaysia showed that consuming a lot of sugar, particularly free sugar or sucrose, can lead to decreased cognitive efficiency in terms of both verbal and visual processing memory. This research adds to our current understanding of the impact of sugar on cognitive function, showing that diets high in sugar can result in cognitive deficits and hinder brain function. These findings align with recent studies emphasizing the importance of controlling sugar intake to prevent cognitive decline in older individuals. [18]

6.4.Behavior, mood, depression

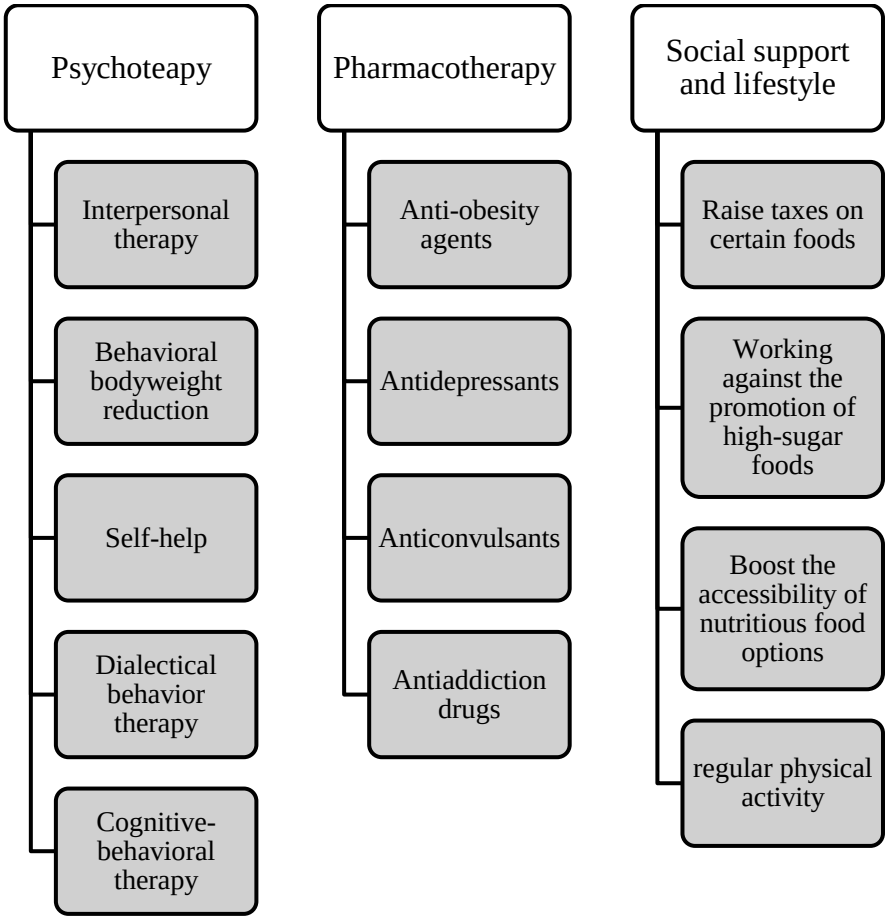
Depression is a psychological condition characterised by feelings of sadness, disinterest and self-blame. It is now considered an important contributor to the rise in "disability-adjusted life years" worldwide. [20] The effect of sugar withdrawal on behaviour in mice has been studied. It was shown that when sugar was withdrawn after a long period of sugar consumption (>4 weeks), symptoms of anxiety and depression occurred as early as 24 hours after withdrawal. At the same time, when access to sucrose was short-term (<4 weeks) anxiety- and depression-like behaviors occurred not until a week after sugar withdrawal. [13]

7. Treatment

The mechanism of sugar addiction is similar to that of drug addiction. Therefore, therapies used for drug addiction may be applicable to sugar abuse. [27] One such therapy is physical activity. Sugar addiction and high sugar diets are often associated with emotional dysfunction and can lead to serious metabolic disorders. Physical activity has been shown to be an effective way to prevent the negative effects of abused substances, which may be an opportunity for sugar addicts. [32] However, it is important to keep in mind how many factors contribute to sugar

addiction, so therapy is complex and consists of psychotherapy, pharmacotherapy, social support and lifestyle changes. [26, 32] (Figure 2)

Figure 2. Types of treatment in sugar addiction



A drug with some results in clinical trials is N-acetylcysteine (NAC). [27] N-acetylcysteine is a modified form of the amino acid cysteine and can be purchased without a prescription as a dietary supplement known for its antioxidant effects. [28] NAC has reduced side effects, but there are some issues about the potential negative effects of taking it in large amounts. [29] In studies on rats, NAC reduced the use of marijuana, cigarettes and cocaine. Based on that, conclusions have been drawn about other types of addiction, and N-acetylcysteine has been shown to minimize dependent-like behaviors to sugary and fatty foods. NAC has been shown to have potential as a pharmacotherapy to aid traditional weight loss methods. [27]

8. Policies

Excessive sugar consumption is associated with a number of public health risks. As a result, the WHO and US dietary guidelines recommend that consumed sugar should account for up to 10% of total food energy. [1] These recommendations are supported by public policies through the

taxation of sweetened beverages, restrictions on marketing, warning tags on the front of the package and the use of educational campaigns. [12, 31]

A few countries and some cities in the United States have introduced excise taxes on sugary drinks. Mexico, for example, imposed a 10% tax on these beverages in 2014. Two years later, there was a 7.6% decrease in sales of sugary drinks, while sales of untaxed drinks like water went up by 2.1%. According to projections, the tax helped prevent around 200,000 cases of obesity and saved nearly $980 million in healthcare expenses from 2013 to 2022. [12]

Summary

The increasing proportion of highly processed foods with high sugar content in the daily diet makes it a major social problem. The research presented here proves the addictive nature of sugar and its negative effects on body weight, cardiovascular system, digestive system, cognitive function and behavior. There are no clearly defined guidelines for treating sugar addiction; however, therapies available for drug addiction may be helpful. Every effort should be made to implement effective methods to combat sugar addiction to prevent the problem from worsening.

Disclosure

Authors do not report any disclosures.

Author's contribution

All authors contributed to the article.

Conceptualization: Kwaśniak K, Magierska A;

Methodology: Kwaśniak K, Magierska A, Banach M;

Software: Foryś A, Niemczyk A, Miłek M, Stawska W, Kmiotek W, Kotowicz Z;

Check: Kwaśniak K, Magierska A;

Formal analysis: Kwaśniak K; Kmiotek W

Investigation: Kwaśniak K, Magierska A, Foryś A, Miłek M, Banach M, Ślusarczyk M, Stawska W, Niemczyk A, Kmiotek W, Kotowicz Z

Resources: Kwaśniak K, Magierska A, Foryś A, Miłek M, Banach M, Ślusarczyk M, Stawska W, Niemczyk A, Kmiotek W, Kotowicz Z;

Data curation: Kwaśniak K, Magierska A, Foryś A, Miłek M, Banach M, Ślusarczyk M, Stawska W, Niemczyk A, Kmiotek W, Kotowicz Z;

Writing - rough preparation: Kwaśniak K, Magierska A, Foryś A, Miłek M, Banach M, Ślusarczyk M, Stawska W, Niemczyk A, Kmiotek W, Kotowicz Z;

Writing - review and editing: Kwaśniak K, Magierska A, Foryś A, Miłek M, Banach M, Ślusarczyk M, Stawska W, Niemczyk A, Kmiotek W, Kotowicz Z

Visualization: Kwaśniak K, Magierska A, Foryś A, Miłek M, Banach M, Ślusarczyk M, Stawska W, Niemczyk A, Kmiotek W, Kotowicz Z;

Supervision: Kwaśniak K, Magierska A;

Project administration: Kwaśniak K, Magierska A;

All authors have read and agreed with the published version of the manuscript.

Funding statement

The study did not receive any external funding.

Institutional Review Board Statement

Not applicable.

Informed Consent Statement

Not applicable.

Data Availability Statement

Not applicable.

Acknowledgments

Not applicable.

Conflict of Interest Statement

The authors declare no conflict of interest.

References:

1. World Health Organization. *Guideline: Sugars Intake for Adults and Children*. Geneva: WHO; 4 march 2015.

2. Departament Analiz i Strategii NFZ. Cukier, otyłość – konsekwencje. Przegląd literatury, szacunki dla Polski. 2019.

3. Michael D Kendig, Cognitive and behavioural effects of sugar consumption in rodents. A review, Appetite, Volume 80, 1 September 2014, Pages 41-54, https://doi.org/10.1016/j.appet.2014.04.028.

4. Bin Yu,Haiyan He, Qing Zhang, Hongmei Wu, Huanmin Du, Li Liu, Chongjin Wang, Hongbin Shi, Yang Xia, Xiaoyan Guo, Xing Liu, Chunlei Li, Xue Bao, Qian Su, Ge

Meng, Jiaqi Chu, Yan Mei, Shaomei Sun, Xing Wang, Ming Zhou, Kaijun Niu, Soft drink consumption is associated with depressive symptoms among adults in China, Journal of Affective Disorders, Volume 172, 1 February 2015, Pages 422-427, https://doi.org/10.1016/j.jad.2014.10.026.

5. Freeman CR, Zehra A, Ramirez V, Wiers CE, Volkow ND, Wang GJ. Impact of sugar on the body, brain, and behavior. Front Biosci (Landmark Ed). 2018 Jun 1;23(12):2255-2266. doi: 10.2741/4704.

6. Greenberg D, St Peter JV. Sugars and Sweet Taste: Addictive or Rewarding? Int J Environ Res Public Health. 2021 Sep 17;18(18):9791. doi: 10.3390/ijerph18189791.

7. Avena NM, Rada P, Hoebel BG. Evidence for sugar addiction: behavioral and neurochemical effects of intermittent, excessive sugar intake. Neurosci Biobehav Rev. 2008;32(1):20-39. doi: 10.1016/j.neubiorev.2007.04.019.

8. Moriconi E, Feraco A, Marzolla V, Infante M, Lombardo M, Fabbri A, Caprio M. Neuroendocrine and Metabolic Effects of Low-Calorie and Non-Calorie Sweeteners. Front Endocrinol (Lausanne). 2020 Jul 16;11:444. doi: 10.3389/fendo.2020.00444.

9. Lennerz B, Lennerz JK. Food Addiction, High-Glycemic-Index Carbohydrates, and Obesity. Clin Chem. 2018 Jan;64(1):64-71. doi: 10.1373/clinchem.2017.273532.

10. Lustig RH. Ultraprocessed Food: Addictive, Toxic, and Ready for Regulation. Nutrients. 2020 Nov 5;12(11):3401. doi: 10.3390/nu12113401.

11. Samaha AN. Sugar now or cocaine later? Neuropsychopharmacology. 2021 Jan;46(2):271-272. doi: 10.1038/s41386-020-00836-z.

12. Malik VS, Hu FB. The role of sugar-sweetened beverages in the global epidemics of obesity and chronic diseases. Nat Rev Endocrinol. 2022 Apr;18(4):205-218. doi: 10.1038/s41574-021-00627-6.

13. Beecher K, Alvarez Cooper I, Wang J, Walters SB, Chehrehasa F, Bartlett SE, Belmer A. Long-Term Overconsumption of Sugar Starting at Adolescence Produces Persistent Hyperactivity and Neurocognitive Deficits in Adulthood. Front Neurosci. 2021 Jun 7;15:670430. doi: 10.3389/fnins.2021.670430.

14. Angela Jacques, Nicholas Chaaya, Kate Beecher, Syed Aoun Ali, Arnauld Belmer, Selena Bartlett, The impact of sugar consumption on stress driven, emotional and addictive behaviors, Neuroscience & Biobehavioral Reviews, Volume 103, 2019, Pages 178-199, ISSN 0149-7634, https://doi.org/10.1016/j.neubiorev.2019.05.021.

15. Wijnant K, Klosowska J, Braet C, Verbeken S, De Henauw S, Vanhaecke L, Michels N. Stress Responsiveness and Emotional Eating Depend on Youngsters' Chronic Stress Level and Overweight. Nutrients. 2021 Oct 19;13(10):3654. doi: 10.3390/nu13103654.

16. Schultchen D, Reichenberger J, Mittl T, Weh TRM, Smyth JM, Blechert J, Pollatos O. Bidirectional relationship of stress and affect with physical activity and healthy eating. Br J Health Psychol. 2019 May;24(2):315-333. doi: 10.1111/bjhp.12355.

17. Wilk K, Korytek W, Pelczyńska M, Moszak M, Bogdański P. The Effect of Artificial Sweeteners Use on Sweet Taste Perception and Weight Loss Efficacy: A Review. Nutrients. 2022 Mar 16;14(6):1261. doi: 10.3390/nu14061261.

18. Chong CP, Shahar S, Haron H, Din NC. Habitual sugar intake and cognitive impairment among multi-ethnic Malaysian older adults. Clin Interv Aging. 2019 Jul 22;14:1331-1342. doi: 10.2147/CIA.S211534.

19. Jamar, G., Ribeiro, D. A., & Pisani, L. P. (2021). High-fat or high-sugar diets as trigger inflammation in the microbiota-gut-brain axis. Critical Reviews in Food Science and Nutrition, 61(5), 836–854. https://doi.org/10.1080/10408398.2020.1747046

20. Danqing Hu, Lixiao Cheng, Wenjie Jiang, Sugar-sweetened beverages consumption and the risk of depression: A meta-analysis of observational studies, Journal of Affective Disorders, Volume 245, 2019, Pages 348-355, ISSN 0165-0327, https://doi.org/10.1016/j.jad.2018.11.015.

21. Tanja C. Adam, Elissa S. Epel, Stress, eating and the reward system, Physiology & Behavior, Volume 91, Issue 4, 2007, Pages 449-458, ISSN 0031-9384, https://doi.org/10.1016/j.physbeh.2007.04.011.

22. Debras C, Chazelas E, Sellem L, Porcher R, Druesne-Pecollo N, Esseddik Y, de Edelenyi FS, Agaësse C, De Sa A, Lutchia R, Fezeu LK, Julia C, Kesse-Guyot E, Allès

B, Galan P, Hercberg S, Deschasaux-Tanguy M, Huybrechts I, Srour B, Touvier M. Artificial sweeteners and risk of cardiovascular diseases: results from the prospective NutriNet-Santé cohort. BMJ. 2022 Sep 7;378:e071204. doi: 10.1136/bmj-2022-071204.

23. Concetta Schiano, Vincenzo Grimaldi, Michele Scognamiglio, Dario Costa, Andrea Soricelli, Giovanni Francesco Nicoletti, Claudio Napoli, Soft drinks and sweeteners intake: Possible contribution to the development of metabolic syndrome and cardiovascular diseases. Beneficial or detrimental action of alternative sweeteners?, Food Research International, Volume 142, 2021, 110220, ISSN 0963-9969, https://doi.org/10.1016/j.foodres.2021.110220.

24. Iizuka K. Is the Use of Artificial Sweeteners Beneficial for Patients with Diabetes Mellitus? The Advantages and Disadvantages of Artificial Sweeteners. Nutrients. 2022 Oct 22;14(21):4446. doi: 10.3390/nu14214446.

25. Ma X, Nan F, Liang H, Shu P, Fan X, Song X, Hou Y, Zhang D. Excessive intake of sugar: An accomplice of inflammation. Front Immunol. 2022 Aug 31;13:988481. doi: 10.3389/fimmu.2022.988481.

26. Vasiliu O. Current Status of Evidence for a New Diagnosis: Food Addiction-A Literature Review. Front Psychiatry. 2022 Jan 10;12:824936. doi: 10.3389/fpsyt.2021.824936.

27. Sketriene D, Battista D, Perry CJ, Sumithran P, Lawrence AJ, Brown RM. N-acetylcysteine reduces addiction-like behaviour towards high-fat high-sugar food in diet-induced obese rats. Eur J Neurosci, 2021; 54: 4877–4887. https://doi.org/10.1111/ejn.15321

28. Deepmala, John Slattery, Nihit Kumar, Leanna Delhey, Michael Berk, Olivia Dean, Charles Spielholz, Richard Frye, Clinical trials of N-acetylcysteine in psychiatry and neurology: A systematic review, Neuroscience & Biobehavioral Reviews, Volume 55, 2015, Pages 294-321, ISSN 0149-7634, https://doi.org/10.1016/j.neubiorev.2015.04.015.

29. Kate Rhodes, Andrea Braakhuis, Performance and Side Effects of Supplementation with N-Acetylcysteine: A Systematic Review and Meta-Analysis, Sports Med DOI 10.1007/s40279-017-0677-3

30. McCullough ML, Hodge RA, Campbell PT, Guinter MA, Patel AV. Sugar- and Artificially-Sweetened Beverages and Cancer Mortality in a Large U.S. Prospective Cohort. Cancer Epidemiol Biomarkers Prev. 2022 Oct 4;31(10):1907-1918. doi: 10.1158/1055-9965.EPI-22-0392.

31. Yoshida Y, Simoes EJ. Sugar-Sweetened Beverage, Obesity, and Type 2 Diabetes in Children and Adolescents: Policies, Taxation, and Programs. Curr Diab Rep. 2018 Apr 18;18(6):31. doi: 10.1007/s11892-018-1004-6.

32. Roberto Codella, Ileana Terruzzi, Livio Luzi, Sugars, exercise and health, Journal of Affective Disorders, Volume 224, 2017, Pages 76-86, ISSN 0165-0327, https://doi.org/10.1016/j.jad.2016.10.035.

33. Waddington GS. Children's fitness, fatness and sugar. J Sci Med Sport. 2019 Dec;22(12):1279. doi: 10.1016/j.jsams.2019.10.007. PMID: 31676024.

34. Len De Nys, Kerry Anderson, Esther F. Ofosu, Gemma C. Ryde, Jenni Connelly, Anna C. Whittaker, The effects of physical activity on cortisol and sleep: A systematic review and meta-analysis, Psychoneuroendocrinology, Volume 143, 2022, 105843, ISSN 0306-4530, https://doi.org/10.1016/j.psyneuen.2022.105843.