

## Sip-Sizing Behaviors in Natural Drinking Conditions Compared to Instructed Experimental Conditions

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**Abstract** To understand disordered physiology, it is first necessary to determine what constitutes normal function. Liquid sip size during swallowing in healthy individuals has been investigated with varied results. Bolus size is a variable that is manipulated in both research studies and clinical

swallowing assessments, so defining normal sip size has relevance in both domains. This study looked at sip size under instruction in experimental tasks and compared it to sip size in free drinking while participants were unaware that drinking was being observed. A statistically significant difference was found in water sip volume between natural drinking (mean = 16 ml) and instructed experimental drinking tasks (mean = 6.6–6.8 ml). This difference far exceeded the magnitude of sip-size variation observed between instructed drinking tasks using different stimuli and as a function of participant's gender or age group.

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Recommended protocols for swallowing assessment usually involve the administration of boluses of different volumes. For example, in her seminal text “Manual for the Videofluorographic Study of Swallowing” [1], Logemann recommends beginning a videofluoroscopic swallowing assessment (VFSS) with stimuli in 1-ml volumes, and then systematically evaluating the patient's tolerance of 3-, 5-, and 10-ml volumes before testing an uncontrolled cup-drinking volume. Several authors previously investigated normative values for sip size. However, the questions, methods, and results of these investigations differ and demand further clarification.

Among the earliest studies of normal sip size are those of Halpern [2] and Jones and Work [3]. Halpern evaluated sip volume in 12 adult participants during single sips of water, a sucrose solution, and cherry Kool-Aid. For water, a mean sip size of 12.75 ml (range = 4–29 ml, SD = 6.97) was reported; mean sip sizes for sucrose and cherry Kool-Aid

were slightly higher at  $13.32 \pm 6.94$  and  $13.61 \pm 6.82$  ml, respectively. Jones and Work [3] asked 24 healthy adult participants to drink the entire contents of a cup filled with 175 ml of water and measured average sip size by dividing the cup volume by the number of sips taken. They reported a larger mean sip size for men (mean = 21.3 ml, SD = 4.9 ml) than women (mean = 13.6 ml, SD = 2.9 ml), but did not evaluate the statistical significance of this gender difference.

Adnerhill et al. [4] measured sip size for three different thin-liquid stimuli (water, cola, and a 40% weight-to-volume barium suspension) in healthy participants. Sixty participants were given cups containing 150 ml of each liquid in a counterbalanced order and asked to freely drink from the cup “so [as to] comfortably swallow the contents in one gulp.” The authors concluded that men had an average thin-liquid sip size of 25 ml, which was significantly larger than the 20-ml sip size seen in women. Sip size for barium was significantly smaller than for the water and cola stimuli.

A more recent study by Lawless et al. [5] had similar results to those of Adnerhill et al. [4] but used slightly different methodology. In the first of two experiments, 100 healthy participants (assigned to two groups on the basis of body size) were asked to take sips of water from cups containing 150, 300, and 600 ml of room-temperature water, and then to expectorate the sip into a sample cup for measurement. The instruction to participants regarding sip size was to take “a normal drink of water—not a ‘taste’ and not a ‘gulp’—an amount that can be taken into the mouth and cleared with one swallow” [5]. Average sip sizes for the normal sip volume task were reported to range from 23.7 to 27.2 ml, with significantly larger sip volumes taken from the larger vessels. Males were reported to have sip sizes “about 50% higher than females,” which was a statistically significant difference.

The second experiment reported by Lawless et al. [5] investigated the stability of sip volume across a different series of sequential swallows, ranging from one to five swallows per series, taken from 300-ml vessels filled to 0.6 mm from the top with water. Both sipping and straw-drinking were evaluated using this method, and a normal sip was once again defined as in the first experiment discussed above. Participants included 67 young and 22 elderly participants. Although descriptive statistics were not reported, average sip volumes (which were larger for sipping than for straw-drinking) were reported to decrease significantly with an increase in the number of swallows requested in the series. Once again, male participants were reported to have significantly larger sip volumes than females; no significant differences were found between the two age groups of participants.

Straw-drinking sip volumes were also studied in a group of 292 healthy volunteers by Nilsson et al. [6]. Participants

were asked to drink from a cup containing 200 ml of water using a straw, while an analog scale provided a continuous record of cup weight. Two discrete swallows of normal volume were performed at normal speed before a timed test using the remainder of the water in the cup. Average sip volumes of  $25.6 \pm 8.5$  ml were reported for the discrete swallows, and smaller sip volumes of  $21.1 \pm 8.2$  ml were reported during the sequential swallows performed during the timed test. The statistical significance of these differences was not explored.

These latter three studies [4–6] concur with each other in reporting average sip volumes in the range of 20–25 ml for thin-liquid stimuli taken by cup or straw. However, these volumes are considerably larger than those reported previously by Halpern [2] and Jones and Work [3]. In reviewing these studies, it is apparent that experimental methods and instructions may well influence sip size. Previous studies from our own laboratory suggest that natural sip-sizing behaviors (i.e., those observed during swallowing when no explicit instruction is given regarding sip size) typically involve smaller volumes than those reported in the studies by Adnerhill et al. [4], Lawless et al. [5], and Nilsson et al. [6]. In a study of tongue movement during reiterated sequential swallows of radiopaque (barium) and nonopaque stimuli, we reported an upper 95% confidence interval boundary for thin-liquid sip volume of 10 cc [7]. Our small sample of eight healthy individuals took significantly larger sip volumes for nonopaque liquids compared to opaque liquids. Recognizing that one important characteristic of barium sulfate suspensions is their density (weight per unit volume), we explored the possibility that sip-size regulation was influenced by density and found that comparisons of sip size using sip mass as the unit of interest (rather than sip volume) did not differ significantly across the different stimuli in that study.

For the present investigation, we conducted further observations of sip-sizing habits during a study of swallowing kinematics. Because prior studies have adopted the convention of reporting average sip-size statistics over a series of swallows, we wanted to confirm the absence of a systematic trend in sip size across sips taken in series. We wanted to further explore the influence of differences in bolus characteristics on sip size, presuming that differences in stimulus density (such as would occur between honey-thick and thin liquids) would influence sip size, while differences in stimulus taste for liquids of equivalent density or viscosity would not. In particular, we wanted to explore the possibility that the instructional nature of studies on sip size creates a bias by drawing attention to sip size as the phenomenon of interest. To the extent possible, we wanted to measure sip-sizing behaviors in individuals performing natural drinking tasks, naïve to the fact that sip

size was under observation. Specifically, we sought to test the following null hypotheses:

1. sip size does not differ across water sips taken in series;
2. sip size does not differ as a function of gender or age;
3. sip size does not differ across stimuli of differing consistency (thin vs. honey-thick liquids);
4. sip size does not differ across thin-liquid stimuli of differing taste (water vs. moderate-intensity sweet vs. moderate-intensity sour vs. moderate-intensity sweet-sour vs. high-intensity sour liquids);
5. sip size does not differ between natural-drinking behaviors and those observed under experimental instructed conditions.

## Methods

### Participants

Data are reported for 32 adults who volunteered as healthy control participants for a study of tongue kinematics during swallowing. Participants were recruited in two age groups: under 50 (8 male, 8 female) and over 50 (8 male, 8 female). All participants underwent a standardized oral mechanism examination and clinical swallowing examination by a registered speech-language pathologist to confirm the absence of any signs or symptoms of swallowing difficulty prior to inclusion in the study. Individuals with prior history of stroke, neurologic disease, gastrointestinal disease, or dysphagia were excluded. The study was approved by the local institutional research ethics board.

### Procedures

This study involved the collection of sip-size data during four different tasks: (1) a natural, uninstructed drinking task, (2) a modified Kidd Water Swallow Test [8], (3) reiterated discrete swallows of thin and honey-thick apple juice (measured during a swallowing kinematics experiment), and (4) reiterated discrete swallows of thin-liquid stimuli differing in taste (again measured during a swallowing kinematics experiment).

The first task, a natural, uninstructed drinking task, was included as part of an intake interview in which the participant's eligibility to participate in a swallowing kinematics study was confirmed. An 8-oz glass filled with 200 ml of cold water (7°C) was provided, resting on a concealed scale, and casually drawn to the participant's attention once with the words, "That water is for you if you're thirsty." The pre-experiment interview took approximately 1 h to complete. The interviews were video-recorded and participants wore a laryngeal microphone (DynaMIC™ TM100 transdermal neck microphone,

ALDS-Distributing Inc., Langley, BC) that recorded an audio signal of swallows as they occurred during the interview. The purpose of this microphone was not to acquire a precise waveform representing acoustic events in swallowing but rather to acquire an audio recording that could be used to assist in verifying the temporal location of sip-swallow events in the session. The two receiver heads of the microphone were positioned over the lateral aspect of the larynx, just inferior to the thyroid cartilage [9], equidistant from the midline of the neck (Fig. 1). The microphone cable was attached to the audio-in port of a digital camcorder that was used to acquire a video of the entire session. Each time a participant took a drink from the cup on the concealed scale, the interviewer discreetly noted the cup weight after drinking. The participant was naïve to the fact that sip size was being monitored by the experimenter and this was subsequently confirmed at the end of the interview when the purpose of the cup was disclosed. For the subsequent analysis, the temporal location of sips to be included as data points was confirmed in the following way: Two research assistants watched the video recordings of the sessions and listened to the audio signal acquired from the throat microphone in order to perceptually identify the temporal location of sounds that were characteristic of swallows (sometimes described in the literature as a double-clunk-swoosh sound [10]). When the identified candidate swallowing sound corresponded to video segments meeting three criteria, the event was confirmed as a



**Fig. 1** This image shows the location of the microphone used in the natural-drinking task to acquire an audio recording to assist in identifying the location of sip-swallow events. The receiving heads of the microphone were positioned over the lateral aspect of the larynx, just inferior to the thyroid cartilage, and equidistant from the midline

sip-swallow event for the purposes of the analysis. The three video criteria were: (1) the participant was observed to take a drink from the cup prior to the sound, (2) there was visible movement of the thyroid cartilage representing a swallow corresponding temporally to the candidate sound, and (3) the digital balance was noted to show a change in cup mass when the cup was returned to the balance following the observed sip-swallow behavior. In the event that a candidate sound did not correspond temporally to both an observed sip from a cup with a subsequent change noted in cup mass and to visible movement of the thyroid cartilage on the video, the candidate sound was determined not to represent a clear sip-swallow event and the number of sips and associated natural-drinking sip size could not be calculated with validity for that participant. Similarly, in the event that thyroid cartilage elevation was observed on the video segment without observation of a preceding sip taken from the cup (with an associated change in cup mass observed on the digital balance) and/or without a corresponding characteristic swallowing sound on the audio recording, it was determined that the number of sips taken by that participant during the natural-drinking task could not be calculated with confidence and this task was excluded from the analysis for that participant. This process resulted in the exclusion of free water sip data from 11 participants for whom the clear correspondence between the video and acoustic recordings and cup mass measurements could not be established. One possible explanation for the difficulty in verifying sip-swallow events in the acoustic recordings collected from these participants is that the microphone came with a fixed, nonexpandable diameter. Consequently, the specific position of the receiver heads was not fixed relative to the front of the neck across participants (due to variations in neck circumference) and thus the receiver head position may not have been ideal in some participants.

The second data collection task was a modified Kidd Water Swallow Test [8], completed as part of the intake procedures to confirm the absence of dysphagia. In this test the participant was presented with a series of six cups, each prefilled by syringe with 20 ml of water. Participants were asked to take six discrete sips in a row (one sip from each cup in series) at a comfortable rate. The cups were weighed before and after completion of this task. This provided a means of observing sip-size variation across individual sips within a series of reiterated discrete swallows.

Finally, sip-size measurements were collected during two different data collection sessions that measured the kinematics of tongue movement in swallowing using electromagnetic midsagittal articulography (described elsewhere [11]). Following preparation, participants were asked to perform reiterated swallows in a discrete manner, with the instruction to “Take a series of sips, taking the cup

an inch away from your mouth each time.” Cups prefilled by syringe with 50 ml of the stimulus were weighed on a digital scale preceding and immediately following each swallowing series. Average sip mass measurements were derived as follows: the difference between pretrial-set cup weight and posttrial-set cup weight, divided by the number of sips taken in the trial. These measurements were then converted to volumetric measures by dividing the average sip mass by the 1/50th of the pretrial-set cup weight (i.e., the weight of 1 ml of the stimulus). In the first of these two data collection sessions, the swallowing tasks included reiterated discrete swallowing of thin apple juice (Allen’s) and honey-thick apple juice (Resource), served at a chilled temperature (7°C). Sip size data for the first two trials of each of these stimuli were extracted for the current analysis. In the second data collection session, swallowing kinematics were measured during reiterated discrete swallowing with five thin-liquid stimuli that differed in taste. Four pure tastant stimuli (without aroma) were prepared to match stimuli used in previous taste and swallowing research [12–15]: a moderate-intensity sweet solution (10% w/v sucrose), a moderate-intensity sour solution (0.15% w/v citric acid), a high-intensity sour solution (2.7% w/v citric acid), and a moderate-intensity sweet-sour solution (1.11% w/v citric acid, 8% w/v sucrose). Water was used as the control taste stimulus. Due to the potential for tastants to have residual effects on swallowing behaviors with subsequent stimuli, each tastant trial was immediately followed by two water trials, the first of which was considered a rinse trial. For the current analysis, sip size data were extracted from the first nonrinse trial of each stimulus served at a chilled temperature (7°C).

### Analyses

Data were entered into a spreadsheet and imported into SPSS 13.0 (SPSS Inc., Chicago, IL) for further analysis. To address the question of variation in sip size across water sips taken in series, repeated-measures analyses of variance (ANOVAs) with a within-participant factor of swallow number (1-6) and between-participant factors of gender and age group (young vs. older) were performed on data for the six discrete water swallows taken from different cups during the Kidd Water Swallow Test task. To address the question of differences in sip volume across liquids of different consistency, repeated-measures ANOVAs with a within-participant factor of stimulus (thin vs. honey-thick apple juice) and between-participant factors of gender and age group (young vs. older) were performed on the discrete swallow data collected during the first swallowing kinematics data collection session. To address the question of differences in sip volume across thin liquids of different taste, repeated-measures ANOVAs with a within-

participant factor of stimulus (water, moderate-intensity sweet, moderate-intensity sour, moderate-intensity sweet-sour, and high-intensity sour) and between-participant factors of gender and age group (young vs. older) were performed on the discrete swallow data collected during the second swallowing kinematics data collection session.

Finally, to address the question of differences in sip size between natural-drinking behaviors and experimentally instructed-drinking conditions, repeated-measures ANOVAs with a within-participant factor of task (natural, the modified Kidd Water Swallow Test, water swallows from the swallowing kinematics data collection sessions) and between-participant factors of gender and age group (young vs. older) were performed. Due to the aforementioned challenge of identifying the location of swallows in the natural-drinking task with confidence, this final comparison could be performed using only the data from the 21 participants who had complete data for all tasks (3 younger females, 5 younger males, 8 older females, and 5 older males). An  $\alpha$  criterion of  $p < 0.05$  was used for all statistical comparisons.

## Results

Descriptive statistics for each task and stimulus are given in Tables 1 and 2. No statistically significant differences were found in sip volume between swallows at different points in the series of sips taken in the Kidd Water Swallow Test [ $F(5,22) = 2.126, p = 0.07$ ], and there were no significant gender effects or interactions. A statistically significant difference in sip size was observed between participants under vs. over age 50 [ $F(1,26) = 7.278, p = 0.012$ ], with the younger participants having larger sip sizes.

In the comparison of thin vs. honey-thick apple juice sipped from a cup, a statistically significant main effect of stimulus was found [ $F(1, 28) = 41.029, p = 0.000$ ] with larger sip sizes observed with the thin-apple-juice stimulus. There were no significant main effects of gender or age group and no significant interactions.

In the comparison of sip size across different tastants, a statistically significant main effect of stimulus was found [ $F(4, 23) = 8.723, p = 0.000$ ]. *Post hoc* pairwise comparisons showed significantly smaller sip sizes for the high-intensity sour tastant compared to all other stimuli. In addition, sip sizes for the moderate-intensity sour tastant and for water were significantly smaller than those observed for the moderate-intensity sweet tastant. There were no significant main effects of gender or age group and no significant interactions.

In the comparison of natural (naïve) to experimentally instructed drinking tasks, a significant main effect of task was observed [ $F(2, 16) = 29.32, p = 0.000$ ], with smaller sips observed during instructed tasks compared to the free-drinking task (6–7 vs. 19 ml). In addition, a significant age group [ $F(1, 17), 22.92, p = 0.000$ ] effect was found, with larger sips taken by the younger participants (16 vs. 8 ml). No significant main effects of gender were observed.

## Discussion

The results of this study strongly suggest a previously unreported phenomenon, namely, that people take smaller sips when instructed to drink than when they are drinking freely without instruction. In this experiment, the overall mean sip volume observed in the natural, free-drinking task was 24 ml compared to the mean sip volume observed across our instructed-drinking tasks (6 ml). Differences between participants aged under 50 versus over 50, although statistically significant in certain comparisons, were of an overall average magnitude of 1 ml or less during instructed-drinking tasks. Furthermore, these data show strong evidence that sip size can vary under a variety of conditions, including (but not necessarily limited to) stimulus taste, stimulus consistency, cup size, and initial content volume. These data help to reconcile the differences reported in previous studies in which sip size has been reported to range from 4 to 30 ml, depending on the tasks and instructions used, and suggest that some prior

**Table 1** Descriptive statistics for sip volume (ml) for water in a natural free-drinking task compared to an instructed condition (modified Kidd Water Swallow Test)

		Natural, free drinking		Instructed drinking											
				Sip 1		Sip 2		Sip 3		Sip 4		Sip 5		Sip 6	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Younger	Females	30.87	12.60	6.66	2.51	8.10	2.83	7.36	2.61	7.61	2.97	8.66	3.08	8.71	3.26
	Males	34.48	16.50	9.57	3.92	7.32	2.44	8.28	2.59	7.29	1.96	9.24	4.04	8.67	4.19
Older	Females	15.47	5.39	5.76	2.97	5.92	3.10	6.35	3.54	8.47	3.99	8.26	3.69	8.90	4.67
	Males	13.86	3.53	3.69	0.68	3.82	1.13	4.33	1.10	4.50	1.58	4.43	0.81	4.74	1.16

**Table 2** Descriptive statistics for sip volume (ml) for different liquids during instructed drinking tasks in a swallowing kinematics experiment

		Instructed Drinking													
		Reiterated Discrete Swallows during Swallowing Kinematics Experiments													
		Thin apple juice		Honey-thick apple juice		Water		Sweet		Sour		Sweet Sour		High Sour	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Younger	Females	5.87	1.63	4.33	1.45	6.67	3.12	6.66	3.03	6.22	2.30	6.35	2.82	5.81	2.98
	Males	5.19	1.17	3.91	1.38	6.50	2.51	6.75	2.63	7.13	2.77	6.41	2.72	5.60	3.04
Older	Females	5.81	1.19	4.31	1.70	5.81	1.76	6.06	1.82	5.83	2.79	5.56	2.23	5.27	2.27
	Males	6.20	1.23	3.81	1.22	4.08	1.99	4.56	1.63	4.15	2.85	4.05	2.11	3.00	2.42

experiments have been more successful than others in mimicking natural-drinking conditions.

Some limitations to the interpretation of these findings must be acknowledged. First, the cups used across the tasks examined in this analysis were not of uniform size and did not contain the same volume of liquid for each task. The six sips of the discrete series of the modified Kidd Water Swallow Test was taken from cups containing 20 ml of water; the cups used in the swallowing kinematics experiment contained 50 ml of liquid; and the cups used in the natural-drinking task contained close to 200 ml of water. This may have been responsible for a ceiling effect on the sip sizes taken from the smaller cups containing less liquid. It should be noted, however, that one cannot attribute our results solely to the potentially limiting factor of cup volume because this would logically have yielded larger sip sizes in the swallowing kinematics task than that observed in the Kidd Water Swallow Test, and this was not the case. Second, because swallowing was being observed unobtrusively in the free-drinking task, the number and occurrence of swallows were collected using a laryngeal microphone and subsequently cross-tabulated with the video recording so that measures of liquid volume consumed per swallow could be calculated. The laryngeal microphone was attached around the back of the neck by a plastic ring that was not adjustable and that fit some participants better than others. This technical problem resulted in missing data for some participants due to poor-quality recordings of the acoustics of the swallow.

These limitations notwithstanding, the observation that sip size differs considerably between normal, typical drinking behavior and drinking behaviors elicited under instruction has immediate relevance for the procedures used by clinicians in bedside swallowing and videofluoroscopic swallowing assessments. Maximum sip volumes in instructed conditions, based on the results of this study, appear to be in the range of 10–12 ml. Swallowing assessment procedures usually involve instructed-drinking conditions and patients are aware that their drinking is being closely observed. Yet these assessments are used to

draw conclusions and make recommendations regarding typical daily drinking (and eating) behavior. To evaluate the risks associated with the swallowing of liquid stimuli of natural (uncontrolled) sip size, we conclude that clinicians should endeavor to incorporate one of two tasks into their assessments. First, it would be ideal to elicit a natural-drinking task for which the patient is not alerted to the possibility that drinking is being observed. Recognizing that this may not be feasible in an assessment context, a reasonable alternative would be to intentionally incorporate large-volume swallowing tasks (in the range of 25–30 ml) into assessment. Clinicians and researchers should recognize that any task in which a patient or volunteer is instructed to “take a sip” is likely to prompt drinking of a smaller volume than the individual might take in an unobserved context, such as drinking at a meal.

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