The timed water test of swallowing: Reliability, validity, and normative data from Indian population

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ABSTRACT

Objectives: Dysphagia post-stroke represents a substantial health issue. The rates of pneumonia are lesser among those individuals who have passed a dysphagia screening test. Only few among the existing screening tests meet the required standards; the timed water swallow test (TWST) is one among them. The purpose of the study was to establish normative data for the TWST in Indian population.

Methods: The present study involved 480 typical individuals in the age range of 8–80.11 years. All the participants performed TWST and indices of volume per swallow, time per swallow, and swallow capacity were obtained for the tasks of normal and rapid swallow across age and gender.

Results: In the first phase of the study, normative data were obtained and summarized by age and gender. The second phase of the study dealt with additional analyses on measures of reliability and validity. Two-way mixed ANOVA was performed with age and gender as the between-group variables, and normal and rapid swallowing as the within-group variables.

Conclusion: Normative values for the performance of Indian population on TWST were obtained. The results revealed a significant difference for all the three indices of swallow performance across age, gender, and type of swallowing. These norms can be used as a screening tool for identifying swallowing dysfunction.

Keywords: Swallowing, deglutition, dysphagia, screening test, post-stroke

Introduction

Dysphagia post-stroke represents a substantial health issue. Up to 70% of individuals may develop swallowing difficulties post-stroke,[1] with aspiration occurring in half of this population.[2] Aspiration has been the leading cause of pneumonia and has an odds ratio of 4.4 for mortality.[3] The morbidity and mortality rates have been directly related to post-stroke dysphagia screening;[4-6] specifically, there are reduced pneumonia rates among individuals who pass a dysphagia screening test.[5]

Dysphagia screening tools, like any other screening procedures, should be simple, valid, and have a reliable method identify the target problem with high sensitivity.[7,8] While there are several dysphagia screening tools, only a few meet the required standards of reliability, validity, and ease of use. A typical approach toward dysphagia screening usually involves some form of a clinical examination of oral structures and its functions, a cranial nerve evaluation, and observation of oral intake. An additional test of swallow with one or more materials may be included.[9-11] A successful screening would result in a predominantly subjective binary decision about the presence or absence of dysphagia. This approach may seem apt for identification and referral for further instrumental assessment in the case of more severe impairment. However, in patients with milder clinical presentation, the distinction between impaired and unimpaired function may be less evident.

Quantitative clinical measures would increase the clinical accuracy and aid in better decision-making. Further, these measures would serve as a valuable metric indicator of functional recovery for some aspects of swallowing. Hughes and Wiles[12] identified this need and developed the timed water swallowing test (TWST) to address the issue. The TWST provides quantitative information on swallow performance on the clinical assessment. It involves ingestion of either 100 or 150 ml of water from an open cup normally and comfortably. The number of swallows and total time taken for ingestion of the liquid are recorded along with clinical behaviors such as a change in voice quality, coughing, and choking. From the raw data, quantitative indices such as volume per swallow (ml), time per swallow (s), and the swallowing capacity (ml/s) are

calculated. The authors also included data from a subgroup of patients with motor neuron disease; the results revealed reduced swallowing capacity and reduced average volume per swallow in the clinical group. However, the test is not without drawbacks. Although the TWST falls short in providing accurate information on diagnostic specificity, the overall discriminative ability of test cannot be ignored. Several studies[13-15] have reported that the measures obtained from the test such as efficiency and speed of swallowing are sensitive enough to identify the presence of a swallowing impairment in a variety of neurological conditions.

One of the principal advantages of the TWST lies in its simplicity and ease of administration; it utilizes an internationally accessible material: Water. We have long been using TWST on a clinical basis, and our experience is that the results vary according to the instructions provided. However, this also motivated questions such as, would the participant's performances vary between the instructions "drink comfortably" versus "drink as fast as possible." The purpose of the study was to address these questions; further, there are no established normative for the TWST in Indian population. Even though the swallow physiology does not necessarily vary with race or nationality, physical attributes such as length and volume of the pharyngeal cavity vary. We believe that these variations in the physical attributes may influence the finer aspects of swallowing such as volume consumed or time taken to complete the swallow. Hence, the present study intended to investigate the performance of Indian population as a function of age and gender on TWST for the task of normal and rapid swallow. In the first phase of the study, normative data were collected and summarized by age and gender for the measures of volume per swallow (ml), time per swallow (s), and the swallow capacity (ml/s). The second phase of the study dealt with additional analyses on measures of reliability and validity.

Methods

Study design

We adopted a cross-sectional design with nonrandomized convenient sampling. The study was carried out at the Department of Audiology and Speech-Language Pathology, Kasturba Medical College, Mangaluru.

Participants

The study protocol was approved and conducted in accordance with the ethical standards of the Institutional Human Ethics Committee. The present study involved 480 typical individuals in the age range of 8–80.11 years, who were further divided into eight groups, as shown in Table 1.

The participants were included in the study after obtaining their written informed consent. For the younger group, parent/

Table 1: Depicting age-wise grouping of participants

S. No.	Groups (years)	Males	Females
1.	8–9.11	30	30
2.	10–11.11	30	30
3.	12–13.11	30	30
4.	14–15.11	30	30
5.	16–17.11	30	30
6.	18–40.11	30	30
7.	41–60.11	30	30
8.	61–80.11	30	30

guardian provided the consent to participate. All participants of the study were screened for speech and language difficulties, cognitive, neurological, or systemic diseases using the modified World Health Organization (WHO) checklist.[16] They were also specifically screened for swallowing difficulties, head and neck, neurological or gastroenterological illness, or injury using the Kannada version of Eating Assessment Tool 10 (EAT 10 K).[17] Only those participants who obtained a score of <3 on the EAT 10 K were included in the study.

Procedure

Participants performed TWST as described by Hughes and Wiles.[12] They were seated comfortably and were asked to drink 150 ml of water from a paper cup normally and comfortably. Then, participants were asked to drink the same amount of water "as quickly as possible." A stopwatch began when the water first touched the lips and stopped when the larynx came back to rest after the last swallow. The number of swallows performed by the participants was noted by observing the number of laryngeal elevations. Parameters such as volume per swallow (ml), time per swallow (s), and the swallow capacity (ml/s) were calculated for both normal and rapid swallow.

For the study of test retest reliability, 50 participants performed the TWST twice in a single session, using the same method of data collection. Within a single session, two raters were present to make independent measures of participant performance as an assessment of inter-rater reliability. Objective measures were collected after 24 h using combined modules of the KayPentax digital swallowing workstation to validate the behavioral findings of the TWST. The validation process was based on study by Huckabee *et al.*[18] with changes to operational definitions with respect to the aims and objectives of the present study. The modules of surface electromyography (sEMG) and the nasal cannula were used to operationally define the number of swallows and total time taken to swallow.

Number of swallows

A swallowing event was denoted by the presence of swallowing apnea in the nasal cannula module, accompanied by a peak in the submental muscle sEMG activity.

Total time taken

The objective measure for total time taken was the duration from the initiation of by sEMG signal until the time in which there was a large acoustic signal, indicating that the participant had said their name to indicate that they had finished.

Data preparation and statistical analyses

Descriptive statistics were performed to obtain mean and standard deviation for the measures of timed test of swallowing across normal and rapid swallowing. Two-way mixed ANOVA was performed with age and gender as the between-group factor, and normal and rapid swallowing as the within-group factors.

Cronbach's alpha and intraclass correlation coefficients were used to evaluate test-retest consistency of performance across the three sessions and inter-rater reliability between two raters in a single session. Intraclass correlation coefficients were obtained to evaluate the validity of behavioral measures when compared with instrumental assessment. Analysis was also conducted to determine the inter-rater reliability between two raters evaluating the objective data. Finally, normative data were established for participants, calculated by age and gender as mean and standard deviation for the derived measures of volume per swallow, time per swallow, and swallow capacity.

Results

Normative data

Normative data represented by the mean and standard deviation for the TWST during the first trial: Volume per swallow [Table 2], time per swallow [Table 3], and swallow capacity

[Table 4]. Normative data are stratified by age, gender, and type of swallow (normal vs. rapid).

Effect of age, gender, and type of swallow

Volume per swallow

Two-way mixed ANOVA was performed with age and gender as between-group factor and type of swallow (normal and rapid swallow) as within-group factor. Results revealed significant difference for volume per swallow across age groups (F = 25.773; df = 7; $P = 0.000$), gender (F = 45.006; df = 1; $P = 0.000$), and type of swallows (F = 553.441; df = 1; $P = 0.000$). Interaction effect was observed between volume and age (F = 7.172; df = 7; $P = 0.000$), volume and gender (F = 5.304; df = 1; $P = 0.000$), and age and gender (F = 2.301; df = 7; $P = 0.26$). However, there was no interaction effect observed between volume, age, and gender (F = 1.075; df = 7; $P = 0.379$). Bonferroni *post hoc* analysis was performed for multiple comparisons from Group 1 to Group 8. The results revealed that there was a significant difference across the age groups from Group 1 to 8, indicating that as age increases, volume per swallow increases. However, the geriatric group did not exhibit significant differences with Groups 2 and 3. It may be indicative that the geriatrics (Group 8) may perform similar to that of the younger age groups with respect to the measure of volume per swallow.

Time per swallow

Comparisons were made using two-way mixed ANOVA with age and gender as between the group factor and type of swallow as within-group factor. Significant difference was seen across age range (F = 16.694; df = 7; $P = 0.000$) and for type of swallow (F = 88.126; df = 1; $P = 0.000$). However,

Table 2: Mean, SD, and CI at 95% of volume per swallow for normal and rapid swallowing across different age groups and gender

Age (years)	Gender	Normal swallow			Rapid swallow		
		Mean (ml)	SD	CI at 95%	Mean (ml)	SD	CI at 95%
8–9.11	Male	13.83	3.86	12.38–15.27	17.52	5.27	12.38–15.27
	Female	13.76	2.18	12.94–14.58	15.47	4.06	13.95–16.99
10–11.11	Male	19.09	4.35	17.47–20.72	22.11	4.49	20.23–23.79
	Female	19.19	3.42	15.06–17.26	22.91	4.80	16.79–19.7
12–13.11	Male	19.19	3.42	17.91–20.47	22.91	4.80	21.11–24.70
	Female	17.12	4.76	15.34–18.9	19.44	5.39	17.43–21.46
14–15.11	Male	21.55	5.07	19.66–23.45	25.51	5.54	23.44–27.59
	Female	18.24	3.51	16.93–19.56	21.84	4.34	20.22–23.46
16–17.11	Male	24.30	7.73	21.41–27.19	30.23	11.41	25.97–34.49
	Female	20.17	4.72	18.41–21.94	23.92	3.86	22.48–25.37
18–40.11	Male	23.67	5.85	21.48–25.86	31.40	8.24	28.32–34.48
	Female	21.16	4.97	19.31–23.02	26.24	5.85	24.05–28.42
41–60.11	Male	24.03	6.47	21.61–26.44	30.78	8.60	27.57–33.99
	Female	19.38	4.33	17.76–21	24.22	4.99	22.35–26.08
61–80.11	Male	20.84	5.04	18.96–22.72	27.75	6.99	25.14–30.36
	Female	18.04	5.63	15.94–20.14	22.86	5.55	20.8–24.91

Table 3: Mean, SD, and CI at 95% of time per swallow for normal and rapid swallowing across different age groups and gender

Age (years)	Gender	Normal swallow			Rapid swallow		
		Mean (s)	SD	CI at 95%	Mean (s)	SD	CI at 95%
8–9.11	Male	1.10	0.32	0.94–1.22	1.01	0.18	0.94–1.08
	Female	1.37	0.49	1.19–1.5	1.11	0.23	1.02–1.19
10–11.11	Male	0.96	0.13	0.91–1.01	0.89	0.17	0.82–0.96
	Female	1.02	0.24	0.86–1.05	0.89	0.18	0.81–0.98
12–13.11	Male	1.02	0.24	0.92–1.11	0.89	0.18	0.82–0.96
	Female	1.02	0.21	0.94–1.1	0.90	0.17	0.83–0.96
14–15.11	Male	0.90	0.14	0.84–0.95	0.78	0.15	0.73–0.84
	Female	1.09	0.29	0.98–1.2	0.92	0.18	0.85–0.99
16–17.11	Male	1.34	0.54	1.14–1.54	1.16	0.41	1–1.31
	Female	1.13	0.30	1.02–1.25	1.02	0.31	0.90–1.13
18–40	Male	1.23	0.35	1.09–1.36	1.05	0.22	0.96–1.14
	Female	1.21	0.27	1.1–1.31	1.02	0.18	0.95–1.09
41–60	Male	1.22	0.36	1.08–1.36	1.07	0.23	0.98–1.15
	Female	1.31	0.29	1.19–1.42	1.07	0.23	0.98–1.56
61–80	Male	1.35	0.48	1.17–1.53	1.37	0.60	1.14–1.6
	Female	1.32	0.31	1.2–1.44	1.12	0.22	1.03–1.2

Table 4: Mean, SD, and CI at 95% of volume per time for normal and rapid swallowing across different age groups and gender

Age (years)	Gender	Normal swallow			Rapid swallow		
		Mean (ml)	SD	CI at 95%	Mean (ml)	SD	CI at 95%
8–9.11	Male	13.57	5.79	11.41–15.74	17.71	6.26	15.38–20.06
	Female	11.29	4.94	9.45–13.15	14.48	4.63	12.75–16.21
10–11.11	Male	20.08	4.75	18.31–21.86	25.10	5.03	23.22–26.98
	Female	19.67	5.26	15.69–19.64	26.27	6.56	18.41–26.37
12–13.11	Male	19.67	5.26	17.7–21.63	26.27	6.56	23.82–28.72
	Female	17.00	4.77	15.22–18.78	21.77	5.45	19.73–23.81
14–15.11	Male	24.19	5.53	22.12–26.26	33.03	7.55	30.21–35.85
	Female	17.66	5.11	15.75–19.57	24.33	4.99	22.46–26.19
16–17.11	Male	19.18	5.29	17.2–21.15	27.08	7.07	24.43–29.72
	Female	18.44	5.11	16.53–20.37	25.05	7.02	22.22–27.64
18–40	Male	20.53	7.73	17.64–23.42	30.47	8.13	27.43–33.51
	Female	18.29	5.89	16.09–20.49	26.28	7.24	23.58–28.98
41–60	Male	20.88	6.94	18.28–23.47	29.11	6.48	26.69–31.53
	Female	15.79	5.87	13.6–17.99	23.81	7.84	20.88–26.74
61–80	Male	18.72	14.21	13.42–24.03	22.07	7.41	19.3–24.84
	Female	14.68	6.11	12.39–16.96	21.14	6.33	18.78–23.51

there was no significant difference could be observed for time per swallow across the gender (F = 0.203; df = 1; P = 0.653). Positive interaction effect was observed between age and gender (F = 3.802; df = 7; P = 0.000). Interaction effect was not observed between time and age (F = 0.832; df = 7; P = 0.561), time and gender (F = 4.675; df = 1; P = 0.031), and time, age, and gender (F = 1.130; df = 7; P = 0.343). Bonferroni *post hoc* analysis was carried out for multiple comparisons from Group 1 to Group 8. It can be inferred that there was a significant difference across the age groups from Group 1 to 8, indicating that as age increases, volume per swallow increases. However, the geriatric group did not exhibit significant differences with Groups 7 and 8, that is, 40–80 years, indicating that geriatric group may behaves like younger age groups with respect to time per swallow with advancements in age.

Volume per time
Two-way mixed ANOVA was performed on age and gender for the comparison of between the group variables, and on normal and rapid swallow for within-group variable. Significant

difference was observed for swallow capacity across age (F = 19.677; df = 7; P = 0.000), gender (F = 37.001; df = 1; P = 0.000), and normal and rapid (F = 538.365; df = 1; P = 0.000) measures of swallow. Interaction effect was observed between capacity and age (F = 5.101; df = 7; P = 0.000). However, there was no interaction effect observed between capacity and gender (F = 0.685; df = 1; P = 0.408), capacity, age, and gender (F = 1.412; df = 7; P = 0.198), and for age and gender (F = 2.557; df = 7; P = 0.014). Bonferroni *post hoc* analysis was carried out for multiple comparisons from Group 1 to Group 8. The results revealed that there was a significant difference across the age groups from Group 1 to 8, indicating that as age increases, swallow capacity increases, with a drop after 60 years of age.

Inter-rater and test-retest reliability

Inter-rater reliability
Cronbach's α for all measures between raters was >0.9, indicating a high level of internal consistency. The ICC values 0.964 for all the measures indicate an excellent internal reliability between the two raters.

Test-retest reliability
Test-retest reliability of TWST was also very high. The values of Cronbach's α ranged from 0.94 to 0.99. The ICC values ranged between 0.83 and 0.98 suggesting a high level of internal consistency.

Validity
The ICC value between instrumental and behavioral measures of the number of swallows, the ICC was 0.85 with a 95% confidence interval from 0.79 to 0.9. The ICC for time was 0.99 with a 95% confidence interval from 0.91 to 1. The ICCs for the reliability of two independent raters of the instrumental measures were >0.95 for the measure of total time taken. The ICC for inter-rater reliability of the number of swallows recorded by instrumental assessment was 0.79.

Discussion

TWST is rapid, requires minimal equipment, and could potentially be incorporated into the routine neurological examination. The test yields indices that can be used to quantify dysphagia at the level of disability, as defined by the WHO. The present study investigated volume per swallow, time per swallow, and swallowing capacity across age and gender for normal and rapid swallowing measures. The results are discussed under the following headings.

Time per swallow

The measure of time per swallow indicates the time taken by an individual to complete single swallow. Results revealed that time per swallow decreases with increase in age, with an increase after 60 years. These results suggest that changes in the vocal tract volume and brain maturation during the

childhood and adolescence decrease the time per swallow from 8 to 18 years and remain plateau during 18–59 years. However, this measure increases after 60 years. Increase in time per swallow in the geriatric group may be an indicator of slower speed of swallowing due to presbyphagia. Such compensations are believed to reduce the threat for aspiration in geriatric individuals. The prolongation of the speed of swallow can be attributed to age-related changes occurring in the oropharynx.[19] A slow swallowing speed can alert the clinician about dysphagia as a potential problem.[20]

The results of the present study did not reveal a significant difference for the measure of time per swallow across the gender. However Moreira and Pereira[21] reported that mean time per swallow were similar for both genders. Results also revealed that time per swallow measure were faster with rapid swallowing than the comfortable swallowing. This could be due to the faster intake in the volume for the rapid swallowing measure in comparison to normal comfortable swallowing. These findings indicate that swallowing speed (<10 ml/s) may be a sensitive indicator of a swallowing problem.[22]

Volume per swallow

Volume per swallow reflects the amount of water consumed in a single swallow. This is calculated by the total volume (150 ml) divided by the total number of swallows. Difference in volume per swallow across age was observed in the present study. This effect may be associated with an increased oral and pharyngeal cavity volume, thus permitting accommodation of larger bolus volumes to be swallowed with advancements in age. However, volume per swallow decreases after 60 years of age. This can be attributed to the loss of the integrity of muscle mass and elasticity results in a loss of strength and speed of movement. Difference in volume per swallow for gender was also observed in the present study. These differences might be due to the fact that males have longer vocal tract in comparison to females. This increased oral and pharyngeal cavity volume in males would have allowed more volume of water to be swallowed than females. On the other hand, significant differences were noted across normal and rapid swallowing for volume per swallow. Greater demand for consuming more volume during rapid swallowing when compared to comfortable swallowing could have been the reasons for the present findings.

Swallow capacity

Swallow capacity reflects the ability of the person to swallow specific quantities of water in a given time. Significant differences in swallowing capacity across age were observed, indicating that swallowing capacity improves with age during the childhood and reaches an adult value. This effect may be associated with an increased oral and pharyngeal cavity volume, letting larger bolus volumes to be swallowed in a shorter period of time with age. However, swallowing capacity decreases after 60 years of age. Reduced swallowing capacity

in geriatrics can be due to the reduction in average bolus volume, or prolongation of average time per swallow, or a combination of both.

Changes in the swallowing capacity due to the reduction in volume per swallow or increased time per swallow in geriatric group may be expected as a compensatory mechanism for the changes in the swallowing behavior as a result of aging.[12] Significant difference in swallow capacity for gender was observed, this can be attributed to the increased oral and pharyngeal cavity volume in males would have allowed more volume of water to be swallowed than females which intern increased the swallow capacity in males. Significant differences were noted across normal and rapid swallowing for swallow capacity. Greater demand for consuming more volume during rapid swallowing when compared to comfortable swallowing could have been the reasons for the present findings.

Changes in average time per swallow and average bolus volume contribute to significant reduction in swallowing capacity seen in healthy aged individuals; "taking smaller sips" and spending longer time on each swallow are obvious ways of reducing the risk of occurrence of overt decompensation.[12] This may pose the individual at risk for developing swallowing problem at the later course of life span. Hence, decreased swallowing capacity is a likely indicator of abnormal swallowing behavior. Furthermore, swallowing capacity has been shown to have high inter-rater and intra-rater reliability and high test-retest reliability.[18]

Reduced swallowing capacity and a reduced average volume per swallow are associated with a number of signs and symptoms indicative of a swallowing problem providing further evidence of the validity of these indices as measures in patients with neurogenic dysphagia. Significant differences in swallowing capacity among gender were observed which implies that swallowing capacity was better in males when compared to females. This can also be attributed to the anatomical changes that are seen with an increased oral and pharyngeal cavity volume.

Conclusion and Future Directives

The present study established normative for the TWST in the Indian population across rapid and normal comfortable swallow. These norms can be used as a screening tool for identifying swallowing dysfunction in the clinical population in the Indian population. Furthermore, these norms would serve as a base for comparison with the disordered swallowing. However, the present study used only 150 ml of water for timed test of swallowing. Even though, TWST was sensitive to parameters of age and gender, it is not without its drawbacks. It cannot differentiate individuals who drink safely but slowly from those who drink quickly and unsafely.

Authors' Declaration Statements

Ethical Approval

Ethical approval of this study was taken from Institutional Human Ethics Committee of Kasturba Medical College, Mangalore, Manipal Academy of Higher Education, Karnataka, India.

Consent to participate: All the participants signed an informed consent form.

Consent for publication: All the authors of the study provide their consent for publication.

Availability of data and material: The data used in this study are available and will be provided by the corresponding author on a reasonable request.

Competing Interest: The authors declare none.

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Authors' Contributions: All the authors have equally contributed in every stage in the preparation of this manuscript.

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