Relationship between Soft Drink Consumption and Salivary pH

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Abstract

Objective: To evaluate the association between soft drink consumption, salivary pH changes, and self-reported oral health in a diverse population**. Material and Methods**: 1,471 participants were recruited from urban and rural communities. A structured questionnaire was utilized to collect demographic, beverage consumption, oral hygiene, and perceived oral health data. Salivary pH was assessed at baseline and at multiple time points (0 to 60 minutes) after consumption of five popular soft drinks (Pepsi, Coca-Cola, Seven Up, Mirinda, and Shani) using a calibrated digital pH device. Data were entered into SPSS and statistical analysis was performed using chi-square and the LSD tests. **Results**: Most participants were young adults aged 26–35 years (32.5%) and were female (90.4%). Pepsi was the most frequently consumed soft drink (35.5%), and 35.4% reported daily intake. All soft drinks tested caused a statistically significant decrease in salivary pH immediately following consumption, with minimum values achieved within 10 minutes after consumption. The minimum pH values for all the soft drink tested ranged between 5.12–5.21 and returned to near baseline values at 60 minutes. Thirty-one percent of survey respondents reported caries, and 21.2% reported staining or calcifications. Despite 94.4% of respondents reporting brushing their teeth regularly, regular consumption of a soft drink remains high. **Conclusion**: There is a strong effect of soft drink consumption on salivary pH, creating relevant conditions for enamel demineralization and caries formation. High-frequency intake of acidic beverages is still a substantially high-risk factor for caries, regardless of a good level of oral hygiene behavior. Public health interventions for promoting educational public health strategies targeting youth about important issues related to soft drink consumption should work to significantly reduce consumption of soft drinks and promote healthier alternatives.

Introduction

Soft drinks have been increasingly identified as an important mediator of the effects on oral health by primarily changes to the salivary pH, as well as shifts in the oral microbiome. The soft drink, especially those containing high levels of sugars and acids, can decrease the salivary pH, causing demineralization of the enamel and stimulating the growth of acidogenic bacteria such as Streptococcus mutans, leading to an elevated risk of dental caries, as well as gingivitis and other diseases of the oral cavity. Both the type and consumption of soft drinks, as well as other oral hygiene habits such as brushing teeth, is critical to the associated oral health

risk. From a significant amount of published literature and evidence, regularly consuming sugary beverages is strongly correlated with dental caries and erosion, especially in young adults and adolescents, who are the most likely to consume high amounts of these drinks [1].

In addition, the pH of saliva is relevant for oral health. Enamel is retained, and oral microorganisms are regulated in a neutral-to-slightly alkaline salivary pH. Relatedly, frequent and extended contact of acidic beverages can prolong the time that the salivary pH is below neutral, which is highly conducive for enamel degradation and the potential shift in microbial composition

(dysbiosis). Research has shown that salivary pH drops in a soft drink trial after consumption and gradually returns to baseline values in varying timeframes depending on individual salivary buffering capacity and oral hygiene [2,3].

Hot drinks (e.g., tea and coffee) can alter oral conditions as well, with noted effects that are not as substantial as an acidic beverage. While tea alone has health benefits due to polyphenols, these benefits could quickly be invalidated if sugar or any artificial sweetener is added. Overall, the study of both hot and soft beverages has been linked to staining, erosion of dental structure, and unsettling oral health conditions [1].

The current study examines a relationship between soft drink consumption, changes in salivary pH values, and oral health through an extensive survey and clinical assessment. It also looks at how demographics – age, gender, residence, and educational level can affect beverage preferences and oral health-related behaviors. This study's findings highlight the current dietary habits of people, particularly the health impacts of soft drink consumption, emphasizing the need for preventative measures, and for public health actions to mitigate the risk of dental diseases attributable to soft drink consumption.

Material and Methods

This study aimed to investigate the relationship between consumption of soft drinks, changes in salivary pH, and oral health status. A questionnaire-based survey combined with clinical measurements of salivary pH assessed this relationship.

Study design and subjects

This cross-sectional study included 1,471 subjects. Participants were recruited from a variety of locations: Baghdad, other governorates, and rural areas. To obtain a wide variety of socio-demographic backgrounds, the study population had diversity in gender, age, educational level, and location. Participation was voluntary, and all subjects gave informed consent.

Survey Questionnaire

A structured questionnaire was used to elicit detailed information regarding demographic data (age, gender, educational level, residence), consumption of soft and hot drinks (types and frequency), oral hygiene habits (frequency and method of tooth brushing), self-reported oral health conditions (caries, gingivitis, calcifications, staining), and systemic health conditions of interest (diabetes, hypertension, and others). The survey also included questions regarding participants' inclination to abstain from soft and hot drinks, and what they perceived to occur the oral cavity after ingestion.

Collections of samples

The product to be used is a 350 ml can of soft drink (Pepsi, Cola, Seven, Mirinda) and Shani (By Baghdad Company). A sample of saliva will be placed in a urine cup or the nearest container of a similar size and shape. The soft drink can will be consumed, rinsing first, then swallowing it while collecting the saliva in different periods (immediately after drinking and then after 10, 20, 30, 40, 50 and 60 minutes) for later pH measurement.

Measurement of saliva pH

Salivary pH was measured using a calibrated digital pH meter (ISOLAB Laborgeräte GmbH, Wertheim, Germany). Carbonation occurs, when pressurized carbon dioxide (CO_2) is infused into liquids, producing carbonic acid and raises dissolved levels of CO_2. A typical carbonated soft drink is composed of approximately 94% water and falls between the pH of 2.5 and 3.5, which therefore is an acidic drink. The carbonation, or partial pressure of the CO_2, determines the level of acidity of the beverage. Typically, soft drinks are carbonated at atmospheric pressures of about 2.5, which would generate high levels of dissolved CO_2 and a pH of about 3.7. Conversely, atmospheric pressure levels of CO_2 in a soft drink would decrease the levels of dissolved CO_2, causing the pH to increase towards 5.7. Therefore, the carbonation of each beverage affects their respective acidity.

In this clinical trial, we examined the impact of consumption of soft drinks on salivary pH. We selected 5 widely available soft drinks—Pepsi, Coca-Cola, Seven Up, Mirinda, and Shani—and conducted a salivary pH assessment. Salivary pH assessments were taken at baseline (i.e., prior to consumption) and after consumption at 0, 10, 20, 30, 40, 50, and 60 minutes. Saliva samples were collected using sterile containers and pH measurements were taken immediately using the digital pH meter to provide accuracy and reliability.

Statistical Analysis

The Statistical Packages for Social Sciences - SPSS (2019) program was utilized to examine the effect of different factors on study parameters (percentage). To compare percentages (0.05 and 0.01 probabilities) chi-square test of independence was used to determine significance. The least significant difference (LSD) test was used to make comparisons in means in this research.

Results

In total, 1,471 participants were recruited and surveyed as part of the study. Age demographics indicated that the largest age group was in the 26–35-year range (32.5%), followed by the 15–25-year age cohort (24.6%). Most participants were female (90.4%) from Baghdad (67.5%). While 35.8% had obtained a bachelor's degree, there were also many students (25.6%) as shown in Table 1.

Soft Drink Consumption Patterns

Pepsi was the most consumed soft drink (35.5%) followed by Coca-Cola (24.2%), Seven Up (10.8%), Mirinda (7.3%) and diet drinks (11.7%). The frequency of soft drink consumption indicated that 35.4% reported one time per day and 31.7% reported another frequency. Tooth brushing habits were reported by 94.4% of participants and 39.4% reported they would abstain from soft and hot drinks upon advice as seen in Table 2.

Hot Drink Consumption

Tea was the most common type of hot drink (50%), coffee ranked second (22.2%), and Nescafé ranked third (20.8%). When asked how many times they drank hot drinks, 40.7% reported only once a day. When asked what their preferred drink was, 30.7% preferred juices, 28.3% preferred hot drinks, 25.6% preferred soft drinks as outlined in Table 3.

Oral Hygiene and Perceived Oral Health

When asked about the frequency of tooth brushing, 41.7% stated once a day and 40.4% stated twice a day. When asked about cleaning methods, 54.9% stated toothpaste and 42.5% stated toothpicks. About 34.1% indicated that they noticed an altered mouth sensation after consumption of soft or hot drinks, while 35.4% were unsure. In terms of oral health conditions, 58.7% rated their oral health as fair and 28.4% as good. Caries was reported by 31.6% of participants, while 21.2% reported calcifications and staining. 8.6% reported gingivitis. Most participants (77.7%) reported no chronic diseases.

Effect of Soft Drinks on Salivary pH

All the tested soft drinks showed a significant reduction in salivary pH immediately after consumption (P≤0.05). The drinks that are tested (Coke, Pepsi, Seven Up, Mirinda, and Shani) all showed a rapid decline to their lower levels within ten minutes (pH of 5.12 to 5.21). After ten minutes of consumption, salivary pH begins to display gradual signs of recovery over the next hour to restore salivary pH within range of baseline, wherein pH at 60 minutes returns to baseline slightly above 7.0.

Out of all drinks, although Shani produced the greatest pH fluctuations between baseline and at the 60-minute mark, statistical analysis between spikes in pH was also maximized document through LSD test. Of beverage comparisons made, Shani (7.19) and Mirinda (7.15) exhibited the greatest pH recovery at the 60-minute observation period as documented in Table 4.

Discussion

The current study provides evidence regarding the relationship between soft drink consumption, salivary pH changes, and self-reported oral health conditions in sizeable and diverse samples. The association between

soft drink consumption and salivary pH was not subtle; soft drink consumption resulted in a statistically significant effect on salivary pH, with the greatest drop evident immediately following the drink and subsequently returning to baseline levels after a period of approximately 60 minutes. The results are consistent with those exhibited in the Stephan curve; a well-established observation reporting how the consumption of fermentable carbohydrates causes rapid declines in both plaque and salivary pH to levels that promote demineralization of enamel and caries formation [4].

The changes in pH at all three time points in this study aligns with previous findings by Kantovitz et al. (2010) [2], and Johansson et al. (2012) [3]. The authors noted similarly rapid changes in pH after soft drink use and equally gradual return to baseline pH related to the buffering nature of saliva. Overall, all the drinks tested in this study (Pepsi, Coca-Cola, Seven Up, Mirinda, and Shani) produced significant drops in pH levels, with the lowest levels occurring at approximately ten minutes post-consumption. This highlights the very high erosive potential of carbonated and acidic soft drinks, supporting existing evidence as noted in earlier studies linking high sugar beverages to enamel erosion [1] and risk for caries.

The high levels of regular consumption reported among participants, along with limited awareness of alcohol effects on oral health, raises the possibility of impaired oral health on some level for this population. While most study participants reported some level of tooth brushing, the reported prevalence of caries (31.6%) and calcifications/staining (21.2%) may suggest self-reporting did not accurately represent oral hygiene measures, as the ability for these measures to overcome repeated acid challenges from soft drink consumption may be limited. Existing studies support this notion, which show that habitual consumption of sugary and acidic beverages can outpace the natural remineralization, leading to an overall loss of enamel [5].

Demographics of the current study suggested young adults (26–35 years) and students dominated the soft drink consumption, this aligns with global evidence which suggests younger populations report increased intake of sugar-sweetened beverages (SSBs) [6]. This is a significant indicator of the need for targeted public health initiatives, especially as 39.4% of participants said they would stop drinking soft drinks if advised. Therefore, recommendations for health information or a behavioral aspect could be an impactful measure.

Notably, Shani and Mirinda achieved the highest pH recovery at 60 minutes. This may be due to differences in drink composition, carbonation, or flavor additives that might have different effects on salivary stimulation and buffering capacity. Further studies that look at the actual acid levels and the buffering capacities of various drinks would help clarify this [7].

This study primarily illustrated that many subjects reported consuming hot drinks, such as tea and coffee, every day. Despite tea having polyphenols that may have antimicrobial effects [8], adding sugar to tea and consuming these drinks as frequently may cancel out any protective role and add to acid exposure and staining.

In conclusion, these results support earlier evidence that dietary intake habits—primarily frequent consumption of acidic soft drinks—factor in daily eating and drinking behaviors which pose a significant risk to dental health and drop salivary pH to below the critical pH for enamel demineralization [9]. As dentists and oral health professionals we should advocate for public health initiatives which would insist on reducing SSB intake frequency, highlighting water and unsweetened alternatives, promoting timely tooth brushing after sugary and acidic drink consumption along with activities such as chewing gum to stimulate saliva production and counteract acid attacks [10].

The limitations of this study would be the fact that we only relied on self-reported oral health data, which may have underestimated or overestimated the actual presence of disease, as well that this study did note account for actual tooth brushing behavior.

Future work should consider looking at direct microbial shifts using microbiome sequencing to better connect salivary pH changes with specific bacterial fluctuations. Periodic studies as compared to longitudinal studies would help understand the causal effects of soft drink habits and cumulative enamel loss.

Conclusions

In conclusion, our findings show that frequent consumption of soft drinks is sufficient to lower salivary pH to levels that are conducive to enamel demineralization and dental caries. Our study complements existing studies showing the popular carbonated soft drinks Pepsi, Coca-Cola Seven Up, Mirinda, and Shani elicit a rapid lowering of salivary pH with recovery occurring on average within one hour which is like the Stephan Curve. The high prevalence of caries and staining in this study and the individual reported oral hygiene practices reflect the

inability of physical tooth-brushing alone to offset frequent acid exposure from soft drinks. The results of our study illustrate the need for a targeted public health education and public health practice aimed at behavior change with consumers, especially for those most frequent soft drink consumers (young adults and students). The good news is that there is opportunity to reduce the amount soft drink consumption, sustain positive beverage choices, and raise awareness of risks to dents erosion and caries. Future studies should explore the relationship of frequency soft drink consumption, salivary buffering capacity, and the oral microbiome changes within the design to inform better preventive strategies.

These results underscore the limitations of conventional retreatment using rotary files and highlight the importance of chemical support, especially when dealing with bioceramic sealers. The use of 20% citric acid, particularly with ultrasonic activation, emerges as a clinically viable and effective supplement to mechanical retreatment techniques. The study supports integrating these protocols into routine retreatment procedures to enhance debridement and improve clinical outcomes.

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Table 1. Sample studied.

Questionnaire	Number of Response	Percentage	Chi-Square (P-value)
Age group (year)			
25-15	362	24.6	164.27 (0.0001)
35-26	479	32.5	
45-36	131	8.9	
55-46	74	5.2	
65-56	36	2.4	
Undefined	389	26.4	
Total	1471	100	--
Education			
Student	377	25.6	271.02 (0.0001)
Bachelor's	526	35.8	
Master's	110	7.6	
Doctorate	68	4.6	
Others	42	2.8	
Undefined	348	23.6	
Total	1471	100	--
Residence			
Baghdad	992	67.5	284.93 (0.0001)
other governorates	394	26.9	
Villages and countryside	19	1.8	
Others	47	3.8	
Total	1471	100	--
Gender			
Male	119	8.2	

Female	1330	90.4	168.55 (0.0001)
Undefined	22	1.4	
Total	1471	100	--

Table 2. Soft drink consumption.

Soft drinks (N and percentage)			Chi-Square (P-vale)
Pepsi	523	35.5	351.28 (0.0001)
Coca cola	357	24.2	
Miranda	108	7.3	
Seven up	151	10.5	
Diet drinks	159	10.8	
Others	173	11.7	
Total	1471	100	--
How often do you drink soft drinks (N and percentage)			
once a day	522	35.4	276.09 (0.0001)
twice a day	140	9.5	
three a day	56	3.8	
four a day	15	1.3	
more than five a day	17	1.1	
others	467	31.7	
undefined	254	17.2	
Total	1471	%10	--
Do you brush your teeth (N and percentage)			
Yes	1389	94.4	359.82 (0.0001)
No	50	3.3	
Undefined	32	2.3	
Total	1471	100	
If you were asked to abstain from soft and hot drinks, would you abstain from doing so (N and percentage)			--
Yes	581	39.4	

No	305	20.8	291.37 (0.0001)
Maybe	577	39.3	
Undefined	8	0.5	
Total	1471	100	

Table 3. Hot drink consumption.

Questionnaire	number of responses	percentage	Chi-Square (P-value)
hot drinks			
Tea	736	50	189.66 (0.0001)
Green tea	46	3.2	
Coffee	327	22.2	
Nscafe	306	20.8	
Others	56	3.8	
Total	1471	100	--
how often do you drink hot drinks			
Once a day	600	40.7	192.52 (0.0001)
Twice a day	354	24.3	
Three a day	205	13.9	
Four a day	65	4.4	
More than five a day	43	2.9	
Others	204	13.8	
Total	1471	100	--
what is your favorite drink			
Soft drink	378	25.6	368.09 (0.0001)
Hot drink	416	28.3	
Juices	451	30.7	
Others	226	15.4	
Total	1471	100	--
How often do you brush your teeth			

Once a day	614	41.7	-- 279.36 (0.0001)
Twice a day	593	40.4	
Three a day	100	6.7	
After every meal	73	4.9	
Other	91	6.3	
Total	1471	100	--
What do you use to clean your teeth			
Toothpaste	809	54.9	407.61 (0.0001)
Mouthwash	9	0.6	
Dental floss	19	1.4	
Tooth pick	8	0.6	
Other	626	42.5	
Total	1471	100	
Did you feel a change in your mouth after drinking soft or hot drinks			
Yes	502	34.1	-- 359.63 (0.0001)
No	414	28.1	
Maybe	522	%35.4	
Others	33	2.4	
Total	1471	100	
What is the condition of your teeth			
Good	419	28.4	392.74 (0.0001)
Fair	864	58.7	
Poor	173	11.7	
Others	15	1.2	
Total	1471	100	--
What cases do you have below			
Caries	465	31.6	347.21 (0.0001)
Gingivitis	127	8.6	
Calcifications and staining	311	21.2	

Other	568	38.6	
Total	1471	100	--
?Do you have a chronic disease			
Pressure diseases	34	2.3	
Diabetes	16	1.0	
Heart disease	16	1.2	539.02 (0.0001)
Respiratory system diseases	75	5.2	
Gastrointestinal diseases	54	3.6	
No	1143	77.7	
Other	133	9.0	
Total	1471	100	--

Table 4. Effect of soft drink and time on PH.

Soft drink name	pH value								
	before	after 0 min	after 10	after 20	after 30	after 40	after 50	after 60	L.S.D.
Pepsi	7.08	6.81	5.17	5.33	5.81	6.23	6.77	7.13	1.079 *
Cola	7.09	6.77	5.15	5.28	5.79	6.15	6.71	7.12	1.164 *
Seven	7.18	6.69	5.21	5.31	5.69	6.09	6.69	7.14	1.195 *
Mirinda	7.19	6.83	5.16	5.25	5.83	6.18	6.80	7.15	1.085 *
Shani	7.02	6.80	5.12	5.27	5.87	6.71	6.82	7.19	1.256 *
L.S.D.	0.327 NS	0.308 NS	0.298 NS	0.271 NS	0.266 NS	0.502 *	0.326 NS	0.273 NS	---
* (P≤0.05).									