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Technology-supported Acceptance and Commitment Therapy for Chronic Health Conditions: A Systematic Review and Meta-analysis

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Abstract

Chronic health conditions (CHCs) are common and associated with functional limitations. Acceptance and commitment therapy (ACT) shows promise in improving functioning, quality of life, and distress across several CHCs. The purpose of this study was to conduct a systematic review of technology-supported ACT for CHCs and perform a meta-analysis on functioning and ACT process outcomes. Multiple databases were systematically searched for randomized controlled trials. A total of 20 unique studies with 2,430 randomized participants were included. CHCs addressed in these studies were chronic pain (*k*=9), obesity/overweight (*k*=4), cancer (*k*=3), hearing loss (*k*=1), HIV (*k*=1), multiple sclerosis (*k*=1), and tinnitus (*k*=1). Internet and telephone

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were the most used technology platforms. All studies included therapist contact with considerable heterogeneity between studies. Random effects meta-analyses found medium effect sizes showing technology-supported ACT outperformed comparator groups on measures of function at post-treatment (Hedges' $g = -0.49$; $p=0.002$) and follow-up (Hedges' $g = -0.52$; $p=0.02$), as well as ACT process outcomes at post-treatment (Hedges' $g = 0.48$; $p<0.001$) and follow-up (Hedges' $g = 0.44$; $p<0.001$). Technology-supported ACT shows promise for improving function and ACT process outcomes across a range of CHCs. Recommendations are provided to optimize technology-supported ACT for CHCs. PROSPERO registration number: CRD42020200230

Keywords

chronic disease; chronic illness; disability; functioning; acceptance

Introduction

Chronic health conditions (CHC), also referred to as chronic diseases or chronic illnesses, are medical conditions lasting one year or longer that result in functional limitations and/or require ongoing care (U.S. Department of Health & Human Services, 2019). Approximately 60% of U.S. adults have at least one CHC and 42% have multiple CHCs (Buttorff et al., 2017). CHCs present significant challenges at the societal and individual level. CHCs are associated with reduced workplace productivity and absenteeism (Collins et al., 2005) and significant healthcare burden (Dieleman et al., 2016). Individuals living with CHCs often experience difficulties adjusting to functional restrictions and making necessary behavioral modifications (e.g., health monitoring, diet, exercise, medication adherence) to best manage the condition(s) (Eton et al., 2013). Further, CHCs affect overall well-being and are associated with high rates of depression, anxiety, and poor quality of life (Clarke & Currie, 2009; Megari, 2013).

Acceptance and commitment therapy (ACT) is a cognitive-behavioral approach that has shown promise for improving functioning, quality of life, and distress across various CHCs, including HIV, cancer, epilepsy, and chronic pain (Gloster et al., 2020; Graham et al., 2016). ACT is based on the psychological flexibility model, a unified model of behavior change that focuses on six core treatment processes: present moment awareness, acceptance, defusion, self-as-context, values, and committed action (Hayes et al., 2006). Briefly, present moment awareness refers to the ongoing non-judgmental contact with here-and-now experiences. Acceptance entails willingness to feel unpleasant private experiences (e.g., thoughts, emotions, body sensations) without making counterproductive attempts to change or avoid these experiences, particularly in the context of pursuing goals. Defusion is a process of de-literalizing thoughts, or seeing thoughts as thoughts rather than absolute truth, and decreasing the influence thoughts have over actions. Self-as-context represents a transcendent aspect of the self that is separate from the content (e.g., thoughts) of the self. Values refer to chosen life directions that are defined as important and meaningful at the individual level, while committed action is the active engagement of values-consistent behavior. These processes are targeted in ACT treatment with the overall goal of increasing

psychological flexibility, or the ability to persist in or stop behavior in the service of values regardless of unwanted private experiences (Hayes et al., 2006).

ACT interventions are particularly suitable for CHCs. A core tenant of the ACT model is that maladaptive behavior typically occurs as a result of experiential avoidance, or the attempt to eliminate or control the form, frequency, or sensitivity of unwanted private experiences, even when doing so causes harm (Hayes et al., 2006). Experiential avoidance can manifest in different ways among individuals with CHCs. For example, people may over- or under-utilize the healthcare system to reduce worry about their condition, engage in substance use or over-eating to manage comorbid depression or anxiety, or fail to initiate and/or maintain disease self-management behaviors such as injections or medications due to physical discomfort. ACT addresses experiential avoidance by situating the client in here-and-now experiences, noticing and distancing from unwanted thoughts that fuel experiential avoidance (e.g., catastrophizing about the condition, ruminating about the past), offering experiential acceptance as an alternative to avoidance, and promoting values-aligned goal setting to motivate behavior change. In this way, ACT shifts the focus of treatment from getting rid of unpleasant private experiences to living a rich, meaningful life regardless of the presence of such experiences. For this reason, the primary outcome of interest in ACT interventions is improved functioning (Feliu-Soler A, 2018), rather than decreased mental health symptoms or condition-specific clinical outcomes (e.g., HbA1c levels or pain severity).

Similar to other cognitive-behavioral approaches, ACT is traditionally delivered in-person, either individually or in groups, across several consecutive weekly sessions. This creates significant barriers to treatment, as many persons with CHCs already attend numerous healthcare appointments, may be immunocompromised, have mobility limitations, or live in remote areas, and thus may not have the time, money, or ability to attend weekly clinic appointments (Brundisini et al., 2013). Recently, this problem has been compounded by the COVID-19 pandemic and restrictions on non-emergency in-person visits, highlighting the need for virtual healthcare delivery (Van Daele et al., 2020). Technology-supported ACT (i.e., ACT delivered partially or completely with the use of technology, including telephone, internet, or smartphone components) has the potential for increasing the accessibility of ACT for CHC populations, either as a replacement of or as a supplement for in-person treatment. Technology-supported ACT for CHCs also is potentially less resource-intensive and more cost-effective for healthcare systems (Elbert et al., 2014).

While several individual studies have supported the utility of technology-supported ACT for CHCs and there is some support for technology-supported ACT for mental health conditions (Brown M, 2016; Thompson et al., 2021), there has been no systematic review or meta-analysis to describe existing studies or examine pooled treatment effects. Given promising results of ACT for CHCs (Dochat et al., 2021; Graham et al., 2016) and high relevancy of technology-supported treatments, the purpose of this study was to conduct a systematic review and meta-analysis of technology-supported ACT interventions for CHCs with an emphasis on functioning and ACT process outcomes. Our aims were to (1) describe the design and methodology of technology-supported ACT interventions for CHCs, including use of specific technology modality(ies) and degree of therapist involvement; (2)

quantitatively examine efficacy using meta-analysis; and (3) provide recommendations for future research.

Materials and Methods

This systematic review with meta-analysis was registered in PROSPERO (ID: CRD42020200230) and conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Liberati et al., 2009). A protocol paper for the review was not prepared.

Eligibility Criteria

We used the five PICOS components (participants, interventions, comparators, outcomes, and study design) to design our research question and eligibility criteria (Moher et al., 2010). Studies were required to meet the following inclusion criteria: (P) sample was adults, 18 years and older, with a CHC; (I) delivered an ACT-based intervention partially or completely using technology; (C) included a comparison condition including other active treatments, treatment as usual, and waitlist control; (O) included a quantitative measure of functioning consistent with the World Health Organization's International Classification of Functioning, Disability, and Health (Jette, 2006) and/or measures of ACT processes; and (S) used a randomized controlled design. Studies were excluded if: (P) the condition or population was primarily mental health-related, including insomnia; (I) intervention delivery did not include technology, technology was used for the purposes of data collection only, or the intervention was not primarily ACT-based; (O) outcomes of interest were not reported or only qualitatively assessed; or (S) study design was cross-sectional, case study, case series, or used non-random assignment to treatment group.

Information Sources and Search Strategy

The online databases of PubMed, PsycINFO, and Web of Science were systematically searched in February 2021. No search limitations or filters were imposed. Only peer-reviewed manuscripts published in English were included. No lower limit to year of publication was imposed. Due to the large number of possible CHCs, we did not specify conditions. Of note, overweight and obesity were included because these conditions are recognized by the American Medical Association and National Institutes of Health as a CHC (Kyle et al., 2016). Below is an example search in PubMed:

(((((Acceptance[Title/Abstract]) AND (Commitment[Title/Abstract])) OR (Acceptance-based[Title/Abstract])) OR (contextual behav*[Title/Abstract])) OR (contextual cognitive behav*[Title/Abstract])) AND ((((((((((((((((((((((((((internet[Title/Abstract]) OR (internet-*[Title/Abstract])) OR (smartphone[Title/Abstract])) OR (mhealth[Title/Abstract])) OR (m-health[Title/Abstract])) OR (ehealth[Title/Abstract])) OR (e-health[Title/Abstract])) OR (electronic[Title/Abstract])) OR (online[Title/Abstract])) OR (app*[Title/Abstract])) OR (video*[Title/Abstract])) OR (web*[Title/Abstract])) OR (web-*[Title/Abstract])) OR (*phone[Title/Abstract])) OR (phone*[Title/Abstract])) OR (phone-*[Title/Abstract])) OR (mobile[Title/Abstract])) OR (mobile-*[Title/Abstract])) OR (blended[Title/Abstract])) OR (tele*[Title/Abstract]))

OR (tech*[Title/Abstract])) OR (computer[Title/Abstract])) OR (computer-*[Title/Abstract])) OR (e-*[Title/Abstract])) OR (virtual[Title/Abstract])) OR (digital[Title/Abstract])) OR (cyber*[Title/Abstract]))

Additionally, reference lists of included manuscripts were inspected as well as databases on the Association for Contextual and Behavioral Science website.

Study Selection

Study selection proceeded in three stages and was independently performed by two study authors (K.M. and B.H.B.). Disagreements were resolved by consensus and consultation with the first author. In stage 1 (screening), all manuscripts returned from database searches were imported into reference management software. These manuscripts received title/abstract review. Studies that clearly failed to meet inclusion criteria or met exclusion criteria were removed. In stage 2 (selection), remaining studies received a full-text review to determine inclusion status. Ineligible studies were removed and categorized according to exclusion reason. In stage 3 (hand-searching), the reference section of studies selected for inclusion were reviewed to identify additional potential manuscripts not previously identified through database searches. The titles, abstracts, and full texts of these manuscripts were examined as necessary. Ineligible studies were removed and categorized according to exclusion reason (see Figure 1).

Data Extraction and Management

EndNote X8 was used to store results from database and hand searches, sort manuscripts, and categorize according to exclusion criteria. Duplicates were removed using the EndNote X8 “remove duplicates” feature and by hand. Study coding and data extraction occurred in Excel and was accomplished by the study team. M.W.L. and A.C. extracted sample characteristics, K.M. and B.B. extracted intervention details, and C.D. and M.T. extracted outcomes, including group means and standard deviations, statistical significance test results, and effect sizes when reported. M.S.H. oversaw and double-checked all data extraction procedures. Results from intention-to-treat (ITT) analyses and unadjusted means and standard deviations were extracted when available. Study authors were contacted for information as needed. Additional information was obtained from any protocol papers published prior to the included manuscript.

Risk-of-Bias Assessment

Study quality was assessed by J.S.W. and M.G. using version 2 of the Cochrane risk-of-bias (RoB) tool (RoB-2) for randomized trials (Sterne et al., 2019). RoB-2 assesses five domains of study design and reporting: randomization, deviations from intended intervention, missing outcome data, measurement of the outcome, and selection of the reported result. Each domain is comprised of questions rated as *yes, probably yes, probably no, no*, or *no information.* Domain-specific algorithms are then used to generate a domain-specific risk-of-bias judgment *(low, high, some concerns).* Domain-specific risk-of bias judgements are synthesized to generate an overall risk-of-bias judgement. Studies are rated *low* risk if all respective domains are rated as low risk, *some concerns* if at least one domain is rated *some concerns* and no domains are rated *high* risk, and *high* risk if at least one domain is

rated *high* or if multiple domains are rated *some concerns* in a way that substantially lowers confidence in the result. Funnel plots, contour-enhanced funnel plots, and Eggers' test were used to assess publication bias across studies included in the meta-analysis.

Meta-analysis

Quantitative analysis of treatment efficacy was conducted using between-group random effects meta-analysis. Random effects models are better suited for meta-analysis in the context of between study heterogeneity (Field & Gillett, 2010), which was anticipated in the present study. Analyses were conducted in R version 3.6.1 using the metafor and dmetar packages (Harrer, 2019), using the inverse variance method and Hedges' g as the standardized mean difference with Knapp-Hartung adjustments to calculate the pooled effect size confidence interval (Knapp & Hartung, 2003). Study effects were weighted by size. This was not imposed, but rather was the natural weighting based on study size, reflecting the relative contribution of each to the pooled effect. Hedges' g values of 0.2 were considered a small effect, 0.5 a medium effect, and 0.8 a large effect. Statistical heterogeneity was assessed using I^2, Cochran's Q-statistic, and τ^2 (using DerSimonian-Laird estimator) (Higgins et al., 2003). I^2 is the percentage of variability in effect sizes due to heterogeneity rather than sampling error (As specified in the Cochrane handbook: 0-40% might not be important; 30-60% may represent moderate heterogeneity; 50-90% may represent substantial heterogeneity; 75-100%: considerable heterogeneity). The Q-statistic is the weighted sum of squared differences between individual study effects and the pooled effect, from which I^2 is derived. The Q-statistic chi-squared significance test is known to be low-powered for analyses with few studies and should be interpreted with caution (Higgins et al., 2003). τ^2 is another metric of between-study variance in effect sizes (Deeks et al., 2019). A prediction interval, which accounts for between-study variance and is less sensitive to number of studies than standard heterogeneity estimates, was also calculated (Harrer, 2019). Prediction intervals provide a range in which future study effects are predicted to fall based on present evidence in the meta-analysis.

Meta-analyses were conducted on functioning and ACT process outcomes at post-treatment and the first follow-up period. While ACT processes refer to proposed mechanisms underlying treatment response, they are also frequently assessed as outcome measures in ACT studies. When studies included more than one measure of functioning, general measures were chosen over condition-specific measures to reduce heterogeneity. When studies included more than one measure of an ACT process outcome, we chose measures that were most reflective of the psychological flexibility model to reduce heterogeneity. For example, the Acceptance and Action Questionnaire (AAQ-II), which is a general measure of experiential avoidance and psychological flexibility, would be chosen over the Chronic Pain Acceptance Questionnaire (CPAQ), which consists of subscales capturing acceptance of pain and engagement in activities despite pain. However, the CPAQ would be chosen over questionnaires capturing individual components of the model (e.g., Cognitive Fusion Questionnaire). To maintain consistency in scoring direction, measures were reverse coded as needed. For function measures, lower scores reflect greater functional improvement/less functional impairment. For ACT process measures, higher scores reflect greater psychological flexibility.

Comparator conditions were considered inactive control comparators if they provided treatment as usual, waitlist, or no intervention, or active control comparators if they provided materials and activities that controlled for time and attention given to participants. Comparator conditions that provided an active intervention including ACT or CBT were classified as active intervention comparators and were not used in meta-analyses. Comparing technology-supported ACT to other ACT-based comparators would be more appropriate for other study designs, such as non-inferiority (e.g., when comparing to in-person delivery) or comparative effectiveness (e.g., when comparing two or more technology-supported ACT conditions with different treatment components). Further, technology-supported ACT would not be expected to outperform a CBT-based comparator. This is supported by a recent review of meta-analyses that found that ACT is generally not superior to CBT (Gloster et al., 2020). For studies with two comparator conditions, active controls were chosen over inactive controls.

Sensitivity analyses were conducted by removing studies with effects determined to be outliers, as indicated when the 95% confidence interval of an individual study did not overlap with the 95% confidence interval of the pooled treatment effect, and studies deemed to be high RoB. We also conducted exploratory post hoc subgroup meta-analyses to explore technology modality (internet versus other), therapist involvement (in-person, telephone, or video versus asynchronous), type of condition (chronic pain versus other), and comparator type (active versus inactive). Due to the number of studies and availability of data at follow-up, these exploratory analyses focused on functioning and ACT process outcomes at post-treatment only. Further, due to the exploratory nature of subgroup analyses, an alpha value of 0.10 was used to warrant inspection of individual subgroups.

Results

Literature Search

Figure 1 shows the number of manuscripts identified throughout the screening, hand-searching, and selection phases. After removal of duplicates, titles and abstracts of 1,510 articles were examined. Of these, 66 underwent full-text review. A total of 45 were deemed ineligible for the following reasons: population did not have a CHC ($k = 1$), not an ACT-based intervention ($k = 4$), intervention was not technology supported ($k = 7$), no comparison condition ($k = 14$), conditions were not randomized ($k = 1$), or article did not include relevant outcomes or was a secondary analysis that did not include unique outcomes of interest ($k = 18$). Two manuscripts deemed eligible were from the same study (Kristjánsdóttir et al., 2013a; Kristjánsdóttir et al., 2013b), were included in the qualitative synthesis as the latter described results from the final follow-up period. This resulted in a total of 21 manuscripts included in the qualitative synthesis representing 20 unique studies(Buhrman et al., 2013; Hawkes et al., 2014; Herbert et al., 2017; Hesser et al., 2012; Ishola & Chipps, 2015; Kristjánsdóttir et al., 2013a; Kristjánsdóttir et al., 2013b; Levin et al., 2020; Lin et al., 2017; Molander et al., 2018; Mosher et al., 2019, 2018; Potts et al., 2020; Proctor et al., 2018; Rickardsson et al., 2021; Sairanen et al., 2017; Scott et al., 2018; Simister et al., 2018; Thorsell et al., 2011; Trompetter et al., 2015; Weineland et al., 2012).

Risk-of-Bias Assessment

Figure 2 shows the RoB for the included studies as judged by study authors (JW, MG). RoB was assessed with information garnered from study manuscripts, pre-registration websites (i.e., clinicaltrials.gov or similar; 13 out of 20), study protocol papers (Hawkes et al., 2009; Lappalainen et al., 2014; Lin et al., 2015; Molander et al., 2015) and email correspondence with study authors (9 out of 20). Because of inconsistent reporting across included studies and inadequate information, it was often not possible to determine whether RoB criteria were met. Thus, the overall RoB for many of the included studies (11 out of 20) indicates 'some' RoB concerns. Of the included studies, five were judged to have a 'low' RoB, and the remaining four were judged to have a 'high' RoB. Across studies, potential bias was identified most commonly in the domains of 'bias due to missing outcome data,' and 'bias in selection of the reported result.' RoB was generally deemed low for 'bias arising from the randomization process, and 'bias due to deviations from intended interventions.' All studies were deemed low for 'bias in measurement of the outcome' according to the RoB-2 criteria. Further, examination of funnel plots, contour-enhanced funnel plots, and Eggers' test did not indicate any strong evidence of publication bias.

Study Characteristics

Table 1 shows characteristics of included studies. There was a total of 2,430 participants across 20 unique studies with a range of 27 to 410 per study. The mean age was 51.8 years (SD=14.3; range: 31.6 to 66.4 years) based on 19 studies that reported mean and standard deviation for their sample. Female gender distribution across studies was 69.7% (range: 17.8% to 100%). Thirteen studies did not report race/ethnicity. Across studies that reported race/ethnicity, 16.3% of participants were identified as non-white (range: 0% to 53%). Chronic pain was the most frequently targeted CHC ($k = 9$), followed by overweight/obesity ($k = 4$), cancer ($k = 3$), hearing loss ($k = 1$), HIV ($k = 1$), multiple sclerosis ($k = 1$), and tinnitus ($k = 1$).

Studies were conducted in various North American and European countries, as well as one study in Nigeria. Regarding study design, 14 out of 20 were RCTs and six out of 20 were pilot RCTs. All studies included a post-treatment assessment and 15 out of 20 included at least one follow-up assessment, ranging from six weeks to one year. The majority of studies reported ITT results, with the exception of Ishola and Chipps (2015), Kristjánsdóttir et al. (2013a, 2013b), and Levin et al. (2020), which reported completer results only. Attrition regarding completion of assessments in technology-supported ACT conditions ranged from 0% to 54% at post-treatment, and 6% to 56% at the first follow-up assessment, with 11 out of 20 and 12 out of 15 studies reporting 20% or greater attrition at post-treatment and follow-up, respectively.

A total of 13 out of 20 studies provided information on the amount of intervention completed; however, reported values varied considerably across studies. For example, 10 out of 20 reported the percentage of participants that completed all treatment sessions/modules, but it was often unclear if provided values were derived from the number of participants that completed the intervention or the number of participants randomized. Only four out of 20 studies provided a clear definition of "completers" or "per protocol" and associated

percentages of participants meeting criteria. Scott et al. (2018), which consisted of two in-person or telephone sessions and eight internet modules, defined completers as those who completed seven out of 10 treatment sessions (61%). Trompetter et al. (2015) defined completers as those who completed six out of nine internet modules (72%). Lin et al. (2017) specified per protocol as completing five out of seven internet modules (Guided Internet: 43%; Unguided: 30%). Rickardsson et al. (2020) defined completers as completing 50% of content (77%).

Technology-supported ACT

Type of technology used.—A range of technology modalities were used, either as standalone means or in combination with other technology or in-person formats (see Tables 1 and 2). Regarding the primary technology modality, internet-based content was most frequently used ($k = 10$), followed by telephone ($k = 6$), smartphone application ($k = 2$), SMS text-messaging ($k = 1$) and video-teleconferencing ($k = 1$).

Intervention design and content.—A summary of technology-supported ACT intervention design and content is detailed in Table 2. Active treatment duration ranged from four weeks to six months, over which five to 10 modules of intervention content were delivered. Content was delivered through combinations of in-person and/or technology-supported sessions with a therapist, written feedback, audio files, video files, texts, informational websites, and self-help readings. Intervention descriptions consistently included acceptance, present moment awareness, defusion, connection with values, and committed action as ACT process outcomes. Most studies ($k = 18$) explicitly reported the use of experiential exercises and/or metaphors to target ACT processes. “Creative hopelessness” is a common ACT treatment method to examine the limitations of control strategies that was explicitly mentioned in five studies.

Therapist involvement.—Several studies used a combination of methods for therapist involvement. The majority of studies ($k = 15$) used in-person and/or telephone contact, while the remaining five studies used methods that did not require real-time contact with a therapist (i.e., asynchronous). Specific methods included in-person ($k = 6$), telephone ($k = 11$), video-teleconferencing ($k = 1$), asynchronous communication via internet (e.g., email; $k = 8$), SMS text messaging ($k = 1$), and no therapist involvement ($k = 1$). Only Lin et al. (2017) directly compared an intervention with and without therapist involvement. Two studies included group (Sairanen et al., 2017) or dyadic (Mosher et al., 2019) interventions while the majority ($k = 18$) were delivered on an individual basis. Study therapists predominantly had graduate training ranging from master’s level psychology students and social workers to clinical psychologists with years of ACT experience. Two studies lacked therapist descriptions (Ishola & Chipps, 2015; Weineland et al., 2012) and another mentioned psychology, nursing, or health promotion degrees without specifying the degree level (Hawkes et al., 2014).

Comparator Conditions

All studies included at least one non-ACT comparator condition, with the exception of Herbert et al. (2017), which was a non-inferiority RCT comparing video-teleconferencing

delivered ACT to in-person delivery. Inactive control comparators included treatment as usual ($k = 5$), no intervention ($k = 1$), and waitlist ($k = 6$). Active control comparators included moderated online discussion forum ($k = 2$), telephone-based therapist-delivered applied relaxation ($k = 1$), self-guided online expressive writing ($k = 1$), telephone-based therapist-delivered education and support ($k = 2$), post-HIV counseling ($k = 1$), and a non-interactive website for pain self-management with ACT-based strategies and exercises ($k = 1$). Active intervention comparators included therapist-guided internet CBT ($k = 1$), in-person ACT ($k = 2$), unguided internet-based ACT ($k = 1$), and ACT self-help intervention with email prompts ($k = 1$).

Because ACT- or CBT-based comparators were not included in meta-analyses, we briefly describe findings related to function and ACT process outcomes in these studies. In Herbert et al. (2017), non-inferiority between video-teleconferencing and in-person delivered ACT was supported on the function outcome (Brief Pain Inventory (BPI) pain interference subscale) at posttreatment and 6-month follow-up. Pooling both conditions together, large effect sizes were observed at both time points (Within-group Cohen's $d = 0.81$ and 0.84, respectively). Further, non-inferiority was supported on the ACT process outcome (CPAQ) at post-treatment, but not at follow-up. Pooling both conditions together, large effect sizes were reported at both time points (Within-group Cohen's $d = 1.19$ and 1.01, respectively). Lin et al. (2017) compared guided internet-based ACT, unguided internet-based ACT, and waitlist control. The guided ACT condition, but not the unguided ACT condition, showed significantly greater improvement on the function outcome (Multidimensional Pain Inventory (MPI) pain interference subscale) compared to the control group at posttreatment (Cohen's $d = 0.58$) and 4-month follow-up (Cohen's $d = 0.58$). There were no significant differences between guided and unguided conditions. Further, neither guided or unguided conditions were associated with significant improvement on the ACT process outcome (AAQ-II) relative to waitlist control. Sairanen et al. (2017) compared an unguided ACT smartphone app, in-person ACT, and a control group that received no intervention. Function was not assessed and both ACT treatments failed to exhibit significant improvement on the ACT process outcome (AAQ-II) compared to the control group. Potts et al. (2020) compared self-help ACT plus telephone coaching, self-help ACT plus email prompting, and waitlist control. Function was not assessed and there were no significant differences on the ACT process outcome (Comprehensive assessment of Acceptance and Commitment Therapy processes; CompACT) across the three groups. Hesser et al. (2012) compared internet-delivered ACT, internet-delivered CBT, and a monitored internet discussion as an active control group. At posttreatment, both ACT and CBT conditions were associated with significant improvements on the function outcome (Tinnitus Handicap Inventory; THI) (Cohen's d: ACT = 0.68; CBT = 0.70) and ACT process outcome (Tinnitus Acceptance Questionnaire; TAQ) (Cohen's d: ACT = 0.59; CBT = 0.45) compared to the active control condition. There were no differences between ACT and CBT conditions.

Outcomes and Meta-Analyses

Functioning.—A total of 15 studies included a measure of functioning, all of which were self-report. As shown in Table 1, these measures were the MPI pain interference subscale ($k = 3$), BPI pain interference subscale ($k = 1$), Fibromyalgia Impact Questionnaire (FIQ; k

= 2), Pain Interference Index (PII; k = 1), Work and Social Functioning Scale (WSAS; k = 1), THI (k = 1), MD Anderson Symptom Inventory (MDASI) global symptom interference subscale (k = 2), Multiple Sclerosis Impact Scale (MSIS) physical subscale (k = 1), Hearing Handicap Inventory for the Elderly-short (HHIE-S; k = 1), the Functional Assessment of Chronic Illness Therapy – Functional Wellbeing subscale (k = 1), and level of function as defined by the Örebro Musculoskeletal Pain Questionnaire (ÖMPQ; k = 1), which was computed by aggregating 5 function items (ability to carry out light work, walk for an hour, complete household chores, shop for groceries, and sleep).

Functioning outcomes from Herbert et al. (2017) and Hawkes et al. (2014) were excluded from meta-analysis due to the in-person ACT comparator and insufficient data, respectively. Thirteen effects were included in the post-treatment meta-analysis. Between-group effect sizes for included studies ranged from small (k = 6), to medium (k = 3), to large (k = 4). Study effects displayed moderate to substantial heterogeneity (I^2 = 61.8%; Q(12) = 31.42, p = 0.001; τ^2 = 0.10). Random effects meta-analysis found that technology-supported ACT significantly outperformed comparator groups at post-treatment with a medium pooled effect size (mean Hedges' g = −0.49, 95% CI [−0.76, −0.22], p = 0.002) (Figure 3a). No outliers were detected. When studies deemed high RoB were excluded (k = 2), heterogeneity slightly decreased (I^2 = 58.4%; Q(10) = 24.06, p = 0.01; τ^2 = 0.08), and results remained significant with a medium pooled effect (mean Hedges' g = −0.57, 95% CI [−0.86, −0.28], p = 0.002).

A total of eight effects were included in the follow-up meta-analysis. Between-group effect sizes ranged from small (k = 4), to medium (k = 3) to large (k = 1). Study effects displayed moderate to substantial heterogeneity (I^2 = 64.2%; Q(7) = 19.55, p = .01; τ^2 = 0.12). Random effects meta-analysis found that technology-supported ACT significantly outperformed comparator groups at follow-up with a medium pooled effect size (mean Hedges' g = −0.52, 95% CI [−0.93, −0.10] p = .02) (Figure 3b). No outliers were detected. When studies deemed high RoB were excluded (k = 2), heterogeneity increased (I^2 = 71.3%; Q(5) = 17.44, p = 0.004; τ^2 = 0.15) and pooled effect effects remained medium but fell outside of statistical significance (mean Hedges' g = −0.52, 95% CI [−1.12, 0.07], p = 0.07).

ACT Processes.—A total of 18 studies included an ACT process measure, all of which were self-report. As shown in Table 1, these measures included the CPAQ (k = 6), AAQ-II (k = 5), Psych Inflexibility in Pain Scale (PIPS; k = 2), Acceptance and Action Questionnaire for Weight-Related-Difficulties (AAQ-W; k = 2), TAQ (k = 1), Hearing Acceptance Questionnaire (HAS; k = 1), and the CompACT (k = 1).

Similar to functioning outcomes, ACT process outcomes from Herbert et al. (2017) and Hawkes et al. (2014) were excluded from meta-analysis due to the in-person ACT comparator and insufficient data, respectively, leaving 16 effects that were included in the post-treatment meta-analysis. At post-treatment, between-group effect sizes for included studies ranged from small (k = 7), to medium (k = 4), to large (k = 5). Study effects displayed moderate to substantial heterogeneity (I^2 = 58.2%; Q(15) = 35.90, p = 0.001; τ^2 = 0.08). Random effects meta-analysis found that technology-supported ACT significantly outperformed comparator groups at post-treatment with a medium pooled effect size (mean Hedges' g = 0.48, 95% CI [0.26, 0.71], p < 0.001) (Figure 3c). One study effect was

determined to be an outlier at post-treatment (Molander et al., 2018). When this study was removed, heterogeneity decreased (I^2 = 34.0%; Q(14) = 21.21, p = 0.10; τ^2 = 0.03), and random effects meta-analysis found a significant medium-sized pooled effect favoring ACT (mean Hedges' g = 0.54, 95% CI [0.38, 0.71], p < 0.001). Further, when studies deemed high RoB were excluded (k = 4), heterogeneity was similar (I^2 = 58.1%; Q(11) = 26.27, p = 0.006; τ^2 = 0.07), and random effects meta-analysis found a significant small pooled effect favoring ACT (mean Hedges' g = 0.40, 95% CI [0.13, 0.66], p = 0.01).

A total of seven effects were included in the follow-up meta-analysis. Between-group effect sizes ranged from small (k = 4), medium (k = 2), to large (k = 1). Study effects displayed minimal heterogeneity (I^2 = 0.0%; Q(6): 2.77, p 0.383; τ^2 = 0.0). Random effects meta-analysis found that ACT significantly outperformed comparator groups with a small pooled effect size (mean Hedges' g = 0.44, 95% CI [0.30, 0.58], p < 0.001) (Figure 3d). No outlier effects were identified. When studies deemed high RoB were excluded (k = 2), heterogeneity remained minimal (I^2 = 0.0%; Q(4) = 1.43, p = 0.84; τ^2 = 0.00), and pooled effects were medium and significant (mean Hedges' g = 0.46, 95% CI [0.30, 0.62], p = 0.001).

Post Hoc Exploratory Subgroup Analyses

Table 3 shows findings of exploratory subgroup analyses. Technology modality (internet vs. other) and therapist contact method (in-person/telephone vs. asynchronous) moderated the pooled effect sizes on function outcomes at post-treatment using the alpha level of 0.10. Specifically, internet-based studies (k = 8) showed significant medium effects (mean Hedges' g = −0.63, 95% CI [−0.97, −0.28], p = 0.004) and non-internet-based studies (k = 5) showed non-significant small effects. Both internet- and non-intemet-based studies showed moderate to substantial heterogeneity. Studies with in-person/telephone therapist contact (k = 8) showed small effects that fell outside of significance (mean Hedges' g = −0.31, 95% CI [−0.65, −0.03], p = 0.07) and studies utilizing asynchronous contact (k = 5) showed significant medium effects (mean Hedges' g = −0.74, 95% CI [−1.23, −0.24], p = 0.01). Both studies with in-person/telephone therapist contact and asynchronous contact showed moderate to substantial heterogeneity. Clinical population (chronic pain vs. other) and comparator type (active vs. inactive) did not moderate pooled effect sizes on function outcomes at post-treatment. Further, technology modality, therapist contact method, clinical population, and comparator type did not moderate pooled effect sizes of ACT process outcomes.

Discussion

To the best of our knowledge, this is the first systematic review and meta-analysis to examine the impact of technology-supported ACT on functioning and ACT process outcomes across multiple CHCs. The purpose of this review was to characterize and examine the efficacy of technology-supported ACT for CHCs. Twenty-one manuscripts describing 20 unique studies met the inclusion criteria, of which only four were rated as having high RoB, attesting to the overall acceptable quality of the studies. Nearly half of the studies were focused on chronic pain; internet and telephone were the most used

technology modalities. Nearly all technology-supported ACT conditions included therapist involvement. Meta-analyses found significant medium pooled effects favoring technology-supported ACT for functioning outcomes and ACT process outcomes at post-treatment and small to medium pooled effects at follow-up. Taken together, this review demonstrates the growing literature on technology-supported ACT for CHCs and provides initial support of its efficacy compared to inactive and active control conditions for outcomes most relevant to ACT and CHCs.

Despite significant advances in technology, the majority of studies included in this review relied on relatively older technology, including internet-based content and telephone, while only two studies utilized smartphone technology. This is somewhat surprising given the interest in smartphone applications generally and advantages of smartphone technology within research settings (e.g., accessibility, real-time data tracking). Previous reviews have demonstrated the efficacy of smartphone applications for CHCs (Alwashmi et al., 2016; Wang et al., 2014), as well as the efficacy of mindfulness- and acceptance-based smartphone applications (Linardon, 2020). ACT-based smartphone applications have been developed and tested for improving diet and exercise (Levin et al., 2017) and chronic pain (Gentili et al., 2020), and therefore future RCTs of ACT-based smartphone applications for CHCs should be forthcoming.

All of the studies included in this review included some level of therapist involvement, making it difficult to systematically examine the specific impact of therapists in technology-supported ACT for CHCs. Only one study directly compared guided and unguided interventions and did not find differences on outcomes but showed lower attrition with the guided compared to the unguided intervention (Lin et al., 2017). Further, we found considerable heterogeneity in the extent of therapist involvement and modality of communication (e.g., phone, email, messaging board); only one study directly compared modality of therapist contact (telephone versus email) and found differences on relevant outcomes (e.g., eating and physical activity) but not on ACT process outcomes (psychological flexibility) (Potts et al., 2020). These limited findings are similar to what was found in previous reviews of internet-based CBT for psychiatric and somatic disorders (Carlbring et al., 2017) and anxiety and depression in individuals with CHCs (Mehta et al., 2019). Further, evidence has accumulated that technology-based interventions, including ACT, with therapist involvement tend to be more effective than unguided interventions for mental health conditions or symptoms (Baumeister et al., 2014; Thompson et al., 2021). However, results from technology-based interventions for CHCs are mixed, in part because many studies do not directly compare guided to unguided formats (Beatty & Lambert, 2013). Thus, well-designed and large studies of technology-supported ACT interventions with CHCs are needed to directly examine the method, amount, intensity, and role of therapist involvement.

The results of our primary meta-analyses showed that technology-supported ACT was efficacious in improving both functioning and ACT process outcomes at post-treatment and follow-up across multiple CHCs. Our findings are broadly consistent with previous reviews of mobile and internet technologies for disease management and distress in CHCs (Beatty & Lambert, 2013; Ebuenyi et al., 2021) as well as reviews of ACT interventions

for chronic pain (Hughes et al., 2017) and multiple CHCs (Dochat et al., 2021). The medium-sized pooled effect sizes found in our analyses were larger than the effect sizes found in previous meta-analyses of internet-supported ACT for mental health outcomes like depression and anxiety (Brown et al., 2016; Thompson et al., 2021). This is possibly a result of heterogeneity due to differing populations, technologies, comparator conditions, and other characteristics of the studies included in this review. Alternately, it is possible ACT interventions to improve functioning in CHCs are well-suited for delivery via technology methods. Our findings also are consistent with previous ACT intervention research showing that post-treatment gains are maintained between post-treatment and follow-up (Gifford et al., 2004; Lee et al., 2015). Further, the small- to medium-sized pooled effect sizes for ACT process outcomes remained robust across timepoints, suggesting that materials designed to address ACT processes for CHCs can be learned through technology means.

To address the heterogeneity observed among included studies, we conducted both sensitivity analyses removing outliers and studies with high RoB, as well as exploratory post hoc subgroup analyses on technology modality, therapist contact type, clinical population, and comparator type. Sensitivity analyses did not substantially alter findings, with the exception of function outcomes at follow-up, which became non-significant after removing two studies deemed high RoB. In post hoc subgroup analyses, we found that both technology modality (internet vs. other) and therapist contact type (in-person/telephone vs. asynchronous) moderated functioning outcomes at post-treatment, with results demonstrating larger effects for internet-based studies and studies utilizing asynchronous therapist contact. It should be noted that four of the five non-internet-based studies were telephone-based, and that these four telephone-based studies also comprised half of the in-person/telephone therapist contact sub-group. Although these results must be interpreted with caution, findings suggest using internet as a mode of technology with asynchronous therapist contact is likely an effective strategy to deliver ACT content for CHCs and potentially better than low technology methods like telephone. Additionally, because of the strong existing evidence for ACT for chronic pain, it is not surprising that the majority of technology-supported ACT trials have been on chronic pain. Although slightly larger pooled treatment effects in function and ACT process outcomes were observed in chronic pain relative to other conditions, between group analyses did not approach significance. Thus, results provide support for the use of technology-supported ACT for chronic pain as well as CHCs other than chronic pain. Further, there were no differences in pooled effects between studies comparing to inactive or active controls, suggesting that technology-supported ACT may hold promise for improving functioning in CHCs in comparison to some active control conditions. Clearly, more research with appropriate research designs and active intervention comparisons are needed to examine whether technology-supported ACT is as effective or more effective than other evidence-based active interventions for improving functioning in CHCs.

Recommendations for Future Research

Technology-supported interventions hold promise for increasing access to treatment. This is particularly relevant in the context of the COVID-19 pandemic and increase in telehealth appointments. This review provides initial support for the utility of technology-supported

ACT for CHCs. However, additional high-quality research is needed to understand how to optimize its delivery and maximize its efficacy. Below are several recommendations to accomplish this task.

1. Expand research to include other CHC populations. The majority of included studies focused on individuals with chronic pain, followed by overweight/obesity, and cancer. There were no technology-supported trials of ACT for other common CHCs such as asthma, diabetes, cardiovascular disease, and chronic kidney disease that met the inclusion criteria for this review. Additionally, multimorbidity of CHCs is common, which further impacts functioning and quality of life and increases health care burden (Buttorff et al., 2017). Populations with multiple co-occurring CHCs are ideal for technology-supported ACT interventions yet are not adequately represented in the literature.

2. Improve methodological rigor of RCTs. The primary methodological concerns among included studies were lack of clarity regarding analyses and missing data/attrition. To reduce reporting bias and promote open science, we recommend pre-specifying data analyses using a standard framework, such as Pre-SPEC (Kahan et al., 2020). Further, attrition in behavioral trials of individuals with CHCs is a well-documented concern in the broader literature (Davis & Addis, 1999), including digital interventions, particularly when interventions are self-guided (Macea et al., 2010). In this review, 11 out of 20 (55%) studies at post-treatment and 12 out of 15 (80%) studies at follow-up reported 20% or greater attrition, which is a common cut-off to indicate potentially problematic attrition (Dumville et al., 2006). Methods to reduce attrition such as email and text message reminders were used by some included studies and are recommended. At minimum, investigators should undertake sensitivity analyses to determine the impact of attrition on study outcomes.

   While the RoB was deemed low for all studies per the Cochrane RoB-2 criteria for ‘bias in the measurement of outcome,’ not all outcome measures were ideal. For example, Thorsell et al. (2011) used select items from the ÖMPQ to assess function, which was designed to predict long-term disability and work absenteeism and is not a measure of functioning per se. Further, the dynamic and context-dependent nature of psychological flexibility makes it an inherently difficult construct to assess using static, global self-report measures that do not consider temporality or situational context. Although measures such as the AAQ-II and CPAQ have been validated and are widely-used, these measures also have been criticized for their content validity (Van Ryckeghem, 2020; Wolgast, 2014). Newer measures of psychological flexibility that address some of these limitations include the Multidimensional Psychological Flexibility Inventory, which was able to distinguish psychological flexibility from distress (Landi et al., 2021), and the Psy-Flex measure, a 6-item measure conducive to repeated sampling that includes situational and temporal specifiers (Gloster et al., 2021).

3. Increase clarity of reporting treatment engagement and strategies to increase treatment engagement. It is important to understand the amount of intervention

delivered through technology (e.g., number of hours or extent of content) in order to help design interventions that deliver adequate exposure to the intervention. Future investigations also are encouraged to systematically quantify and report the amount and level of intervention exposure by both treatment completers and non-completers. Further, future studies are encouraged to include strategies to help maximize treatment engagement. This may include integrating positive reinforcement (e.g., praise and rewards for completing tasks), ensuring that system components are familiar and attractive to users, and considering sociodemographic information known to affect response rates, including gender, age, and severity of the CHC (Karekla et al., 2019).

4. Directly compare technology-supported ACT for CHC using different technology modalities and varying levels of therapist involvement. Given the changes made to delivery of healthcare as a result of the COVID-19 pandemic, technology-supported interventions will likely become even more prevalent and necessary. Thus, there is a great need to optimize their impact and determine the extent of required therapist involvement. Once optimized, large-scale non-inferiority trials comparing virtual to in-person delivery and comparative effectiveness trials examining technology-supported ACT with differing treatment components are needed to firmly establish the efficacy of technology-supported ACT for CHCs.

5. Address lack of diversity. The majority of included studies did not report race/ethnicity. Across studies that did, only 16% of samples were non-white. This shortcoming is important to address in both technology-supported interventions and ACT-based interventions generally (Woidneck et al., 2012). While access to the internet has steadily increased across the globe, the “digital divide” persists. For example, black and Latino adults are less likely to use technology to assess health management websites and search for health information compared to white adults (Mitchell et al., 2019). Further, questions remain on how to best deliver mindfulness- and acceptance-based interventions among underserved populations that may be facing adversity (Sobczak & West, 2013). There is a need to increase the inclusion and reporting of diverse racial and ethnic populations in technology-supported ACT for CHCs to avoid creating additional healthcare access inequities. Similarly, the majority of participants in these studies were female. While we are unaware of any literature that shows sex differences in ACT, there are documented sex differences in CHCs, including chronic pain (Bartley & Fillingim, 2013) and diabetes risk (Ding et al., 2006). Future research is encouraged to recruit a more balanced women-to-men ratio that reflects the prevalence of the specific CHC and examine sex differences.

6. Leverage unique technology-based opportunities including ecological momentary assessment and just-in-time interventions. Life with CHCs occurs outside of medical and mental healthcare visits. Symptoms, behaviors, and psychological processes pertinent to these conditions fluctuate across and within days, and therefore may not be adequately captured by standard self-report measures or adequately addressed during discrete healthcare appointments. The

inclusion of real-time, ambulatory assessment methods such as accelerometry and ecological momentary assessment may better inform our understanding of the lived experiences and treatment needs of people with CHCs. These data can in turn inform adaptive just-in-time interventions (Nahum-Shani et al., 2018) that can provide tailored ACT intervention components at times when individuals can benefit most (Levin et al., 2019).

Strengths and Limitations

This study has several strengths. We provide a systematic review and meta-analysis of technology-supported ACT for functioning and ACT process outcomes across multiple CHCs. We included only RCTs and examined only between-group effects, which allows stronger conclusions to be drawn about intervention efficacy than does examination of single-arm trials and within-group effects. In addition to a quantitative approach to examining functioning and ACT process outcomes at post-treatment and follow-up, qualitative detailed descriptions of intervention content and therapist involvement are helpful for the clinical guidance and application of technology-supported ACT. Further, recommendations for future research are provided to inform the development and evaluation of future RCTs of technology-supported ACT.

Nonetheless, our study has shortcomings. Not all studies reported functioning and ACT process outcomes or reported outcomes at both post-treatment and follow-up time points, which limited the number of studies that could be included in the quantitative analyses. Additionally, many prominent CHCs were not represented, including diabetes and cardiovascular disease. Thus, it is uncertain if our results generalize to these conditions. Studies that focus on additional populations are needed to better assess the effectiveness of technology-supported ACT for CHCs. Gray literature was not included in our search. While there is ongoing debate on the impact of excluding gray literature in meta-analyses (Schmucker et al., 2017), it is possible that publication bias may have influenced study results. Although we examined several established indicators of publication bias, these methods are themselves limited, particularly when analyzing a small number of treatment effects. Clinical heterogeneity in terms of intervention format, treatment intensity/dose, clinical population, level of clinician involvement, specific technology modality used, and comparator condition characteristics likely contributed to the observed statistical heterogeneity and may have impacted conclusions about efficacy. While we examined some sources of heterogeneity, others should be quantitatively explored in future reviews using subgroup or network meta-analysis. Further, the majority of studies included condition-specific measures of function which are considered more sensitive to change. Future studies and larger meta-analyses are encouraged to include both condition-specific and general measures of functioning. Finally, we did not conduct meta-analyses with active intervention comparators. This should be kept in mind when contextualizing the pooled effects from this study.

Conclusion

Technology-supported ACT shows promise to improve functioning and ACT process outcomes across a range of implementation methods, CHC populations, and comparator conditions. Included studies used a variety of technology modalities to deliver ACT content and nearly all studies involved a therapist to motivate participation and/or facilitate content comprehension. Meta-analyses showed that technology-supported ACT outperformed comparator conditions in improving functioning and ACT process measures at post-treatment and follow-up. Additional high-quality research is needed to demonstrate short- and long-term efficacy compared to other active interventions and to inform treatment optimization. As use of technology in healthcare delivery grows, evidence for the efficacy of technology-assisted behavioral interventions mounts and availability of technology-based interventions increases. Continued research in this area holds promise for improving quality of life among millions of individuals living with CHCs worldwide.

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Highlights

- Technology-supported ACT outperformed comparison groups on function and ACT outcomes.
- Technology modality and therapist contact moderated effects.
- Recommendations provided to optimize technology-supported ACT.

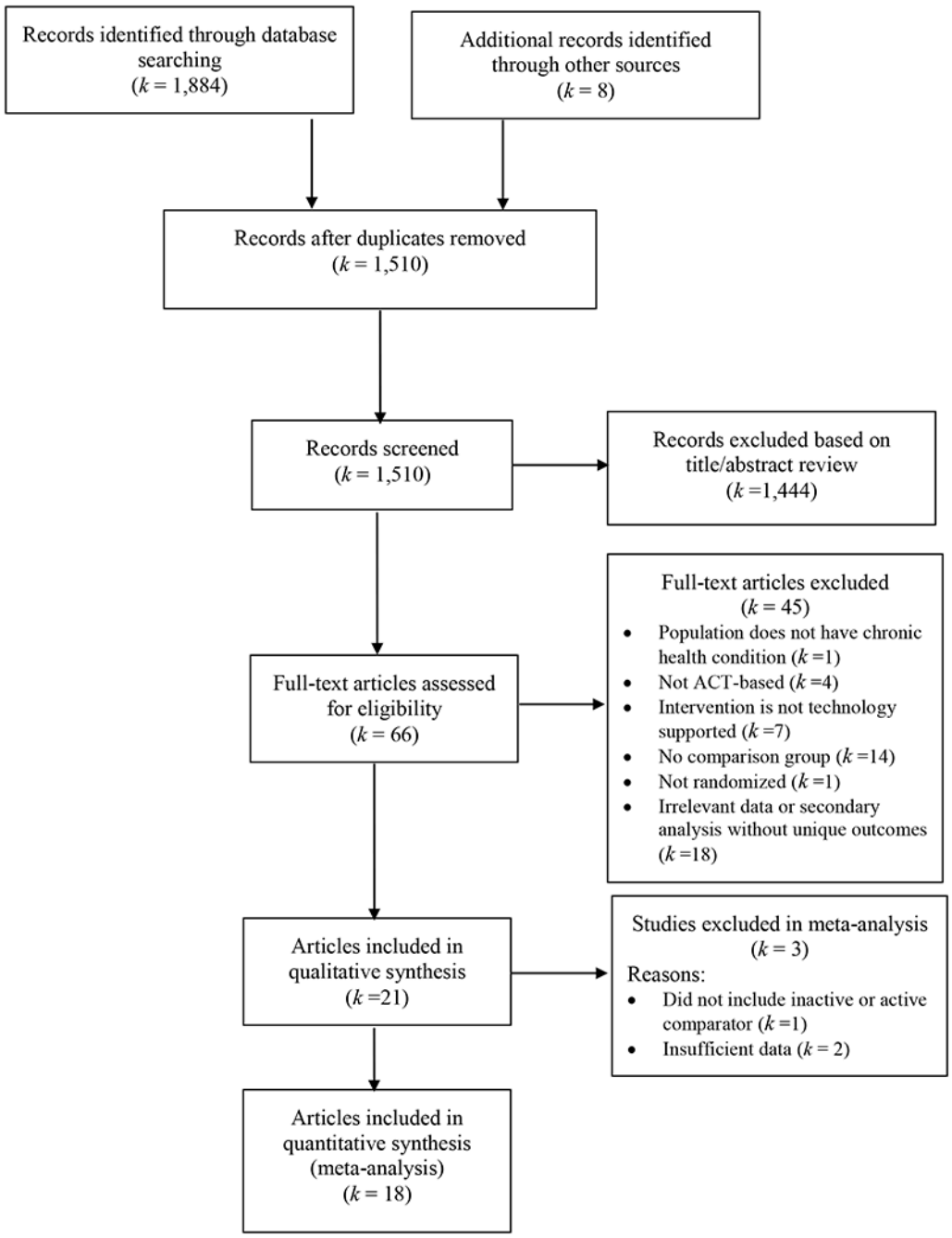

Figure 1:
Flow diagram

Figure 2:
Risk of bias domains

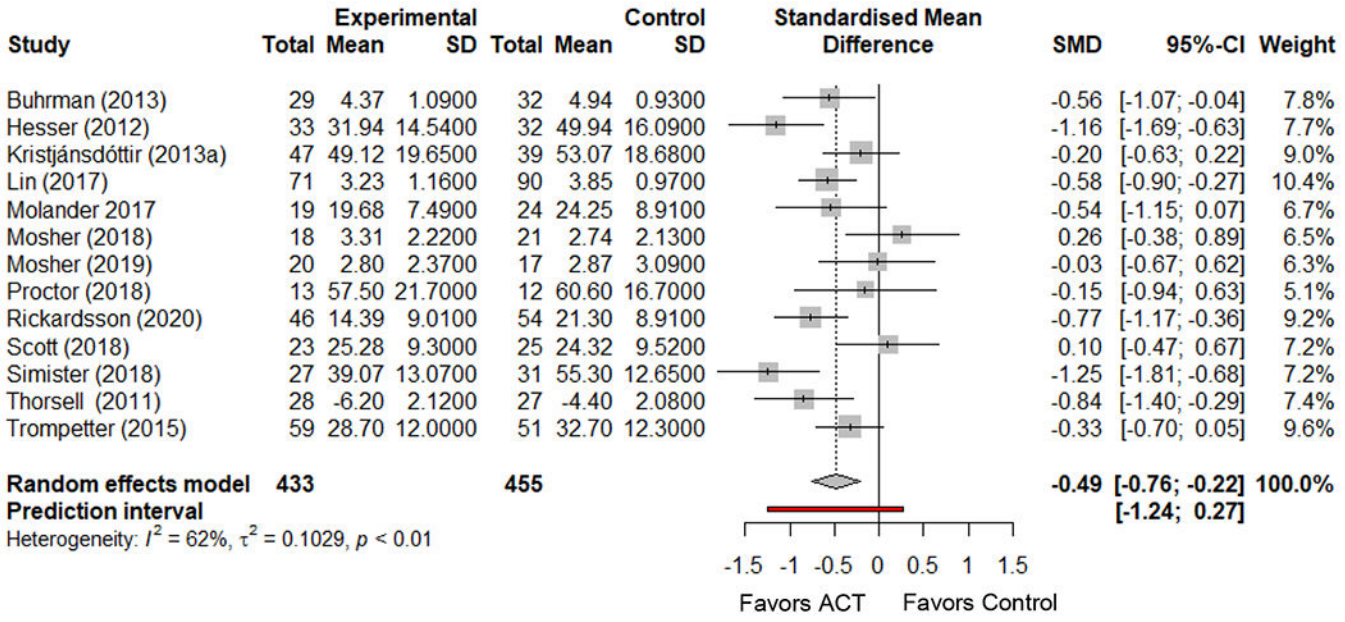

Figure 3a.

Between-group meta-analysis results and forest plot for function outcomes at post-treatment.

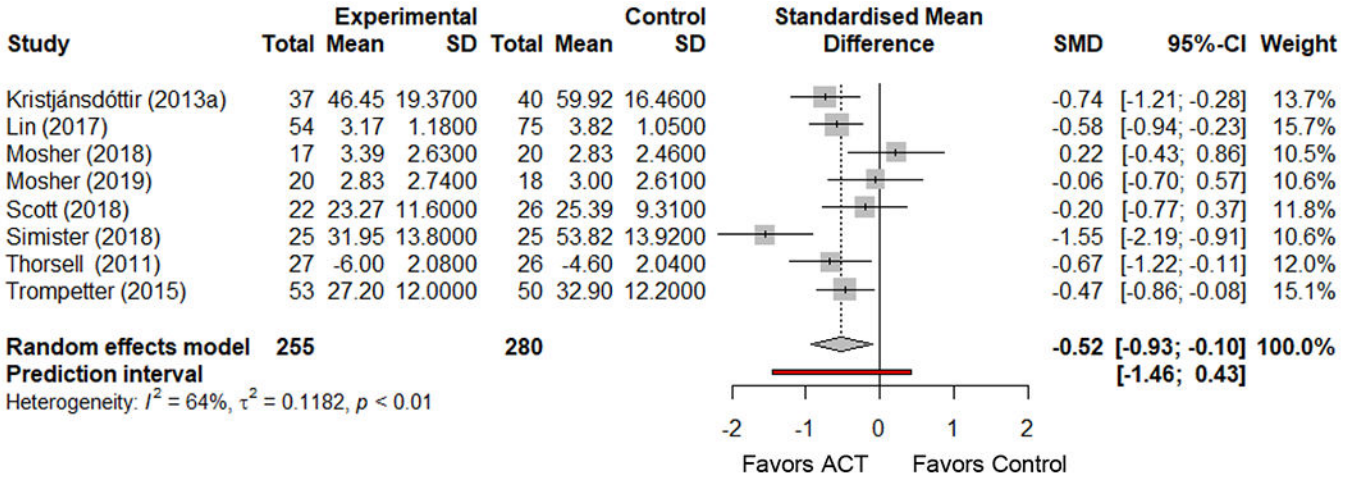

Figure 3b.

Between-group meta-analysis results and forest plot for function outcomes at follow-up.

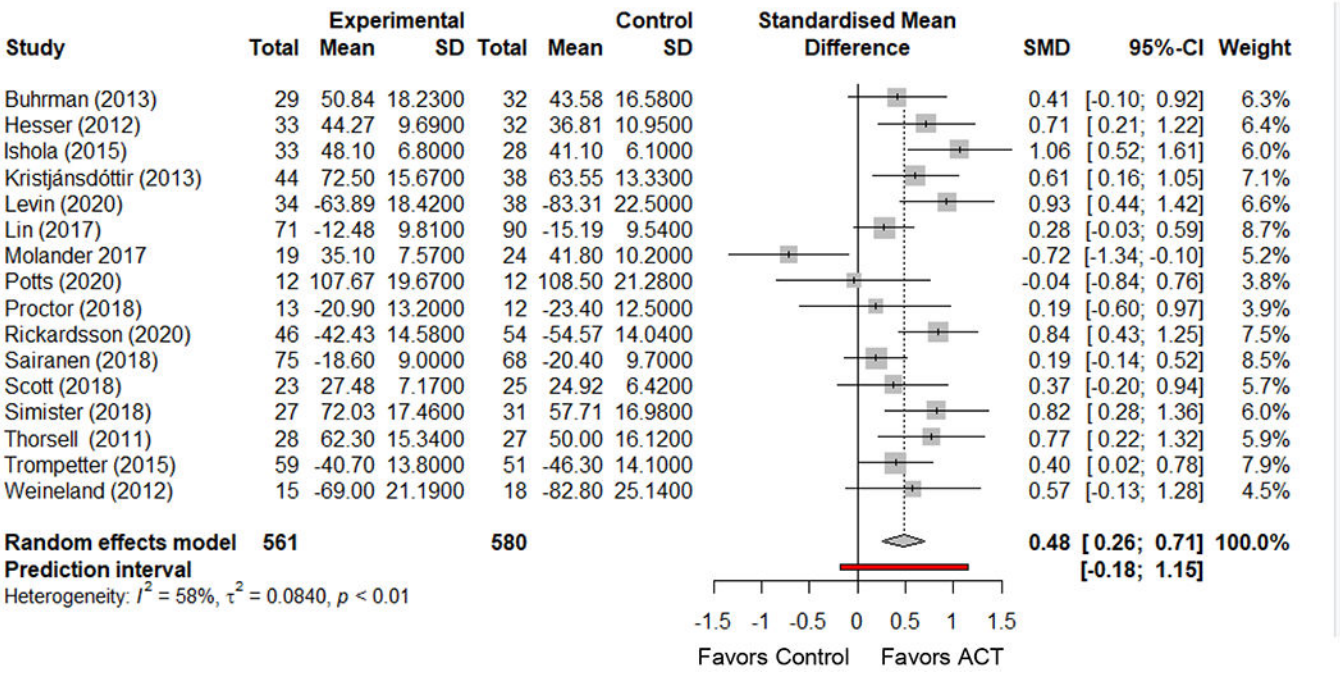

Figure 3c.

Between-group meta-analysis results and forest plot for ACT process outcomes at post-treatment.

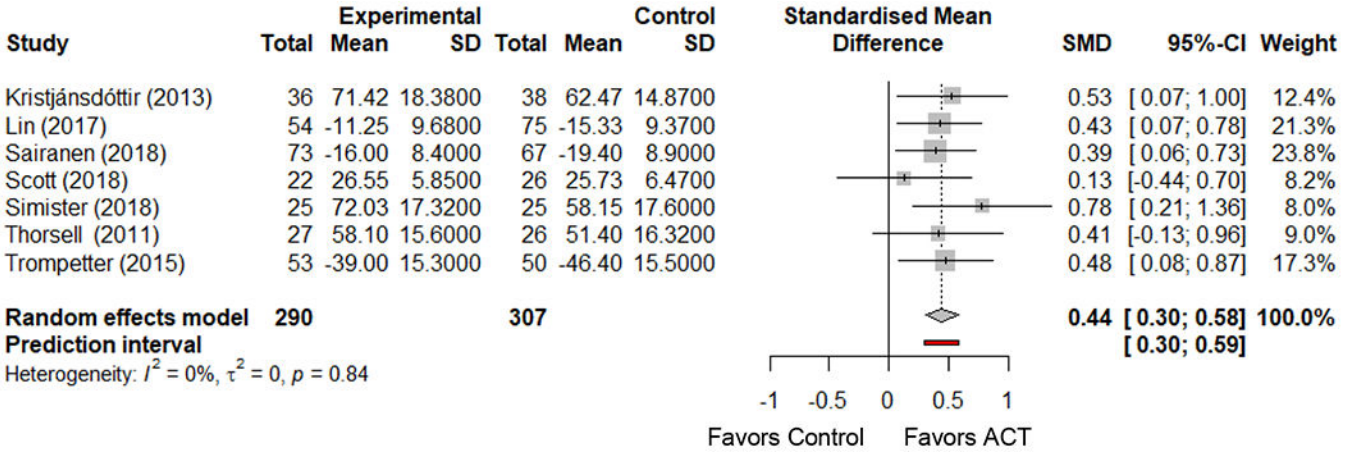

Figure 3d.

Between-group meta-analysis results and forest plot for ACT process outcomes at follow-up. Note: Error bars are 95% confidence intervals; dashed line is pooled effect size; red line is prediction interval. SD = standard deviation. SMD = standardized mean difference, calculated as Hedges' *g*. For function outcomes, negative SMD values indicate greater functional improvement/less functional impairment. For ACT process outcomes, positive SMD values indicate greater indicators of psychological flexibility. Unadjusted means and SDs were obtained for Mosher et al. (2018, 2019) and Scott et al. (2018).

Table 1:

Characteristics of included studies (K = 20)

Study (country)	Participant characteristics	Assessment schedule	Technology-supported ACT conditions and comparators	*n*	Attrition ▫ (post-tx, F/U)	Functioning Outcome	ACT Process Outcome
Chronic Pain							
Buhrman, 2013 (Sweden)	N=76 M_{age} =49.1 Female: 59.2% Non-white=NR	Baseline, post-tx, 6-month F/U	A. ACT guided internet B. Moderated online discussion	A. 38 B. 38	A. 24%, 24% B. 16%, NA	MPI-I	CPAQ *
Herbert, 2017 (USA)	N=129 M_{age} = 52.0 Female: 17.8% Non-white=53%	Baseline, mid-tx, post-tx, 3-month FU, 6-month F/U	A. ACT video-teleconferencing B. ACT in-person	A. 65 B. 64	A. 47%, 55% B. 23%, 28%	BPI-I	CPAQ
Kristjansdottir, 2013a,b (Norway)	N=140 M_{age} = 44.2 Female: 100% Non-white=NR	Pre-inpatient, Post-inpatient/Baseline, post-tx, 5-month F/U, 11-month F/U	A. ACT smartphone app B. Non-interactive website for pain self-management w/ ACT-based content	A. 70 B. 70	A. 33%, 47% B. 47%, 43%	FIQ ^	CPAQ *^
Lin, 2017 (Germany)	N=302 M_{age} = 51.7 Female: 75.0% Non-white=NR	Baseline, post-tx, 4-month F/U	A. ACT guided internet B. ACT unguided internet C. Waitlist control ±	A. 100 B. 101 C. 101	A. 29%, 46% B. 33%, 45% C. 11%, 26%	MPI-I *^	AAQ-II
Rickardsson, 2021 (Sweden)	N=113 M_{age} = 49.5 Female: 84.1% Non-white=NR	Baseline, post-tx, 3-month F/U, 6-month F/U, 12-month F/U	A. ACT guided internet B. Waitlist control	A. 57 B. 56	A. 19%, 25% B. 4%, NA	PII *	PIPS *
Scott, 2018 (U.K.)	N=63 M_{age} = 42.5 Female: 63.5% Non-white=19.1%	Baseline, post-tx, 6-month F/U	A. ACT guided internet B. Treatment as usual	A. 31 B. 32	A. 26%, 26% B. 22%, 19%	WSAS	CPAQ-8
Simister, 2018 (Canada)	N=67 M_{age} = 39.7 Female: 95% Non-white=NR	Baseline, post-tx, 3-month F/U	A. ACT guided internet B. Treatment as usual	A. 33 B. 34	A. 18%, 24% B. 9%, 26%	FIQ-R *^	CPAQ *^
Thorsell,2011 (Sweden)	N=115 M_{age} = 46.0 Female: 64.4% Non-white=NR	Baseline, post-tx, 6-month F/U, 12-month F/U	A. ACT self-help w/ telephone sessions B. Telephone-based applied relaxation	A. 61 B. 54	A. 54%, 56% B. 50%, 52%	O¨MPQ *^	CPAQ *^
Trompetter, 2015 (Netherlands)	N=238 M_{age} = 52.8 Female: 76% Non-white=NR	Baseline, post-tx, 3-month F/U	A. ACT guided internet B. Expressive writing ± C. Waitlist control	A. 82 B. 79 C. 77	A. 28%, 36% B. 35%, 37% C. 19%, 17%	MPI-I *^	PIPS *^
Overweight and Obesity							

Study (country)	Participant characteristics	Assessment schedule	Technology-supported ACT conditions and comparators	*n*	Attrition ¤ (post-tx, F/U)	Functioning Outcome	ACT Process Outcome
Levin, 2020 (USA)	N=79 M_{age} = 39.6 Female: 82.3% Non-white=7.6%	Baseline, post-tx, 2-month F/U	A. ACT guided internet B. Waitlist control	A. 39 B. 40	A. 13%, 8% B. 5%, NA	---	AAQ-W *
Potts, 2020 (USA)	N=55 M_{age} = 39.6 Female: 82.3% Non-white=7.6%	Baseline, post-tx	A. ACT self-help w/ telephone sessions B. ACT self-help w/ email prompts C. Waitlist control ±	A. 17 B. 20 C. 18	A. 29% B. 40% C. 28%	---	CompACT
Sairanen, 2017 (Finland)	N=254 M_{age} = 49.5 Female: 84.5% Non-white=0%	Baseline, post-tx, 6-month F/U	A. ACT unguided smartphone app B. ACT in-person C. No intervention ±	A. 85 B. 84 C. 85	A. 12%, 14% B. 26%, 29% C. 20%, 21%	---	AAQ-II
Weineland, 2012 (Sweden)	N=39 M_{age} = 43.1 Female: 89.7% Non-white=NR	Baseline, post-tx	A. ACT guided internet B. Treatment as usual	A. 19 B. 20	A. 21% B. 10%	---	AAQ-W *
Cancer							
Hawkes, 2014 (Australia)	N=410 M_{age} = 66.4 Female: 46.1% Non-white=NR	Baseline, post-tx, 6-month F/U	A. ACT telephone B. Treatment-as-usual	A. 205 B. 205	A. 17%, 22% B. 14%, 20%	FACIT-F	AAQ-II *
Mosher, 2018 (USA)	N=47 M_{age} = 56.2 Female: 100% Non-white=11%	Baseline, post-tx, 1-month F/U	A. ACT telephone B. Telephone-based education/ support	A. 23 B. 24	A. 22%, 26% B. 12%, 17%	MDASI	---
Mosher, 2019 (USA)	N=50 M_{age} = 62.6 Female: 44% Non-white=14%	Baseline, post-tx, 1-month F/U	A. ACT telephone B. Telephone-based education/ support	A. 25 B. 25	A. 20%, 20% B. 28%, 28%	MDASI	---
Hearing Loss							
Molander, 2018 (Sweden)	N=61 M_{age} = 58.7 Female: 67.2% Non-white=NR	Baseline, post-tx	A. ACT guided internet B. Waitlist control	A. 31 B. 30	A. 13% B. 3%	HHIE-S *	HAQ *
HIV							
Ishola, 2015 (Nigeria)	N=66 M_{age} = 31.6 Female: 100% Non-white=NR	Baseline, post-tx	A. ACT text messages B. Post-HIV counseling	A. 33 B. 33	A. 0% B. 15%	---	AAQ-II *
Multiple Sclerosis							

Study (country)	Participant characteristics	Assessment schedule	Technology-supported ACT conditions and comparators	*n*	Attrition ▫ (post-tx, F/U)	Functioning Outcome	ACT Process Outcome
Proctor, 2018 (U.K)	N=27 M_{age} = 45.9 Female: 88.9% Non-white=NR	Baseline, post-tx	A. ACT self-help w/ telephone sessions B. Treatment as usual	A. 14 B. 13	A. 7% B. 8%	MSIS-P	AAQ-II
Tinnitus							
Hesser, 2012 (Sweden)	N=99 M_{age} = 48.5 Female: 43.4% Non-white= NR	Baseline, post-tx, 1-year F/U	A. ACT guided internet B. CBT guided internet C. Moderated online discussion ±	A. 35 B. 32 C. 32	A. 6%, 6% B. 6%, 14% C. 0%, 0%	THI *	TAQ *

Note: AAQ-II = Acceptance and Action Questionnaire; AAQ-W = Acceptance and Action Questionnaire for Weight; BPI-I = Brief Pain Inventory – Pain Interference subscale; CompACT = Comprehensive Assessment of Acceptance and Commitment Therapy Processes; CPAQ = Chronic Pain Acceptance Questionnaire; CPAQ-8 = 8-item Chronic Pain Acceptance Questionnaire FACIT-F = Functional Assessment of Chronic Illness Therapy-Functional Wellbeing subscale; FIQ = Fibromyalgia Impact Questionnaire; ; FIQ-R = Fibromyalgia Impact Questionnaire Revised; F/U = follow-up; HAQ=Hearing Acceptance Questionnaire; HHIE-S=Hearing Handicap Inventory for the Elderly-S; MDASI=MD Anderson Symptom Inventory; MPI-I=Multidimensional Pain Inventory – Pain Interference Subscale; MSIS-P=Multiple Sclerosis Impact Scale-Physical Health subscale; NR=not reported; ÖMPQ = 5 aggregated function items from the Örebro Musculoskeletal Pain Questionnaire; PII=Pain Interference Index; PIPS= Psychological Inflexibility in Pain Scale; post-tx = post-treatment; TAQ=Tinnitus Acceptance Questionnaire; THI= Tinnitus Handicap Inventory; WSAS=Work and Social Functioning Scale

▫ Attrition is in regard to completed assessments; F/U refers to first follow-up timepoint

* significant improvement favoring technology-supported ACT at posttreatment

^ significant improvement favoring technology-supported ACT condition at first follow-up timepoint

± denotes comparison condition. Underlined text signifies outcomes that were included in meta-analysis.

Table 2:

Intervention details of technology-supported ACT treatments for chronic health conditions (K=20)

Study	Primary ACT Intervention Delivery Method	Intervention Content	Therapist Involvement	Therapist Characteristics
Chronic Pain				
Buhrman, 2013	7 weekly guided internet modules with information, metaphors and assignments; MP3 files with mindfulness and experiential exercises	Behavioral approach to chronic pain; creative hopelessness; willingness and acceptance; defusion and goal setting; self-as-context; values and committed action; willingness in accordance with values; maintenance of learned strategies; mindfulness exercises	Provided weekly feedback on homework via online platform; after module 3 and at 7 weeks, completed structured telephone calls lasting less than 30 mins to motivate participation and answer questions	Graduate students in final term of five-year clinical psychology program receiving weekly supervision from clinical psychologist
Herbert, 2017	8 weekly video-teleconferencing sessions with metaphors and experiential exercises; at-home assignments	Limits of control; focus on experience; values; cognitive defusion; acceptance; mindfulness; committed action; continued action in support of values	Delivered weekly individual manualized ACT sessions, each 60 mins long	At least master's level psychology graduate students with weekly group supervision
Kristjansdottir, 2013a and Kristjansdottir, 2013b	One in-person session; 4 weeks of 3 daily diary entries via smartphone; audio files with mindfulness exercises; informational website	Cognitive defusion; mindfulness; values and values-based action; acceptance vs avoidance	Provided one in-person individual session; daily, personalized, situational feedback via secure website; final feedback provided in a summary	Therapists had experience in health care sciences (nursing and/or psychology) and ACT training; content of feedback was supervised
Lin, 2017	A. 7 weekly guided internet modules with information, assignments, metaphors and mindfulness exercises, video and audio files; automatically generated text-messages (SMS) to support integration of concepts into daily life; B. 7 weekly unguided internet modules with information, assignments, metaphors and mindfulness exercises, video and audio files; automatically generated text-messages (SMS) to support integration of concepts into daily life;	A. Pain psychoeducation; creative hopelessness; mindfulness; control and acceptance; primary and secondary suffering; defusion; self-as-context; thoughts, emotions, and goal setting; values; willingness and committed action; summary of program and maintenance B. Same content as condition A	A. "e-Coaches" provided weekly personalized and standardized feedback by e-mail via a secure web-based platform after module completion; approximately 2 hours total per participant B. No therapist involvement	A. Psychologists (eCoaches) trained and supervised by an experienced clinical psychologist B. N/A
Rickardsson, 2021	8 weeks of daily internet content in "microlearning" format with text, audio, illustrations, experiential exercises and value-oriented exposure	Acceptance; defusion; present moment awareness; exposure; behavior analysis; pain education; values	Via text messages (SMS) provided feedback, support, clarifications, encouragement, and reminders to engage in treatment; responded within 48 hours; at least one weekly contact with each participant; phone support upon request; averaged 12 ½ mins per week per participant	Three licensed psychologists and two intern psychologists who worked at a tertiary pain clinic
Scott, 2018	2 in-person or telephone sessions; 8 guided internet video sessions (twice weekly for 3 weeks, once weekly for 2 weeks) with experiential exercises, metaphors and questions; completed in 10-12 weeks	Creative hopelessness; values; openness; cognitive defusion; values-based action; awareness; self-as-context; committed action; reviewed progress and planned maintenance of gains	Provided in-person or telephone individual sessions; after each session provided individualized feedback within 24 – 72 hours via email.	Master's level psychologist with supervised ACT experience; 3 experienced doctoral level psychologists; weekly meetings and regular supervision
Simister, 2018	7 guided internet modules self-paced over a 2-month period with MP3s, videos and	Creative hopelessness; acceptance; values; psychoeducation; cognitive defusion; contact	Reviewed homework and provided written feedback via online platform	Master's level therapist under guidance of a registered psychologist with ACT expertise

Study	Primary ACT Intervention Delivery Method	Intervention Content	Therapist Involvement	Therapist Characteristics
	pdfs containing metaphors, vignettes and experiential exercises	with present moment; self-as-context; willingness and committed action		
Thorsell, 2011	2 in-person sessions, 7 weeks using self-help manual with 6 weekly telephone sessions; CD with supplementary exercises (Telephone)	Psychoeducation; avoidance-suffering cycle; values; defusion; mindfulness; willingness and acceptance; committed action; action plan and obstacles	Provided initial and concluding in-person 90-min individual sessions; 30-min weekly telephone sessions; responded to participant email questions as needed	Psychology interns trained in ACT and supervised
Trompetter, 2015	9 guided internet modules with text, experiential exercises and metaphors over 9-12 weeks; audio files with mindfulness exercises; personal diary	Psychoeducation; avoidance of pain; values; committed action; pain acceptance; cognitive defusion; self-as-context; pain, social context & communication; experiences of previous ACT-participants	Provided weekly structured personalized response on participants' progress via enclosed and encrypted web-based system	Graduated psychology students trained and supervised by a registered CBT therapist experienced with ACT
Overweight and Obesity				
Levin, 2020	8 weekly guided internet modules with text, videos and interactive exercises	Nutrition and physical activity education; strategies to increase physical activity and improve diet; weight stigma; being stuck; defusion; acceptance; mindfulness; values; committed action; recommitting after slips	Monitored online learning management system usage and provided 5–10-min weekly coaching telephone calls to increase adherence and provide support in implementing program	Doctoral student in clinical/ counseling psychology
Potts, 2020	A. 7 book chapters completed over 8 weeks; weekly telephone sessions; weekly online chapter quiz; journaling B. 7 book chapters completed over 8 weeks; weekly online chapter quiz; journaling	A. The Diet Trap" book by Lillis et al., 2014, which covers key ACT skills and concepts to reduce harm from weight self-stigma and increase motivators for engaging in meaningful health and quality of life improving behaviors B. Same content as condition A	A. Initial and final 30-min coaching call; 6 weekly 5-10 min calls to motivate participation and generalize skills to daily life; weekly email reminder of tasks and brief, tailored, supportive statements; contact time approximately 120 minutes over 8 weeks per participant B. Weekly email reminder of tasks and brief tailored, supportive statements; if needed two supportive email reminders; contact and preparation time approximately 90 minutes over 8 weeks per participant	A. Advanced clinical/counseling psychology doctoral student B. Same as condition A
Sairanen. 2017	8-week intervention; one in-person meeting; Smartphone app with 41 exercises with text, audio and video components	Values clarification; acting according with values; mindfulness skills; observing self; and acceptance skills. Focus was on ACT skills, but minor parts of mindful eating, relaxation, and everyday physical activity included	Presented an overview of ACT intervention and the smartphone app during one in-person group meeting	Trained psychologist
Weineland, 2012	2 in-person sessions; 6 weekly internet modules with texts, mindfulness audio files, written exercises and videos	Creative hopelessness; defusion; self-as-context; acceptance; committed action; contact with the present moment; values	Provided 2 in-person sessions including behavior analysis of avoidance and weekly telephone support of ACT content	Not described
Cancer				
Hawkes, 2014	11 individual telephone sessions over 6-month period (10 bi-weekly sessions for 5 months and final session 4 weeks later); handbook; postcards; pedometer	Cancer psychoeducation; values; mindfulness; defusion; acceptance; committed action; motivational interviewing; problem solving; action planning; goal setting; review and monitoring health behaviors	Provided manualized individual health coaching sessions via telephone	Degrees in nursing, psychology, or health promotion and 5 years of experience; six weeks of study training; weekly supervision with investigators
Mosher, 2018	6 weekly telephone-based sessions; handouts; CD	Mindfulness; suffering and control; perspective taking; cognitive defusion; acceptance;	Provided 50–60-min telephone sessions; assessed participant and strategies for	Master's level social worker with experience in ACT

Study	Primary ACT Intervention Delivery Method	Intervention Content	Therapist Involvement	Therapist Characteristics
		transcendent sense of self; values clarification and committed action in face of distress/ symptoms; responding more effectively to symptoms	managing symptoms; covered week's topic; assessed home practice and skills; discussed home practice	trained and supervised by two psychologists
Mosher, 2019	6 weekly telephone-based sessions (dyadic for sessions 1 and 4-6, individual for sessions 2 and 3); handouts; CD	Mindfulness; control vs non-control strategies; perspective taking; cognitive defusion; acceptance; values clarification; committed action	Provided 50-60 min dyadic and individual telephone sessions regarding coping, mindfulness, and other skills; discussed home practice for the week ahead	Master's level social worker with experience in ACT trained and supervised by two psychologists
Hearing Loss				
Molander, 2018	8 weekly internet-based modules with printable text files and audio files; homework; feedback	Psychoeducation about hearing, hearing strategies and devices; suffering; values; relaxation; acceptance; defusion; mindfulness; mindful communication; maintenance of gains; experiential avoidance; summary	Provided weekly feedback on exercises and answered questions through online platform	One licensed psychologist with ACT experience and four supervised master-level students
HIV				
Ishola, 2015	1 in-person session; weekly texts (SMS) over a 3-month period	Acceptance; cognitive defusion; being present; self as context; values; committed action; post HIV test counseling	Delivered 1 in-person ACT session	Not described
Multiple Sclerosis				
Proctor, 2018	8 weekly telephone sessions with a self-help book	"Get Out of Your Mind and Into Your Life" book which covers all components of the ACT model	Provided weekly, theoretically oriented support calls that averaged 14 minutes per participant	Trainee clinical psychologist with supervision from an experienced ACT practitioner-researcher
Tinnitus				
Hesser, 2012	8 weekly internet-based modules as downloadable PDF's; homework; online messages exchanged with therapist; MP3s	Mindfulness; cognitive defusion; identifying personal values and goals; willingness in context of value-based behavior change; information about tinnitus; as needed addressed common and specific problems; skill maintenance	Monitored homework; between each module provided feedback, guidance and support via secure encrypted web page; averaged 9 mins per week per participant	One licensed psychologist and six master's level students; trained in CBT and internet-based ACT for tinnitus; therapists supervised weekly

Table 3:

Post-hoc exploratory sub-group analyses at post-treatment

Outcome	Subgroup	*k*	Hedges' *g*	95% CI	Heterogeneity (I^2)	Test for differences
Technology Modality						
Function	Internet	8	−0.63	(−0.97, −0.28)	60.9%	Q(1) = 3.09, *p* = 0.08
	Other	5	−0.22	(−0.73, 0.29)	46.3%	
ACT process	Internet	10	0.48	(0.16, 0.80)	63.9%	Q(1) = 0.01, *p* = 0.94
	Other	6	0.49	(0.07, 0.92)	54.4%	
Therapist Contact Method						
Function	In-person/phone	8	−0.31	(−0.65, 0.03)	54.3%	Q(1) = 3.43, *p* = 0.06
	Asynchronous	5	−0.74	(−1.23, −0.24)	63.4%	
ACT process	In-person/phone	11	0.57	(0.34, 0.79)	39.6%	Q(1) = 0.80, *p* = 0.37
	Asynchronous	5	0.32	(−0.38, 1.03)	75.8%	
Clinical Population						
Function	Chronic pain	8	−0.54	(−0.87, −0.22)	58.6%	Q(1) = 0.47, *p* = 0.49
	Other	5	−0.35	(−1.05, 0.35)	71.4%	
ACT process	Chronic pain	8	0.53	(0.33, 0.72)	8.2%	Q(1) = 0.39, *p* = 0.53
	Other	8	0.39	(−0.10, 0.87)	74.5%	
Comparator Type						
Function	Active	7	−0.42	(−0.86, 0.01)	65.0%	Q(1) = 0.30, *p* = 0.58
	Inactive	6	−0.56	(−1.04, −0.09)	60.9%	
ACT process	Active	6	0.62	(0.37, 0.87)	0.0%	Q(1) = 1.82, *p* = 0.18
	Inactive	10	0.37	(0.03, 0.72)	67.3%	