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Feasibility of implementing mobile technology-delivered mental health treatment in routine adult sickle cell disease care

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Abstract

Sickle cell disease (SCD) is a severe hemoglobinopathy characterized by acute and chronic pain. Sufferers of the disease, most of whom are underrepresented minorities, are at increased risk for mental health disorders. The purpose of this study is to test the acceptability and implementation of a computerized cognitive behavioral therapy (cCBT) intervention, *Beating the Blues*, to improve depression, anxiety, and pain in patients with SCD. Adults with SCD and significant symptoms of depression (Patient Health Questionnaire [PHQ-9] score ≥ 10) or anxiety (Generalized Anxiety Disorder Scale [GAD-7] score ≥ 10) were eligible to participate and be randomized to either receive eight sessions of cCBT with care coach support or treatment as usual. Participants reported daily pain and mood symptoms using a mobile diary app. Depression, anxiety, and pain symptoms were assessed at 1, 3, and 6 months. Thirty patients were enrolled: 18 to cCBT, and 12 to control. The cCBT intervention was feasible to implement in clinical settings and acceptable to participants. Patients in the cCBT arm reported a marginally greater decrease in depression at 6 months (-3.82, $SE = 1.30$) than those in the control group (-0.50, $SE = 1.60$; $p = .06$). There were no significant effects of treatment on anxiety; however, cCBT was associated with improved daily pain reported via a mobile diary app ($p = .014$). cCBT, delivered via mobile device, is a feasible strategy to provide mental health care to adults living with SCD. cCBT was acceptable to the target population; was able to be implemented in real-world, nonideal conditions; and has the potential to improve patient-reported outcomes.

Keywords

Health information technology, Mental health, Depression, Cognitive behavioral therapy, Sickle cell disease

INTRODUCTION

Sickle cell disease (SCD) is a severe hemoglobinopathy that affects approximately 100,000 people in the USA and is one of the most frequently occurring genetic diseases [1,2]. Sickle cell primarily affects individuals of African descent and is subject to significant disparities in health care and research [3,4]. Despite the relatively high prevalence of the disorder, compared with another rare genetic disease such as cystic fibrosis, SCD receives one tenth the research funding per patient [5].

Implications

Practice: Technology-delivered cognitive behavioral therapy can be used to provide evidenced-based mental health care to underserved, minority chronic disease patients who may not otherwise receive treatment for comorbid mental health conditions.

Policy: Policymakers who want to improve the quality of care and outcomes for patients living with chronic conditions should explore cost-effective, scalable, technology-delivered, mental health intervention that patients can access anywhere, 24/7, via mobile device.

Research: Future research should be aimed at testing the effectiveness of computerized cognitive behavioral therapy for improving long-term mental health and disease outcomes in a large, community-based sample.

Patients living with the disease typically suffer from daily chronic pain as well as recurrent, unpredictable, vaso-occlusive episodes ("pain crises") that often require immediate medical attention [6]. The severity and chronicity of SCD lead to high morbidity and early mortality [7]. Sufferers of the disease, most of whom are ethnic minorities from disadvantaged backgrounds, report significant psychosocial stress and may be at risk for psychiatric disorders [8].

A recent systematic review found that 25% to 50% of patients with SCD report clinically significant depressive symptoms, and studies have also found that adults with SCD experience symptoms of anxiety [9,10]. The rates are both significantly higher than what has typically been recognized and diagnosed in typical medical settings for individuals with SCD (2%–7%), and higher than the rates seen in the general population or among those with other chronic medical conditions [11,12]. This suggests that mental health needs for patients with SCD who receive

routine clinical care often go unmet. Addressing internalizing symptoms in patients with SCD is particularly important because their symptoms may negatively affect their pain outcomes, health care utilization, quality of life, and overall self-management [10,13–16]. Self-management tasks include medication adherence, attending appointments, and maintenance of positive health behaviors such as diet and exercise. Symptoms may also interfere with recognition of disease-related symptoms, which is critical for timely treatment of vaso-occlusive episodes and other SCD-related complications. In other patient populations, depression and anxiety have been found to affect not only quality of life, but also disease outcomes and risk of mortality [17–19]. Thus, when left untreated, poor mental health can have significant adverse effects on the lives of patients with SCD.

Despite the pressing need for mental health treatment as part of SCD care, there are no clinical trials testing evidence-based mental health interventions among adults with SCD [20]. Cognitive behavioral therapy (CBT) has been the gold standard treatment for depression and anxiety [21], and it has been shown to be effective in reducing mental health symptoms among chronic disease populations [22–25]. Although CBT has been used in SCD for the treatment of pain with some short-term success, it is not clear whether CBT for mental health treatment can be effective in improving health outcomes such as depression, anxiety, and pain, among adults with SCD [26].

There has been increasing interest in Internet-delivered mental health treatment, as it presents an advantage over traditional mental health care that is often expensive and difficult to access, particularly for underserved patients [27] such as those living with SCD. Online mental health treatment provides flexibility for those with tenuous life circumstances such as an inability to miss work, caregiving responsibility, and transportation challenges, all of which disproportionately affect underserved patient groups. Although limited access to the Internet among disadvantaged groups remains a concern, the emergence of mobile technology has helped bridge the "digital divide" and increased access to online interaction (e.g., email, social media) in low-income and racial and ethnic minority populations (http://www.pewresearch.org/fact-tank/2017/03/22/digital-divide-persists-even-as-lower-income-americans-make-gains-in-tech-adoption/).

Patients with SCD may benefit from behavioral interventions that can be accessed on computers or mobile phones. Specifically, computerized CBT (cCBT) adapts traditional tenets of CBT into an interactive e-learning online experience that teaches users how to manage their mood through lessons, exercises, and quizzes [28,29]. Internet-delivered cCBT has been proven effective in reducing depression and anxiety [30,31]; however, few CCBT trials

have included nonwhite participants [32], and no studies have tested cCBT among adults with SCD. One recent pilot trial of cCBT for pain among adolescents with SCD and their parents demonstrated that this mode of intervention delivery is feasible and acceptable [33]. Thus, it is likely similar interventions may also engage adults with SCD and potentially lead to improved mental health outcomes. Due to the need for mental health treatment and the barriers of in-person therapy for underserved populations, cCBT may be an effective way to deliver evidence-based CBT to patients with SCD, thereby addressing their disease-related pain, psychosocial stress, and symptoms of depression and anxiety. The utility, effectiveness, and implementation of cCBT in patients with SCD have not been studied to date.

The primary objective of this feasibility study was to test the acceptability and implementation of an online, mobile-ready, cCBT intervention called *Beating the Blues*. We hypothesized that cCBT would be an acceptable mental health treatment for patients and could be easily integrated into routine clinical care. We also explored possible effects of cCBT on depression, anxiety, and average daily pain, which we hope to investigate in a subsequent larger study.

In this article, we first present our study methods and analysis plan. We then present the results for participant engagement with the cCBT program and treatment effects on mental health outcomes and daily pain as assessed via a smartphone app. Finally, the article presents the qualitative findings from interviews with participants and a focus group.

METHODS
This study was designed as a pragmatic trial conducted in real-world clinical practice settings, with typical SCD patients. Thus, eligibility criteria were relaxed, and there were no direct incentives or compensation for participation.

Patient population

Inclusion and exclusion criteria
All adult patients (ages 18–65) with a diagnosis of SCD (HgbSS, HgbSC, SB+Thal, or SB0Thal), receiving routine care at either of two U.S. urban comprehensive tertiary care centers, located in the Southeast (Nashville, TN) and Northeast (Pittsburgh, PA) regions, were eligible to be screened for this study. The study protocol (ClinicalTrials.gov Identifier: NCT02384590) was approved by the University of Pittsburgh and Vanderbilt University Institutional Review Boards. Patients were screened from March 2015 through March 2016 by a nurse or other medical provider, as part of usual care. Depression was assessed using the Patient Health Questionnaire (PHQ-9) [34], anxiety symptoms with the Generalized Anxiety

Disorder Scale (GAD-7) [35], and pain intensity with the Brief Pain Inventory (BPI) [36]. Patients with significant symptoms (defined as PHQ-9 score ≥ 10 or GAD-7 score ≥ 10) were seen by a licensed clinical psychologist or clinical psychology graduate student who reviewed the results of the self-report screener with them and determined if they would probably benefit from mental health treatment. Eligible patients were approached by study staff and consented. There was no payment or compensation for participation.

All consented patients received a tablet computer (Apple iPad Mini) with unlimited data, preinstalled with a pain and mood diary app that participants would use to enter symptoms daily: the Sickle cell Mobile Application to Record Symptoms via Technology (SMART; see SMART: daily electronic pain diary). After patients were registered on the device and shown how to use the tablet computer and installed apps, they were randomized 2:1 to either receive cCBT with care coach support or receive treatment as usual (TAU). Treatment assignment was randomly generated electronically via the SMART app and was presented on the iPad screen to the participant and sent via email to the research team at the time the participant was registered on the device.

SMART: daily electronic pain diary

The SMART pain diary app prompts patients to complete a pain and mood survey, once a day, at a time the patient specifies. If they do not complete the assessment at that time, they have the option to snooze the prompt until a more convenient time. A twice-daily prompt asks the user to report current pain with a visual analog scale ranging from "0" for "no pain" and "10" for "the worst pain possible." After pain level is entered, the subsequent screen allows users to enter location(s) of the pain from a drop-down list. Users are also asked about treatments used and are able to enter whether they take their long-acting or short-acting opioids for pain [37,38]. There were no incentives for participants to complete the daily diary entries.

cCBT + care coach arm

The cCBT intervention sessions were provided with *Beating the Blues*, an evidence-based, computerized e-learning experience delivering CBT for depression and anxiety. This program has been shown effective in clinical trials [39,40] and endorsed for standard clinical care by the National Institute for Health and Clinical Excellence [28].

Participants were registered to the *Beating the Blues* mobile-optimized website and asked to use the tablet device weekly to complete eight, 1-hr *Beating the Blues* CBT sessions over the following 3 months. Each participant in the cCBT arm was introduced to a care coach, a master's degree-level research assistant with a background in psychology, who would contact them on a weekly basis by telephone and throughout the week by email or text for 1 month, and then as needed for two additional months. Discussion with the care coach focused on current stressors, applicable cCBT skills, barriers and solutions to completing modules, and technical questions regarding the iPad, SMART app, or *Beating the Blues* website.

Treatment as usual arm

The SMART app prompted the TAU patients to complete the pain and mood diary daily. No other activities were required as part of the study.

Outcomes

Depressive symptoms (PHQ-9), anxiety symptoms (GAD-7), and pain intensity (BPI) were collected from screener data as baseline measures. At 1, 3, and 6 months, a blinded assessor called patients to update these measures. The same depression, anxiety, stress, and pain screener items were administered over the phone by the assessor or self-administered by patients electronically via an email link provided by the assessor. Any data received more than 6 weeks later were considered outside the assessment window and counted as missing. There were no incentives for participants to complete the follow-up assessments.

Health care utilization

Medical chart abstraction extracted emergency department and hospital visits for 12 months before enrollment and 12 months following enrollment.

Qualitative interviews and focus groups

After the study, each cCBT participant was invited to a voluntary, in-person, individual interview. Participants completed 20-min interviews using a semistructured qualitative interview guide. Qualitative interview questions included "What did you like about the intervention program?" "What did you not like?" "Tell me about your experience working with the therapists or care-coach?" "How could they improve the quality of care you received?" "How was the program helpful or not helpful for addressing your distress and pain symptoms?" In addition to the one-on-one interviews, patients were invited to attend a focus group to discuss their experience working with the cCBT program.

Usability and acceptability of cCBT

We recorded Web data on the number of site logins, time spent on the site per log in, and sessions completed of the *Beating the Blues* program. We used these data, in conjunction with qualitative data, as indicators of patient usability and acceptability of the program.

Analysis

Quantitative analyses
To compare differences between the cCBT and TAU groups at baseline, t tests and Fisher's exact tests were used for continuous and categorical variables, respectively. We used paired t tests to examine 1-, 3-, and 6-month changes in outcomes variables and used difference scores to estimate effect size. To control for the overall false discovery rate (FDR) at 0.05 in multiple tests at 3 months, we used the Benjamini and Hochberg FDR method (BH-FDR) for the pairwise t test. In exploratory analyses, we examined differences in the slopes of depression symptoms (PHQ-9), anxiety symptoms (GAD-7), and current 0−10 pain level across the four assessment points: baseline, 1 month, 3 months, and 6 months. We then tested the treatment-by-time interaction effect to determine group differences in symptom changes over time.

We analyzed these data using linear mixed models with restricted maximum likelihood estimation. To account for within-patient correlation, we fitted several linear mixed models, including both fixed effects for the independent variables and random effects at the patient and institution levels. We examined PHQ-9 scores with and without Box−Cox power transformation due to its nonsymmetric distribution. All two-sided hypothesis tests were conducted at a significance level of .05.

SMART daily pain data
We analyzed daily visual analog pain data from the SMART app for up to 6 months from first report at the study start date. Our model assumes that treatment was given at time of first report. A linear mixed model including random intercept and slope for each participant was used to compare cCBT and TAU on daily pain reports. Due to the limited number of clinics (two), only a fixed effect for institution was included. The models also included fixed effects of other covariates such as age, gender, SC genotype, and medication use in addition to the treatment, time, and treatment-by-time interaction.

Qualitative analyses
The interviews and focus groups were audio-recorded and transcribed verbatim. Transcripts were analyzed using thematic analysis, a qualitative method aimed at pinpointing central aspects in a set of data, by means of detailed pattern identification. Two independent coders familiar with the study read through transcriptions to identify patterns in the data, reflecting common themes in the participants' experiences of the treatment. Responses were organized into general themes that were then categorized as barriers, facilitators, or opportunities for program improvement. Within each of these categories, each statement was labeled with a theme as defined by each coder and in accordance with the goals of the study. A third coder reviewed all coding, resolved any conflicting categorization between the two primary reviewers, and merged overlapping themes where appropriate.

RESULTS

Across two institutions, 212 patients were screened for anxiety and depression and 63 qualified with clinically significant depression or anxiety symptoms. Of those who qualified, 34 patients were approached to participate (Supplemental Figure 1). A number of patients were not approached (n = 27) primarily due to a psychologist not being available to review the screener with the patient. Of those approached, four declined to participate. We consented 30 patients, randomizing 18 to cCBT and 12 to TAU (Table 1). Twenty-one were women (70%), and the average age was 32.9 (SD = 11.01) years old. The majority of patients had the most severe SCD genotype variants: HgbSS/SB0Thal (n = 16, 53%). The cCBT group was significantly older than the TAU group (a mean age of 34.5 [SD = 12.7] vs. 30.4 [SD = 7.8] years, respectively; p < .05). The treatment groups did not differ on any other demographic or clinic variables.

Engagement with the CBT program

On average, participants progressed to at least session 4 of 8 in the *Beating the Blues* program delivered via iPad. Only three participants progressed to the eight session and completed the program, and only one participant did not log in at all. A programing error at session 3.4 stopped several participants from advancing to the next session; many of them did not continue the program at that point even after the issue was resolved. Six participants discontinued the program at session 3.

Pain and mental health outcomes

Baseline data were available for all 30 patients, and 27 patients completed all three follow-up assessments; only one patient, in the cCBT arm, did not provide any outcome data within the expected time frame. Mean and SD of current pain intensity, PHQ-9, and GAD-7 scores by treatment group along with the pairwise t test results and effect sizes are shown in Table 2.

After adjusting for the effect of age, gender, genotype and institution as well as within-patient correlation in the mixed models, there was a significant difference in PHQ-9 score changes between two treatment groups in the original scale (p value for the treatment-by-time interaction test was .023; F-test value of 3.34 [df = 3, 77]), yet after transforming the outcome using the Box−Cox method the treatment-by-time effect only reached the marginal level of significance (p = .06; Fig. 1). Patients in the cCBT arm reported a greater decrease in PHQ-9 depressive

Table 1 | Descriptive statistics for adult patients with sickle cell disease receiving mental health care via computerized cognitive behavioral therapy or treatment as usual

Variable	cCBT (*N* = 18)	TAU (*N* = 12)	All (*N* = 30)	*p* Value
Age, mean (SD)a	34.56 (12.78)	30.42 (7.81)	32.90 (11.10)	.57
Female	12 (66.7%)	9 (75.0%)	21 (70.0%)	.70
HgbSS/SB0Thal	7 (38.9%)	9 (75.0%)	16 (53.3%)	.07
PHQ-9, mean (SD)	12.50 (5.46)	12.00 (4.45)	12.30 (5.00)	.90
GAD-7, mean (SD)	10.28 (3.74)	11.00 (5.44)	10.57 (4.42)	.69
Pain, current	5.20 (3.30)	5.67 (3.00)	5.38 (3.13)	.57
Long-acting opioids, n (%)	10 (55.6%)	9 (75.0%)	19 (63.3%)	.44
Short-acting opioids, n (%)	16 (88.9%)	10 (83.3%)	26 (86.7%)	›.99

cCBT computerized cognitive behavioral therapy; *GAD-7* Generalized Anxiety Disorder Scale; *PHQ-9* Patient Health Questionnaire; *TAU* treatment as usual.

[a]*p* Values are computed using the independent group *t* test for continuous variables and Fisher's exact test (chi square) for categorical variables. There is no evidence of significant difference in demographics and baseline outcomes between two treatment groups at the significance level of .05.

symptoms from baseline to 6 months (*p* = .02), whereas those in the TAU group reported no change in depressive symptoms (*p* = .82; Table 2).

There were no group differences for change in GAD-7 anxiety symptoms or current pain intensity level (*p* values for the treatment-by-time interaction were .51 and .29, respectively). Therefore, we tested whether the changes in GAD-7 scores and current pain levels from baseline were significant. After adjusting for the effect of age, gender, SC genotype, and institution as well as the within-patient correlation, there was a significant change in current pain intensity level (*p* value of .023; *F*-test value of 3.39 [*df* = 3, 73]). The score changes on GAD7 was not significant (*p* value of .22; *F*-test value of 1.5 [df = 3, 79]).

SMART daily pain

Participants used the SMART app for 164.6 ± 109.6 days, with a mean of 67.2 ± 60.4 pain reports per participant. Mean pain scores over the 6-month study period were 4.7 ± 2.1 (range 0−10). The median use of SMART was similar at both institutions, and there were no differences in use by treatment group. A significant treatment-by-time interaction ($F_{(1,1235)}$ = 6.09, *p* = .014) showed that mean daily pain decreased for the cCBT group, whereas daily pain increased for the TAU group (Fig. 2).

Table 2 | Means and *SD* for current pain level, PHQ-9, and GAD-7, by treatment group and time among adults with sickle cell disease

Variable		Total			cCBT			TAU	*p*	Cohen's da
	N	Mean (SD)	*p*	N	Mean (SD)	*p*	N	Mean (SD)		cCBT–TAU
Current pain level										
Baseline	24	5.38 (3.13)		15	5.20 (3.30)		9	5.67 (3.00)		
1 month	26	5.12 (2.94)	.24	16	4.19 (2.40)	.12	10	6.60 (3.24)	.81	−0.586
3 months	26	4.96 (3.16)	.10	16	4.94 (3.13)	.35	10	5.00 (3.37)	.19	0.124
6 months	28	5.57 (2.86)	.85	17	5.31 (2.87)	.92	11	5.97 (2.93)	.77	−0.057
PHQ-9 score										
Baseline	30	12.30 (5.00)		18	12.50 (5.46)		12	12.00 (4.45)		
1 month	27	11.19 (5.13)	.35	16	11.81 (5.26)	.86	11	10.27 (5.04)	.25	0.199
3 months	28	11.55 (6.46)	.46	17	10.38 (5.63)	.14	11	13.36 (7.47)	.64	−0.666
6 months	28	9.96 (6.02)	.06	17	8.82 (4.77)	.02	11	11.73 (7.46)	.82	−0.652
GAD-7 score										
Baseline	30	10.57 (4.42)		18	10.28 (3.74)		12	11.00 (5.44)		
1 month	27	9.89 (5.29)	.50	16	10.69 (4.88)	.74	11	8.73 (5.88)	.22	0.581
3 months	27	9.82 (6.06)	.41	16	10.44 (5.45)	.76	11	8.91 (7.04)	.41	0.488
6 months	28	8.68 (6.22)	.08	17	9.00 (5.86)	.23	11	8.18 (7.00)	.24	0.334

BH-FDR Benjamini and Hochberg false discovery rate; *cCBT* computerized cognitive behavioral therapy; *GAD-7* Generalized Anxiety Disorder Scale; *PHQ-9* Patient Health Questionnaire; *TAU* treatment as usual.

[a]The Cohen's *d*-type effect size of treatment at each time point is defined as the difference between the standardized mean score change of cCBT and TAU. We used the effect size formula with bias correction due to small samples [41]. After controlling the overall type I error rate at 0.05 using the BH-FDR method, none of the pairwise comparisons based on the pairwise *t* test were significant. The PHQ-9 score changes from baseline to the month of 6 for cCBT patients was close to the marginal level (*p* value of .018 is marginally greater than the adjusted *p* value of .017 by the BH-FDR method), whereas the difference at 6 months for the TAU patients was not significant.

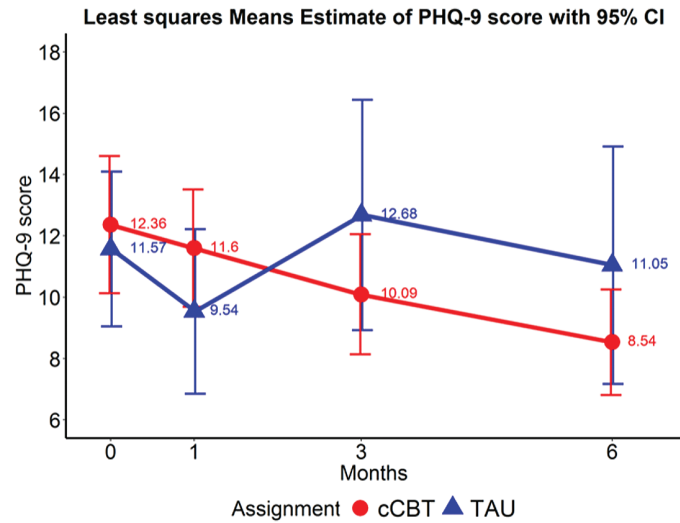**Least squares Means Estimate of PHQ-9 score with 95% CI**

Fig 1 | Means of Patient Health Questionnaire (PHQ-9) scores by treatment group at baseline, 1, 3, and 6 months, among adult patients with sickle cell disease.

Qualitative data analysis

Of the 18 patients randomized to the cCBT arm, 16 patients completed individual interviews and 3 patients attended a 1-hr focus group. Interview scripts and data were coded based on the socioecological model and the behavior change wheel framework [42]. Patients' comments and feedback on the cCBT program were categorized into "facilitators," "barriers," and "opportunities" (Table 3). Several themes emerged from the data. There were a number of facilitators to using the cCBT program. Patients expressed liking the structure, care coach support, simplicity of the language, homework activities, and practicality, with one saying, "It really does work once you start listening and paying attention." Although patients perceived that overall, cCBT-delivered coping skills were helpful for managing distress, a few patients identified some barriers related to how programing

was delivered; for example, they found that the educational vignettes were not relatable and that the program either "got boring" or had too slow of a tempo. Several participants indicated they wanted the ability to go at their own pace. Two participants found typing words challenging (because of difficulty with spelling) and had difficulty with the reading portions.

DISCUSSION

As the life expectancy for patients with SCD has improved, management of the disease has begun to transition toward long-term and chronic care, in which there is a growing need to screen for and treat internalizing problems such as depression and anxiety that can result from disease burden and other psychosocial stressors. The present study aimed to show the feasibility of identifying and providing evidence-based treatment for depression

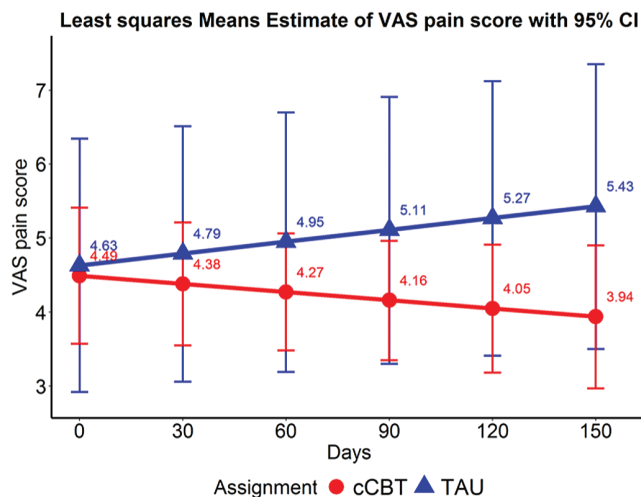**Least squares Means Estimate of VAS pain score with 95% CI**

Fig 2 | Estimated means for daily visual analog scale (VAS) pain scores over time for adult patients receiving computerized cognitive behavioral therapy (cCBT) or treatment as usual (TAU). Models include institution, gender, age, genotype, and opioid medication use.

Table 3 | Qualitative analysis of interview and focus group data from adult sickle cell patients who participated in the computerized cognitive behavioral therapy treatment arm

Facilitators		Barriers		Opportunities	
Theme	Example quote	Theme	Example quote	Theme	Example quote
Presentation and structure of content	–The way it was presented to me is—I understood it –It wasn't very time consuming –I just loved the organization	Lack of incentives or reminders	–Keep you motivated –Not something that you think to do every day	Convenience of mobile device	People are on their phones all day
Care coach support	If you ran into any problem you could contact [Ellen] and she would let you know what to do or how to fix it, so it was very helpful.	Poor concentration while depressed	Not something that you want to focus and concentrate on [when very depressed]	Increase relatability	"See people that we can relate to"
Relatability	I could relate to [clips] that have happened in my past or, like I said, I plan on taking it with my future	Slow pace of program	"Some of (the actors') stories are kind of lengthy" "have to kind of go at their pace instead of your own pace"	Increase pace of program	"a way you could have speed up the tempo maybe in each step and it should teach you how to deal with that part of that step, and then number two: teach you how to deal with that part of the step."
Interactive activities	I really liked the idea of like the charts	Technical difficulties	–Actually, remember when I told you about that one time where I got stuck on [Session 3.4] – [Login Process] Sometimes it would work and then sometimes you had to go back and enter everything over again.	Decrease pace of program	"maybe in each step and it should teach you how to deal with that part of that step, and then number two: teach you how to deal with that part of the step."
Practicality	–Helped me a little to more or less express myself a little bit more, to improve –Very great program to help with everyday life and situations	Inconvenience of tablet device	–I think that I would've used it more if it would've been on my phone—you don't want to lose the iPad, or risk getting it damaged, or someone stealing it	Progress indicator	"helpful if it had one that shows check, like you completed lesson one, you completed lesson two"
Skills	–The one thing I took from the program is not to always overthink things –It shows you how to look at a lot of things at different aspects	Literacy	I can't read that good and I can't write that good, so that's why I really haven't been writing certain things down	Direct application of skills	I would have it teach more about how you should deal with your situations in session 1&2
Convenience of mobile device	It was on hand at all times so if you had your iPad with you and had some downtime you could do one of the programs or lessons.				
Positive outcomes	–Helped me to more or less see things on the brighter side of life –I'm not as stressed anymore as how I used to be.				

and anxiety in an adult SCD clinical population by implementing mental health screening and randomizing patients with elevated depression and/or anxiety into a mobile CBT program or TAU. This study also provided preliminary data to assess the potential efficacy of a mobile technology-based mental health treatment for adults with SCD.

We successfully established routine screening for both depression and anxiety into our clinic flow at two medical center clinics and recruited patients with

SCD and elevated symptoms of depression and/or anxiety into a randomized trial for mental health treatment. This study confirmed the high rates of mental health comorbidity in adults presenting for routine SCD care [9], with over 25% of patients in our sample reporting clinically significant depressive symptoms. Adults with SCD are a difficult-to-reach population; nevertheless, we were able to enroll patients to meet our recruitment goal, retained 97% of the enrolled patients, and achieved at least one timely follow-up assessment for nearly all patients. This was particularly surprising given reports of high dropout (>25%) in studies with this population [43,44] and an average of 20% attrition rate among similar CBT trials [45].

Findings from the present study provide preliminary evidence that cCBT in SCD may be helpful in reducing symptoms of depression and anxiety in adults with SCD. There have been few psychological intervention studies addressing behavioral or mental health diagnoses in this population, and even fewer have attempted to specifically screen for or treat depression. A recent systematic review found 11 studies testing psychological interventions in patients with SCD [26], but only one of these studies examined depression as an outcome; this study found that a psychoeducational intervention did not decrease depressive symptoms in pediatric patients with SCD [46]. Four studies tested the efficacy of CBT on pain, coping, psychological distress, and health care utilization, but the findings were mixed. Because of the poor quality of these studies (e.g., small sample size, no control group, unclear intervention protocol), the impact of CBT, or any other evidence-based mental health treatment, on behavioral outcomes in SCD is unclear [26]. One feasibility study [47] offered six manual-assisted individual CBT sessions to 35 adults with SCD, but there were no significant differences in pain and health care utilization after the intervention. Although patients reported a reduction in anxiety symptoms, the decrease in depressive symptoms was not significant. The lack of efficacy, however, may have been in part due to high dropout (by 14 of 35 participants). Patient engagement and retention may be as important, or more important, than the actual treatment content or modality.

More recently, Palermo et al. [33] tested the feasibility and acceptability of cCBT in adolescents with SCD and their parents. This pilot trial successfully recruited 25 dyads, who were randomized to either cCBT or pain education delivered over the Internet. The study reported high engagement with the intervention (>90%) and high retention (80%). In addition, similar to the present study, participants enjoyed the cCBT program and thought the skills were beneficial. Thus, early data would suggest that cCBT is a convenient, feasible, and acceptable method for delivering evidence-based behavioral treatment to patients living with SCD.

Measuring outcomes using ecological momentary assessment

CBT is also shown to be effective for treatment of pain [48]. We were able to record daily pain using an app installed on patients' phones that prompted them to record their pain twice a day. These daily reports showed that patients enrolled in the cCBT program experienced a decrease in pain symptoms, whereas those patients receiving TAU experienced a relative increase in their daily pain. Although the treatment effects on daily pain were significant, due to a small sample size, the statistical inference made in this report may be overly optimistic and not reproducible with larger data. These results should, therefore, be considered only exploratory and helpful for guiding future hypothesis testing of ecological momentary assessment data in SCD. Furthermore, these data demonstrate that collecting daily pain reports in this population as part of a clinical trial is feasible and may serve as a valuable outcome measure in larger studies.

Limitations

Despite some encouraging preliminary findings about the promise of cCBT in this population, overall engagement with the technology remained low. Few patients completed all eight sessions of cCBT, and on average, patients completed less than half of the required eight sessions. Only three participants completed the entire program. Several barriers made it difficult for patients to complete the program, including inability of users to control the pace of the program or the order of the modules, as well as technical difficulties. More specifically, one programing error at session 3.4 that stopped several participants from advancing to the next session may have negatively affected engagement. Many participants did not continue the program even after the issue was resolved. Six participants discontinued the program at session 3, although we were unable to ascertain whether this was due to frustration with the programing error or some other factor because we did not directly ask participants why they did not complete sessions; rather, we generally asked what they liked and did not like about the program.

Because *Beating the Blues* is an "off-the-shelf" program, its design was not developed with minority users, particularly those living with SCD, in mind, and its content was for the most part not culturally relevant to this population. For example, the didactic examples did not address stressors affecting racial minorities or an economically diverse population, and none of the characters in these examples were living with pain or a chronic condition. Furthermore, prior research in patients with SCD has shown that the way patients cope with disease-related stressors, including but not limited to pain (e.g., disruptions in daily life functioning, uncertainty about the future), is related to depressive symptoms [49]. Additional

research should be done to test the efficacy of a cCBT program whose design and content are tailored for individuals living with SCD. Adding features such as community forums, linkages to social media for sharing progress and achievements, and gamification are also some strategies that can be used to create interventions that may resonate with users and be more engaging for patients with SCD or other underserved populations.

Despite these limitations, cCBT remains a potential alternative or adjunct to traditional mental health treatment approaches for patients with SCD.

CONCLUSION

This study presented the utility and uptake of a cost-effective, scalable, technology-delivered, mental health intervention that patients can access anywhere, 24/7, via mobile device. Although patients reported they enjoyed the intervention and may have benefited from its use, long-term engagement will need to be improved to maximize the effectiveness of this mental health intervention strategy. Overall, we find there is a significant need for behavioral interventions that are culturally tailored and delivered via mobile devices to improve the health and multidisciplinary care of patients living with SCD.

SUPPLEMENTARY MATERIAL

Supplementary material is available at *Translational Behavioral Medicine* online.

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