Web-based physical activity promotion in young people with CF: a randomised controlled trial

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ABSTRACT

Background Physical activity levels are known to decline following hospitalisation for people with cystic fibrosis (pwCF). However, optimal physical activity promotion strategies are unclear. This study investigated the effect of a web-based application (ActivOnline) in promoting physical activity in young pwCF.

Methods Multicentre randomised controlled trial with assessor blinding and qualitative evaluation. People with CF (12–35 years) admitted to hospital for a respiratory cause were eligible and randomised to the 12-week ActivOnline intervention (AO) or usual care (UC). The primary outcome was change in device-based time spent in moderate-to-vigorous physical activity (MVPA) from baseline to post-intervention. Follow-up was at 6 months from hospital discharge when qualitative evaluation was undertaken.

Results 107 participants were randomised to AO (n=52) or UC (n=55). Sixty-three participants (59%) contributed to the intention-to-treat analysis. Mean (SD) age was 21 (6) years (n=46, <18 years). At baseline, physical activity levels were high in both groups (AO 102 (52) vs UC 127 (73) min/day). There was no statistically significant difference in MVPA between groups at either timepoint (post-intervention mean difference (95% CI) −14 mins (−45 to 16)). Uptake of the intervention was low with only 40% (n=21) of participants accessing the web application.

Conclusion A web-based application, including individualised goal setting, real-time feedback and motivation for behavioural change, was no better than usual care at promoting physical activity in young pwCF.

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WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Greater physical activity participation is associated with improved health outcomes for people with cystic fibrosis (CF); however, many people with CF do not meet physical activity guideline recommendations, and physical activity promotion is known to decline after respiratory exacerbation.

WHAT THIS STUDY ADDS

⇒ A web-based application, including individualised goal setting, real-time feedback and motivation for behaviour change, was no better than usual care at promoting physical activity in young people with CF following hospital discharge.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ This is the first randomised controlled trial to describe a technology-based strategy to promote physical activity in young people with CF; the negative findings described highlight important therapeutic considerations for clinicians in light of increasing use of remotely delivered interventions in response to restrictions associated with COVID-19.

INTRODUCTION

Physical activity and exercise participation confers benefits for people with cystic fibrosis (CF), including improved cardiovascular and bone health, enhanced blood glucose control, clearance of pulmonary secretions and relief of breathlessness.1 International treatment guidelines for CF recommend regular physical activity and exercise participation2 as higher levels of activity and aerobic fitness have been related to reduced hospitalisation,3 slower rate of lung function decline,4 5 and increased life expectancy.6 Despite the favourable health outcomes for people with CF associated with physical activity participation, adherence to activity recommendations is often poor with commonly cited barriers including a lack of interest, energy or time.7 In CF, higher physical activity levels have been associated with reduced need for hospitalisation8...
and decreased systemic inflammation post-exacerbation. However, in the period immediately following hospitalisation, physical activity levels have been shown to decline by over 50%. Despite clear associations between low physical activity levels and adverse clinical outcomes, few interventions promoting physical activity have been tested in randomised controlled trials (RCTs), and none have targeted the period following hospitalisation for a respiratory exacerbation. Small cohort studies of relatively short duration provide limited evidence that interventions to promote exercise and/or physical activity using technology are feasible and acceptable to both children and adults, with CF. In an 8-week pilot study in 10 young adults with CF, a technology-based intervention to promote physical activity participation, that incorporated behaviour change strategies, was feasible and acceptable to participants, with the majority (70%) identifying the ideal time to use such a programme as during or immediately after hospital admission for a respiratory exacerbation. As a result of the intervention, there was some improvement in daily activity (step count) (mean difference 2050 steps (95% CI –1230 to 5330)) but this was not statistically significant and limited by the small sample size. Whether a technology-based intervention to promote physical activity can improve activity levels in people with CF following a respiratory exacerbation is unclear.

The aim of this study was to investigate the effect of a web-based application (ActivOnline) in promoting physical activity in young people with CF. We also sought to evaluate the effect of such a technology-based intervention, undertaken in the period immediately following hospitalisation, on key clinical outcomes, including: health-related quality of life (HRQoL), psychological well-being, lung function, sleep quality, exercise capacity and healthcare utilisation. Additionally, we wished to understand participant attitudes toward physical activity and their experience of the intervention.

METHODS
Study design and participants
This multisite RCT, with assessor blinding and embedded qualitative evaluation, was undertaken at eight CF centres in Australia (see online supplemental material). The Alfred Health Human Research Ethics Committee approved the study for all sites, with governance approvals obtained from participating sites. The trial was registered prospectively and the trial protocol published. Participants were recruited during a hospital admission for a respiratory cause. Full details of eligibility requirements, and inclusion and exclusion criteria have been published previously and are described in the online supplemental material. Initially, only adolescents with CF (12–24 years) were included in the trial; however, due to slower than anticipated recruitment over the first 12 months and following approval of a protocol amendment in October 2018, recruitment was opened to individuals up to age 35 years. Therefore, the study findings will also be applicable to young adults, with both adolescence and young adulthood corresponding to key life stages where changes in physical activity behaviour are known to occur. All participants and/or their carer provided written informed consent.

Randomisation and masking
Participants were randomised 1:1, to the usual care control group or to the technology-based intervention ‘ActivOnline’, using a computer-generated block scheme with stratification for recruitment site and school enrolment status (full-time primary or secondary school enrolment vs not in full-time schooling). The randomisation sequence was generated by an individual independent of the study. Participants were advised of their group allocation by a researcher independent of their clinical care team. All outcome assessments were completed by an assessor blind to group allocation.

Study procedures
Participants were recruited during their inpatient stay and completed baseline questionnaires and collection of demographic information prior to hospital discharge. Baseline physical activity monitoring was undertaken during the first week following hospital discharge, prior to randomisation. Follow-up assessments were completed post the 12-week intervention period, and at 6 months from hospital discharge. Postintervention and 6-month follow-up assessments were completed in-person at the site of recruitment in conjunction with a scheduled clinic appointment, or remotely via post where assessment did not coincide with a clinic visit, to ease participant burden. All participants received usual care and were provided with information, via a web link, on age-appropriate recommendations for being physically active. In addition, participants randomised to the intervention (ActivOnline) group were provided with individualised access (username and password) to a secure web platform (www.activonline.com.au). Details of the previously piloted intervention have been published elsewhere, with additional details available in the online supplemental material. In brief, the web platform was used to record and monitor physical activity, and set goals, for the 12-week intervention period. Data entered were updated in real time and feedback presented in graphical display (online supplemental figure S1). ActivOnline could be accessed from any internet-enabled device. Participants were free to choose the frequency with which they logged their activity, but received an email reminder notification after 3 days of no-activity.

Outcomes
The primary outcome, as recommended for the assessment of physical activity in people with CF, was change in device-based average daily moderate-to-vigorous physical activity (MVPA) from baseline to the end of the 12-week intervention period (ActiGraph Link; ActiGraphcorp LLC, Pensacola, Florida, USA). Secondary outcomes (see online supplemental material 1) included measures of physical activity (self-reported), self-determination for exercise, HRQoL, psychological well-being, exercise capacity (modified shuttle test) and lung function. All participants were offered the opportunity to participate in a semistructured qualitative interview to examine attitudes to physical activity and experiences of the intervention (see online supplemental material 1 and table S1). Interviews were undertaken by the blinded assessor following the 6-month follow-up assessment, either in-person or over the telephone. Healthcare utilisation (hospital admissions and hospital days) were assessed from the medical record at 12 months following completion of the intervention period.

Analysis
Sample size calculations indicated that 56 participants (28 in each group) were required. This was based on a between-group difference of 20 min/day MVPA, with an SD of 26, to achieve 80% power, with alpha set at 0.05. While it was planned to randomise 75 participants, allowing for 25% dropout, recruitment was extended beyond this initial target due to poorer than anticipated rate of return of activity monitoring devices used for...
assessment of the primary outcome measure over the first 18 months of the trial.13

Statistical analyses were conducted using IBM SPSS statistics (V.26.0; IBM, Armonk, New York, USA). All data were analysed by intention-to-treat (ITT). A post hoc per-protocol analysis was also undertaken to assess whether there were effects in those who received the intervention. Differences between groups for change over time were analysed with linear mixed models, accounting for recruitment site. Models included treatment group, time, group×time interaction and a random effect for participants. The baseline value of the outcome variable was included as a covariate. A per-protocol analysis of participants who did versus did not achieve age-recommended daily physical activity levels was intended, but there were insufficient numbers of participants who did not achieve these targets.

Qualitative interviews were audio-recorded and transcribed verbatim. Two authors (NSC, JYTL) undertook independent line-by-line iterative thematic analysis of de-identified interview transcripts.18 Data analysis was in accordance with the six steps for ensuring trustworthiness of qualitative data identified by Nowell and colleagues19: data familiarisation, initial code generation, searching for themes, reviewing themes, defining themes and describing findings. Initial stages of data analysis, including development of codes and themes, were undertaken independently. Development of overarching themes was determined by discussion, with consideration of predominant themes and subthemes, until a consensus was achieved. A third author (AEH) was available for arbitration if necessary.20 See also online supplemental material 1.

RESULTS
Between September 2017 and February 2020, 109 participants, from 549 potentially eligible hospital admissions, were recruited (20%). In total, 107 participants were randomised (figure 1). Two participants changed their mind about study participation between consenting and undertaking the baseline assessment. At the conclusion of the trial, data were available for 63 participants (59%) for the primary outcome (intervention: n=29 (56%); control: n=34 (62%)). There were no intervention-related adverse events reported by any participants. There was one instance of server failure, resulting in participants being unable to access the web portal, which was resolved inside 24 hours.
Table 1  Participant characteristics at baseline

| Characteristic                  | ActivOnline intervention, n=52 | Usual care control, n=55 |
|--------------------------------|-------------------------------|-------------------------|
| Age, years                     | 21 (7)                        | 20 (6)                  |
| Age <18 years, n (%)           | 22 (42)                       | 24 (44)                 |
| Male/female, n                 | 24/28                         | 23/32                   |
| FEV₁, L                        | 2.2 (1.0)                     | 2.5 (0.9)               |
| FEV₁ %predicted                | 63 (24)                       | 72 (20)                 |
| FVC, L                         | 3.3 (1.3)                     | 3.5 (1.1)               |
| FVC %predicted                 | 78.4 (20.4)                   | 86.7 (17.1)             |
| Height, cm                     | 166 (13)                      | 164 (10)                |
| Weight, kg                     | 57 (15)                       | 56 (12)                 |
| BMI, kg/m²                     | 21 (3)                        | 21 (3)                  |
| Cystic fibrosis-related diabetes |                               |                         |
| Other                          | 2 (4)                         | 3 (5)                   |
| Unknown                        | 0                             | 1 (2)                   |
| Modulator therapy, n (%)       | 22 (42)                       | 12 (22)                 |
| Full-time school attender, n (%)| 18 (35)                      | 26 (47)                 |
| MVPA, min/day                  | 102 (52)                      | 127 (73)                |
| HADS                          |                               |                         |
| Anxiety                        | 6 (4)                         | 7 (3)                   |
| Case†, n (%)                   | 19 (37)                       | 22 (40)                 |
| Depression                     | 4 (3)                         | 4 (4)                   |
| Case‡, n (%)                   | 3 (6)                         | 6 (12)                  |
| CES-D                          | 17 (11)                       | 16 (11)                 |
| CES-D anxiety                  | 6 (4)                         | 7 (4)                   |
| No case, n (%)                 | 32                             | 21                      |
| Case†, n (%)                   | 18                             | 29                      |
| BREQ-2                         |                               |                         |
| Amotivation                    | 0.5 (0.8)                     | 0.4 (0.7)               |
| External regulation            | 1.0 (1.0)                     | 0.8 (0.8)               |
| Introjected regulation         | 1.1 (1.1)                     | 1.3 (1.2)               |
| Identified regulation          | 2.4 (1.0)                     | 2.7 (1.0)               |
| Intrinsic regulation           | 2.3 (1.3)                     | 2.2 (1.2)               |

Data are mean (SD) unless indicated.
*HADS case definition score ≥11.
†CSES-R case definition score ≥3.8.
‡PSQI case definition score ≥5.
BMI, body mass index; BREQ-2, Behavioural Regulations in Exercise Questionnaire; CES-D, Centre for Epidemiological Studies Depression Scale; CFQ-R, Cystic Fibrosis Questionnaire—Revised; CFD, cystic fibrosis-related diabetes; HADS, Hospital Anxiety and Depression Scale; HAES, Habitual Activity Estimation Scale; MVPA, moderate-to-vigorous physical activity; %predicted, percentage of predicted normal; PSQI, Pittsburgh Sleep Quality Index.

Participant characteristics are presented in table 1. The mean (SD) age of participants was 21 (6) years with 46 participants (43%) aged younger than 18 years. At baseline, per cent predicted FEV₁ was higher in the control group (control group: 72 (20) %predicted; intervention group: 63 (24) %predicted). Thirty-four participants (32%) were prescribed modulator therapy, and 55 (51%) were homozygous for ∆F508.

Use of the online intervention (ActivOnline) was variable. Of the 52 participants allocated to the intervention group, only 21 (40%) logged on to the web application (online supplemental tables S5 and S6). Participants logged a total of 633 entries to the ActivOnline platform (range 1–179 entries per participant); however, individualised goal setting was rarely completed.

The ITT analysis found no significant difference between groups for time spent in MVPA from baseline to either post-intervention or at the 6-month follow-up (table 2). There were no within-group differences in MVPA from baseline to either timepoint (figure 2). Similar findings were seen in the per-protocol analysis (online supplemental table S7).

Post-intervention there were no between-group differences for HRQoL (CFQ-R), psychological well-being (CES-D, HADS), self-reported physical activity (HAES), sleep quality (PSQI) or lung function (table 2). Postintervention, better external motivation for exercise favoured the intervention group (mean difference (MD) 0.6 points, 95% CI 0.1 to 1.1); however, intrinsic motivation for exercise was poorer in the intervention group (MD −0.8 points (95% CI −1.2 to −0.3; table 3). At the 6-month follow-up, change scores on the role function domain of the CFQ-R (MD −22.6 points (95% CI −34.1 to −11.1)) and self-reported weekday active hours (MD −1.9 hours (95% CI −3.2 to −0.5)) favoured the control group. For all other outcomes there were no differences between the intervention group and control group at 6-month follow-up. There were similar findings in the per-protocol analysis with the exception that participants in the control group self-reported more weekday active hours (MD −1.6 hours (95% CI −3.2 to −0.1)) at 6-month follow-up.

In post hoc analyses there was no difference in time spent in MVPA according to age (online supplemental table S4) or use of modulator therapy (online supplemental table S9).

Fewer than half of all participants (47%) completed assessment of exercise capacity (modified shuttle test—25 levels) at baseline, with only 25% completing this outcome post-intervention. Failure to assess exercise capacity was primarily due to participants declining to undertake the test and/or completing their evaluation remotely. As such, a between-group comparison for exercise capacity was unable to be meaningfully analysed (online supplemental table S3).

Qualitative interviews

Forty-four participants (control n=24; intervention n=20) completed a qualitative interview (online supplemental table S10). Mean (SD) interview duration was 14.6 (4.4) min (range 7.5–24.5 min). Five overarching, but interlinked, themes were identified in relation to physical activity, exercise and, for those allocated to the intervention group, the use of the intervention (table 3 and online supplemental table S11).

Healthcare utilisation

During 12 months of follow-up, 19 participants in the intervention group and 25 in the control group had at least one all-cause hospital admission (relative risk 0.8 (95% CI 0.51 to 1.27) (n=18 and n=24 at least one respiratory admission, respectively). There was no statistically significant difference between groups for median (IQR) number of all-cause hospitalisations per participant (intervention 1 (0–3) vs control 1 (0–2), Z=−0.04, p=1.0) or respiratory hospitalisations (1 (0–3) vs 1 (0–2), Z=−0.5, p=0.6), nor for time to first admission (all-cause or respiratory) (online supplemental figures S2 and S3).
hospital days (all cause: 29 (13–64) vs 18 (14 to 45); respiratory related: 29 (12 to 62) vs 15 (13–43), p=0.3).

**DISCUSSION**

The web-based application, ActivOnline, comprising individualised goal setting, feedback and motivation for behaviour change, was no better than usual care at promoting physical activity in younger people with CF following hospital discharge. For the primary outcome of change from baseline in device-based MVPA, there was no difference between groups either post the 12-week intervention or at 6-month follow-up. Although participants were open to using technology to support being active, including activity tracking, engagement with the online intervention was low. There were no intervention-related adverse events.

### Table 2

**Clinical outcomes—intention-to-treat analysis**

|                          | Within-group differences from baseline (95% CI) | Between-group differences (95% CI) |
|--------------------------|-----------------------------------------------|-----------------------------------|
|                          | ActivOnline, n=29                              | Usual care control, n=34          | ActivOnline–Control (95% CI) |
|                          | Post-intervention 6 months                     | Post-intervention 6 months        | Post-intervention 6 months |
| **Primary outcome**      |                                               |                                   |                            |
| MVPA, min/day            | 1 (−25 to 23)                                 | −12 (−34 to 9)                   | −33 (−71 to 6)             | −14 (−45 to 16)            | −4 (−37 to 29)          |
| **Secondary outcomes**   |                                               |                                   |                            |
| FEV₁, L                  | 0.1 (−0.1 to 0.2)                             | 0.1 (−0.03 to 0.2)               | −0.1 (−0.3 to 0.1)         | 0.0 (−0.1 to 0.1)          | 0.1 (−0.3 to 0.1)       | 0.1 (−0.1 to 0.3)       |
| FEV₁, %predicted         | 0.5 (−0.4 to 5.0)                             | −0.4 (−4.1 to 3.3)               | −3.9 (−7.8 to 0.5)         | −1.2 (−4.9 to 2.4)         | 0.3 (−3.7 to 6.2)       | −0.3 (−5.2 to 4.6)      |
| FVC, L                   | 0.1 (−0.01 to 0.3)*                           | 0.2 (0.03 to 0.3)*               | −0.2 (−0.3 to 0.04)        | 0.4 (−0.4 to 1.1)          | 0.2 (−0.2 to 0.6)       | −0.1 (−0.5 to 0.3)      |
| FVC, %predicted          | 1.7 (−3.8 to 7.1)                             | 1.2 (−2.9 to 5.2)                | −3.5 (−7.3 to 0.3)         | −3.3 (−9.1 to 2.4)         | 1.2 (−4.3 to 6.7)       | 1.1 (−4.4 to 6.6)       |
| **CFQR**                 |                                               |                                   |                            |
| Physical                 | 15.5 (3.8 to 27.3)*                           | 11.3 (2.1 to 20.5)*              | 17.5 (4.9 to 26.4)*        | 0.9 (−11.4 to 13.2)        | −10.1 (−22.7 to 2.5)    |
| Vitality                 | 7.6 (−3.4 to 18.5)                            | 16.0 (6.1 to 25.8)               | 12.9 (2.6 to 23.2)         | −5.3 (−18.3 to 7.7)        | −8.3 (−21.3 to 4.5)     |
| Treatment                | 4.0 (−2.1 to 10.1)                            | 6.9 (0.1 to 13.7)*               | 11.1 (−15.0 to 27.7)       | −2.3 (−11.3 to 6.7)        | −7.3 (−16.5 to 1.9)     |
| Respiratory              | 4.4 (−3.1 to 12.0)                            | 7.5 (0.2 to 14.9)*               | 10.2 (−1.3 to 21.7)        | −2.6 (−13.3 to 8.1)        | −4.8 (−15.8 to 6.3)     |
| **HAES**                 |                                               |                                   |                            |
| Weekday somewhat active, hours | −0.0 (−0.8 to 0.8)                      | 0.4 (−0.8 to 1.6)                | 0.3 (−1.0 to 1.6)          | −0.2 (−1.5 to 1.1)         | −0.2 (−1.6 to 1.2)      | 0.8 (−0.6 to 2.1)       |
| Weekday active, hours    | 0.5 (−0.6 to 1.6)                             | 1.1 (0.0 to 2.2)*                | 1.6 (0.6 to 2.7)*          | −0.7 (−2.0 to 0.6)         | −1.9 (−3.2 to −0.5)*    |
| Weekday total activity, hours | 0.5 (−0.5 to 1.5)                           | 1.5 (0.2 to 3.1)                 | 1.4 (0.1 to 2.8)*          | −0.8 (−2.6 to 0.9)         | −1.3 (−3.1 to 0.5)      |
| Weekend somewhat active, hours | −0.6 (−2.1 to 0.9)                          | −1.2 (−2.5 to 0.1)               | −0.2 (−1.2 to 0.8)         | 0.3 (−1.3 to 1.9)          | 0.3 (−1.3 to 1.8)       |
| Weekend active, hours    | 0.3 (−0.6 to 1.2)                             | 1.3 (0.3 to 2.8)                 | 0.8 (−0.1 to 1.7)          | −0.6 (−2.0 to 0.9)         | −0.6 (−2.0 to 0.8)      |
| Weekend total activity, hours | −0.3 (−2.0 to 1.4)                          | 0.2 (−1.7 to 2.1)                | 0.5 (−0.8 to 1.9)          | −0.2 (−2.3 to 2.0)         | −0.3 (−2.4 to 1.8)      |
| **BREQ-2**               |                                               |                                   |                            |
| Amotivation              | 0.1 (−0.3 to 0.5)                             | 0.04 (−0.4 to 0.5)               | 0.02 (−0.2 to 0.2)         | −0.1 (−0.2 to 0.1)         | 0.2 (−0.2 to 0.6)       | 0.2 (−0.2 to 0.6)       |
| External                 | 0.5 (0.04 to 0.9)*                            | 0.1 (−0.3 to 0.5)                | −0.1 (−0.4 to 0.2)         | −0.2 (−0.5 to 0.1)         | 0.6 (0.1 to 1.1)*       | 0.5 (−0.01 to 1.0)      |
| Introjected              | 0.2 (−0.1 to 0.5)                             | −0.02 (−0.3 to 0.2)              | −0.01 (−0.3 to 0.3)        | −0.01 (−0.5 to 0.5)        | 0.1 (−0.3 to 0.6)       | −0.05 (−0.5 to 0.4)     |
| Identified               | 0.01 (−0.3 to 0.4)                            | 0.1 (−0.2 to 0.4)                | −0.1 (−0.4 to 0.2)         | −0.3 (−0.6 to 0.1)         | −0.2 (−0.6 to 0.3)      | −0.03 (−0.5 to 0.4)     |
| Intrinsic                | −0.5 (−1.2 to 0.3)                            | −0.2 (−0.9 to 0.6)               | 0.5 (−0.2 to 1.2)          | 0.4 (−0.3 to 1.1)          | −0.8 (−1.2 to −0.3)*    | −0.2 (−0.7 to 0.2)      |
| CES-D                    | −1.0 (−4.1 to 2.1)                            | −0.3 (−4.5 to 4.1)               | −0.2 (−5.5 to 0.8)         | −3.0 (−8.1 to 2.1)         | 1.2 (−3.8 to 6.3)       | 3.1 (−2.1 to 8.3)       |
| HADS-A                   | 0.4 (−0.8 to 1.6)                             | 0.0 (−1.9 to 1.9)                | −0.6 (−2.1 to 0.9)         | −0.7 (−2.4 to 0.9)         | 0.8 (−1.4 to 3.0)       | 0.7 (−1.5 to 2.9)       |
| HADS-D                   | −0.6 (−1.7 to 0.5)                            | −0.9 (−2.2 to 0.4)               | −0.4 (−1.8 to 1.1)         | −0.3 (−2.2 to 1.5)         | 0.2 (−1.6 to 2.1)       | 0.2 (−1.7 to 2.1)       |
| PSQI                      | −0.9 (−2.0 to 0.3)                            | −0.3 (−1.3 to 0.6)               | −0.4 (−1.8 to 0.9)         | −1.0 (−2.2 to 0.2)         | −0.1 (−1.8 to 1.6)      | 0.9 (−0.9 to 2.7)       |

Data are mean difference and 95% CIs adjusted for baseline values.

*p<0.05

BREQ-2, Exercise Regulation Questionnaire; CES-D, Centre for Epidemiological Studies–Depression scale; CFQR, Cystic Fibrosis Questionnaire–Revised version; HADS-A, Hospital Anxiety and Depression Scale–Anxiety; HADS-D, Hospital Anxiety and Depression Scale–Depression; HAES, Habitual Activity Estimation Scale; MVPA, moderate-to-vigorous physical activity; PSQI, Pittsburgh Sleep Quality Index.
The rapid growth of the digital health sector has created the opportunity to reduce therapeutic burden and promote treatment adherence in people with CF. Upwards of 80% of young adults access the internet regularly, and the use of digital technology to support symptom monitoring and CF care delivery is acceptable to patients. However, non-compliance with data-entry procedures for technology-based interventions has been reported to exceed 50%. Limited engagement with the online intervention, and study procedures, was noted in the present study, with 60% of participants allocated to the intervention failing to access the web-based platform and 40% of participants not completing scheduled study assessments. This is not dissimilar to a large RCT with a multicomponent physical activity intervention where adherence was just over 50%, but is in contrast with two recent small studies in CF that reported intervention adherence of 70%–85%, in children and adults with CF. However, both of these interventions made use of videoconferencing to directly interact with participants and support an exercise training programme. Despite favourable feedback for the ActivOnline web application on earlier pilot testing with a group of young people with CF, it is possible that adherence to the intervention was affected by failure of the web application to keep pace with technological advances. Adoption of consumer fitness tracking technology has increased almost fourfold since 2015 with end-users having greater experience and higher expectations in terms of design, connectivity and interactivity. This was confirmed by qualitative data with some participants indicating a preference for applications that offered rewards, incentives and interactive features. Whether young people with CF would demonstrate greater engagement with a technology-based intervention by using a high specification, consumer device remains to be investigated. Additionally, participants were provided with group allocation and intervention information by a researcher independent of their clinical care. Recent evidence highlights the importance of the CF care team, as perceived by patients and their families, in providing support and assistance to adhere to therapeutic interventions. Whether targeted input from the CF care team regarding use of the web application and/or an add-on intervention such as an in-person motivational interviewing session would enhance adherence warrants investigation.

The physical activity levels found in the present study are high in comparison to other device-based activity assessment in CF. Device-based assessment methods are recommended when assessing physical activity in people with CF and can overcome typical issues of over-reporting seen with self-report measures of physical activity. A wrist-worn accelerometer was chosen to support wear compliance and acceptability, as preferred by young people with CF. However, wrist-worn devices can lead to misclassification of activity intensity such that light intensity activity associated with vigorous wrist movement may be classified as more intense activity. In addition, recent evidence suggests that population specific cutpoints for categorising physical activity intensity may be required to delineate activity levels in clinical populations. That participants in the current study self-reported activity levels nearly four times less than the device-based assessment suggests further investigation of activity classification in this group is warranted.

Beyond data processing variables, the high activity levels in our participants may reflect increased activity in response to monitoring or incidental recruitment of individuals who are more interested in being physically active. Although a non-significant difference in MVPA was detected between groups, given that both groups achieved daily MVPA above guideline recommended levels at all time points it is unlikely that this difference in MVPA performance (14 min) is clinically relevant. Further, a notable theme identified from participant qualitative interviews was the ‘reminder’ and ‘motivation’ to be active inferred from wearing the accelerometer (the ‘watch’). Whether the relatively high levels of physical activity reported in the present study are a function of consenting participants being those who are more active already, reflect awareness of the act of physical activity monitoring as indicated by qualitative data, or relate to the application of non-CF-specific data cut points for analysis is not clear and has implications for the generalisability of our findings. It is possible monitoring activity over a longer period might have diminished any unintended Hawthorne effect, but longer monitoring periods also come with the risk of reduced wear compliance.

Strengths of this study include participants from diverse geographical locations, an intervention underpinned by behaviour change theory and device-based assessment of physical activity. Recruiting from multiple sites around Australia, all of which had similar underlying CF management strategies, enhanced the potential generalisability of our findings. However, recommendations for physical activity in the Australian context may not be the same as found in CF centres in other countries, with possible differences relating to cultural, economic and meteorological factors. A key limitation of this work is the lack of engagement with the intervention by participants in the ActivOnline group, as well as collection of the primary outcome in only 61% of participants at the end of the intervention. While our intervention included key components associated with physical activity promotion strategies, namely capacity for self-monitoring, real-time feedback and goal setting, it may have failed to address factors associated with adherence to

| Table 3 Qualitative themes and descriptors |
|------------------------------------------|
| Theme                     | Descriptor                                                      |
| Using the app              | Participants were not averse to using mobile applications or technology to support their physical activity, but the perceived key components of any such application or technology varied across individuals. While some participants desired a bespoke application, ideally with additional remote-monitoring capabilities, such as distance tracking, others would like forced-choice options for data entry to streamline use. |
| The ‘watch’ as a physical reminder | Participants described the accelerometer (the ‘watch’) as a reminder and motivation to exercise/be active, but they would have preferred a device that was more aesthetically pleasing, and which ideally provided feedback or reminders for activity. |
| Impact of symptoms         | Fatigue, a lack of energy and coughing were regularly reported barriers to physical activity. Conversely, some participants described how being active made them feel good and had a positive impact on their respiratory symptoms, making physical activity something they felt they were more likely to do. |
| Motivation for physical activity and exercise | Getting enjoyment out of physical activity, and having the support or company of friends or family while being active, were important for motivation. |
| Time                      | Competing demands, such as from school, work or family commitments, and a feeling of being time poor meant that activity was often not prioritised. |
internet-based interventions. Theoretical models suggest adherence to internet-based interventions is determined by end-user characteristics, environmental factors and website/application (intervention) factors. While there are presently no consistent features attributed to those who do or do not engage with web-based programmes, sustained engagement is believed to be a product of user perception of the usability, relevance, interactivity, motivational and persuasive features of the intervention. Usability, together with motivation and interactive features of ActiOnline were reported to be positive, or adapted in response to feedback, during pilot testing of the programme. However, the mean age of participants in the current study were younger than those in the pilot, and it is possible that the intervention did not address the needs of this younger group. In addition, the intervention was designed to be ‘light touch’ in an effort to minimise participant burden. This may have had the confounding effect of failing to provide participants with sufficient motivation or persuasion to regularly engage. Recent meta-analyses suggest that greater physical activity behaviour change success is achieved when interventions include more than once-weekly contact.

Although we conducted an ITT analysis with inclusion of all participants regardless of exposure to the intervention, the nature of the primary outcome (device-measured physical activity) meant that we did not have available data on those who did not wear or return the device. This meant that a reduced number of participants could be included in the ITT analysis. We chose not to impute the missing data because the proportion of data unavailable was large (nearly 40%) increasing the risk that confirmative findings may be erroneously generated with multiple imputation. Failure to complete physical activity monitoring at the end of the intervention was predominantly a result of participants failing to wear or return or losing the activity monitoring device. Although this was unexpected, a recent systematic review of adherence to activity monitor device wear in adults with cardiac disease reports average monitoring device adherence of 59% at final follow-up, while in adolescents’ adherence to activity monitoring device wear decreased from 75% at baseline to 56% at follow-up 10 weeks later, despite a gift voucher reward for device return. Future studies employing device-based activity assessment may need to account for higher than anticipated attrition rates.

Future research considerations
Our minimal burden intervention, including individualised goal setting, is in keeping with suggestions from recent publications supporting a ‘low-pressure’ approach to motivating people with CF to be physically active. Despite this, we had low uptake of the intervention and poor compliance with study procedures. Future studies may need to consider intervention designs that more explicitly target physiological, psychological and practical factors associated with achieving long-term behaviour change with respect to physical activity. This might include study designs that allow participants their choice of intervention. Choice-based interventions have been shown improve participant retention, adherence, satisfaction and behaviour change. Of individuals assessed for eligibility, 61% declined to participate. The underlying reasons for declining participation in this trial are unable to be elucidated; however, in other respiratory populations undertaking exercise/activity-related studies, a preference for receiving a specific treatment arm is commonly cited. Further, interventions with greater co-design elements, that have the capacity to replace or substitute for an existing treatment rather than in addition to usual treatments, may more effectively address research priority areas identified by people with CF and their carers and reduce participant burden.

CONCLUSIONS
A web-based application, including individualised goal setting, feedback and motivation for behaviour change, was no better than usual care at promoting physical activity in adolescents and young adults with CF following hospital discharge. Low engagement with the intervention, as well as high baseline physical activity levels—irrespective of group—likely limited any intervention effect and may not make these results generalisable to all adolescents and young adults with CF. For people with CF who need support to increase their physical activity levels, the best way to facilitate this remains to be determined.

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