A digital self-management platform for adult asthma: randomized attention-placebo controlled trial

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Aaron Kandola[1, 2] PhD; Kyra Edwards[3] BSc, MSc; Joris Straatman[1] BA, MSc; Bettina Dührkoop[1]; Bettina Hein[1]; Joseph Hayes[1, 3, 4]

[1]juli Health Hull US
[2]MRC Unit of Lifelong Health and Aging UCL London GB
[3]Division of Psychiatry UCL London GB
[4]Camden and Islington NHS Foundation Trust London GB

Corresponding Author:
Joseph Hayes
Division of Psychiatry
UCL
Maple House
149 Tottenham Court Road
London
GB

Abstract

Background: Asthma is one of the most common chronic conditions worldwide, with a substantial individual and healthcare burden. Digital apps hold promise as a highly accessible, low-cost method of enhancing self-management in asthma, which is critical to effective asthma control.

Objective: We conducted a fully remote trial to assess the efficacy of juli, a commercially available smartphone self-management platform for asthma.

Methods: We conducted a pragmatic single-blind, randomised controlled trial of juli for asthma management. Our study included participants aged 18 and above who self-identified as having asthma and had an asthma control test (ACT) score of 19 or less (indicating poorly controlled asthma) at the beginning of the trial. Participants were randomised (1:1 ratio) to receive juli for eight weeks or a limited attention-placebo control version of the app. The primary outcome measure was the difference in ACT scores after eight weeks. Secondary outcomes included remission (ACT score greater than 19), minimal clinically important difference (an improvement of three or more points on the ACT), worsening of asthma, and health-related quality of life. The primary analysis included participants using the app for eight weeks (per-protocol), a secondary analysis used modified intention-to-treat.

Results: We randomised 411 participants between May 2021 and April 2023: 152 engaged with the app for eight weeks and were included in the per-protocol analysis, 262 completed the week two outcome assessment and were included in the modified intention-to-treat analysis.

In the per-protocol analysis, the intervention group had a higher mean ACT score (17.93, standard deviation = 4.72) than the control group (16.24, standard deviation = 5.78) by week eight (baseline adjusted beta-coefficient 1.91, 95% confidence intervals = 0.31 to 3.51, p=0.020). Participants using juli had greater odds of achieving or exceeding the minimal clinically important difference at eight weeks (adjusted odds ratio = 2.38, 95% confidence intervals = 1.20 to 4.70, p=0.013). There were no between-group differences in the other secondary outcomes at eight weeks. The results from the modified intention-to-treat analysis were similar.

Conclusions: Users of juli had improved asthma symptom control over eight weeks compared with users of a version of the app with limited functionality. These findings suggest that juli is an effective digital self-management platform that could augment existing care pathways for asthma. Clinical Trial: The trial was pre-registered (ISRCTN87679686).

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A digital self-management platform for adult asthma: randomized attention-placebo controlled trial

Aaron Kandola[1,2], Kyra Edwards[3], Joris Straatman[2], Bettina Dührkoop[2], Bettina Hein[2], Joseph F Hayes*[2,3,4]

1 MRC Unit of Lifelong Health and Aging, UCL
2 juli Health
3 Division of Psychiatry, UCL
4 Camden and Islington NHS Foundation Trust

*Corresponding author:
Joseph Hayes
6th Floor Maple House,
149 Tottenham Court Road,
London
joseph.hayes@ucl.ac.uk

Abstract

Background

Asthma is one of the most common chronic conditions worldwide, with a substantial individual and healthcare burden. Digital apps hold promise as a highly accessible, low-cost method of enhancing self-management in asthma, which is critical to effective asthma control.

Objective

We conducted a fully remote randomized controlled trial (RCT) to assess the efficacy of juli, a commercially available smartphone self-management platform for asthma.

Methods

We conducted a pragmatic single-blind, RCT of juli for asthma management. Our study included participants aged 18 and above who self-identified as having asthma and had an asthma control test (ACT) score of 19 or less (indicating poorly controlled asthma) at the beginning of the trial. Participants were randomized (1:1 ratio) to receive juli for eight weeks or a limited attention-placebo control version of the app. The primary outcome measure was the difference in ACT scores after eight weeks. Secondary outcomes included remission (ACT score greater than 19), minimal clinically important difference (an improvement of three or more points on the ACT), worsening of asthma, and health-related quality of life. The primary analysis included participants using the app for eight weeks (per-protocol), a secondary analysis used modified intention-to-treat.

Results

We randomized 411 participants between May 2021 and April 2023: 152 engaged with the app for eight weeks and were included in the per-protocol analysis, 262 completed the week two outcome assessment and were included in the modified intention-to-treat analysis. Total attrition between baseline and week eight was 259 individuals (63.02%).

In the per-protocol analysis, the intervention group had a higher mean ACT score (17.93, standard deviation = 4.72) than the control group (16.24, standard deviation = 5.78) by week eight (baseline adjusted β-coefficient 1.91, 95% confidence intervals = 0.31 to 3.51, p=0.020). Participants using juli had greater odds of achieving or exceeding the minimal clinically important difference at eight weeks (adjusted odds ratio = 2.38, 95% confidence intervals = 1.20 to 4.70, p=0.013). There were no between-group differences in the other secondary outcomes at eight weeks. The results from the modified intention-to-treat analyses were similar.

Conclusions

Users of juli had improved asthma symptom control over eight weeks compared with users of a version of the app with limited functionality. These findings suggest that juli is an effective digital self-management platform that could augment existing care pathways for asthma. Retention of patients in RCTs and real-world usage of digital healthcare apps is a major challenge.

Trial Registration

The trial was pre-registered (ISRCTN87679686).

KEYWORDS: asthma; mobile health; self-management; randomized controlled trial

Introduction

Asthma is one of the most common chronic conditions worldwide, with an increasing prevalence that currently affects one in ten people at some time [1-3]. The inflammatory disease causes mild-to-severe respiratory symptoms, including shortness of breath, chest tightness, wheezing, and cough. It significantly burdens patients and healthcare services, including the need for long-term treatment, emergency care, and hospitalizations that will cost the United States economy an estimated $300 billion over the next 20 years in direct healthcare expenditure [4]. Effective asthma control is necessary to reduce these costs and improve quality of life for people with the condition.

Asthma management is based on achieving symptom control and reducing the frequency and severity of exacerbations [5]. This involves the use of inhaled anti-inflammatory medications, and the avoidance of asthma triggers. Symptom control is associated with improved quality of life, reduced healthcare costs, and better work performance [6]. However, a significant proportion of individuals with asthma have suboptimal control because of poor adherence to medication, insufficient recognition of triggers, comorbidities (such as rhinitis or obesity), health behaviors (such as smoking) and inadequate information about treatment [7]. Mobile applications may address some of these treatment challenges by enabling people with asthma to more easily and consistently self-manage their condition compared to existing treatment plans. For example, digital apps can offer timely reminders to improve medication adherence or real-time feedback to identify and adapt to possible triggers and health behaviors [8, 9].

A 2017 systematic review and meta-analysis of randomized controlled trials (RCTs) of mobile, web-based and messaging service applications to support asthma self-management [9] concluded that these interventions could improve asthma control, but that effectiveness and important features of the apps varied. The majority of these apps included combinations of medication prompts, patient education, electronic diaries, actin plans and professional support facilitation [9]. A similar 2018 review of RCTs and observational studies concluded that, in adults with asthma, mobile apps were more effective than other types of digital interventions, such as web-based interventions [10]. Studies of app-based interventions published since these reviews have generally been feasibility trials or small underpowered RCTs [11-14]. A 2022 Cochrane review examined the effect of digital apps for asthma medication adherence, concluding they were likely to be useful in poorly adherent populations, but again highlighting heterogeneity among mobile or web-based interventions [8]. Despite the mixed evidence for effectiveness, a number of apps are publicly available. These apps frequently incorporate behavioral change techniques and gamification. Reviews of these apps have highlighted that they vary considerably in quality, employ a range of behavioral change techniques, struggle with adequate engagement and retention, and lack clinical validation of efficacy [15-17]. The Global Strategy for Asthma Management and Prevention (GINA) highlights that, despite use of digital technologies rapidly increasing in patients with asthma, “high-quality studies are needed to evaluate their utility and effectiveness”[3].

We aimed to address the fundamental issue that commercially available apps require sufficient evaluation of their effectiveness, by conducting an RCT of juli. This is a digital health app that aims to support people with asthma by combining numerous approaches that have been shown effective in research-grade apps for asthma, including symptom tracking, medication reminders, trigger identification (including geolocated weather, pollen and air pollution data), data visualization of respiratory symptoms, mood, exercise, activity, sleep, and heart rate variability and behavioral activation recommendations about how to improve these parameters [18, 19]. Our RCT was fully remote, increasing time-efficiency, cost-effectiveness, and reach. We hypothesized that participants randomized to juli would have a greater reduction in asthma symptoms at eight weeks than those randomized to attention-placebo control.

Methods

Study design and participants

We conducted a fully remote pragmatic single-blind, placebo control randomized controlled trial to test the

efficacy of juli in adults with asthma. The trial was open to individuals from anywhere in the world, providing they were aged 18 to 65, English-speaking, had access to a smartphone, and self-identified as having asthma. We also only included people with asthma symptoms that were moderately or poorly controlled according to a score of 19 or lower on the asthma control test (ACT) at baseline. An ACT score of $\leq$19 is consistent with GINA-defined partly controlled/uncontrolled asthma [20].

Recruitment

Recruitment ran from May 2021 until April 2023. We recruited via self-help groups for asthma, online adverts and social media posts. For the duration of the RCT we modified the onboarding so that recruitment was automated with study information provided to participants within the app.. Support for potential participants interested in the RCT was provided by the study team via email.

Ethical considerations

The University College London Ethics Committee gave full ethical approval (ID: 19413/001). All participants supplied written informed consent within the app, with additional information on a dedicated webpage. Data required for the RCT was stored separately in anonymized format. The juli app is Health Insurance Portability and Accountability Act, Service Organization Control Type 2 and General Data Protection Regulation compliant. Participants in both arms of the RCT were entered into a prize draw at 2, 4, 6 and 8 weeks with the possibility of winning $20 at each timepoint. The trial was entered on the ISRCTN registry (ISRCTN87679686). At the same time we were running an RCT of the juli app for depression. This RCT had a similar design and analysis [21].

Randomization and masking

We assigned participants in a 1:1 ratio to either an attention-placebo control, or the full version of juli. We automated and conducted randomization within the app, employing random block sizes ranging from four to eight. To ensure data integrity, the treatment allocation was concealed from both the research team and independent statisticians until the analysis was finalized.

Intervention

The juli app was developed by gamification experts in collaboration with patients, a psychiatrist and a pulmonologist. A patient with asthma and a psychiatrist with expertise in mental health/physical health interface are the Chief Technical Officer and Chief Medical Officer of juli respectively. We held development and user testing interviews with ten patients with asthma (5 women, aged 18-65) The app underwent multiple iterations following feedback from these patient panel interviews and discussion with a pulmonologist. Our trial used a full version of the juli app for the intervention group and a limited version in the attention-placebo control group. Participants with the complete juli app received automatic prompts to open the app each day at a user-inputted time. The app asked participants about how their asthma was affecting them on a five face emoji scale, their emergency inhaler usage that day, how often they had a shortness of breath episode, and whether they woke in the night due to shortness of breath. Individuals could also track various factors they regarded as relevant to their asthma symptoms, such as tobacco smoke exposure [19]. The app connects to smart peak flow meters (such as Smart Peak Flow or MIR Smart One) through Google Fit or Apple HealthKit, or participants could enter this information manually.

The app presented participants with regular, geolocated weather, pollen and air pollution data relevant to their asthma [22]. All participants could also access passively gathered smartphone data on relevant health-related factors, including, activity, menstrual cycle, and sleep. Participants could check this information daily and see associations with their asthma [23-25]. If they had them, participants with wearables that they chose to connect to the app would see additional data on workouts, and heart rate variability, and improved data on activity and sleep. However, lack of access to a wearable was not an exclusion criteria.

The app also uses behavioral activation techniques to provide personalized recommendations about these

factors to encourage healthy behaviors. The app includes customizable medication reminders to improve medication adherence [26]. The juli app also encouraged participants to use the positive affect journaling function [27]. The design of the juli app guides participants towards all elements of the app but allows them to flexibility choose where they want to engage.

Attention-placebo control
Participants in the control arm had a limited version of the app. The app prompted participants to open it each day and rate how they were feeling on the five emoji scale, but they did not have access to any further functionality or intervention. There was no change to usual care in either arm.

Assessment tools
Participants in both arms completed baseline assessments and follow-up assessments at two, four, six and eight weeks remotely from within the app. Assessments included the ACT for asthma symptoms and the 12-Item Short Form Health Survey (SF-12) for health-related quality of life. The ACT is a widely used, self-completed asthma symptom scale that is responsive to change with scores ranging from 5-25 [28]. A cut-off score of 19 or less identifies patients with poorly controlled asthma. The SF-12 is a self-reported measure assessing the impact of health on an individual's everyday life. Scores ranging from 0-100 with higher scores indicating better quality-of-life [29].

Outcomes
The total ACT score at eight weeks was our primary outcome. Secondary outcomes were: continuous ACT score at two, four, six, and eight weeks in a repeated measures analysis using mixed-effect models; remission, defined as a score of >19 at eight weeks; remission at two, four, six, and eight weeks in a repeated measures analysis; SF-12 physical and mental component scores at eight weeks and; SF-12 physical and mental component scores at four and eight weeks in a repeated measures analysis.

We added achieving a minimal clinically important difference (MCID) at eight weeks (3-point increase on the ACT)[30], and a worsening of asthma symptoms (i.e., a decrease in ACT scores from baseline) as post-hoc outcomes.

Sample Size estimation
The best MCID estimate for the ACT is between 2.2 and 3.0 (standard deviation (SD) = 3.1 to 4.7) [30]. A two-sided 5% significance level at 80% power requires a total sample size of 146 for an MCID of 3. We aimed to recruit 90 participants per arm, allowing for 23% attrition [31].

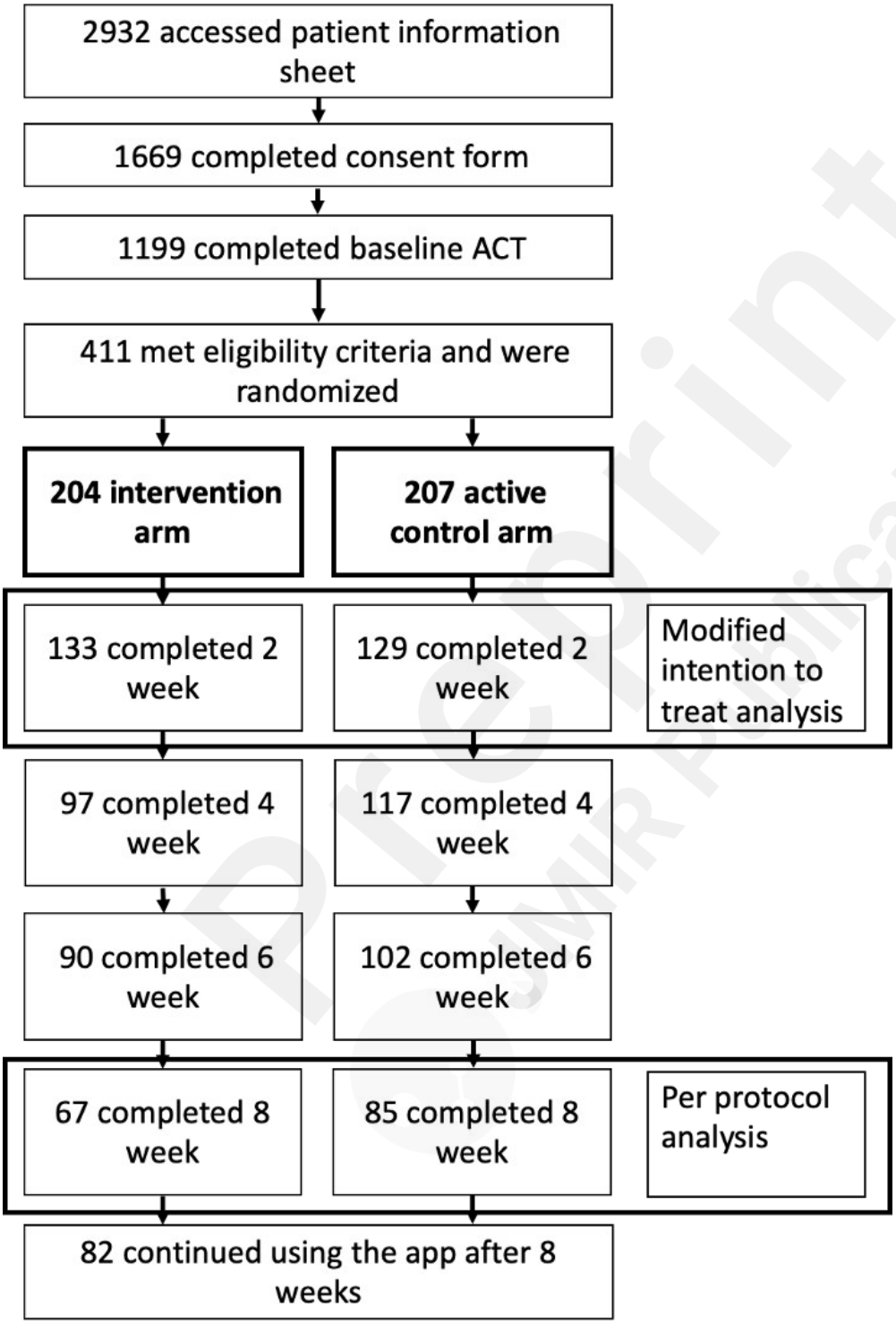
Statistical analyses
We pre-printed the analysis plan on UCL Discovery[32] ,and pre-registered the RCT on the ISRCTN registry with a description of the primary and secondary outcomes before the trial started. In reporting and analyzing our data we followed the Consolidated Standards of Reporting Trials (CONSORT) guidelines [33].

Our primary outcome was the difference in total ACT score at eight weeks between the control and intervention groups in a per-protocol analysis. We estimated this difference with a linear regression model adjusted for baseline ACT and any imbalanced baseline covariates. We tested how robust the result was to model specification by also using a Poisson model and adjusting for any variables not balanced at baseline. We used logistic regression to calculate the odds ratio (OR) of remission at eight weeks (ACT>19), achieving MCID (≥3 point ACT improvement) and worsening of asthma, adjusting for baseline ACT. We completed the repeat measures analyses using linear or logistic mixed-effect models adjusting for ACT at baseline.

We repeated analysis of all outcomes in a modified intention-to-treat analysis. This analysis included all randomized participants with a complete baseline and week two ACT score, dropping participants who were randomized but never used the app (see Figure 1). We imputed the missing ACT scores first using multiple

imputation models and then using last observation carried forward [34]. The multiple imputation models included predictive mean matching with five nearest neighbors and 50 iterations. This method means that only plausible values are imputed, and is more robust to model misspecification than fully parametric imputation [35].

Figure 1. CONSORT diagram



An independent statistician with no conflicts of interest with the company providing juli completed the analyses. All analyses we conducted using Stata (Version 17) and R (Version 4.3.1 for Windows).

Results

Participants

Of 1199 participants who completed the baseline ACT, 411 met eligibility criteria and were randomized: 204 to the intervention arm and 207 to the active control arm. Of those randomized 325 (79.08%) were from the United States. Attrition was similar in both arms: 71 participants (34.80%) in the intervention arm and 78 (37.68%) in the active control arm left the study before the week 2 ACT. The remaining 262 contributed to our modified intention-to-treat analysis (Figure 1). Further attrition occurred between week 2 and week 8: 66 participants left the intervention group and 44 left the active control group (49.62% and 34.11% respectively). The remaining 152 participants contributed to our per-protocol analysis (Figure 1). Participants included in the modified intention-to-treat and per protocol analyses were similar in terms of baseline characteristics (see Table 1 and Supplement Table 1).

Per-protocol analysis

Participants were mostly females (122, 80.26%) who had been diagnosed with by a physician more than five years ago (115, 75.66%) and had ongoing contact with a doctor about their asthma (134, 88.16%) (Table 1). Participants had a mean baseline ACT score of 12.84 (SD = 4.00).

Table 1. Baseline characteristics

	Intervention (n=67)	Control (n=85)	All (n=152)
Age	35.73 (11.48)	36.62 (13.23)	36.23 (12.45)
Gender			
Female	52 (77.61)	70 (82.35)	122 (80.26)
Male	13 (19.40)	13 (15.29)	26 (17.11)
Other	2 (2.99)	2 (2.35)	4 (2.63)
Asthma duration			
<1 month	1 (1.49)	1 (1.18)	2 (1.32)
1 to <3 months	2 (2.99)	2 (2.35)	4 (2.63)
3 months to <1 year	2 (2.99)	4 (4.71)	6 (3.951)
1 year to <2 years	4 (5.97)	5 (5.88)	9 (5.92)
2 years to <5 years	11 (16.42)	5 (5.88)	16 (10.53)
>5 years	47 (70.15)	68 (80.00)	115 (75.66)
Physician contact			
Regular	22 (32.84)	30 (35.29)	52 (34.21)
Occasional	42 (62.69)	40 (47.06)	82 (53.95)
Not anymore	3 (4.48)	10 (11.76)	13 (8.55)
Never	0 (0)	5 (5.88)	5 (3.29)
Diagnosed by a physician			
Yes	67 (100)	81 (95.29)	148 (97.37)
No	0 (0)	4.71 (4.71)	4 (2.63)
ACT total score[1]	12.60 (4.10)	13.04 (3.93)	12.84 (4.00)
SF-12 physical health subscale[2]	39.28 (8.95)	39.86 (9.04)	39.61 (8.98)
SF-12 mental health subscale[3]	38.35 (9.84)	37.74 (10.74)	38.01 (10.32)

Data are n (%) or mean (SD). [1]Asthma control test (possible range 5–25), [2]Short-Form Health Survey-12 physical health subscale

(possible range 0–100), [3]Short-Form Health Survey-12 mental health subscale (possible range 0–100). Data used in per-protocol analysis of individuals completing week 8 ACT

Intervention group participants had a mean ACT score of 17.93 (SD = 4.72) compared with 16.24 (SD = 5.78) in the control group after eight weeks (see Figure 2). After adjusting for baseline ACT score, the intervention group showed a greater improvement in symptom scores at eight weeks than those in the control group (adjusted β-coefficient = 1.91, 95% confidence interval (CI) = 0.31 to 3.51, p=0.020) (Table 2). After adjusting for imbalanced baseline characteristics, the improvement was 2.01 points on the ACT (95%CI = 0.48 to 3.53, p=0.010). Using Poisson regression rather than linear regression did not alter our results.

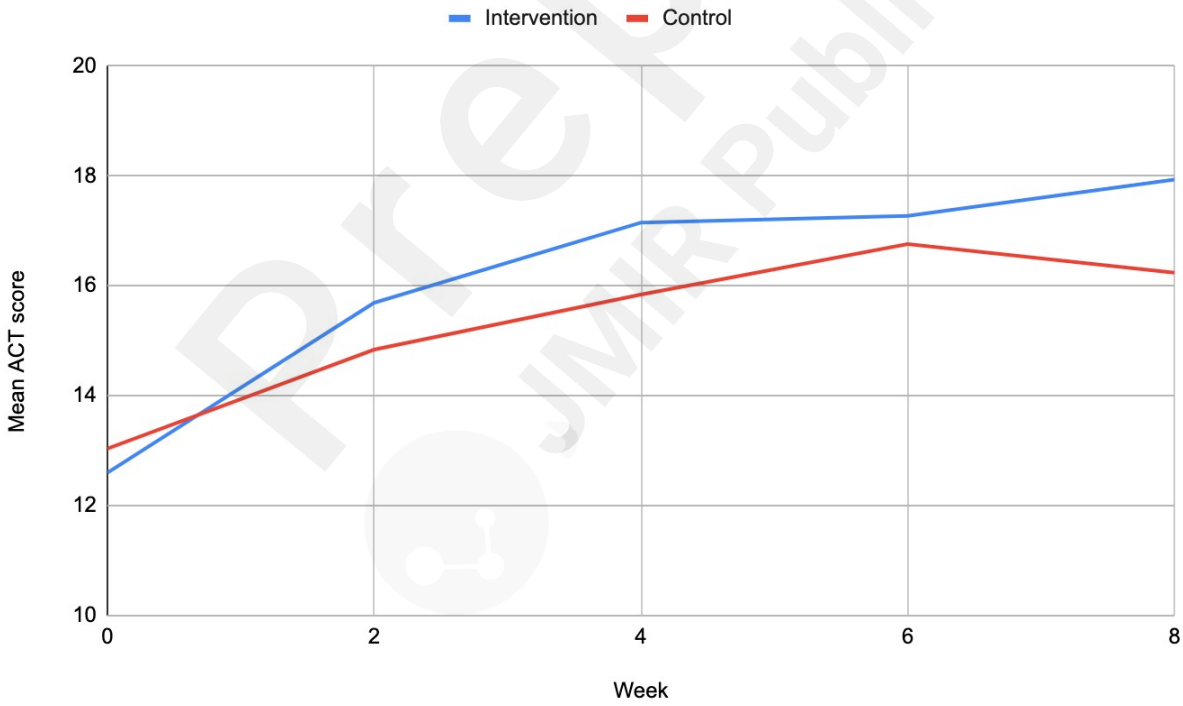
Table 2. Outcomes

	Effect estimate	**p-value**
Per protocol (N=152)		
ACT at 8 weeks[1]	1.91 (0.31 to 3.51)	0.020
Remission at 8 weeks[2]	1.47 (0.75 to 2.90)	0.264
ACT repeated measures (2, 4, 6, 8 weeks)[1]	1.34 (0.15 to 2.53)	0.028
Remission repeated measures (2, 4, 6, 8 weeks)[2]	1.67 (0.62 to 4.52)	0.311
SF-12 physical component score at 8 weeks[1]	0.81 (-1.49 to 3.10)	0.488
SF-12 mental component score at 8 weeks[1]	0.84 (-1.97 to 3.65)	0.557
SF-12 physical component score repeated measures (4, 8 weeks)[1]	0.611 (-1.32 to 2.54)	0.534
SF-12 mental component score repeated measures (4, 8 weeks)[1]	0.91 (-1.21 to 3.03)	0.399
MCID at 8 weeks[2]	2.38 (1.20 to 4.70)	0.013
Worse at 8 weeks[2]	0.55 (0.23 to 1.32)	0.182
Intention to treat, multiple imputation for missing outcomes (N=262)		
ACT at 8 weeks[1]	1.56 (0.32 to 2.79)	0.013
Remission at 8 weeks[2]	1.45 (0.80 to 2.63)	0.215
ACT repeated measures (2, 4, 6, 8 weeks)[1]	1.23 (0.33 to 2.12)	0.007
Remission repeated measures (2, 4, 6, 8 weeks)[2]	1.40 (0.85 to 2.32)	0.187
SF-12 physical component score at 8 weeks[1]	0.58 (-1.45 to 2.60)	0.578
SF-12 mental component score at 8 weeks[1]	0.73 (-1.75 to 3.22)	0.564
SF-12 physical component score repeated measures (4, 8 weeks)[1]	0.75 (-1.15 to 2.64)	0.440
SF-12 mental component score repeated measures (4, 8 weeks)[1]	0.23 (-1.93 to 2.40)	0.833
MCID at 8 weeks[2]	2.17 (1.25 to 3.78)	0.006
Worse at 8 weeks[2]	0.76 (0.39 to 1.56)	0.451
Intention to treat, last		

observation carried forward for missing outcomes (N=262)		
ACT at 8 weeks[1]	1.17 (0.02 to 2.31)	0.046
Remission at 8 weeks[2]	0.92 (0.53 to 1.57)	0.753
ACT repeated measures (2, 4, 6, 8 weeks)[1]	1.03 (0.12 to 1.93)	0.027
Remission repeated measures (2, 4, 6, 8 weeks)[2]	0.88 (0.41 to 1.93)	0.762
SF-12 physical component score at 8 weeks[1]	0.17 (-1.67 to 2.02)	0.853
SF-12 mental component score at 8 weeks[1]	0.61 (-1.63 to 2.85)	0.592
SF-12 physical component score repeated measures (4, 8 weeks)[1]	-0.13 (-2.21 to 1.95)	0.904
SF-12 mental component score repeated measures (4, 8 weeks)[1]	0.76 (-1.69 to 3.21)	0.543
MCID at 8 weeks[2]	1.95 (1.17 to 3.24)	0.010
Worse at 8 weeks[2]	0.65 (0.35 to 1.21)	0.172

[1]β-coefficient, [2]odds ratio

Figure 2. Mean change in ACT score over 8 weeks



The chance of being in remission by week eight did not differ between the intervention and control groups group after accounting for baseline asthma. However, participants in the intervention group were more likely to experience a MCID (adjusted OR = 2.38, 95%CI = 1.20 to 4.70, p=0.013) than those in the control group. This effect was consistent across the two, four, six, and eight-week assessments (Table 2). The odds of worsening symptoms were similar in the both arms (adjusted OR = 0.55, 95%CI = 0.23 to 1.32, p=0.182). There were no between group differences in SF-12 mental or physical component scores .

Intention-to-treat analysis

The baseline characteristics of participants in the intervention and control groups were similar to the per-protocol analysis. Following multiple imputation of missing outcomes, there was a greater improvement in ACT scores in the intervention group than in the active control group (adjusted β-coefficient = 1.56, 95%CI = 0.32 to 2.79, p=0.013) (Table 2). MCID was more common in the intervention group than the control group (adjusted OR = 2.17, 95%CI = 1.25 to 3.78, p=0.006). Both arms had similar odds of remission, worsening of symptoms, and SF-12 scores. Results from the last observation carried forward data set were consistent with the per-protocol and multiply imputed results.

Discussion

Principal results

Our primary analysis showed that juli users had a greater improvement in asthma symptoms at eight weeks compared to an attention-placebo control. The mean improvement in the intervention group was 5.33 compared with 3.20 in the control group. This total improvement and the difference between arms is consistent with a clinically important effect of juli on asthma control [30]. Participants assigned to juli had more than twice the odds of a 3-point (MCID) or greater improvement on the ACT. However, the mean ACT score at 8 weeks in both arms fell below the established cut point for “well controlled” asthma, and there was no difference between arms in terms of odds of remission. The results from our multilevel models covering outcomes from two to eight weeks and the modified intention-to-treat analysis with all individuals who were randomized and used the app for at least two weeks were consistent with these primary findings.

Participants entering our trial had a mean baseline ACT score of approximately 13, indicating they fulfilled the Global Initiative for Asthma (GINA) definition of very poorly controlled asthma [20], and most reported having asthma for several years with routine physician contact, suggesting difficulties with long-term asthma control. The results of this trial indicate that juli can augment the treatment of uncontrolled asthma as indicated by improved ACT scores over eight weeks. There is consistent evidence that low ACT scores are associated with rescue medication use, asthma exacerbations, reduced lung function, reduced asthma-specific quality of life, sleep, work and productivity [6]. Increases in ACT scores are associated with decreased healthcare utilization and healthcare costs [6].

It is unclear which component of juli resulted in improved ACT scores, but participants likely chose elements that suited them, which is a strength of juli’s design; allowing for a degree of self-personalization. Previous research into asthma app functionality has highlighted symptom tracking, clinical questionnaires, goal setting, performance feedback, medication reminders and tracking as valuable to patients [17]. Gamification and contingent rewards are also important features incorporated into juli [17]. Positive affect journaling is a novel, evidence-based addition to juli’s functionality [36]. Other commercially available apps for adult asthma self-management employ similar behavioral change techniques, health education, symptom recording, environmental data, medication reminders and data presentation. A recent review identified over 500 asthma-related mobile and inhaler-based monitoring apps [37]. However, only a small number of these had any degree of scientific evaluation; with positive fully-powered trials being rare [37]. An additional problem for patients is the high rate of failure of companies providing these apps, with only a small number with evidence being available currently. These include AsthmaMD [14], Kiss myAsthma [38], ASTHMAXcel [39] and eAMS [40], which each having positive pilot data.

The juli app is available in Android and Apple formats globally. It is a highly accessible platform for people with asthma, and our trial provides methodologically robust evidence of its efficacy in managing asthma. Additional research is required to understand the most cost-effective support procedures to improve adherence to digital self-management tools and how best to integrate them into clinical practice. The majority of the early attrition in our RCT was in participants who never began to use the app. To reduce this,

future RCTs of digital interventions may benefit from a run-in period, in which participants become familiarized with the app before randomization [41].

Strengths and limitations

There were several strengths and limitations to this RCT. We successfully and remotely recruited, screened, randomized, treated, and assessed participants worldwide. People could easily participate in the trial as our modified version of the juli app allowed consent, randomization, and assessments to occur within the platform. This facilitated a low-cost global recruitment strategy and a pragmatic trial design with good external validity. However, our focus on reducing participant burden limited the types and richness of data we were able to collect at baseline. For example, we lack relevant information on income, education, and other social determinants of health. Despite this, we did achieve post-randomization balance in recorded characteristics at baseline, indicating successful randomization. Most of the participants were female, reflecting established differences in sex-specific rates of asthma [42], health behaviors and healthcare utilization in adults [43].

Participants completed the ACT, which is a recommended primary endpoint in clinical trials for asthma [6]. We also pre-registered our primary and secondary outcome measures along with a full analysis plan, which we adhered to. However, we lacked a broader battery of outcome measures that could have further contextualized our findings and identified possible mechanisms of action.

Attrition was greater than we predicted. The attrition in our trial follows a similar pattern to other digital RCTs, including for asthma apps, where it mostly occurs between randomization and week two. Dropout rates in previous RCTs have ranged from 20 to 60% [10]. However, studies recruiting via social media have had low retention at 30 days (<20%) [44], and a similar, all remote RCT of mobile health support for asthma had attrition of 62% at 9-weeks [45]. To manage attrition we continued recruiting and randomizing participants until we had a sufficient number of participants completing the week eight outcome measures to meet our sample size calculation. We examined differences in completers versus non-completers (see Table 1 and Supplement Table 1). There were unlikely to be differences between those who dropped out of the study and those who completed it, based on their baseline characteristics, including asthma severity. Our modified intention-to-treat and primary analysis findings were similar, suggesting the intervention would have had a similar effect in those who dropped out. The intention-to-treat analysis employed two imputation methods that make different assumptions [34], and results were consistent using both methods. Despite this it is impossible to rule out attrition bias and our results should be seen as reflecting the effect in people motivated and able to use juli.

Conclusion

The juli app has been demonstrated to decrease asthma symptoms within an eight-week period, with an increased chance of achieving MCID. As such, juli represents a low-risk and low-cost adjunct to the care regimen of individuals with asthma.

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The current study was funded by juli Health.

Data Availability
All data produced in the present study are available upon reasonable request to the authors.

Conflicts of Interest
AK, BD, BH, JS and JFH are shareholders in juli Health. AK has received consultancy fees from juli Health and Wellcome Trust. BD, BH, JS and JFH are a co-founders of juli Health. JFH has received consultancy fees from juli Health and Wellcome Trust. KE has no conflicts of interest. The funders played no part in the analysis of the data.

Author Contributions
JFH conceived the study; JFH, AK, BD, BH and JS designed the study; AK, BD and BH collected the data; KE analysed the data; JFH wrote the initial draft; all authors edited and approved the final manuscript.

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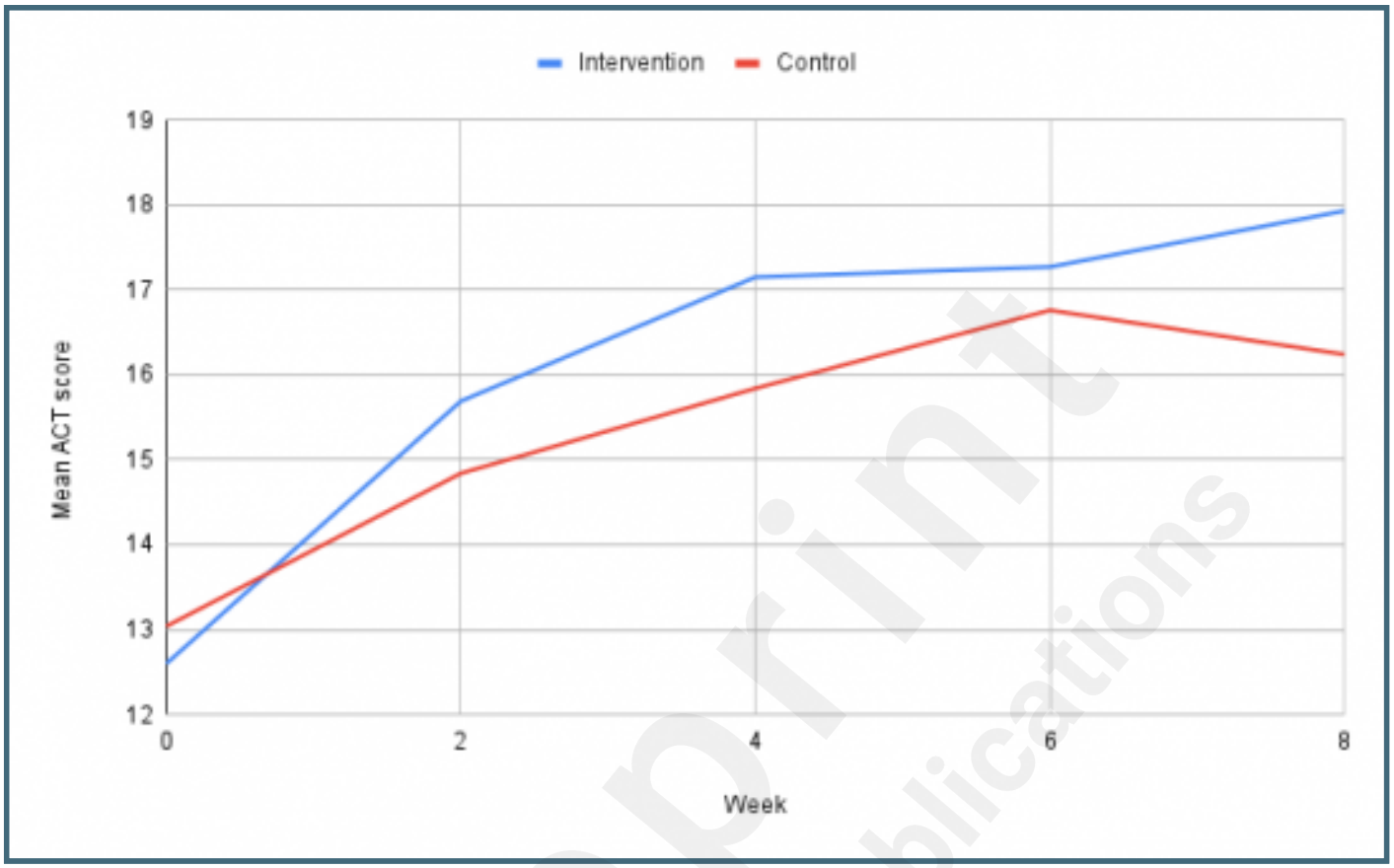
Supplementary Files

Untitled.



Multimedia Appendixes

Supplemental Table 1.
URL: http://asset.jmir.pub/assets/2a32a134a329e321bd70282f26f7f3f3.docx

CONSORT (or other) checklists

URL: http://asset.jmir.pub/assets/7fbbc152d34b358872435e1e208a08de.pdf