

Internet-based Behavioral Cough Suppression Therapy for Refractory Chronic Cough: A Randomized Controlled Trial

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Abbreviation List:

Analysis of covariance (ANCOVA)

Baseline assessment (T0)

Behavioral cough suppression therapy (BCST)

Cough hypersensitivity syndrome (CHS)

Internet-behavioral cough suppression therapy (IBCST)

Leicester Cough Questionnaire (LCQ)

Post-test at one-week post-treatment (T1)

Post-test at four-weeks post-treatment (T2)

Refractory chronic cough (RCC)

Visual Analog Scale (VAS)

Urge-to-cough (UTC)

Abstract

Objectives: Assess the efficacy of internet-based behavioral cough suppression therapy (IBCST) and explore users' experiences.

Design: A prospective, single-blind, randomized, controlled trial comparing the efficacy of a five-week IBCST and healthy-lifestyle education control intervention in patients with refractory chronic cough. Additionally, qualitative interviews were conducted and analyzed using grounded theory methodology.

Interventions: IBCST and the healthy lifestyle control included five weeks of asynchronous content delivered via video and text on a study-specific website. IBCST emphasized education and cough suppression.

Outcomes: The Leicester Cough Questionnaire (LCQ) and Cough Severity Visual Analog Scale (VAS) were the primary and secondary outcome measures, respectively, and were administered at baseline (T0), one-week post-treatment (T1), and one-month post-treatment (T2). Semi-structured qualitative interviews were conducted with a subgroup of IBCST participants.

Results: Thirty-nine adults with refractory chronic cough enrolled and 30 (27 women; mean age, 61 years) completed the study (18 IBCST, 12 control). IBCST resulted in clinically significant improvements for 72% of participants in LCQ total score at T1 with a mean change of 3.74, ($p = .014$, $\eta^2 = 0.205$), and 76% of participants at T2 with a mean change of 4.1 ($p = .033$, $\eta^2 = 0.163$). VAS changes did not reach the minimum clinically meaningful threshold but trended in that direction for the IBCST group at T1 ($p = 0.056$, $\eta^2 = 0.128$). Qualitative analysis revealed IBCST participants liked the convenience and quality of treatment and experienced improvements in symptom control.

Conclusions: IBCST was feasible, efficacious, and resulted in total LCQ score changes on par with what has been reported for other BCST interventions, paving the way for adaptation to a digital therapeutic.

Key Words List:

Behavioral cough suppression therapy

Cough hypersensitivity syndrome

Internet-behavioral cough suppression therapy

Refractory chronic cough

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Introduction

About seven million people in the United States suffer every year from refractory chronic cough (RCC; Chung & Pavord, 2008; Song et al., 2015), with far-reaching socioeconomic and quality-of-life impacts, including a high rate of clinical depression (Dicpinigaitis et al., 2006; McGarvey et al., 2006). Recent research has identified cough hypersensitivity syndrome (CHS) as the primary pathophysiological driver of RCC (Chung et al., 2022, Drake et al., 2023). CHS, also referred to as “neurogenic cough” (Altman et al., 2015), is characterized by hypertussia (i.e., excessive coughing to low levels of tussive stimuli), allotussia (i.e., cough triggered by non-noxious stimuli such as vocal use, cold air, or fragrant scents), and laryngeal paresthesia (Chung et al., 2022). CHS is most commonly precipitated by an upper respiratory infection where the sensitized cough reflex persists well beyond the period of illness resolution (Driessen et al., 2017; Farrell & Mazzone, 2019; Mazzone et al., 2013; Udem et al., 2015).

Findings from behavioral and neuroimaging studies have revealed that the cough reflex is not a stereotypic response but is instead modulated by higher-level brain activity. Behavioral studies have shown that even when experiencing a very strong urge-to cough (UTC), individuals can volitionally modify or entirely suppress their motor cough output (Hegland et al., 2012; Hutchings et al., 1993). However, individuals with RCC are less able to do so relative to healthy individuals (Cho et al., 2019). Furthermore, the cough reflex can be influenced by cognitive and environmental factors, such as attentional manipulation, beliefs about the harmfulness of a cough stimulant, and being in an environment with other coughers (Janssens et al., 2014, 2015;

Pennebaker, 1980; Perry & Troche, 2019, 2021). Functional magnetic resonance imaging studies illuminate differences in central nervous system structures and functions related to UTC perception and inhibitory cough suppression motor activity in patients with RCC compared to healthy controls (Ando et al., 2016; Moe et al., 2024). While more work is needed to better elucidate the higher-level brain mechanisms behind CHS, it is becoming clear that targeting peripheral mechanisms alone is unlikely to improve the underlying condition behind RCC.

This link to high-level brain activity and interplay between perceptions of internal body sensations (i.e., UTC interoception) and cough suppression abilities provides clues to the mechanistic underpinnings of behavioral cough suppression therapy (BCST). BCST is an evidence-based treatment, typically provided by voice and upper-airway specialized speech-language pathologists (SLPs), that results in significant improvements in cough-related quality of life and reductions in cough severity for approximately 80% of patients with RCC (Chamberlain Mitchell et al., 2016; Simmons et al., 2023; Slovarp, et al., 2021; Sundholm et al., 2022; Vertigan et al., 2006; Wright, 2021; Yi et al., 2024). BCST is commonly described in the literature to include education, instruction in cough suppression strategies, recommendations to improve laryngeal hygiene, and psychoeducational counseling (Chamberlain Mitchell et al., 2016; Vertigan et al., 2006, 2019). Most iterations of BCST are delivered across approximately four sessions in a one-on-one format, either in-person or via telehealth. Eight studies examining the efficacy of BCST have reported changes in the Leicester Cough Questionnaire (LCQ; Chamberlain Mitchell et al., 2016; Kapela et al., 2020; Patel et al., 2011; Ryan et al., 2009, 2010; Slovarp et al., 2021; Vertigan et al., 2016; Wright, 2021), a valid patient-report outcome measure (Birring et al., 2003) that is routinely used as a primary outcome measure in behavioral and pharmaceutical RCC treatment efficacy studies. These studies have shown an approximately

four-point increase in the LCQ total score (higher score indicates better cough-related quality of life), which is more than twice the minimal clinically important difference (Raj et al., 2009).

Despite the documented efficacy of BCST, no side effects, low cost compared to pharmaceutical treatment, and acknowledgement in the American College of Chest Physicians CHEST guidelines for the treatment of unexplained chronic cough (Gibson et al., 2016) and European Respiratory Society's guidelines for the treatment of chronic cough (Morice et al., 2020), BCST is widely underutilized (Chamberlain et al., 2015; Slovarp et al., 2021). A 2021 survey by Slovarp and colleagues highlighted the arduous journey patients with RCC in the United States endure before being referred to a BCST provider. Over half of the 164 survey respondents had seen at least four physicians, tried at least four medications, and had a cough for over two years before being referred to BCST. Nearly 60% of respondents reported being “quite satisfied” or “completely satisfied” with their cough status following BCST. These results reflect inefficiencies in current RCC management and highlight the need for expedient pathways to connect patients to BCST.

Barriers to timely BCST access are exacerbated in rural areas where healthcare services, particularly specialized ones, are scarce. Patients in these regions face additional challenges such as geographical distance, limited availability of services, and the costs associated with traveling to access care (Mashima et al., 2003; Meit et al., 2014; Towey, 2012; Wilson et al., 2002). The exact number of BCST providers nationwide has not been captured, but given this therapy is typically provided by a subset of voice-specialized SLPs, who make up only 5% of certified SLPs in the United States (American Speech-Language-Hearing Association, 2016), there is clearly an insufficient number of qualified BCST providers given the high prevalence of RCC.

Additionally, in cases where there are qualified providers, problems exist with lack of physician awareness of these services further contributing to underutilization of services.

We sought to address these problems related to accessibility and availability of BCST in the current study by designing an online, asynchronous, BCST intervention. Online, asynchronous, cognitive behavioral therapy interventions have been robustly researched in the field of psychology with demonstrated efficacy in treating anxiety and depression (Andersson, 2025; Andersson, et al., 2019; Andrews et al., 2010; Arnberg et al., 2014; Pauley et al., 2023). This treatment modality has also been found to be efficacious in the field of audiology, with research exploring internet-cognitive behavioral therapy for the management of tinnitus (Andersson, et al., 2002; Beukes et al., 2019; Manchaiah et al., 2020).

The primary aim of this study was to investigate the efficacy of internet-based behavioral cough suppression therapy (IBCST) compared to a healthy-lifestyle education control using a prospective, single-blind, randomized design. The secondary aim was to understand IBCST participants' experiences using semi-structured qualitative interviews.

Method

This study was conducted with approval and oversight from the University of Montana Institutional Review Board (protocol #163-22). Individuals with RCC in the United States were recruited for the study via social media campaigns, newspaper advertisements, flyers sent to voice and upper airway clinics, word-of-mouth, and Facebook support groups (see Appendix A for a full list of eligibility criteria). Participants provided informed consent online via the study website (hosted by the iTerapi ePlatform). Prior to study recruitment, participant identification numbers were sorted by a random number generator to determine grouping and then were assigned to participants based on chronological study enrollment. Participants were blinded to

their group assignment. They were contacted by a member of the study team and participated in a short training phone call or HIPAA-compliant audio/video call instructing them on how to navigate the study website and access the study materials.

Intervention

The IBCST and control treatments included five weeks of content presented in weekly modules consisting of video explanations and demonstrations, supplemental text explanations, and a downloadable handout. Participants were prompted to answer a treatment adherence question at the beginning of each week to indicate whether they consistently followed the recommendations for the previous week. The participants received automated reminders via their preferred mode of communication (email or text) to complete the study questionnaires and alert them when new content was available.

The IBCST intervention included education on cough hypersensitivity syndrome and the rationale for BCST, vocal hygiene education, instruction in cough suppression strategies, functional practice of cough suppression in daily life, and implications for long-term management. The healthy lifestyle education control treatment was informed by the control treatments described in prior BCST randomized controlled trials (Chamberlain Mitchell et al., 2016; Vertigan et al., 2006) and was based on publicly available information from the Centers for Disease Control and Prevention. Topics included general education, physical activity, healthy eating, stress management, and relaxation techniques. Table 1 summarizes the components of each intervention. Control participants were provided with the opportunity to participate in the IBCST intervention after their study participation ended.

Table 1. IBCST and Control Intervention Overview

Week	IBCST		Control	
	Content Summary	Practice Recommendation Summary	Content Summary	Practice Recommendation Summary
1	Education on cough hypersensitivity syndrome, the rationale for behavioral cough suppression therapy, and vocal hygiene	Not applicable	Education on importance of a healthy lifestyle	Not applicable
2	Instruction in cough suppression strategies (e.g., cough control breathing, box breathing, effortful swallow, Masako maneuver, and combinations of techniques)	10 repetitions of a breathing technique 4-5x/day when not experiencing UTC; implementation of cough suppression technique(s) as soon as feeling UTC and continue until UTC is gone or low as possible	Education on importance of physical activity	150 minutes of moderate intensity physical activity (30 minutes 5 days/week)
3	Instruction in functional (i.e., deliberate) cough suppression with known cough triggers	Continue Week 2 recommendations; practice gradual, controlled exposure to a known cough trigger at least 2x/week (e.g., odors, cold air, deep breaths, exercise, vocal use, dry/crumbly foods)	Education on balanced nutrition	Make healthy eating choices at least one meal 5 days/week
4	Continued functional cough suppression practice; trouble shooting for difficult triggers (e.g., vocal use, respiration); importance of anticipating and preparing for challenging scenarios	Same as Week 3	Education on stress management	Choose at least one stress management technique to practice throughout the week
5	Education on long-term considerations (e.g., progress maintenance, possibility of recurrence)	Continue implementing cough suppression techniques as needed	Instruction in relaxation Techniques	Choose at least one relaxation technique to practice throughout the week

Assessments/Outcome Measures

Changes in cough-related quality of life and perception of cough severity were used to assess the efficacy of IBCST compared to the control treatment. The LCQ is a 19-item, validated,

reliable, and repeatable self-report questionnaire about cough-related quality-of-life (Birring et al., 2003) and was the primary outcome measure. A higher score indicates better cough-related quality-of-life. The secondary outcome measure was the Cough Severity Visual Analog Scale (VAS) which is a 100-millimeter line with anchors of 0 “no problem” and 100 “worst possible problem” where participants place a mark to represent the severity of their current cough problem. These assessments were administered online using the iTerapi ePlatform at baseline (T0), one-week post-treatment (T1), and one-month post-treatment (T2). A change of 1.3 is considered the minimally important clinical difference on the LCQ (Raj et al., 2009) and a reduction of at least 30-millimeters is considered clinically meaningful for the Cough Severity VAS (Martin Nguyen et al., 2021).

Semi-Structured Qualitative Interview Procedures

Consecutively enrolled IBCST participants were asked to participate in a semi-structured qualitative interview after T2. Interviews were continued until data saturation was reached. Grounded theory was chosen as the qualitative research methodology because IBCST is a new treatment and there is no prior work or existing theory to explain what participants’ experiences with this specific intervention might be. Therefore, we aimed to arrive at a new theory using an inductive approach that aligns with the framework of grounded theory research (Glaser & Strauss, 1967; Suddaby, 2006).

Interview questions were developed from Levesque et al.’s (2013) five dimensions of access to gain a comprehensive understanding of participants’ experiences. The interview questions are presented in Appendix B. The first and second authors (referred to as “the researchers”) conducted and recorded interviews via a healthcare-licensed Zoom account and made analytic memos of their impressions and insights during or immediately after each

interview. The second author or a graduate research assistant transcribed all interviews verbatim using the Zoom recording. The interview transcripts were independently reviewed and coded line-by-line by the researchers. NVivo 14 software (Lumivero, 2023) was used for all coding and an Excel spreadsheet was used as the codebook.

The coding procedures were informed by Corbin and Strauss' (1990) work which involves concept labeling (i.e., the basic units of analysis) and categorizing (i.e., grouping of concepts with the same phenomena). Concepts in the data were labeled in an open, initial coding process with an emphasis on using verbs to describe actions, processes, and consequences (Charmaz, 2006). Concepts that did not relate to the interview question or appeared infrequently were set aside. Concepts with similar phenomena were grouped into initial categories which revealed the processes, actions, and consequences of the data. In addition to initial coding, focused coding (Charmaz, 2006), constant comparative analysis, and theoretical sampling (Glaser & Strauss, 1967) were used as data were iteratively collected, analyzed, and compared across the interviews. The researchers met after individually coding the first transcript to complete focused coding and triangulate their findings by reviewing their line-by-line concepts and categories. This process was repeated after subsequent interviews where they compared concepts within and between interviews to arrive at a deeper understanding of perspectives and ensure that the data were descriptively rich.

The researchers noted the categories that arose from the focused coding in a codebook and made updates to the codebook as new insights emerged. The concepts and categories from all interviews were compared with one another to examine the relationships among the data, and a set of finalized categories was generated during the triangulation process. Data from earlier and later interviews were compared and notes were made if new views on the process, actions, or

beliefs emerged. From these final categories, the researchers developed core themes that shaped a theory explaining the IBCST participant experience.

Several steps were taken to maximize the trustworthiness of the research, according to Lincoln and Guba's (1985) recommendations, by establishing credibility, transferability, dependability, and confirmability. Member checking was used to ensure that the themes and theory that emerged were tested with the interviewees to see if they aligned with their experience. Transferability and confirmability were established by using a thick description of the data, triangulation, and expert review of one participant's transcription coding process by the third author and a qualitative research expert. Additionally, the researchers maintained a conscientious assessment of the data by bracketing personal judgments and biases, and took care in carefully comparing concepts, categories, and themes to build a theoretical model from a sound and trustworthy base.

Statistical Analyses

The original sample size goal was calculated with a power analysis (G*Power 3.1, Faul et al., 2009) and determined to be 48 participants based on a one-tailed independent samples (pre-post) *t*-test with an effect size of 0.80, alpha level of .05, and power set at .85. The power level of .85 was deemed sufficient based on the only prior randomized control trial examining the efficacy of BCST that used the LCQ as a primary outcome measure (Chamberlain Mitchell et al., 2016). A large effect size of .80 was chosen as a conservative value which would be advantageous as we planned to run an analysis of covariance (ANCOVA) and not a *t*-test to analyze LCQ score change. To account for the possible attrition rate of 16.5% reported in a previous study (Chamberlain Mitchell et al., 2016), we had a goal to recruit 56 participants. This sample target size number was modified as the study progressed due to multiple factors,

including a shorter than anticipated recruitment timeline related to a funding delay, and interim analyses that showed a large difference in the primary outcome measure between groups.

Analyses were conducted using R-4.4.2 (R Core Team, 2021). Group differences in mean total LCQ and VAS scores from T0-to-T1 and T0-to-T2 were examined, accounting for T0 assessment scores using an ANCOVA. The variance in responses for both LCQ and VAS scores was very high, making it difficult to determine linearity between T0 and T1 and T2 scores. Therefore, an interaction term between the treatment group and T0 score was considered to account for the potential different treatment effects at different T0 scores. All interaction terms were not statistically significant ($p = .26$, $p = .46$, $p = .95$, $p = .36$) for LCQ at T1, LCQ at T2, VAS at T1, or VAS at T2, respectively, suggesting homogeneity of the regression slopes. Shapiro-Wilk tests suggested insufficient evidence of non-normality of residuals ($p = .89$, $p = .09$, $p = .29$, $p = .38$). Lastly, Levene's test found no evidence of error variance heterogeneity ($p = .30$, $p = .74$, $p = .58$, and $p = .47$). Thus, the basic assumptions necessary for the ANCOVA were met.

Results

Thirty-nine individuals with RCC enrolled in the study between July 2023 and June 2024. Twelve participants completed the control treatment (11 women; mean age, 60 years) and 18 completed the IBCST treatment (16 women; mean age, 62 years). See Figure 1 for full details of the participant flow. One IBCST participant was lost to follow up at T2 and so was not included in T2 analyses. IBCST participants were contacted sequentially after T2 to schedule an interview. One participant indicated they did not have adequate Zoom capabilities and four others did not respond to the request. Ultimately, six participants (three of whom achieved clinically meaningful improvement on the LCQ at T1 and T2, two of whom only at T2, and one of whom

only at T1) participated individually in a semi-structured qualitative interview (interviews were completed approximately six weeks after their T2 assessment).

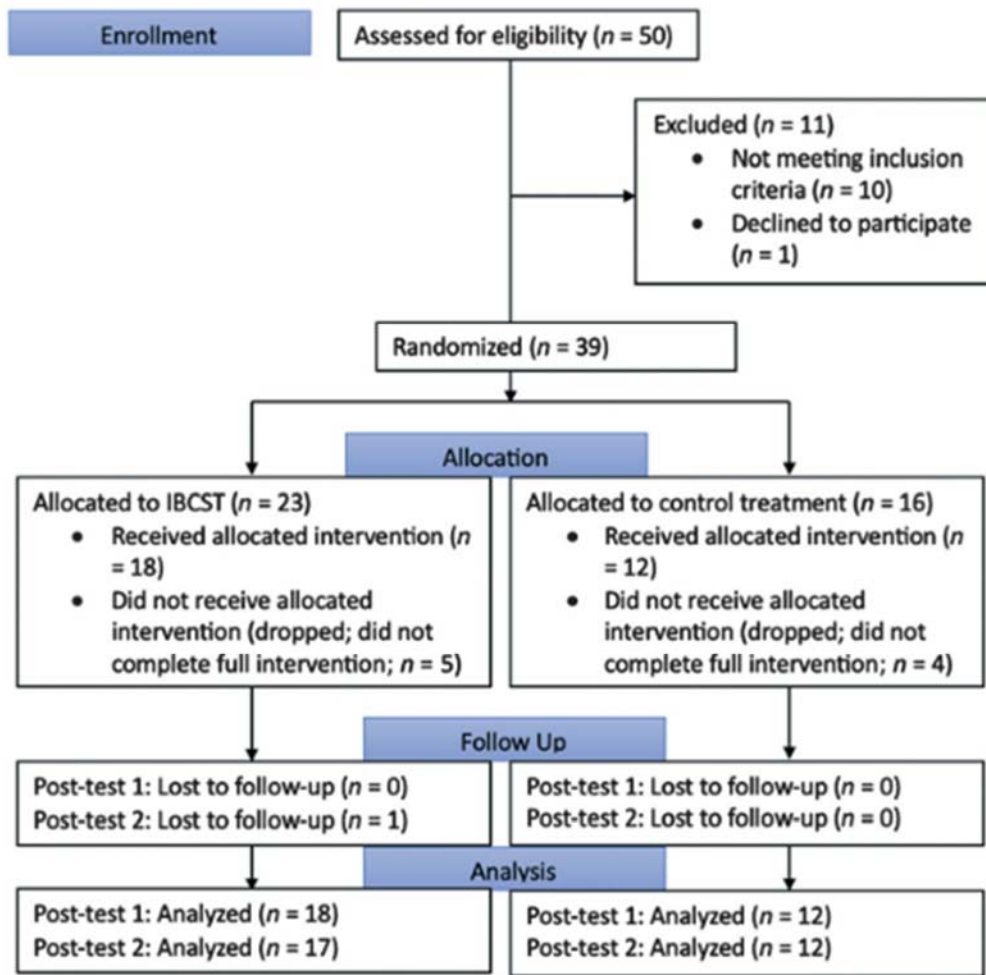


Figure 1. CONSORT flowchart diagram of participant flow.

Adherence

At the beginning of weeks 3, 4, and 5, participants were asked to respond “yes” or “no” to the question, "Did you review all the content from last week and complete all treatment activities as recommended?" If they marked "no" they received a response to go back and review the previous week's content before reviewing the new content. IBCST participants responded “yes” (n = 17, 15, 13), “no” (n = 0, 1, 0), or did not respond (n = 1, 2, 5) for the first, second, and

third adherence checks, respectively. Control participants responded “yes” (n = 10, 12, 11), “no” (n = 0, 0, 0), or did not respond (n = 2, 0, 1), for the first, second, and third adherence checks, respectively.

Leicester Cough Questionnaire

See Figure 2 for the IBCST and control group LCQ total score results at each assessment period for each participant. At T1, 72% of IBCST participants achieved a meaningful improvement in LCQ total score and this increased to 76% at T2. Mean domain and total LCQ scores for both groups during each assessment period are shown in Table 2. Change in mean total LCQ scores from T0-T1 was 3.74 and 0.58, and from T0-T2 was 4.10 and 0.83, for the IBCST and control groups, respectively. ANCOVA analysis revealed mean total LCQ score changes were significantly greater in the IBCST group than in the control group from T0-to-T1 (mean difference between groups = 3.24, 95% CI = 0.72-5.76, standard error = 1.227, $p = .014$, $\eta^2 = 0.205$), and T0-to-T2 (mean difference between groups = 3.30, 95% CI = 0.286-6.32, standard error = 1.467, $p = .033$, $\eta^2 = 0.163$).

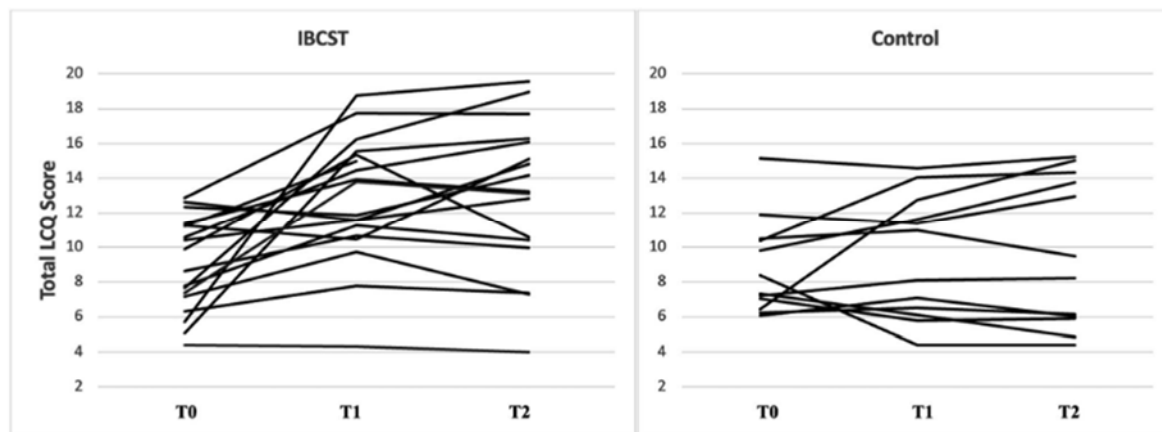


Figure 2. Total LCQ scores for all IBCST and control treatment participants at baseline (T0), one-week post-treatment (T1) and one-month post-treatment (T2). The LCQ has a total possible score of 21 with a higher score reflecting better cough-related quality-of-life.

Table 2. Mean LCQ and VAS Scores

		LCQ				VAS
		Physical	Social	Psych	Total (SD)	Total (SD)
IBCST	T0	3.58	2.82	2.64	9.04 (2.76)	49 (15.97)
	T1	4.62	4.03	4.13	12.78 (3.69)	33.94 (21.32)
	T2	4.71	4.22	3.88	13.03 (4.3)	44.18 (22.85)
Control	T0	3.67	2.75	2.45	8.87 (2.76)	49.08 (22.39)
	T1	3.74	3.04	2.67	9.45 (3.50)	50.08 (22.39)
	T2	3.75	3.17	2.79	9.70 (4.29)	56.42 (23.74)

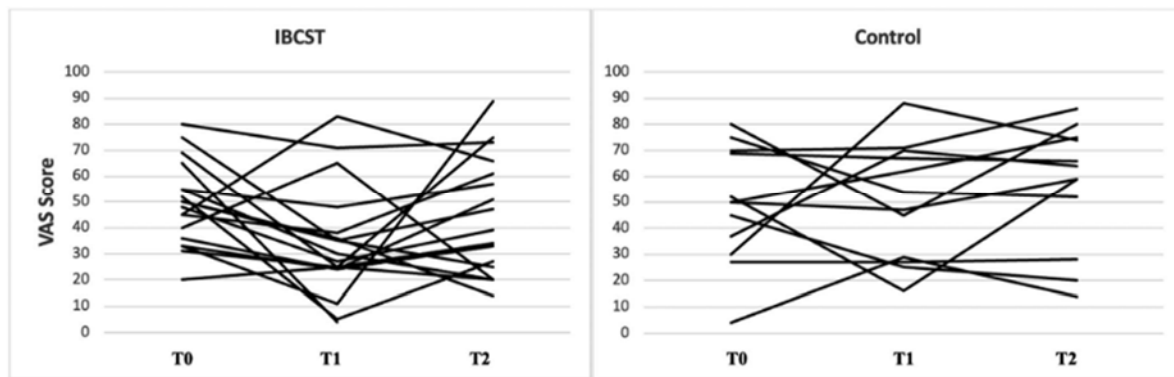


Figure 3. Total VAS scores for all IBCST and control treatment participants at baseline (T0), one-week post-treatment (T1) and one-month post-treatment (T2). The VAS has a total possible score of 100 with a lower score reflecting less severe perception of cough severity.

Cough Severity Visual Analog Scale (VAS)

See Figure 3 for the IBCST and control group VAS total score results at each assessment period for each participant. Mean VAS scores for both groups at each assessment period are shown in Table 2. Change in mean total VAS scores from T0-T1 was -15 and 1, and from T0-T2 was -7 and 7, for the IBCST and control groups, respectively. ANCOVA analysis revealed there was mild evidence of a larger decrease from T0-to-T1 for the IBCST group compared to the control group (mean difference between groups = -16.1, 95% CI= -32.7-0.46, Std error = 8.804, $p = .056$, $\eta^2 = 0.128$), with no evidence of a difference in the mean score change from T0-to-T2

(mean difference between groups = -11.73, 95% CI = -28.53-5.06, Std. error = 8.170, $p = .338$, $\eta^2 = 0.073$).

Results of Semi-Structured Qualitative Interviews

Multiple themes arose from the six participant interviews and helped inform the theory of IBCST participant experience. In short, IBCST participants were highly motivated to find a non-pharmacologic treatment for their cough and found the cough suppression strategies helpful for controlling cough while in the study but had difficulty continuing to implement them long term. The online format was unanimously perceived as convenient. Participants liked the flexibility of when to access it and commented on the videos as being a favorite part of treatment as they could rewatch demonstrations and build confidence in executing techniques. Two participants commented on challenges remembering to continue to use cough suppression techniques after the study ended and two reported they did not perceive their underlying cough condition to be changed in response to treatment, but that they gained improved control of their cough and could suppress cough while using cough suppression techniques.

Theme 1: Motivation.

All participants were highly motivated to seek help for RCC. As one participant stated, *“I’ve spent a lot of time going to a lot of different specialists. Allergist, the pulmonologist twice, asthma person, ENT, GI, family care. It’s been, cardiology,....nothing has really helped. I cough constantly...so, it [coughing] affects my quality of life more than anything else.”* The time spent on prior failed treatments for RCC contributed to feelings of desperation and openness to exploring a novel treatment. One participant reflected, *“I’m tired of my children saying that I have had this cough for 25 years, and so I was looking for..I was out on the internet looking for solutions.”* Half of the participants voiced worries about the side effects of prior pharmaceutical

treatments. As shared by one woman, *“I have had this cough forever, and was taking amitriptyline, but I’m a little uncomfortable taking medicine long term so I wanted to learn other possible strategies or ways to deal with my cough.”*

Theme 2: Convenience.

All participants liked the convenience and flexibility of the online treatment modality and five participants commented on the clarity of therapy materials, particularly the instructional videos. Participants identified the ability to independently review treatment videos at their convenience as helpful in building confidence with their understanding of and ability to accurately perform treatment techniques (e.g., cough control breathing). This sentiment was captured succinctly by one participant, *“I could do it when I had time, and the quality of the videos was very good and very clear. The audio and the video it was very step-by-step, so.. I knew what I was being asked to do.”* The treatment design was admired for the convenience and flexibility with when and how participants could access it, for example, *“It gave you a chance to do it when you wanted to, you could go back and look at it again if you had questions.”* One participant commented, *“I think it was just perfect for that [online modality] because it had the video involved.. I am not sure [BCST] would have been really any better in person, actually.”*

Theme 3: Maintenance.

Five participants (one reported no issue with sustaining improvement) reflected on the challenges of continuing to implement cough suppression strategies after the study ended and felt their cough had worsened again because of this. *“At the time [during the study] it [using cough control breathing to suppress cough] was good, it’s just I’m so used to having this frequent cough that now I just try to do it if it’s like uncontrollable, but It worked very well if I used it..I’m probably not as good as I used to be trying to prevent it, the cough.”* Some attributed this to the

chronicity of their condition interfering with their ability to implement techniques. As one participant said, *“I’m so used to my cough it’s hard for me to pay attention to it to think about trying suppress.”* Another reflected, *“If you have been coughing for a long time as I have it [the cough] is not just going to go away, but you can gradually, by continuing to apply these techniques, you can get better control of your cough.”*

Theme 4: Preferred technique.

Four participants preferred effortful swallowing over cough control breathing as a suppression technique, commenting that it was easier to perform and that the cough control breathing technique increased instead of decreased the UTC. This is exemplified by the quote, *“The breathing does not [help suppress my cough] it just makes me cough more”*. While there was information and recommendations provided on how to modify this technique to troubleshoot this problem (e.g., slow down nasal inhalation and extend the pursed lip exhalation phase), participants did not report trying modifications. Instead, participants tended to stick with the simplest strategy (e.g., *“The hard swallowing I kind of memorized I so could try it, but then I found I forgot what other tricks were”*).

Theme 5: Trustworthiness.

Three participants communicated how the study team’s expertise helped build confidence in the treatment recommendations and contributed to feeling validated in their experience with RCC. While this was only half of participants, this was an important reflection that emerged given the online, asynchronous therapy modality. Many participants described having past experiences with providers or clinicians which cast doubt on their ability to help them. As reflected by one woman, *“You folks were obviously very knowledgeable and have studied this. I did try to go to a speech pathologist at one point for my cough and she like, did not really know*

anything about cough, ..so it felt good to be able to interact with people who are working on this issue.” The study team’s expertise in this area was reassuring and helped with the buy-in for treatment.

Theme 6: Future directions.

All participants were open to the future use of BCST smartphone applications and integration of cough frequency tracking. Participants acknowledged the popularity of smartphone applications and noted that it would be convenient to access BCST in an application format. One individual was particularly interested in the possibility of tracking and analyzing her own cough frequency data from a smartphone application, *“I like the idea of being able to track my coughs...sit down and look at it and kinda compare and see when I’m coughing more or less...”*

Discussion

The IBCST intervention was developed to overcome traditional barriers to accessing BCST by offering treatment components in an asynchronous, online format, accessible at any time. To the best of our knowledge, this is the first version of BCST that does not require real-time interaction with a clinician. The results showed changes in the mean total LCQ scores comparable to those seen in conventional BCST, with total scores improving by approximately four points (Chamberlain Mitchell et al., 2016; Kapela et al., 2020; Patel et al., 2011; Ryan et al., 2009, 2010; Slovarp et al., 2021; Vertigan et al., 2016; Wright, 2021), suggesting both feasibility and efficacy of the IBCST approach. Interestingly, while the LCQ scores indicated improvements in all domains, changes in the VAS did not reach clinically meaningful levels (>30) at either post-test interval. The reason for this discrepancy is unclear but is likely due to insufficient sensitivity of the VAS, which has been found to be less strongly correlated with objective changes in cough frequency than the LCQ (Decalmer et al., 2007; Kelsall et al., 2011). Future

investigations should consider the addition of ambulatory cough frequency monitoring as an outcome measure to obtain a holistic understanding of changes in cough severity.

Grounded theory analysis of the interviews revealed that IBCST was widely accepted as convenient and useful, with strengths being the flexibility of accessing the treatment and clarity of treatment materials. Videos to support new learning of cough suppression techniques were highly valued by participants. Kapela et al., (2020) found no significant benefit when adding supplemental videos to in-person individual BCST; however, the benefit of supplemental videos may be different for different modalities of BCST, warranting further investigation.

Despite this being an asynchronous, online treatment, participants acknowledged the trustworthiness of study personnel and confidence in their expertise. Additional investigation into the specific components that led to this perception (e.g., patients feeling validated in their experience and struggle with RCC through the program's introductory education, or a factor such as representation of multiple universities on the study team) is warranted. Establishing trust in the therapeutic relationship at the outset of BCST, against a backdrop of many prior failed treatment approaches offered by specialty physicians, likely heavily influences an individual's adherence to treatment recommendations and warrants additional investigation to inform strategies for promoting self-efficacy in any modality of BCST.

Most interviewees reported experiencing improvements in cough control (i.e., preventing or lessening the severity of coughing) while actively engaged in study procedures, with effortful swallowing as the preferred cough suppression technique. However, most did not report experiencing lasting change in the severity of their condition (i.e., reduced UTC frequency) and largely attributed this to inconsistency in long-term implementation of cough suppression. A shortcoming to understanding this phenomenon better lies in the variability of the timing of when

participants were interviewed post-treatment, and lack of individualization of long-term treatment recommendations provided in the final week (participants were instructed to continue using cough suppression techniques “as needed”). Additionally, we did not assess participant understanding of the rationale for cough suppression to gauge if our education was effective at conveying the importance of diligent cough suppression to promote long-term neuroplastic change of the cough reflex to restore normal sensitivity. Future mixed-methods work is needed to uncover how participant’s understanding of treatment rationale and cough suppression habits influence treatment outcomes, and to further investigate cough-related quality of life changes.

Other points that warrant increased attention in future IBCST adaptations are adherence to treatment recommendations and provision of individualized feedback. Adherence responses for the IBCST group diminished in the final check (five participants did not respond to the question) and future IBCST adaptations should work to track consistency more closely. In the clinic, the researchers find emphasizing the need for extremely diligent and repetitive cough suppression when experiencing an UTC, to be critical to optimizing treatment success. Future IBCST iterations should also consider modifications to enhance individualization of treatment recommendations. The current design placed a high level of expectation on self-directed problem-solving. Participants were encouraged to revisit prior treatment materials and education as needed and to adapt cough suppression strategies to meet their needs (e.g., use modifications to cough control breathing technique if it increased instead of decreased an UTC), but individualized feedback tailored to each participant was not provided as it would be in traditional BCST. Therefore, it is likely that participants may not have gained maximum benefit from the treatment.

Integrating ambulatory cough frequency monitoring with IBCST may enhance therapeutic outcomes by helping patients recognize effective techniques, identify areas for improvement, and better prepare to use cough suppression techniques. The addition of cough frequency monitoring to any modality of BCST would go beyond the traditional limitations of clinical sessions to provide salient and timely information to patients about changes in their cough frequency in daily life. It may also serve as a valuable clinical tool for assessing patient appropriateness and responsiveness to therapy. As BCST evolves into asynchronous, online, or app-based interventions with reduced clinician oversight, it is essential to incorporate measures to ensure patient appropriateness for therapy. These should include thorough screening for therapy suitability, mechanisms to track symptoms throughout treatment, and appropriate follow-up with the patient's medical team. Such safeguards are critical to maintaining clinical rigor and ensuring patient safety as BCST moves out of traditional clinical settings and into the hands of patients.

Conclusions

IBCST is feasible, efficacious, acceptable to participants, and paves the way for future adaptations of BCST and other specialized speech-language pathology interventions into digital therapeutics. This study provides valuable evidence supporting the potential benefits of adapting other specialty speech-language pathology interventions (e.g., respiratory retraining for inducible laryngeal obstruction) to reach a wider population of patients, particularly in rural areas. This design could allow for scalable and low-cost interventions or supplements to traditional interventions in cases where there is a long wait time or a lack of access to specialized speech-language pathology services. While more work is needed to increase the number of specialized SLPs delivering voice and upper airway services and to increase physician awareness of the

availability and efficacy of these services, online, asynchronous adaptations of therapy offer a way to bridge this gap.

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Data Availability Statement

The datasets generated during the current study are available from the corresponding author upon reasonable request.

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Learning Outcomes

1. Appraise the efficacy of internet-behavioral cough suppression therapy (IBCST).
2. Connect findings from qualitative semi-structured interviews to understand IBCST user experience.
3. Apply the findings from this study to consider how future BCST iterations and other online speech-pathology interventions could be implemented to meet the needs of rural populations.