ORIGINAL RESEARCH

CURRENT DEVELOPMENTS IN NUTRITION

Eating Behavior and Qualitative Assessments

SWEET MAPS: A Conceptualization of Low-Calorie Sweetener Consumption Among Young Adults

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ABSTRACT

Background: The extent to which low-calorie sweeteners (LCSs) are helpful or harmful for weight management and metabolic health is unclear, because LCS effects may depend on the context in which they are consumed.

Objective: To develop a conceptual framework for LCS consumption.

Methods: Young adults ages 18–35 y, who reported LCS consumption, were recruited from a private, urban, university in the mid-Atlantic United States. Concept mapping, a mixed-method approach was used to identify, organize, and quantify determinants of LCS consumption. First, participants ($n = 68$) identified reasons for their LCS consumption through brainstorming; content analysis of those reasons identified 37 specific determinants of LCS consumption. Second, participants ($n = 93$) sorted all 37 determinants conceptually. Third, participants ($n = 97$) rated the extent to which each of the 37 determinants was reflective of their own consumption. Similarity matrices, multidimensional scaling, and hierarchical cluster analysis produced a series of 2-dimensional concept maps (SWEET MAPS).

Results: The SWEET MAPS identified 37 determinants, organized within 8 factors reflective of 3 overarching motives: perceived health benefits, palatability, and accessibility of LCSs. At the determinant level, the most highly rated determinants that exceeded the boundary (rating >3.0) were: "I want something that tastes sweet," "I am trying to maintain/control my weight," "They contain fewer calories," "They are available," and "I want to save calories because I am eating a high-calorie meal."

Conclusions: LCS consumption is a function of many inter-related determinants spanning biological, psychological, and social domains. The SWEET MAPS are an important and novel use of concept mapping methods that can be used to inform the design and interpretation of future studies evaluating LCS effects. *Curr Dev Nutr* 2018;3:nzy103.

Introduction

Low-calorie sweeteners (LCSs) provide sweetness with no or few calories and are found in a wide variety of foods and beverages, including diet soft drinks, reduced-calorie cereals and snack foods, light yogurts, sugar-free desserts, sugar-free condiments, and tabletop packets (1). Because excess consumption of dietary sugar is associated with the development of obesity and type 2 diabetes, public health emphasis has been placed on reducing sugar intake, and food and beverage manufacturers have begun reformulating their products to replace sugar with LCSs (2, 3). As such, the prevalence of LCS consumption has increased in the United States (4), with recent data demonstrating that over 40% of adults and 25% of children report consumption of LCSs on a given day (5).

Keywords: artificial sweeteners, diet soda, obesity, concept mapping, non-nutritive sweetener

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Abbreviations used: BI, bridging index; LCS, low-calorie sweetener; MDS, multidimensional scaling.

Despite their growing and widespread use, the extent to which LCSs are beneficial for weight management and metabolic health is unclear (6). Human intervention studies demonstrate that replacement of added sugars with LCSs may be beneficial (7), yet epidemiologic studies report that LCSs may promote weight gain and development of chronic disease (8). Discrepancies in the findings of observational compared to interventional studies suggest LCS effects may be largely dependent on the context in which they are consumed (9). Interestingly, however, contextual factors including the increasing sweetness of the American diet (10) and consumer perceptions surrounding the "healthfulness" of specific products (11) have not been adequately studied in intervention trials to date. Although there are exceptions (12–14), human intervention studies evaluating LCS effects on body weight are often conducted in the context of weight-loss programs (15–17), and most studies test LCSs as 1:1 replacements for added sugars. However, LCSs may also be used in addition to added sugars in the diet, rather than strictly as replacements, which may have important implications for health (15).

To study the role of LCSs more effectively in weight and health, the unique biological, psychological, and social contexts in which individuals consume LCSs require more careful examination (15). According to the biopsychosocial model, behavioral etiology stems from the dynamic interactions between these domains and therefore requires a multilevel integrated approach (18) to examine the biological, psychological, and social contexts surrounding LCS use. Concept mapping (19) is an innovative, applied social research mixed methodology, which engages LCS consumers in the development of a series of illustrative concept maps that create insight, understanding, and consensus regarding their conceptualization of the unique, yet shared determinants that drive LCS consumption. Therefore, the primary purpose of this study was to develop, at the intersection of biology, behavior, and external influences, a consumer-driven conceptual framework to understand and evaluate the relative significance of various determinants of LCS use among young adults.

Methods

Study design

Concept mapping is a method for mirroring the ideas of a group through a stepwise series of participant-driven activities, including: 1) brainstorming, 2) sorting, and 3) rating (19). After obtaining approval from the Institutional Review Board, we recruited a convenience sample of students between the ages of 18 and 35 at a private university located in a mid-Atlantic metropolitan city in the United States who regularly (at least once per week) consume LCSs. Eligibility for study participation was determined using a brief, 5-item screening questionnaire that assessed consumption of foods, beverages, and/or packets containing LCSs. Participants were recruited from campus locations with large volumes of students, such as dining areas, cafes, and student recreation centers, as well as social media platforms. Participants provided informed consent before participation in any study activities. For the majority of participants who participated in-person on campus, study activities were completed in a designated private space under researcher supervision. If a subject was unable to complete the study activities in person, they were provided with a link to allow them to complete the activity remotely. Although some participants contributed to all 3 of the study activities (brainstorming, sorting, and rating, detailed below), concept mapping does not require participants to take part in all 3 tasks (20). Thus, some participants completed only 1 or 2 of the activities (e.g., brainstorming, but not sorting and rating). Given the time and inconvenience associated with participation (i.e., approximately 5 min for brainstorming and 15 min for sorting and rating), participants were entered into a lottery for $100 Amazon gift cards for each activity completed. Participants contributed their data on iPads or laptop computers using The Concept System® Global MAX™ license package, which allowed for the ease of collecting extensive participant data using a secure interface for the brainstorming, sorting, and rating activities.

Brainstorming

The purpose of this activity was to identify all of the reasons young adults consume LCSs. Participants ($n = 68$) were asked to complete the focus prompt, "I consume low-calorie sweeteners and/or products labeled 'diet,' 'sugar-free,' or 'no sugar added' because …" by generating a list of statements for all the reasons that they consume LCSs. Saturation of ideas was reached when new statements were no longer being generated (19) and was determined after 68 participants had completed brainstorming. Participants' statements were then pooled together, resulting in a total of 195 statements. This raw statement list was then refined through idea synthesis, a form of qualitative content analysis, in which redundant ideas were synthesized into 1 statement, maintaining participants' collective wording (19). Statements that were relevant, understandable, and able to be rated were retained. This resulted in 37 independent statements, edited for syntactic consistency across all of the statements, which represented the entire set of ideas brainstormed by the participants with regard to determinants of LCS consumption.

Sorting

The purpose of sorting was for participants ($n = 93$) to independently organize the 37 statements into piles in a manner that made sense to them using a drag-and-drop method on the online data-collection interface. Participants were instructed to sort the statements into as many or as few piles, as necessary, given their own individual conceptualization of the statements. When sorting, they were instructed not to: 1) sort the statements by relevance to them personally; 2) create a "miscellaneous" or "other" pile (thus a statement can stand on its own); and 3) leave any statements without a pile (even if the pile comprised only 1 statement, it should still be named to reflect its meaning). As part of the sorting activity, participants were also asked to name each of their piles.

Rating

The purpose of rating was for participants ($n = 97$) to independently quantify the relevance of each of the 37 statements as related to their own LCS use. Participants rated each of the 37 statements using a 1–5 Likert-type scale from 1 (never true for me) to 5 (always true for me). Upon completion of the rating activity, participants responded to a 6-item survey developed to assess the nuanced behavioral habits surrounding participant LCS consumption (see **Table 2**).

FIGURE 1 Point map of the 37 determinants of LCS consumption. Each point represents 1 of the 37 determinants that were brainstormed and sorted by the participants. Point location is an indicator of that point's relation to all other points, where points located closer together are more similar to one another than points located distally. The numbers that appear next to each point on the map are not an indication of quantitative value; the numbers serve merely to identify each specific determinant (statement) and were randomly assigned. LCS, low-calorie sweetener.

Statistical analysis

Analysis of sorting and rating data was carried out in a stepwise progression. First, a similarity matrix was constructed from the sorting data, followed by multidimensional scaling (MDS) yielding a 2-dimensional solution. In MDS, points were placed on a point map with each point representing 1 of the 37 LCS consumption statements. Each point's placement on the map was an indicator of its relation to all other points; that is, points closer to one another on the map represented statements that were sorted together more often by participants (see **Figure 1**). Likewise, points farther apart from one another were sorted together less frequently. The stress value produced by Concept Systems was used as a measure of the point map's goodness of fit. Stress values generally range from 0 to 1 with lower values indicating better congruence of the raw and processed data. For 2-dimensional MDS solutions, values below 0.39 have less than a 1% probability of the arrangement of the objects within the matrix of having no structure or a random structure (21). In a pooled analysis of concept mapping studies, the mean stress value was 0.28 (22). Our point map yielded a stress value of 0.09, thereby indicating it was neither random nor without structure and represented our set of multivariate data very well (23). This is important because the point map is the foundation from which all subsequent concept maps were derived.

Next, hierarchical cluster analysis, using Ward's algorithm, was conducted on the MDS solution. This partitioned the points on the map into thematic clusters, creating point-cluster maps of varying solutions (i.e., clusters). We performed several iterations of the cluster replay maps, which displayed maps with varying cluster-solutions. Cluster maps with 7, 8, 9, and 10 cluster-solutions were again closely examined, and of these, the eight-cluster map yielded the best conceptual representation of the data. When the 8-cluster map was subsequently examined at the statement level, we identified 5 data points (i.e., statement numbers 5, 6, 24, 25, and 28) partitioned in clusters whose adjacent cluster was a better conceptual fit. These statements were quantitatively examined using spanning analysis, in order to examine each statement's bridging index (BI) value, which functioned as a measure of the extent to which a statement was sorted with nearby statements (i.e., values closer to 0) or with statements located elsewhere on the map (i.e., values closer to 1). Using this quantitative approach, along with the judgment of our research team, the 5 statements were redistributed to adjacent clusters that were a better conceptual fit. Without altering the statement's spatial location on the map, the cluster boundaries were redrawn (see **Figure 2**). From this modified 8-cluster map, a cluster-rating map was computed, which used cluster layering to display the quantitative rating data in 3-dimensional space based on the mean rating data for all the statements within a cluster. Therefore, clusters with a greater number of layers were rated more highly with regard to their relevance among the participants (see **Figure 3**).

We also computed a radar graph based on mean rating scores for the 37 statements. Radar graphs provide a streamlined method for visually organizing multivariate data (24). In our analysis, ratings above 3.0 were considered of greater influence to consumption behavior, and therefore, the outer boundary of the radar graph was set to a mean rating of 3.0 (see **Figure 4**).

Results

Participant characteristics are described in **Table 1**, and their habits surrounding their LCS consumption are described in **Table 2**. Participants most frequently reported consuming LCSs at restaurants (18.6%), while on campus (14.7%), and at their residence (13.7%). Reported LCS consumption occurred most commonly during snacking (28.4%), followed by dinner (25.5%) and least often at breakfast (17.7%).

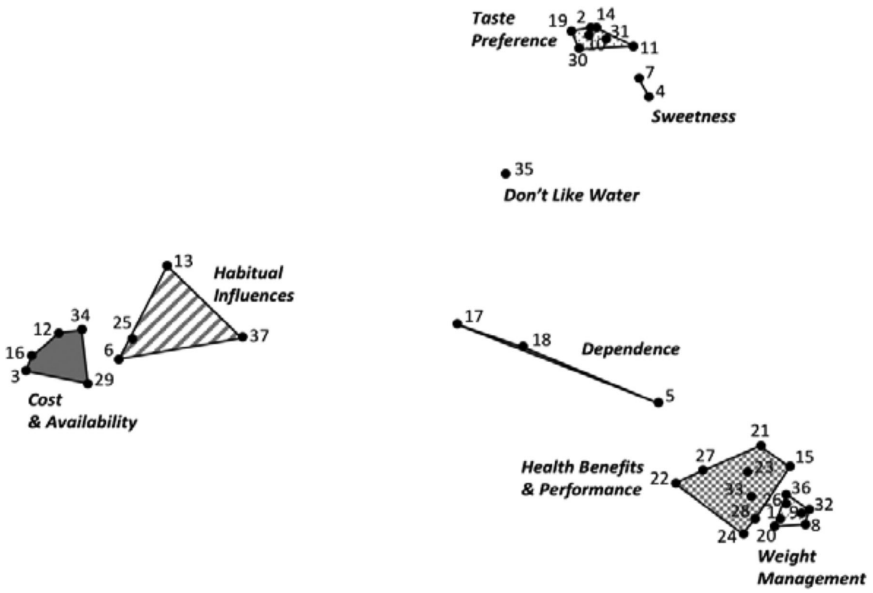

FIGURE 2 Point-cluster map of clustered dimensions of LCS consumption. Each of the 8 clusters indicates a dimension of thematically similar content, conceptualized from the 37 determinants. These 8 clusters represent 3 overarching factors driving consumption: palatability, accessibility, and perceived physiological effects. LCS, low-calorie sweetener.

The majority of participants (73.3%) reported consuming beverages presweetened with LCS, whereas 34.3% added LCSs to their beverages. The most commonly reported LCS-containing beverages were diet soda (80.4%) and light juice or lemonade (19.6%). Among participants who reported adding LCSs to their beverages, LCSs were most commonly added to coffee and tea (97.9%). Only 7.5% of participants added LCSs to their food, whereas 51.4% reported consuming foods already containing LCSs, such as light yogurt (49.2%), ice cream or candy (43.1%), and sugar-free/low-sugar jam or syrup (22.1%). The 37 determinants of LCS use, rank-ordered from highest to lowest, based on participants' personal consumption, are listed in **Table 3**. Finally, descriptive statistics of the 37 determinants, organized by cluster, are listed in **Table 4**. For the purposes of this paper, the concept maps generated from the multivariate analyses, including the point map, cluster map, and cluster-rating map, are collectively referred to as the SWEET MAPS.

SWEET MAPS

The point map (Figure 1) represents the inter-relatedness of the 37 determinants of LCS consumption. From the point map, a hierarchical cluster analysis was applied to create a point-cluster map (see Figure 2), which partitioned the 37 determinants into 8 distinct, yet related clusters of LCS consumption rationale. Notably, the 8 clusters (i.e., Taste Preference, Sweetness, Don't Like Water, Weight Management, Health Benefits & Performance, Dependence, Habitual Influences, and Cost & Availability) were representative of 3 overarching factors driving consumption: 1) palatability, 2) perceived physiological effects, and 3) accessibility (see Figure 3). The cluster names reflect those provided by participants most frequently when sorting the statements into piles and that were most appropriately representative of the statements grouped within each cluster. Among the 8 clusters, the lowest BI values were observed for Weight Management (0.03), Taste Preference (0.13), and Health Benefits & Performance (0.21), indicating more narrowly focused thematic content as illustrated by the relatively compressed shape on the cluster map (see Figure 2). Table 4 reports the mean BI for each cluster.

Figure 3 displays the 3-dimensional cluster-rating map, in which the height of the clusters is directly proportional to the degree to which it drives LCS consumption among young adults. Weight Management, Sweetness, Taste Preference, and Habitual Influences were the top 4 rated clusters. Mean rating values for the 37 determinants that make up the 8 clusters of LCS consumption ranged from 1.62 to 3.60 (Table 3). When examining the data more closely at the determinant level (see Figure 4), 4 determinants were rated outside the designated boundary (i.e., mean value >3.0): "I want something that tastes sweet" (4), "I am trying to maintain/control my weight" (8), "They contain fewer calories" (9), and "They are available" (12).

Discussion

We used concept mapping to develop the SWEET MAPS, an integrative, consumer-driven framework that conceptualized determinants of LCS consumption among young adults. The SWEET MAPS visually display 37 distinct determinants of consumption, organized within 8 factors that are influenced by three-overarching perceptions of LCSs: 1) perceived beneficial physiological effects resulting from LCS use (Weight Management, Health Benefits & Performance, Dependence); 2) palatability (Taste Preference, Sweetness, Don't Like Water); and 3) accessibility (Habitual Influences, Cost & Availability) of LCSs. The SWEET MAPS illustrate that consumption of LCSs (behavior) is a function of many determinants within a person's life space spanning biological, psychological, and social domains, likely mediated by the broader sociocultural context in which they are consumed.

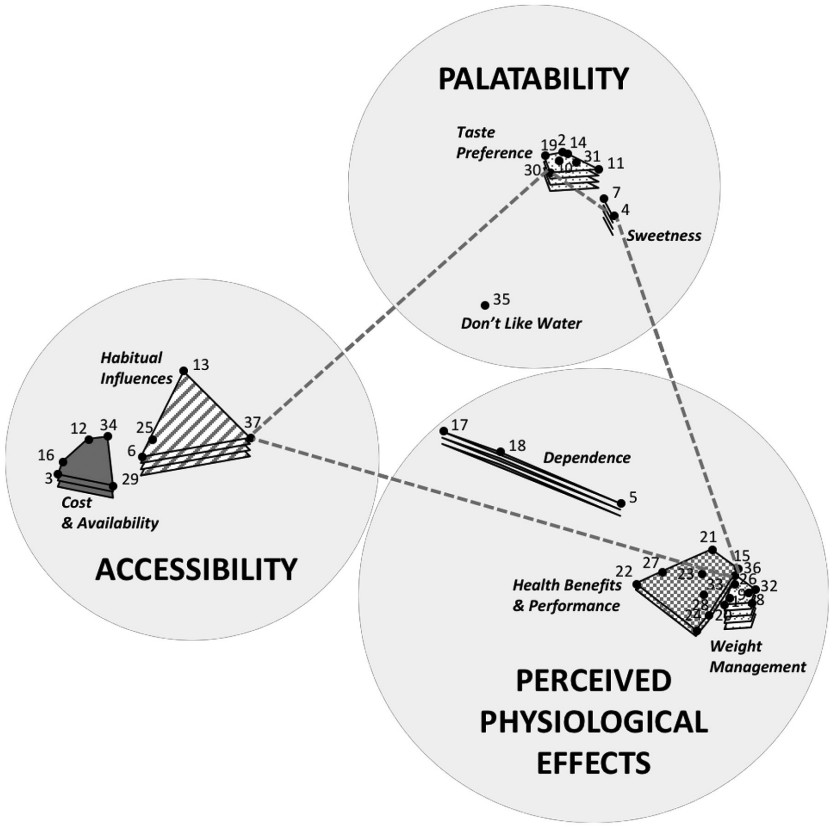

FIGURE 3 Cluster-rating map of LCS consumption. The cluster-rating map illustrates the mean personal consumption rating for each cluster; those with a greater number of layers indicate they were rated more influential to participants' LCS consumption. The top 4 rated factors, Weight Management, Sweetness, Taste Preference, and Habitual Influences, are connected via dashed lines. LCS, low-calorie sweetener.

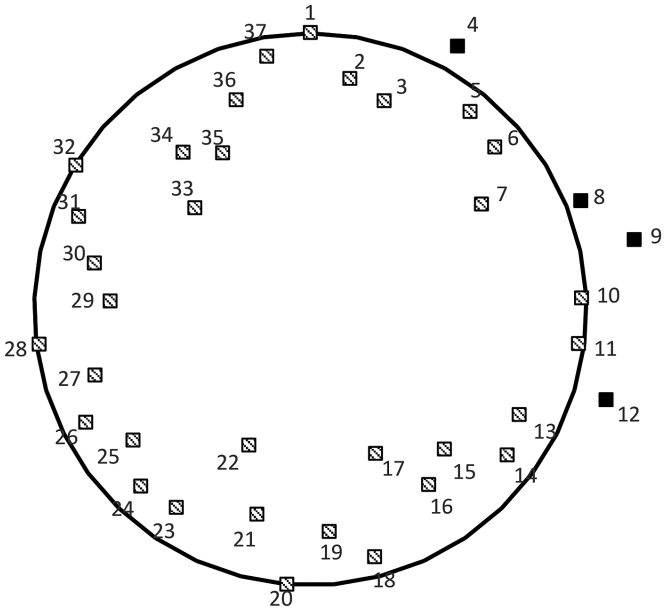

FIGURE 4 Radar graph of LCS consumption. The radar graph illustrates the mean personal consumption rating for the 37 LCS determinants. Ratings outside the outer boundary (3.0) are considered influential to LCS consumption behavior and include determinants 4, 8, 9, and 12.

Consistent with the biopsychosocial model, the 3 overarching factors elucidated the importance of social and behavioral factors in understanding the effects of LCSs on the biological effects of weight and health. Our findings underscore the need to assess LCS consumption holistically rather than focusing exclusively on any one single domain.

Perceived physiological effects

Among all 8 factors identified, our findings indicate that determinants of weight management were among the most influential for LCS consumption. These findings were not surprising, because by virtue of their noncaloric nature, replacement of added sugars with LCSs reduces the calorie content of foods and beverages. As such, LCSs are intended to assist consumers in achieving negative energy balance to promote and sustain weight loss. For example, in a cross-sectional study of over 400 participants in the National Weight Control Registry who had successfully maintained weight loss, LCS consumption was commonly reported (25). This finding is interesting because the majority of observational studies report associations between LCS consumption and weight gain, and thereby challenge the perceived benefits of LCSs for weight management. It is unclear whether participants of these observational studies used LCSs strictly for the intended purpose of lowering energy intake, as was the case among the weight-loss maintainers in the study referenced above (25). Although LCSs are commonly studied as replacements for added sugars in the biological

TABLE 1 Participant characteristics

	Percentage ($N = 100$)
Gender	
Male	30
Female	70
Age range, y	
18–22	51
23–34	49
Ethnicity	
Non-Hispanic white	61
Hispanic	6
African American	8
Asian	18
Native Hawaiian or other Pacific Islander	1
Mixed race	5
Other	1
BMI, kg/m^2	
Underweight (<18.5)	4
Normal weight (18.5–24.9)	60
Overweight (25.0–29.9)	26
Obese (>30)	10

context of weight management (7), the present findings indicate that LCSs are consumed for numerous other distinct, yet inter-related reasons.

Notable psychosocial determinants related to perceived benefits of LCSs for health and performance were identified within the SWEET MAPS that warrant increased attention in the broader communities of public health, nutrition, medicine, and fitness. One of the more intriguing findings illustrated by the SWEET MAPS was the perception that LCS-containing foods are "healthier," and could thus offset consumption of other "unhealthy" foods and beverages or even a lack of exercise. Beliefs that consumption of LCS-containing products may rationalize consumption of high-calorie or nutrient-poor foods has been previously documented (26). This is consistent with the concept of "health halos," in which health claims that are often present on LCS-containing products, such as sugar-free or reduced-sugar, may lead consumers to have more positive attitudes toward these products, regardless of their actual healthiness (27). This phenomenon has also been reported for products labeled as gluten-free (28) or reduced fat (29). In these cases, consumers mistakenly perceive these ingredient and nutrition labels as indicative of product "healthfulness" and subsequently consume excess calories from increasing their portions sizes of these products.

Beyond nutrient-content claims (e.g., sugar-free, reduced fat, gluten-free), health halos can also be embedded within the product name itself, such as "protein bar" (30) and "diet beverage." Repeated exposure to food advertising, with implicit or explicit health halo messaging, may lead consumers to purchase nutritionally poor products based on the false premise that these foods will benefit their health (31). Widespread consumer misperceptions that result from health halos call attention to the need for more targeted nutrition education at the psychological (e.g., knowledge, attitudes) and social (e.g., friends, family, social media) levels to change cultural narratives that may motivate consumer behavior. The perception that "calorie savings" may justify consumption of unhealthy foods warrants further study, particularly considering the wide variety of nutrition information and stimuli (e.g., social media, news articles, blogs) to which young adult consumers are increasingly exposed. This misinformation will only propagate existing misperceptions about the health benefits or detriments of specific food products or ingredients (32).

Physiological determinants of LCS consumption, such as the need for energy or caffeine, and feeling addicted to products containing LCSs, were also reported. Given that many diet beverages are caffeinated, and LCSs were most commonly used by participants to sweeten coffee and tea, these findings are not surprising. Although reported dependence is likely due to caffeine rather than a biological dependence on LCSs per se, functional benefits resulting from caffeine use and avoidance of the discomfort associated with caffeine withdrawal symptoms may further reinforce LCS use. Importantly, LCSs have also been shown to affect central reward pathways (33, 34), which is an important topic of ongoing investigation (35, 36).

Palatability

"I want something that tastes sweet" was the third most highly rated determinant, ranking above "I am trying to control my weight" and "I want to save calories" (see Table 3). These findings demonstrate that palatability is also driving consumption of LCSs among young adults. The desire for "something that tastes sweet" and the perception that LCSs "provide more sweetness" than sugar raises the question as to whether LCS use may promote or reinforce sweetness preferences and/or cravings (37). Although LCSs are not sweeter than sucrose (table sugar) (38), the high sweetness potency of LCSs (hundreds or thousands of times more potent than sucrose by weight) allows them to be used in very small quantities in foods and beverages. As such, LCSs are listed at the very end of the ingredients list (1) and are often consumed unintentionally (39).

Concerns have emerged surrounding sweetening of the food supply and the broader impacts of this trend on diet and health (10). Recent studies evaluating associations between LCS use, nutrient intakes, and dietary patterns have reported mixed findings (40–43), which are likely attributable to how and why LCSs are used. Because the present study was cross-sectional in design and did not evaluate the time course, history, or trajectory of LCS use, we are unable to speculate as to whether the initiation of LCS use may have preceded reported cravings for sweetness or vice versa. Therefore, the extent to which reported determinants of LCS use correlate with dietary patterns is another important topic for further study.

Accessibility

Access was also identified by the SWEET MAPS as a driving factor of LCS consumption. Habitual influences was among the top 4 clusters rated as most influential, containing determinants such as "They are in the foods I eat" and "I grew up drinking them." The increasing incorporation of LCSs into foods since the late 1980s (26), in combination with concurrent increases in diet programs and LCS-marketing (44), has created a culture wherein young adults are ubiquitously exposed to products with LCSs. A significant increase in household purchases of LCS-containing beverages in households with children from 2000 to 2010 has also been documented, further supporting this notion (45).

Exposure to LCSs at an early age may promote a preference for LCSs (46), further encouraging LCS consumption in adolescence and young adulthood, independently of any intention to manage weight

TABLE 2 Percentages of reported participants' LCS habits[1]

	Percentage[2]
I consume LCSs and/or products labeled "diet," "sugar-free," or "no sugar added" when I am…	
At a restaurant	18.6
Studying/in class/on campus	14.7
At my dorm/home	13.7
At the movies	11.4
At a coffee shop	10.2
At work	10.2
Watching sports events	7.7
Outside and it is hot	7.5
Participating in athletics/exercise	3.5
Other	2.6
I consume LCSs and/or products labeled "diet," "sugar-free," or "no sugar added" during…	
Snacking	28.4
Dinner	25.5
Lunch	24.2
Breakfast	17.7
Other	4.3
Do you add LCSs (e.g., Splenda, Sweet'N Low, Equal, etc.) to your beverages?	
No	65.8
Yes	34.3
If yes, typically which drinks?	
Coffee/tea	97.9
Do you consume beverages (e.g., diet soda, light juices, sugar-free drinks) that contain LCSs, not added by you?	
No	26.7
Yes	73.3
If yes, what beverages?	
Diet soda	80.4
Light juice/lemonade	19.6
Sport/energy drinks	5.9
Coffee	3.9
Sparkling water	2.0
Do you add LCSs (e.g., Splenda, Sweet'N Low, etc.) to your foods?	
No	92.5
Yes	7.5
If yes, what foods do you add it to?	
Oatmeal/pudding	45.5
Yogurt	27.3
Dessert/baking	18.2
Do you consume foods (e.g., sugar-free/low-sugar jam or syrup, no sugar added/low-sugar oatmeal, no sugar added ice cream, light yogurt, etc.) that contain LCSs not added by you?	
No	48.6
Yes	51.4
If yes, what foods?	
Yogurt	49.2
Ice cream/candy	43.1
Syrup/jam	23.1
Oatmeal/cereal	18.5
Peanut butter	3.1
Snacks	3.1
Nutritional bars	1.5
Salad dressing	1.5

[1] LCS, low-calorie sweetener.
[2] Percentages do not add to 100 because "if yes" items were open-ended responses, and other items instructed participants to select all that applied.

or improve one's health. Factors including cost and availability were also reported as important determinants of LCS consumption. For example, statements including "they are available" and "they are free" were ranked highly. If individuals consume products with LCSs simply because "they are available," LCSs are likely not being consumed as 1:1 replacements for added sugars and would instead be consumed in addition to usual dietary intake (26). This further reiterates that findings of intervention studies testing effects of diet beverages strictly as replacements for sugar-sweetened beverages (13, 16, 47, 48) do not sufficiently consider the complexity of LCS consumption, nor do they account for the broader context in which LCSs are used, limiting their applicability to LCS consumption in the general population.

TABLE 3 Rank ordering of the LCS determinants based on personal consumption rating[1]

Ranking	LCS determinant (statement no.)	Mean rating values
1	They contain fewer calories (9)	3.60 ± 1.39
2	They are available (12)	3.36 ± 1.29
3	I want something that tastes sweet (4)	3.28 ± 1.19
4	I am trying to control/maintain my weight (8)	3.17 ± 1.47
5	I want to save calories, since I know that I am eating a heavy, high-calorie meal (1)	3.01 ± 1.39
6	I want to keep in shape (20)	3.00 ± 1.45
7	I want to lose weight (32)	2.99 ± 1.42
8	I try to minimize my sugar consumption (28)	2.97 ± 1.36
9	I like the taste (10)	2.95 ± 1.35
10	They taste similar to regular soda (11)	2.94 ± 1.34
11	They are in the foods I eat (37)	2.79 ± 1.30
12	I need caffeine (18)	2.78 ± 1.56
13	I need energy (5)	2.76 ± 1.33
14	They seem healthier than sugar (26)	2.73 ± 1.45
15	They taste similar to sugar (31)	2.71 ± 1.22
16	I am with other people that consume them (6)	2.67 ± 1.21
17	I don't want to get diabetes (24)	2.66 ± 1.43
18	I prefer the taste compared to regular drinks (14)	2.66 ± 1.43
19	Sugar harms my teeth (23)	2.60 ± 1.43
20	I prefer the taste compared to sugar (2)	2.55 ± 1.34
21	I grew up drinking them (13)	2.54 ± 1.46
22	I want to avoid becoming addicted to sugar (27)	2.44 ± 1.38
23	I prefer the taste compared to unsweetened drinks, e.g., water (19)	2.42 ± 1.31
24	I am calorie-conscious when drinking alcohol (36)	2.42 ± 1.48
25	They are free (3)	2.41 ± 1.37
26	I prefer the taste compared to unsweetened foods (30)	2.40 ± 1.24
27	My parents drink them (25)	2.39 ± 1.43
28	I want to suppress my hunger (21)	2.30 ± 1.31
29	They are on sale (16)	2.30 ± 1.29
30	My parents buy them (34)	2.20 ± 1.38
31	They provide more sweetness than sugar (7)	2.19 ± 1.24
32	It is the only available option (29)	2.18 ± 1.23
33	They make unhealthy foods healthier (15)	2.10 ± 1.24
34	I don't want to drink water (35)	1.95 ± 1.19
35	I feel addicted to them (17)	1.72 ± 1.15
36	They make up for not exercising (33)	1.67 ± 1.03
37	They boost my athletic performance (22)	1.62 ± 1.05

[1]Values are means ± SDs. Each of the numbers in parentheses at the end of each determinant is the identifying number on the point map and point-cluster map; these numbers do not signify any value. Mean rating values ranged from a low of 1 (never true for me) to 5 (always true for me). LCS, low-calorie sweetener.

Limitations and future directions

Although the present findings provide a novel framework for understanding LCS consumption, our analyses were subject to limitations. Most notably, the limited sample size and relative homogeneity of participant weight status precluded our ability to perform subgroup comparisons based on demographic factors and other sample characteristics. Moreover, the sampling scheme used in our study limits the external validity of our findings. In addition, for study inclusion, regular LCS use was defined as consumption of ≥1 LCS-containing food, beverage, or packet per week. Therefore, we were unable to examine whether determinants of LCS consumption and their relative significance differed by specific characteristics of LCS consumption, such as the frequency of LCS use, amount of LCS ingestion, or the type of LCSs consumed.

Despite these limitations, the SWEET MAPS are the first-ever conceptual framework for understanding multiple integrated factors underlying LCS consumption. This provides novel insight into the likelihood that the benefits or detriments of LCSs on weight and health are largely dependent on the reasons and context underlying their use. Although comparisons across socio-demographic characteristics were not possible in this study, differences in the prevalence of LCS use across population subgroups (5) are well documented. Potential variability in LCS effects may depend on socio-demographically related lifestyle practices and health beliefs, as well as genetic predispositions. Taken together, the SWEET MAPS provide an integrated biopsychosocial conceptual framework upon which comparisons across socio-demographic subgroups can be conducted in subsequent studies with larger sample sizes.

Conclusions

With a rapidly changing nutrition landscape and increased emphasis on reducing the consumption of added sugars (2), LCSs have become omnipresent in the food supply (49). Meanwhile, the extent to which

TABLE 4 Rating and bridging index for the 37 low-calorie sweetener determinants by cluster

	No.	Determinant	Personal consumption	Bridging value
Weight Management			2.99	0.03
	9	They contain fewer calories	3.60	0.00
	8	I am trying to control/maintain my weight	3.17	0.01
	1	I want to save calories since I know that I am eating a heavy, high-calorie meal	3.01	0.03
	20	I want to keep in shape	3.00	0.02
	32	I want to lose weight	2.99	0.02
	26	They seem healthier than sugar	2.73	0.04
	36	I am calorie-conscious when drinking alcohol	2.42	0.06
Sweetness			2.73	0.40
	4	I want something that tastes sweet	3.28	0.45
	7	They provide more sweetness than sugar	2.19	0.36
Taste Preference			2.66	0.13
	10	I like the taste	2.95	0.10
	11	They taste similar to regular soda	2.94	0.18
	31	They taste similar to sugar	2.71	0.11
	14	I prefer the taste compared to regular drinks	2.66	0.09
	2	I prefer the taste compared to sugar	2.55	0.10
	19	I prefer the taste compared to unsweetened drinks, e.g., water	2.42	0.13
	30	I prefer the taste compared to unsweetened foods	2.40	0.18
Habitual Influences			2.60	0.69
	37	They are in the foods I eat	2.79	0.91
	6	I am with other people that consume them	2.67	0.51
	13	I grew up drinking them	2.54	0.78
	25	My parents drink them	2.39	0.56
Cost & Availability			2.49	0.38
	12	They are available	3.36	0.36
	3	They are free	2.41	0.30
	16	They are on sale	2.30	0.33
	34	My parents buy them	2.20	0.43
	29	It is the only available option	2.18	0.47
Dependence			2.42	0.84
	18	I need caffeine	2.78	0.87
	5	I need energy	2.76	0.65
	17	I feel addicted to them	1.72	1.00
Health Benefits & Performance			2.30	0.21
	28	I try to minimize my sugar consumption	2.97	0.05
	24	I don't want to get diabetes	2.66	0.11
	23	Sugar harms my teeth	2.60	0.17
	27	I want to avoid becoming addicted to sugar	2.44	0.32
	21	I want to suppress my hunger	2.30	0.33
	15	They make unhealthy foods healthier	2.10	0.20
	33	They make up for not exercising	1.67	0.09
	22	They boost my athletic performance	1.62	0.38
Don't Like Water			1.95	0.98

they exert clinically relevant metabolic effects in humans remains a topic of ongoing debate (50), and it is not yet clear whether the continuing trend of increasing LCS intake is ultimately beneficial or detrimental to health (15). The SWEET MAPS provide an important and novel use of concept mapping in nutrition research that captures the dynamic interactions between biological, psychological, and social domains of influence for the contextual and behavioral intricacies of LCS use. Along with other multilevel integrated approaches, the SWEET MAPS will be critical for informing the design of future studies evaluating LCS effects. Specifically, the SWEET MAPS will allow for more translatable findings that, taken together, will be capable of informing currently inconclusive dietary guidance (51, 52) supporting or challenging LCS use. Importantly, our use of concept mapping engaged key stakeholders who were LCS consumers and assessed the determinants of their LCS consumption using both qualitative and quantitative approaches rather than relying on a priori constructs for hypothesizing consumers use of LCS. This allowed us to creatively and meaningfully develop a comprehensive framework, capturing the fundamental motives for LCS consumption among young adults at the intersection of dynamic and highly integrated biology, psychology, and broader social influences.

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