Original Article

Effect of Stepwise Sugar Reduction on the Satisfaction of Sucrose-Sweetened Drink

Khimsuksri S, DDS, MS[1], Tangkabutra S, DDS[2], Tapananont T, DDS[3], Sangaroon S, DDS[4], Rattanathongkom A, DDS, MS, PhD[1], Paphangkorakit J, DDS, PhD[1,5]

[1] Department of Oral Biomedical Science, Faculty of Dentistry, Khon Kaen University, Khon Kaen, Thailand
[2] Dental Department, Kumpawapi Hospital, Udon Thani, Thailand
[3] Dental Department, Chumphae Hospital, Khon Kaen, Thailand
[4] Sirindhorn College of Public Health, Khon Kaen, Thailand
[5] Neuroscience Research and Development Group, Khon Kaen University, Khon Kaen, Thailand

Background: High sugar intake increases risk of dental caries, obesity, and other non-communicable diseases. The amount of daily sugar intake per person among Thai population was much higher than of which the WHO recommends for health benefit. Decreasing added sugar is always recommended. A methodologically protocol would be useful and help altering sweet preference successfully.

Objective: To determine 1) the amount of sugar in test drink that can be reduced and still remains individual's satisfaction, and 2) the time used to reach the lowest satisfactory sugar concentration (LSSC).

Materials and Methods: Thirty-five volunteers (20 to 25 year-old, male = 14) were asked to taste and have a series of test drinks (containing sucrose, red coloring, sala flavor) which had been gradually decreased sucrose concentration daily. The initial satisfactory sugar concentration (ISSC) was set for each volunteer individually depending on his/her sweet preference. Each volunteer was allowed to take some days to get use to the new test drink with lower sugar concentration, before further sugar reduction. The stepwise sugar reduction protocol continued until the volunteer unsatisfied with the new test drink. The LSSC which the volunteer satisfied with and total number of days spent during the stepwise sugar reduction protocol were recorded.

Results: The ISSC ranged from 6% to 15% w/v (mean = 10.26±2.29%). The LSSC ranged from 1.5% to 9.0% w/v (mean = 5.17±1.85%). In average, the sugar concentration could be decreased by 49.96±14.00% compared to the ISSC. The average time taken in stepwise sugar reduction protocol was 10 days.

Conclusion: This stepwise sugar reduction protocol is effective in reducing individual's sweet preference within a reasonably short period of time.

Keywords: Sucrose, Sugar-sweetened, Drink, SSBs

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Although the link between added sugar and risk of non-communicable disease has been questioned in some studies, laboratory and epidemiological studies showed that high sugar consumption contributed to the excessive energy intake, leading to obesity and other metabolic disorders[1,2]. World Health Organization[3] has recommended that free sugar should be less than 10% of dairy total energy intake or less than 5% for more health benefits. A common source of added sugar mostly consumed is sugar-sweetened beverages (SSBs)[4]. The consumption of SSBs may increase risks of non-communicable diseases (NCDs) including dental caries[5,6]. Reduction of sugar added in SSBs seems to be effective to cut off the excessive energy intake. However, the abrupt change in sugar reduction may be difficult because sugar can trick the brain and body similar to what happens in addiction[7,8] and during stress[9,10]. Sugar reduction also affects hedonic perception in both children and adults[11]. Difference threshold (DT) is the level of sugar concentration in which a subject just distinguishes the difference of sweetness. Thus, the change in sugar concentration larger than the subjects' sweet DT will affect sensory and hedonic perception[11]. In contrast, a gradual decrease of sugar concentration without any noticeable change of taste may be a better option since the satisfaction to the taste would not be affected[12,13]. Since the sugar reduction protocol daily tailored for individual has never been studied, the authors developed a novel stepwise sugar reduction protocol and investigated the amount of sugar that could be reduced as well as the time used to reach the lowest satisfactory sugar concentration in a test SSB.

Correspondence to:
Khimsuksri S.
Department of Oral Biomedical Science, Faculty of Dentistry, Khon Kaen University, Khon Kaen 40002, Thailand.
Phone: +66-81-8992743, **Fax:** +66-43-202862
E-mail: sawita@kku.ac.th

Materials and Methods

This interventional observational study was approved by the Human Research Ethics Committee, Khon

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Kaen University (HE582201). Sample size was calculated from a pilot study. Thirty-nine healthy volunteers were recruited from dental students at Khon Kaen University. Those who had smoking and drinking habit, taste and/or smell disorders were excluded. All volunteers were those who had regular SSB consumption at least 3 times/week (80% of the volunteers had at least 1 serving of SSB daily), and did not reject the test drink.

Preparation of the test drink

A survey of red color, sala flavor, sugar-sweetened drink samples from 16 shops in Khon Kaen was conducted. The sugar concentration in the samples was determined using MA871 Digital Brix Refractometer (Milwaukee Instruments, Inc., NC, USA.). The highest sugar concentration was 14.43% w/v and the lowest sugar concentration was 9.14% (mean = 12.54%). In order to control the color and odor, red food coloring, sala flavor, and sugar were used for test drink preparation instead of the commercial concentrated sala syrup. The test drink was kept at 20°C.

Determination of individual's difference threshold

Using the pair-comparison method, the volunteers were asked to tell if the sweetness of two test drink concentrations (25 ml each) were different. Reference sugar concentration was set at 15% (according to the survey). Each volunteer tasted the reference drink followed by another test drink with 1%, 2% and 3% less sugar concentration (i.e. difference of 6.7%, 13.3%, and 20.0% w/v respectively), until the difference was noticed. Volunteers rinsed their mouth with drinking water after each cup of test drink. The concentration difference with respect to the reference at which the volunteer started to distinguish the sweetness was assumed to be each individual's DT and used in setting the level of sugar reduction in the protocol. By this method, DTs were 1% in 14 volunteers, 2% in 16 volunteers and 3% in 5 volunteers.

Initial satisfactory sugar concentration (ISSC)

To determine the ISSC for each volunteer, volunteers were asked to taste a 25-ml sample of test drink varying from 5% to 15% sugar concentration (starting from 5% in consecutive order, rinsing with drinking water after each cup of test drink) and rated their perception on the five-point hedonic scale (dislike very much-dislike-not sure-like-like very much). The ISSC was the most favorite drink rated by the volunteer which they rated as 'like very much'.

Stepwise sugar reduction protocol

The protocol started with ISSC test drink. On each following day, a test drink with lower concentration was prepared after the volunteer tasted and rated the test drink. The new concentration was determined as following:

Day 1: ISSC
Day 2: [1] - (DT - 0.5) → like very much → new drink = [1] - (DT - 0.5)
→ like → new drink = [1] - (DT - 1)
→ not sure → new drink = [1]
→ dislike or dislike very much → end of protocol

Then volunteers received a 250 ml bottle of test drink daily. The protocol was run for 21 days or ended whenever the volunteer disliked the new test drink. The last concentration of drink each volunteer had was recorded as the lowest satisfactory sugar concentration (LSSC). Total time each volunteer was participated until end were also recorded.

Data analysis

The data were analyzed using Small Stata 14.2 for Windows. The percentage change of the sugar of each volunteer was calculated for LSSC compared to ISSC and shown as mean and standard deviation. Median survival time was used to determine the time spent by the volunteer to achieve LSSC. The differences between groups of DT were tested using Kruskal Wallis rank test. Statistical significance was considered at p-value <0.5.

Results

Thirty-five volunteers (14 males 21 females, aged 20 to 25 years old) completed the protocol. The ISSC ranged from 6% to 15% (mean = 10.26±2.29%). The LSSC ranged from 1.5% to 9.0% (mean = 5.17±1.85%). On average, the sugar concentration could be decreased by 49.96±4.81% compared to ISSC. Summary of ISSC, LSSC, the percentage change of sugar were shown in Table 1. The change in sugar concentration after completing the protocol in DT 3 group was significantly greater than DT 1 group (p = 0.02).

Volunteers spent 5 to 21 days until the LSSC was achieved. The mean survival time in this stepwise sugar reduction protocol was 11 days. Data showed in Table 2.

Table 1. Summary of ISSC, LSSC, and the amount of sugar reduction

Group	n	ISSC		LSSC		Sugar reduction (%)	
		Mean ± SD	95% CI	Mean ± SD	95% CI	Mean ± SD	95% CI
Total	35	10.26±2.29	(9.47, 11.04)	5.17±1.85	(4.53, 5.81)	49.9±14.00	(45.15, 54.77)
DT 1	14	10.00±0.65	(8.67, 11.33)	5.61±0.41	(4.77, 6.45)	43.39±3.38	(36.53, 50.25)
DT 2	16	10.81±0.53	(9.73, 11.90)	5.31±0.47	(4.35, 6.28)	51.32±3.10	(45.03, 57.62)
DT 3	5	9.20±1.02	(7.13, 11.27)	3.50±0.87	(1.74, 5.26)	64.00±5.79	(52.24, 75.76)

Table 2. Time spent in the sugar reduction protocol (days)

Group	n	Mean	Minimun	Maximum	Median	95% CI of median
Total	35	11.89	6	21	11	(8, 13)
DT 1	14	15.57	8	21	15	(11, 20)
DT 2	16	10.19	6	18	10	(8, 11)
DT 3	5	7	6	8	7	(6, -)

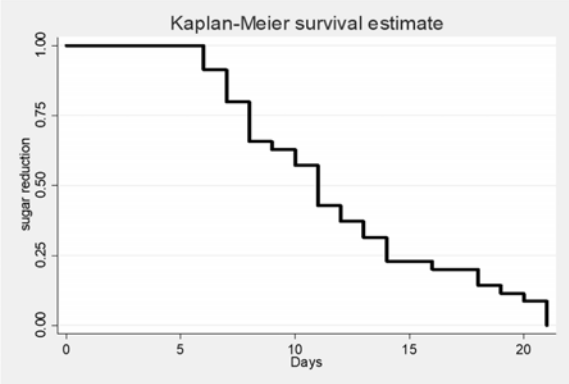

Figure 1. Average time (median time) to achieve LSSC.

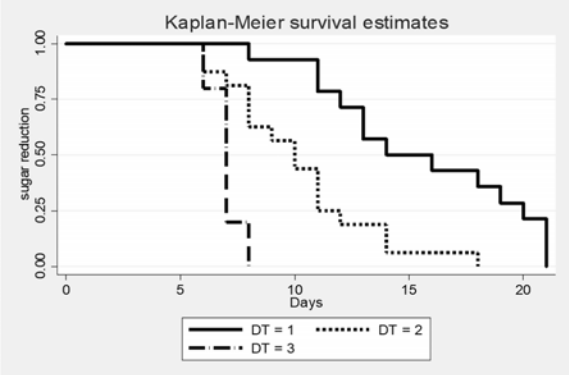

Figure 2. Average time to achieve LSSC, divided by DT.

Volunteers who have higher DT were likely to spent shorter time than those who have lower DT. The DT 3 group was spent significantly shorter time than the DT 1 group. The average (median) time spent in the protocol were shown in Figure 1 and 2.

Discussion

Gradual reduction of sugar has been suggested as a proper way to reduce sugar intake without affecting hedonic perception[12]. Previous study indicated that the gradual sugar reduction according to the liking score was preferred over the stepwise method[14]. The protocol used in this study combined two methods together by gradually decreasing the amount of sugar (lower than DT), and also providing some time for the volunteer to get used to the new lower concentration before further sugar reduction. However, this study was framed within 21 days which was probably not long enough for some volunteers to get used to the new lower sweet level and be able to reach LSSC. This was observed in 2 volunteers. More sugar might be reduced with a longer experiment time.

After completing the protocol, volunteers reported that the SSBs they used to have were too sweet. This may have resulted from the volunteers being asked to avoid other SSBs during the program which helped them reduce daily added sugar, and get accustom to the new sweet level. People seem to choose the taste they familiar with[15]. Sweet hedonic perception or sweet liking has positive correlation with carbohydrate and total energy intake[16]. Thus, this protocol may help to change sweet sensitivity and perception, resulting in reduction of excessive energy intake.

Different composition in the drink can affect sweet perception and detection threshold[17]. Thus, the results from this study limit to the red color, sala flavor, sugar-sweetened drink or similar. Noted that the volunteers in this study are dental students, who may have high compliance since they concerned about excessive sugar intake. Various population group may have different result. In addition, other health outcome may be measured in the future, such as blood sugar level, stress hormone, and body mass index. Retention of the sugar reduction result and sweet perception may also be added in further study.

The ISSC set in this study was not fixed for all volunteers, but selected from their favorite one among the drinks they rated as 'like very much', which may not as sweet as the commercial SSBs. Therefore, the amount of sugar reduction by the protocol in real life might be different from the value obtained in the study. According to taste response curve, perceived sweet intensity increase responding to higher sugar concentration until reaching the saturated point of sweet sensory response[17]. It is likely that the percentage reduction would be larger if the commercial SSBs sugar concentration is higher than the ISSC.

Wipassawong et al[18] investigated the preference of sweetened test drinks in 12-year-old children and found that the median sugar concentration most liked by the children was 0.20 mol (6.85% w/v) which was approximately 50% less than the concentration of SSBs surveyed in the present study. Taken together with our finding, the LSSC could be further reduced in children.

What is already known on this topic?

Sugar reduction may affect hedonic perception, particularly in people under stress[10]. Gradual sugar reduction is a recommended method to decrease added sugar in SSBs[12,13] and is favored over stepwise technique[14]. A previous study employed the gradual sugar reduction at population level and found that gradual reduction of sugar was acceptable for customers, but the wide variation of liking score was observed[19].

What this study adds?

The authors developed a stepwise sugar reduction protocol which gradually decreased the amount of sugar concentration within the individual's DT and was able to maintain individual satisfaction. This protocol was designed for individual level and allowed time for individuals to get accustomed to the new lower concentration before further sugar reduction. Almost half of sugar in SSBs can be reduced within 21 days.

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Potential conflicts of interest

The authors declare no conflicts of interest.

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ผลของการลดน้ำตาลทีละขั้นต่อความพึงพอใจในเครื่องดื่มรสหวาน

สวิตา คิ้มสุขศรี, ศรีวิสุทธิ์ ถังคบุตร, จิติภัสร์ ตาปนานนท์, ศุภาพิชญ์ แสงอรุณ, อาริยา รัตนทองคำ, จรินทร์ ปภังกรกิจ

ภูมิหลัง: การบริโภคน้ำตาลปริมาณมากมีผลเพิ่มความเสี่ยงต่อโรคฟันผุ โรคอ้วน และโรคไม่ติดต่อเรื้อรังอื่นๆ โดยเฉลี่ยคนไทยบริโภคน้ำตาลต่อวัน เกินกว่าปริมาณที่องค์การอนามัยโลกแนะนำเพื่อให้มีสุขภาพที่ดีค่อนข้างมาก การลดการเติมน้ำตาลในอาหารและเครื่องดื่มเป็นวิธีหนึ่งที่สามารถทำได้ ซึ่งวิธีการและขั้นตอนที่ชัดเจนอาจช่วยให้ประสบความสำเร็จในการปรับลดน้ำตาลได้

วัตถุประสงค์: เพื่อศึกษา 1) ปริมาณน้ำตาลในเครื่องดื่มที่ลดได้โดยยังคงระดับความพึงพอใจของอาสาสมัคร และ 2) ระยะเวลาที่ใช้ในการปรับลดน้ำตาลกระทั่งถึงความเข้มข้นสุดท้ายที่ยังคงพึงพอใจ

วัสดุและวิธีการ: อาสาสมัคร 35 คน (อายุ 20 ถึง 25 ปี, ชาย 14 คน) ได้รับการทดสอบกับเครื่องดื่มรสหวาน (ประกอบด้วย น้ำตาล แต่งสีแดงและกลิ่นสละ) ที่มีการลดความเข้มข้น ของน้ำตาลอย่างต่อเนื่องทุกวัน โดยให้อาสาสมัครเลือกความเข้มข้นของเครื่องดื่มรสหวานที่พึงพอใจเป็นความเข้มข้นเริ่มต้น จากนั้นอาสาสมัครแต่ละคนจะได้รับเครื่องดื่ม รสหวานที่ได้รับการปรับลดความเข้มข้นของน้ำตาลลงทีละน้อย และให้อาสาสมัครใช้เวลาปรับตัวกับเครื่องดื่มดังกล่าวจนกว่าพึงพอใจในความเข้มข้นที่ลดลงนั้น เมื่ออาสาสมัครพึงพอใจในความเข้มข้นที่ลดลงแล้วจึงทำการลดความเข้มข้นของน้ำตาลลงอีก ทำเช่นนี้อย่างต่อเนื่องทุกวัน และการทดสอบสิ้นสุดเมื่ออาสาสมัครไม่พึงพอใจในรสหวานของเครื่องดื่มที่ใช้ทดสอบ บันทึกความเข้มข้นที่น้อยที่สุดที่อาสาสมัครพึงพอใจ และจำนวนวันที่ใช้ในการทดสอบ

ผลการศึกษา: ความเข้มข้นของน้ำตาลเริ่มต้นที่อาสาสมัครพึงพอใจเท่ากับ 6 ถึง 15% (ค่าเฉลี่ย = 10.26±2.29%) โดยมวลต่อปริมาตร และเมื่อทำการลดน้ำตาล ทีละขั้น พบว่าความเข้มข้นน้อยที่สุดที่อาสาสมัครพึงพอใจเท่ากับ 1.5 ถึง 9.0% (ค่าเฉลี่ย = 5.17±1.85%) โดยมวลต่อปริมาตร การปรับลดความเข้มข้นของน้ำตาลในเครื่องดื่มโดยการปรับลดทีละขั้นนี้สามารถลดน้ำตาลลงได้เฉลี่ย 49.96±14.00% เมื่อเทียบกับความเข้มข้นเริ่มต้น และใช้เวลาในการปรับลดเฉลี่ย 10 วัน

สรุป: การปรับลดน้ำตาลทีละขั้นเป็นวิธีที่ได้ผลดีในการลดความชอบรสหวาน และสามารถทำได้ในระยะเวลาไม่นาน