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Research Article

Objective and Subjective Clinical Swallowing Outcomes via Telehealth: Reliability in Outpatient Clinical Practice

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Purpose: The COVID-19 pandemic has drastically increased the use of telehealth. Prior studies of telehealth clinical swallowing evaluations provide positive evidence for telemanagement of swallowing. However, the reliability of these measures in clinical practice, as opposed to well-controlled research conditions, remains unknown. This study aimed to investigate the reliability of outcome measures derived from clinical swallowing tele-evaluations in real-world clinical practice (e.g., variability in devices and Internet connectivity, lack of in-person clinician assistance, or remote patient/caregiver training).
Method: Seven raters asynchronously judged clinical swallowing tele-evaluations of 12 movement disorders patients. Outcomes included the Timed Water Swallow Test (TWST), Test of Masticating and Swallowing Solids (TOMASS), and common observations of oral intake. Statistical analyses were performed to examine inter- and intrarater reliability, as well as qualitative analyses exploring patient and clinician-specific factors impacting reliability.
Results: Forty-four trials were included for reliability analyses. All rater dyads demonstrated "good" to "excellent" interrater reliability for measures of the TWST (intraclass correlation coefficients [ICCs] ≥ .93) and observations of oral intake (≥ 77% agreement). The majority of TOMASS outcomes demonstrated "good" to "excellent" interrater reliability (ICCs ≥ .84), with the exception of the number of bites (ICCs = .43–.99) and swallows (ICCs = .21–.85). Immediate and delayed intrarater reliability were "excellent" for most raters across all tasks, ranging between ICCs of .63 and 1.00. Exploratory factors potentially impacting reliability included infrequent instances of suboptimal video quality, reduced camera stability, camera distance, and obstruction of the patient's mouth during tasks.
Conclusions: Subjective observations of oral intake and objective measures taken from the TWST and the TOMASS can be reliably measured via telehealth in clinical practice. Our results provide support for the feasibility and reliability of telehealth for outpatient clinical swallowing evaluations during COVID-19 and beyond.
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The global pandemic caused by *severe acute respiratory syndrome coronavirus 2* has drastically shifted the health care landscape. The multimodal nature of viral transmission via contact, aerosols, and droplets, as well as a limited understanding of mechanisms underlying superspreading events and asymptomatic carriers, poses significant risk to health care providers (Frieden & Lee, 2020; Pasnick et al., 2020). For the dysphagia practitioner, the potential for aerosol and droplet generation from coughing, sneezing, or speaking during clinical and instrumental swallowing evaluations is high (Miles et al., 2020; Stadnytskyi et al., 2020; Workman et al., 2020). The use of telecommunication technologies to support long-distance clinical health care, or telehealth, provides an opportunity to eliminate these risks for both the patient and health care provider. In the United States, for example, several federal and state restrictions have been lifted, paving the way for the rapid adoption of telehealth during the pandemic. In fact, one U.S. health care system, composed of four hospitals and more than 500 ambulatory locations, had a 4,345% daily increase in nonurgent virtual visits (Mann et al., 2020). Together, this highlights the need for research studies identifying clinical

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measures and outcomes that can be reliably adapted from the traditional in-person service delivery to telehealth.

Remote modalities for evaluating and treating dysphagia have existed for nearly 2 decades, most recently focusing on the feasibility and preliminary efficacy of the administration and interpretation of clinical swallowing evaluations and teletreatment services (Burns et al., 2017; Malandraki et al., 2013, 2014; Ward et al., 2014, 2012; Weidner & Lowman, 2020). Specifically, the feasibility of using telehealth for clinical swallowing evaluations has been shown in a variety of patient populations, including patients with cerebral palsy, head and neck cancer, stroke, and neurodegenerative disease (Kantarcigil et al., 2016; Morrell et al., 2017; Sharma et al., 2011; Ward et al., 2013, 2014, 2009, 2012). Researchers have identified adequate agreement between telehealth and in-person clinical swallowing evaluations (Morrell et al., 2017; Ward et al., 2014, 2012), as well as high inter- and intrarater reliability across multiple components of the evaluation, including orientation and alertness, pre-oral stage components (e.g., feeding independence, utensils used), oromotor function, food and liquid trials, and clinical recommendations (Kantarcigil et al., 2016; Ward et al., 2012). Implementation of a telehealth model for swallowing management has also resulted in reductions in the number and duration of in-person contacts and reductions in cost (Burns et al., 2019, 2017), and has been associated with increased patient and provider satisfaction (Burns et al., 2019; Malandraki et al., 2014). Collectively, the aforementioned studies provide preliminary evidence for the feasibility, validity, reliability, and clinical utility of telehealth for clinical swallowing evaluations and management. These findings suggest that clinical swallowing evaluations delivered via telehealth have the potential to be equivalent to in-person services in clinical practice—an important requirement from several accrediting bodies, including the American Speech-Language-Hearing Association (2020).

Despite this growing body of literature supporting the use of telehealth for clinical swallowing evaluations and management, there are two major gaps in the literature that warrant investigation in order to promote translation of research findings to clinical practice. First, prior studies of clinical swallow tele-assessments have largely focused on subjective ratings of common clinical parameters of oral intake, such as anterior labial leakage, number of swallows, or overt signs of aspiration (Sharma et al., 2011; Ward et al., 2014, 2012), but have not included objective clinical measures of swallowing, such as the Timed Water Swallow Test (TWST; Hughes & Wiles, 1996) or the Test of Masticating and Swallowing Solids (TOMASS; (Huckabee et al., 2018; Lamvik-Gozdzikowska et al., 2019). The TWST and the TOMASS attempt to standardize measures of swallowing performance, providing clinicians with objective outcomes to compare with normative data in healthy adults (Huckabee et al., 2018; Hughes & Wiles, 1996) and children (Frank et al., 2019). The TWST involves drinking 100–150 ml of water "as quickly as is comfortably possible" while the clinician records the time, volume, and number of swallows taken to consume the liquid (Hughes & Wiles, 1996), which can be used to calculate aggregate outcomes (e.g., average volume consumed per swallow, time per swallow, and volume per second). The goal of the TOMASS is to quantify oral efficiency by recording the number of bites, masticatory cycles, swallows, and time to consume a solid bolus (Huckabee et al., 2018). Though these tasks do not provide direct visualization of oral or pharyngeal physiology, they offer valuable quantified information to help guide the generation of hypotheses during a clinical swallowing evaluation through a highly standardized and objective approach. However, the reliability and feasibility of incorporating these objective tools into telehealth clinical swallowing evaluations is currently unknown. Reliability is an important psychometric property of measurement tools because it ensures that ratings are stable between and within raters and provides appropriate precision to track change over time due to changes with therapy or disease progression (Cook & Beckman, 2006).

A second gap in the literature is that the majority of the aforementioned telehealth studies have been conducted under well-controlled conditions, which may be difficult for clinicians to adopt given limited resources, including time and financial constraints. For example, the majority of prior studies involving telehealth for clinical swallowing evaluations have included trained facilitators, minimum Internet connectivity requirements, and specialized hardware and equipment configured and assembled by researchers or expert technical staff, including custom videoconferencing software, noise-canceling microphones, external custom light sources, and multiple cameras remotely controlled by the telehealth clinician (Kantarcigil et al., 2016; Sharma et al., 2011; Ward et al., 2013, 2014, 2009, 2012). Furthermore, the clinician was often situated in the same facility as the patient (Ward et al., 2013, 2012). Whereas some of these factors, such as facilitator training, may be feasible for clinicians, others like the use of high-tech main and peripheral equipment may be less feasible. It is unknown whether the specialized equipment or controlled conditions used in these prior studies are still required to ensure the reliability of clinical measures given the increased availability of broadband Internet and improvements in camera and microphone quality of mobile devices. Though the validity and implementation of telehealth for the clinical swallowing assessment has been previously described in a real-world clinical practice model (Burns et al., 2019; Ward et al., 2012), the reliability of administering assessment tools via telehealth in clinical practice as opposed to well-controlled research conditions (i.e., without specialized hardware or software, multiple cameras, minimum Internet requirements, or trained clinicians nearby) has not been explicitly investigated. Therefore, it is important to examine the reliability of objective and subjective components of the clinical swallowing evaluation in clinical practice to ensure clinical translation of findings during and after COVID-19.

Given the rapid adoption of telehealth by dysphagia practitioners during the pandemic, ever-evolving technological advancements, and the urgency of incorporating feasible and reliable measures in evaluating dysphagia via telehealth, the primary aim of this study was to examine

the reliability of clinical outcome measures derived from standardized clinical swallowing evaluations via telehealth in clinical practice, specifically without the benefit of specialized technology, in-person clinician assistance before or during the evaluation, or exclusion of patients based on minimum technological factors. We investigated the reliability of the TWST, the TOMASS, and observations of oral intake across multiple clinicians with varying years of experience with dysphagia management and with the TWST and the TOMASS. Based on prior literature and our clinical experience, we hypothesized that all outcomes would demonstrate "good to excellent" inter- and intrarater reliability defined a priori as intraclass correlation coefficient (ICC) of ≥ .80 for continuous variables or exact agreement of ≥ 90% for categorical variables. A secondary aim was to explore patient- and clinician-specific factors, which might have influenced reliability of these assessments in a remote-only environment.

Method

Participant Criteria

Participants with suspected dysphagia were prospectively recruited from referrals by Movement Disorders Fellowship–trained neurologists to a clinical research initiative for clinical evaluations of swallowing via telehealth. Inclusion criteria remained broad so as to examine the feasibility of the assessment procedures across as many patients as possible who were referred for services. Inclusion criteria were (a) a diagnosis of a neurological disorder; (b) at least 18 years of age; (c) Internet connection; (d) a device with audio and video capability; (e) a glass, measuring cup, and cracker; (f) minimum visualization of the mouth and upper neck for oral trials; and (g) the presence of a caregiver/facilitator in the household. Facilitators/caregivers for dysphagia telehealth services may be helpful in assisting patients with connecting to the virtual visit, with feeding or modifying the environment or the stimuli (e.g., changing the camera angle or the seating of the patient), and more critically intervening to address any safety issues (Malandraki et al., 2014; Sharma et al., 2011). The facilitators/caregivers in this study were asked to be in the household during the evaluation in the case of a medical emergency. They were not required to directly assist with the evaluation, unless needed. Additionally, no criteria were set regarding the type or size of glass/cup that the participants used in order to accurately reflect the home environment. Exclusion criteria included the inability to use videoconferencing software independently or with assistance from a caregiver. This study received approval by the institutional review board at (Teachers College, Columbia University), and electronic informed consent was obtained from all participants before initiating study procedures.

Study Procedures

Ethical Approval: All procedures performed were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Participants underwent a standardized clinical swallowing evaluation administered via telehealth. Three primary speech-language pathologists completed the evaluations. Two speech-language pathologists had 2 years of clinical experience, with telehealth prior to the COVID-19 pandemic, and all clinicians reviewed the literature and consulted online telehealth recommendations before initiating evaluations (Malandraki, 2020). These same three clinicians were represented in the seven raters; however, all raters completed the ratings offline at least 1 week after the evaluation. Evaluations were performed with Zoom, a videoconferencing platform (Zoom Video Communications, Inc., 2016), recorded in real-time via Zoom, and then deidentified and stored to a secure server. Primary medical diagnoses, age, and self-reported oral diet per the International Dysphagia Diet Standardization Initiative (IDDSI) guidelines (Cichero et al., 2017) were recorded for each participant. Participants were instructed to use a device with a camera (i.e., computer, tablet, phone) in a private room at home and be seated in an upright position that provided visualization of their face and upper body. If the patient could not independently achieve adequate positioning, the clinician provided additional verbal instructions to guide the patient. If optimal visualization (face, neck, and upper torso) was not accomplished after 5 min of maximum clinician cueing and caregiver assistance but the minimum requirement for inclusion criteria (mouth and upper neck) was met, the evaluation was performed in order to determine the feasibility and reliability of subjective and objective assessment components across all patients. No other instructions or criteria regarding equipment or training were provided to further represent current variable clinical practices. There were no prespecified criteria for lighting; however, visualization of the mouth and neck was required per inclusion criteria. Cognition was screened with the Mini-Mental State Examination (MMSE), which has shown acceptable reliability via telehealth (McEachern et al., 2008). Internet download and upload speeds (i.e., throughput) were obtained from an online speed test (www.speedtest.net). This was performed by the clinician and patient in the respective locations where the evaluations took place. The standardized clinical swallowing evaluation began with a medical case history, cranial nerve assessment, and measure of swallowing-related quality of life (SWAL-QOL; McHorney et al., 2000, 2002). Next, trials of various bolus volumes (e.g., 30 ml, 90 ml, patient-preferred volume) and consistencies (IDDSI Levels 0, 1, etc.) were performed, which were determined based on the patient's case history and reported diet. For example, if the patient had a prior instrumental swallowing evaluation available to the clinician, specific volumes and consistencies were excluded if the patient previously aspirated with them. If the patient did not have a previous instrumental evaluation and reported consuming all consistencies independently at home, thin liquid and dry solid boluses were trialed. Next, the TWST and the TOMASS were administered as previously specified. Similarly, these tasks were deferred if the patient had an instrumental swallowing evaluation demonstrating aspiration with the volume

or consistency required for the task. A conservative approach to the evaluation was utilized to ensure patient safety given the impact of the COVID-19 pandemic on the health care system and the current lack of evidence for the use of telehealth for dysphagia evaluations under present conditions. For the TWST, in order to ensure the patient consumed the correct amount of liquid, the patient was required to measure the volume of liquid specified by the clinician into a measuring cup before consumption. For the TOMASS, the patient was asked to use a saltine but was allowed to use any available type of cracker for the task if a saltine was not available.

Rater Criteria

Seven raters asynchronously (using store-and-forward video recordings) judged the aforementioned tasks: TWST, TOMASS, and observations of oral intake. Raters without at least one graduate-level course in swallowing disorders were excluded. In order to ensure a representative sample of raters, no minimum requirements for the amount of clinical exposure evaluating and treating dysphagia or using the TWST and the TOMASS were prespecified. Furthermore, no guidelines were provided regarding equipment type or audiovisual settings for raters to further increase generalizability of these measurement approaches to clinicians. There were also no prespecified requirements for the raters' environments; all raters completed ratings from their homes. Rater training involved judging prerecorded videos of individuals with Parkinson's disease performing three trials of the TWST and two trials of the TOMASS (approximately 30 min to complete). Upon completion of the training, raters compared their results to ratings previously performed by the primary investigator to ensure accuracy. However, no prespecified accuracy threshold was required to start rating telehealth data, in order to increase generalization of our findings to a wide range of clinicians who may have little to no experience with these measures. Following completion of ratings, raters provided free-text qualitative factors that they felt influenced their confidence in the ratings they made.

Data Analysis

Videos were spliced into individual trials, blinded, and randomized for each rater. RedCap (Research Electronic Data Capture), a secure web-based data collection tool (Harris et al., 2009), was used to store ratings. There were no specifications regarding raters' device type or size and resolution of their screen. Each rater viewed and measured videos of the TWST, the TOMASS, and observations of oral intake. For each video, raters were instructed to complete ratings in a single viewing. Once these ratings were inputted into RedCap, raters completed an additional viewing and rating of the same video before proceeding to the next trial. For the TWST, raters judged the amount of liquid consumed, time, number of swallows, and overt signs of aspiration. Time was measured using an electronic stopwatch application with the "lap" function and was recorded from when the cup touched the patient's bottom lip until the larynx returned to rest after the final swallow (Hughes & Wiles, 1996). For the TOMASS, raters judged the number of bites, masticatory cycles, swallows, time, and overt signs of aspiration. Bites were determined by counting the number of discrete pieces of cracker the participant placed in their mouth. Masticatory cycles were determined by observations of jaw movement during chewing. Lingual movements manipulating the cracker in the oral cavity were not counted as masticatory cycles. Time was recorded from when the cracker passed the patient's lips until they said "finished" to indicate the task was completed (Huckabee et al., 2018). For all other trials of varying bolus volumes, raters judged common observations of oral intake, including the number of swallows, anterior labial leakage, overt signs of aspiration (i.e., cough, throat clear, and wet vocal quality), and nasal regurgitation. Raters remeasured 100% of the TWST and TOMASS trials, as well as a randomized 50% of observations of oral intake trials at least 72 hr following the initial measurement session. Finally, the frequency of events that related to the qualitative factors identified by raters to influence confidence was identified.

Statistical Analysis

Two-way random effects (single measure, absolute agreement) ICCs were used for the following continuous variables: time, amount of liquid consumed, and number of bites, masticatory cycles, and swallows. Percent exact agreement was used for binary observations of oral intake: anterior labial leakage, nasal regurgitation, signs of aspiration, throat clear, and wet vocal quality. Interrater reliability estimates were reported for each possible rater dyad across all variables. ICC values were interpreted as follows: $< .50$ = *poor*, .50–.75 = *moderate*, .75–.90 = *good*, and $> .90$ = excellent (Koo & Li, 2016). Based on prior literature (Huckabee et al., 2018; Ward et al., 2012), an a priori threshold for acceptable reliability was set at $\geq 90\%$ exact agreement for categorical variables and an ICC of $\geq .80$ for continuous variables. Two types of intrarater reliability were examined: immediate and delayed. Videos immediately reanalyzed during the first rating session were used for immediate intrarater reliability. For delayed intrarater reliability, comparisons were made between the first trial of the first session and the second session. Statistical analyses were performed in R Version 4.0.1 (R Core Team, 2018).

Results

Patient Demographics and Telehealth Specifications

Evaluations from 12 consecutive patients (nine men, three women) referred for clinical swallowing evaluations were included in this study (see Table 1). Participants had an average age of 66 years (SD = 11.44). Primary diagnoses included Parkinson's disease (n = 7), Parkinsonism with Lewy body dementia (n = 2), multiple systems atrophy (n = 2), and Type 3 spinocerebellar ataxia (n = 1). Average disease duration from symptom onset was 5.45 years (SD = 4.07). All participants reported consuming a regular solid (IDDSI Level 7) and thin liquid (IDDSI Level 0)

Table 1. Participant demographics and ideal visualization criteria.

ID	Primary diagnosis	Age	MMSE	TWST	TOMASS	Head and upper torso in frame (% trials)	Device in stable position (% trials)	Stable Internet connection (% trials)	No obstruction of head or neck during task	Met all ideal visualization criteria (no. of trials)
1	PD	54	28	WNL	WNL	0	100	100	100%	0/2
2	PD	61	16	ONL	ONL	0	33	100	100%	0/3
3	PD	64	29	ONL	ONL	80	60	100	80%	2/5
4	PD	66	24	ONL	WNL	83	100	100	67%	4/6
5	PD	75	30	WNL	ONL	100	100	75	100%	3/4
6	PD	75	26	ONL	WNL	0	100	100	100%	0/4
7	PD	76	N/A	WNL	WNL	100	100	50	100%	2/4
8	PD with LBD	74	23	ONL	N/A	67	100	100	100%	2/3
9	PD with LBD	82	25	WNL	WNL	100	100	50	100%	2/4
10	MSA	60	30	WNL	N/A	100	100	100	100%	1/1
11	MSA	61	30	WNL	WNL	100	100	100	100%	4/4
12	SCA-3	41	26	ONL	ONL	100	100	100	75%	3/4

Note. MMSE = Mini-Mental State Examination; TWST = Timed Water Swallow Test; TOMASS = Test of Masticating and Swallowing Solids; PD = Parkinson's disease; WNL = within normal limits; ONL = outside normal limits (on at least one parameter); N/A = not administered; LBD = Lewy body dementia; MSA = multiple systems atrophy; SCA-3 = spinocerebellar ataxia Type 3.

diet. Patients had a wide range of Internet speeds, ranging from 7.20 to 934.48 Mbps for download and from 0.60 to 944.20 Mbps for upload speeds (see Table 2). Patients used a variety of devices, including handheld (36%), laptop (55%), and desktop (9%) computers. Nine out of 11 participants demonstrated adequate cognition on the MMSE, with scores ranging from 16 to 30. One participant was unable to complete the MMSE and test of Internet speed, resulting in missing demographic data. However, this participant's videos were still rated for the reliability analysis.

Rater Demographics

Raters had an average of 6.71 years of experience with dysphagia management (range: 0–16 years) and 1.14 years of exposure to the TWST and the TOMASS (range: 0–4 years). Specifically, five raters were licensed speech-language pathologists (two with PhDs, Raters A and B), and two raters were master's level speech-language pathology students (Raters F and G). Raters judged 12 trials of the TWST, 10 trials of the TOMASS, and 22 observations of oral intake. Observations of oral intake included four trials of 30-ml thin liquid (IDDSI Level 0), nine trials of 90-ml thin liquid, and nine trials of patient-preferred volume of thin liquid.

TWST

All rater dyads demonstrated "good" to "excellent" interrater reliability (ICCs > .80) for the amount of liquid consumed, time, and number of swallows (see Table 3 and Supplemental Material S1 for detailed dyads ratings). When judging overt signs of aspiration on the TWST, 12 out of 21 rater dyads demonstrated "excellent" reliability (> 92% agreement) and nine dyads had "good" reliability (75%–83%; see Supplemental Material S1). For immediate intrarater reliability, all raters achieved "excellent" reliability (ICCs > .90 and > 92% agreement) across all TWST outcomes (see Supplemental Material S3). For delayed intrarater reliability, all raters demonstrated "excellent" reliability (ICCs > .90) for the following TWST outcomes: amount of liquid consumed, time, and number of swallows. When judging signs of aspiration, six out of seven raters achieved "excellent" (≥ 92% agreement), and one had "good" (83% agreement) delayed intrarater reliability.

Participants required an average of 19.27 s (*SD* = 15.38) and eight swallows (*SD* = 4.46) to complete the TWST. Six participants fell outside normative values on at least one outcome on the TWST (see Table 1).

TOMASS

All rater dyads demonstrated "good" to "excellent" interrater reliability (ICCs > .80 and ≥ 90% agreement) for the following TOMASS outcomes: number of masticatory cycles, time, and overt signs of aspiration (see Table 3). When rating the number of swallows during the TOMASS, seven out of 21 rater dyads demonstrated "good" interrater reliability (ICCs = .75–.85), 10 dyads demonstrated "moderate" reliability (ICCs = .50–.64), and four dyads had "poor" reliability (ICCs = .21–.38). When rating the number of bites, 12 dyads achieved "excellent" reliability (ICCs ≥ .92), four dyads had "good" reliability (ICCs = .76–.85), two dyads had "moderate" reliability (ICCs = .61–.62), and three had "poor" reliability (ICCs = .43–.48; see Figure 1). All raters achieved "good" to "excellent" immediate intrarater reliability (ICCs > .82 and ≥ 90% agreement) across all TOMASS outcomes (see Supplemental Material S4). For delayed intrarater reliability, all raters also demonstrated "good" to "excellent" reliability (ICCs > .81 and ≥ 90% agreement) across all outcomes, except number of swallows. Five raters achieved "good" (ICCs = .80–.89), and two raters had "moderate" (ICCs = .63–.64) delayed intrarater reliability when rating the number of swallows.

Table 2. Participant technological details.

ID	Geographic location	Participant Internet download speed (Mbps)	Participant Internet upload speed (Mbps)	Device	Camera type	Clinician device	Clinician Internet download speed (Mbps)	Clinician Internet upload speed (Mbps)
1	New Jersey, USA	75.00	75.00	MacBook Pro	Internal	Microsoft Surface Pro	33.38	30.75
2	New York, USA	231.69	8.96	MacBook Pro	Internal	MacBook Air	48.37	45.89
3	New Jersey, USA	76.64	N/A	iPhone	Internal	MacBook Air	48.37	45.89
4	New Jersey, USA	63.65	56.63	iPad	Internal	MacBook Air	48.37	45.89
5	Colorado, USA	7.2	0.60	MacBook Pro	Internal	HP ENVY 13 Laptop	277	187
6	New York, USA	37.78	40.21	Dell Inspiron Laptop	Internal	HP ENVY 13 Laptop	277	187
7	New York, USA	N/A	N/A	N/A	External	MacBook Air	48.37	45.89
8	New York, USA	24.51	5.27	Windows Desktop	Internal	MacBook Air	48.37	45.89
9	New Jersey, USA	94.86	N/A	iPhone	Internal	HP ENVY 13 Laptop	277	187
10	New Jersey, USA	85.96	7.56	Dell Latitude Laptop	Internal	Microsoft Surface Pro	33.38	30.75
11	New Jersey, USA	115.61	37.16	iPad Pro	Internal	Microsoft Surface Pro	33.38	30.75
12	New York, USA	934.48	944.20	MacBook Pro	Internal	HP ENVY 13 Laptop	277	187

Note. Internet download and upload speeds were obtained from www.speedtest.net. Mbps = megabits per second; N/A = not administered/available.

On average, participants required 37.14 s (*SD* = 20.09), three bites (*SD* = 3.86), 38 masticatory cycles (*SD* = 19.37), and two swallows (*SD* = 0.74). Four participants were outside normative values on the TOMASS (see Table 1).

Observations of Oral Intake

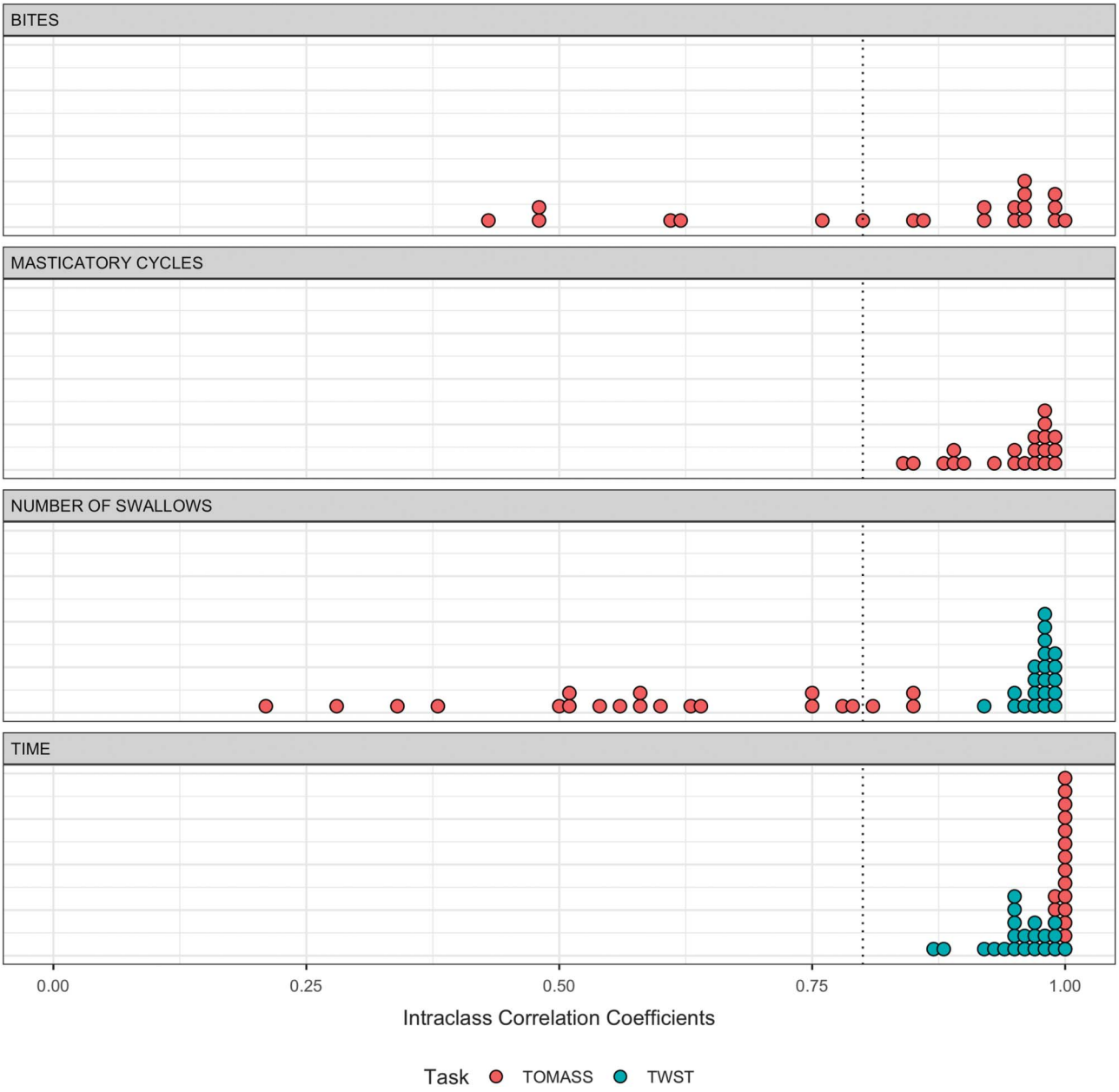
For observations of oral intake, all rater dyads achieved "excellent" interrater reliability (ICCs ≥ .93 and > 95% agreement) for the number of swallows, nasal regurgitation, anterior labial leakage, and presence of a cough or throat clear (see Table 3). When judging the presence of a wet vocal quality, 15 out of the 21 rater dyads demonstrated "excellent" interrater reliability (> 90% agreement), and six dyads had "good" reliability (77%–86% agreement; see Supplemental Material S2). All rater dyads demonstrated "excellent" immediate intrarater reliability (ICCs ≥ .98 and > 90% agreement) across all outcomes. For delayed intrarater

Table 3. Inter- and intrarater reliability across raters for all tasks.

Outcome	Interrater reliability	Immediate intrarater reliability	Delayed intrarater reliability
Timed Water Swallow Test			
Amount of liquid consumed	1.00 (1.00)	1.00 (1.00)	1.00 (1.00)
Time	.96 (.94–.97)	1.00 (.97–1.00)	1.00 (1.00)
No. of swallows	.98 (.97–.98)	.99 (.99–1.00)	.98 (.95–1.00)
Signs of aspiration	92% (85%–93%)	100% (97%–100%)	100% (92%–100%)
Test of Masticating and Swallowing Solids			
Bites	.92 (.75–.91)	1.00 (.99–1.00)	.99 (.91–1.00)
Masticatory cycles	.97 (.92–.96)	1.00 (.98–1.00)	.98 (.96–.99)
Time	1.00 (.99–1.00)	1.00 (.95–1.00)	1.00 (.99–1.00)
No. of swallows	.58 (.51–.67)	.90 (.87–.97)	.81 (.71–.87)
Signs of aspiration	90% (93%–97%)	100% (96%–100%)	100% (94%–100%)
Observations of oral intake			
No. of swallows	.98 (.96–.98)	.99 (.99–1.00)	.96 (.81–.99)
Anterior labial leakage	100% (100%)	100% (100%)	100% (100%)
Nasal regurgitation	100% (100%)	100% (100%)	100% (100%)
Cough	100% (100%)	100% (100%)	100% (100%)
Throat clear	96% (97%–99%)	100% (97%–100%)	100% (100%)
Wet vocal quality	96% (89%–95%)	100% (96%–100%)	100% (93%–100%)

Note. Reliability estimates reported are medians and 95% confidence intervals.

Figure 1. Distribution of interrater reliability intraclass correlation coefficients (ICCs) across all rater dyads for the Timed Water Swallow Test (TWST) and the Test of Masticating and Swallowing Solids (TOMASS). Dotted line represents a priori threshold of ICC ≥ .80.



reliability, "excellent" reliability (100% agreement) was achieved for all raters across all outcomes with the exception of the number of swallows and presence of a wet vocal quality (see Supplemental Material S5). When rating the number of swallows, five raters achieved "excellent" delayed intrarater reliability (ICCs ≥ .98), one rater had "good" reliability (ICC = .84), and one rater had "moderate" reliability (ICC = 0.64). When judging the presence of a wet vocal quality, six raters had "excellent" delayed intrarater reliability (100% agreement), and one rater had "good" reliability (84% agreement).

Qualitative Factors Affecting Clinician Confidence

Several qualitative technology and patient-specific factors were identified by raters as potentially negatively impacting the confidence of their ratings at times, including suboptimal video quality (i.e., momentary video freezing during tasks), reduced stability of the video and camera, distance from the camera (i.e., patient is either too far or close), obstruction of the patient's mouth during tasks, or performing extraneous lingual movements that obscured counting bites, masticatory cycles, and swallows. Factors that

were thought to facilitate rater confidence by improving visualization included a slightly oblique view of the upper body with a lower camera angle, a clear glass, a prominent thyroid notch, and audible gulping.

In order to understand their potential impact, we examined the prevalence of each of these factors across participants and trials (see Table 1). All participants met the minimum criteria of their mouth and upper neck in the frame of view during oral trials. Nine of 12 participants were able to achieve optimal positioning with their heads and upper torsos within the frame of view on the majority of trials (see Table 1). Ten of 12 participants completed the evaluation with the device in a stable position. Nine of 12 participants had a stable Internet connection during the session, whereas the remaining three participants demonstrated momentary video freezing on 25%–50% of trials. Additionally, clinicians noted that nine of 12 participants utilized a clear glass (which allowed visualization of the liquid by the clinician). Nine of 12 participants completed the tasks without obstructing their head and neck with their hands or cups. Instances of obstruction occurred on four trials (9%). Twenty-three trials (52%) met all ideal visualization criteria; however, only two of 12 participants met ideal visualization for all of their trials.

Discussion

Given the impact of the global pandemic caused by severe acute respiratory syndrome coronavirus 2 on the health care system and the subsequent rapid adoption of telehealth among speech-language pathologists, there is an urgent need to provide evidence for swallowing management via telehealth in the current clinical context and to understand the precision of these measurements to ensure reliable outcomes in clinical practice. Thus, as a first step, this study aimed to examine the reliability of objective and subjective components of the clinical swallowing evaluation via telehealth, specifically the TWST, the TOMASS, and common observations of oral intake, in a sample of outpatients referred to a university clinic for swallowing assessments. Overall, we found high levels of reliability across all tasks in this investigation, largely supporting our hypothesis. Specifically, raters achieved acceptable inter- and intrarater reliability with few exceptions.

This study examined the implementation of the TWST and the TOMASS in clinical practice via telehealth. The results reveal the feasibility of reliable outcome measurement related to the TWST and the TOMASS via this service delivery model within real-world clinical practice. Our findings support prior research demonstrating adequate reliability when judging similar subjective outcomes (i.e., number of swallows, overt signs of aspiration, wet vocal quality) under well-controlled conditions (Ward et al., 2014, 2012). In fact, our findings are also largely similar to studies that have reported reliability of these measures completed during in-person evaluations. Though the original validation of the TWST did not examine the reliability of raters (Hughes & Wiles, 1996), our findings parallel other studies that have reported acceptable levels of reliability with the TWST or similar timed water swallowing tasks (Athukorala et al., 2014; Nathadwarawala et al., 1992). Our findings suggest that all TWST outcomes can be judged reliably both between and within raters via telehealth. Regarding the TOMASS, we found similar levels of reliability with respect to the amount of time to consume the solid bolus and the number of masticatory cycles. However, interrater reliability for the number of bites and swallows was slightly lower than prior studies in healthy adults and individuals with Parkinson's disease (Athukorala et al., 2014; Huckabee et al., 2018). These discrepancies might be partially explained by our diverse sample of participants with progressive neurodegenerative diseases, including parkinsonism with Lewy body dementia, multiple systems atrophy, and spinocerebellar ataxia, many of which presented with TOMASS values outside normal age- and sex-matched normative values. These participants often demonstrated extraneous lingual movements and consecutive piecemeal bites of the bolus, which may have been mistaken for masticatory cycles and negatively impacted reliability. Additionally, telehealth-specific barriers, such as suboptimal positioning or occasional obstruction of the mouth during chewing, might have hindered reliability for these outcomes. Nonetheless, overall, these findings suggest that these tasks largely demonstrate equivalent reliability via telehealth compared to in-person delivery.

This study also revealed substantial inter- and intrarater reliability ("good" to "excellent") for more subjective observations of oral intake. These findings are comparable to prior investigations of reliability in telehealth conducted under well-controlled research conditions with similar patient populations, most notably acquired or progressive neurological disease (Sharma et al., 2011; Ward et al., 2012). The observations of oral intake examined in this study (i.e., anterior labial leakage, nasal regurgitation, and signs of aspiration) are common parameters that are often assessed in person or via telehealth (Kantarcigil et al., 2016; Ward et al., 2014, 2012). We further demonstrated that these subjective ratings can be reliably observed both between and across raters in the absence of specialized equipment, extensive training, or assistance from in-person facilitators. However, it should be noted that there was a low incidence of abnormal findings for these outcomes in our sample of outpatients.

Importantly, the results of this study highlight the utility and reliability of objective and subjective components of the clinical swallowing evaluation administered via telehealth and support their use in clinical practice. We did not limit participation in the study based on telehealth/technology-specific parameters, particularly Internet upload and download speeds and type of device, in an effort to promote generalizability and implementation of the findings. Despite this, reliability was good to excellent. There is evidence from prior dysphagia telehealth research demonstrating successful sessions with relatively low Internet speed (as low as 128 kbps). However, in some of these studies, issues with audio or video quality and connectivity were reported (Malandraki et al., 2011; Ward et al., 2013); therefore, the use of higher

Internet speeds (i.e., throughput) has been suggested whenever possible. In fact, according to the American Telemedicine Association (ATA) guidelines, Internet speeds should be at minimum 384 kbps for both upload and download speed (ATA, 2014; Gough et al., 2015). In this study, overall reliability was maintained even with the inclusion of cases with lower throughput; however, all of the patients included in this study had adequate Internet speeds according to ATA guidelines. Additionally, patients used a diverse set of devices during the evaluations, with variability in microphone and camera qualities and placement. However, raters did report that suboptimal video quality (i.e., momentary video freezing during tasks) and reduced stability of the video and camera reduced rating confidence at times. To our knowledge, this is the first study demonstrating reliability of clinical swallowing outcomes via telehealth without control of specific patient or clinician devices or the inclusion of peripheral cameras and external microphones.

Adequate visualization is an essential element for the valid and reliable administration of clinical swallowing evaluations via telehealth. The raters in this study identified the patient's distance from camera as being a factor, which, when not optimal, reduced the confidence of their ratings. All participants achieved minimum visualization (mouth and upper neck) with minimal guidance, and the majority generally achieved optimal visualization, with 66% of trials including the head, neck, and upper torso in frame despite the absence of training and in-person facilitators. Trials with suboptimal visualization were largely due to motor or cognitive limitations, and attempts were made to correct the visualization on subsequent trials. Though verbal instructions were provided to all patients, we proceeded with the best visualization that a patient could reasonably achieve (after 5 min of instruction) in order to examine generalization across patients' abilities. This decision was made in order to better reflect actual clinical challenges that clinicians may face when optimizing visualization via telehealth with movement disorders patients who also often have concomitant cognitive impairments. Though it is encouraging that acceptable reliability was maintained despite a portion of the trials not demonstrating optimal visualization, it is important to conduct research studies to better understand the minimum visualization required to maintain reliability while also accounting for validity.

The raters in this study also identified several factors that improved the confidence of their ratings. A slightly oblique view of the upper body with a lower camera angle, a clear glass, and a prominent thyroid notch were all thought to improve visualization of swallows when drinking liquids and to facilitate identification of the number of swallows. Some raters also reported that audible gulping during swallowing might have facilitated rating this outcome. Overall, the qualitative findings from this study highlight the importance of providing explicit instructions related to device and camera positioning, patient positioning, and types of cups used during clinical swallowing evaluations via telehealth, as used in prior controlled studies (Ward et al., 2014, 2012). Future studies should examine the relative influence of positioning, as well as patient-specific factors, on reliability in a larger cohort of individuals with dysphagia. Furthermore, potential facilitatory manipulations that may enhance reliability, such as adding an additional caregiver camera, tape to the participant's thyroid notch to assist visibility of laryngeal movement, or specific camera and microphone placements (e.g., Ward et al., 2014, 2012), will require further systematic investigation in real-world clinical practice.

The findings from this study also highlight the feasibility and safety of using the TWST and the TOMASS as part of the clinical swallowing assessment via telehealth in outpatient settings. Of critical importance, no safety issues were apparent during any of the assessments. Feasibility is further supported by the fact that clinical outcomes evaluated in this study were reliable in patients with suspected dysphagia, various levels of cognitive decline, minimal equipment requirements, variable Internet connectivity parameters, no direct caregiver involvement, and minimal rater expertise or practice. Additionally, it was promising to find high levels of immediate and delayed intrarater reliability. Given that raters were instructed to perform these ratings in a single viewing, these findings indicate that ratings may be performed in real time with adequate reliability, further enhancing their use in clinical practice. Of note, differences in reliability were not descriptively appreciated between novice and experienced raters, suggesting that novice clinicians can reliably rate these clinical outcomes with minimal training. However, future studies are necessary to statistically examine the effects of practice and clinician experience on reliability in these tasks.

This study is not without limitations. The small sample size and predominance of individuals with few overt signs of aspiration and normal to mild cognitive impairment may limit the generalizability of these findings to more severely impaired patients. However, portions of our sample did demonstrate abnormal values on the TWST and the TOMASS, as well as longer disease durations, which have been associated with more severe disease. Additionally, despite the fact that patients were not excluded due to technology-specific factors, all had adequate Internet upload and download speeds, were in a metropolitan area (New York City), and utilized high-quality devices. Future studies will be required to examine the reliability of these outcomes via telehealth in a larger cohort of individuals with more severe swallowing dysfunction, cognitive impairments, and a more diverse set of technological parameters. Though the present investigation did not examine all components of the clinical swallowing evaluation, clinical outcomes were selected due to prior reports of high reliability in well-controlled research conditions (Ward et al., 2012). Furthermore, other aspects of the clinical swallowing evaluation, such as the cranial nerve examination, have been previously examined via telehealth (Blue et al., 2020). Though this study examined reliability with asynchronous ratings, we attempted to replicate "real-time" ratings that would occur during an evaluation by limiting raters to a single viewing for each video. Additionally, all raters completed ratings via a secure platform

from their homes; thus, we did not control for rater equipment or audiovisual settings. Though we did not specify explicit lighting requirements for the patient, we did require minimum visualization of the mouth and upper neck. Future studies will be necessary to determine the effects of lighting and visualization on reliability. Finally, this study's aims were limited to reliability and did not examine the accuracy or validity of raters' measurements. Future studies will be required to examine the effects of various technology and patient-specific factors on the efficacy and validity of clinical swallowing outcome measures and subsequent recommendations via telehealth.

Conclusions

The results of this study add to a growing body of literature supporting the safety, feasibility, and reliability of clinical swallowing evaluations and outcome measurement via telehealth. These results further suggest that objective measures taken from the TWST and the TOMASS can be reliably measured via telehealth and confirm existing evidence that common subjective observations of oral intake can be reliably assessed via telehealth. Importantly, the clinical outcomes measured were reliable despite variability in equipment by patients and clinicians, Internet speeds, environments, and/or facilitator involvement. Lastly, this study provides support for the use of telehealth for outpatient clinical swallowing evaluations during COVID-19 and beyond.

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