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Cost-effectiveness of adding a smartphone app (BlueIce) to the mental health care of adolescents who repeatedly self-harm

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ABSTRACT

Digital interventions can offer crises support although their cost-effectiveness is unknown. We undertook an economic evaluation alongside a two-arm, single blind, randomised controlled trial. 170 adolescents aged 12–17, receiving child and adolescent mental health care who had self-harmed ≥2 in the past 12 months were randomised to usual care with or without an app (BlueIce). The Risk-Taking and Self-Harm Inventory for Adolescents (RTSHIA), and Child Health Utility 9-Dimensions (CHU-9D) were completed at baseline, 12-weeks, and 6-months. Mental healthcare use was extracted from clinical records. CHU-9D responses were converted to preference-based utility values to estimate quality-adjusted life-years (QALYs). Generalised linear models examined the effect of BlueIce from the NHS and Personal Social Services perspective on costs and QALYs. The cost of BlueIce was £32.26 with the mean cost of mental healthcare over 6 months ranging between £1750 - £2472 per participant. The 6-month difference in mean costs [-£722.09 (95 % CI:1998.84, 334.65)] and the utility score [0.009 (95 %CI:0.033, 0.052)] both favoured BlueIce. Youth derived QALYs showed an incremental net monetary benefit (NMB) at 6-months of £782.09 with an almost 70 % probability of being cost-effective. Given the low intervention cost, the addition of an app could be considered a good investment.

1. Background

Self-harm has been defined as any form of non-fatal self-poisoning or self-injury (including cutting, taking an overdose, hanging, self-strangulation, jumping from a height and running into traffic) irrespective of motive (NICE 2022). It is common during adolescence with 17 % of adolescents and 13 % of young adults being estimated to self-harm (Swannell et al., 2014; Trafford et al., 2023). Self-harm is a major public health issue and is linked to other mental health problems such as depression, anxiety, and substance misuse and with an increased risk of suicide (Hawton et al., 2012). Although most self-harm occurs in private and does not result in health care service use (Geulayov et al., 2018), the costs associated with hospital use following self-harm are nonetheless high (Tsiachristas et al., 2020). However, little is known about the mental health costs of treating self-harm with the available evidence mainly focusing on adults and general hospital costs (Tsiachristas et al., 2020).

In recent years, the use of digital interventions to improve access and support the delivery of health care interventions have become more widespread (NHS England, 2019). Digital interventions are well accepted and provide a useful means for supporting suicide prevention in adolescents (Forte et al., 2021) although evidence for their effectiveness is limited (Cliffe et al., 2021; Melia et al., 2020). One form of digital intervention, smartphone applications, are popular with adolescents and offer the potential for a low-cost, accessible and scalable means of support which can be accessed 24/7 at times of crisis (Lecomte et al., 2020). In a recent randomised controlled trial, the addition of an app (BlueIce) to the usual mental health care of adolescents who repeatedly self-harm resulted in reductions in self-harm and improvements in mental health (Stallard et al., 2024). However, clinical improvements were observed in both arms and there were no statistically significant differences between the group who received BlueIce and

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those who did not (Stallard et al., 2024).

Whilst many mental health apps designed for self-harm or suicide prevention have not been evaluated (Cliffe et al., 2021; Larsen et al., 2016) their value for money is unknown (Gentili et al., 2022). A recent review identified only three mobile phone-based applications in which cost-effectiveness analysis was also conducted and none focused on self-harm (Gentili et al., 2022).

The objectives of this study are: to estimate the cost of introducing the BlueIce app in usual care; to detail the mental healthcare resource utilisation associated with treating adolescents with significant mental health problems who repeatedly self-harm. Finally, to explore the cost-effectiveness of adding BlueIce to usual mental healthcare for the reduction of self-harm in adolescents by presenting results from a full within-trial incremental cost effectiveness analysis.

2. Methods

2.1. Study design

The Beating Adolescent Self-Harm (BASH) study was a superiority two-arm, single-blind, randomised controlled trial (RCT) comparing the addition of the BlueIce self-help app to usual face-to-face specialist mental healthcare (UC+BI) with usual care (UC). It tested whether adding BlueIce to the usual care provided by specialist child and adolescent mental health services (CAMHS) for young people who repeatedly self-harm reduced self-harm, improved how they felt and resulted in fewer emergency contacts and overall healthcare resource use (Greenhalgh et al., 2021).

2.2. Recruitment

Participants were recruited through specialist CAMHS provided by the Oxford Health NHS Foundation Trust, covering Bath and North-East Somerset, Swindon, Wiltshire, Buckinghamshire, and Oxfordshire. Young people were eligible if they: (1) were receiving treatment from specialist CAMHS at the time of referral; (2) had self-harmed at least twice in the last 12 months; and (3) were aged between 12 and 17 years. Exclusion criteria included: (1) a diagnosis of psychosis; (2) a significant learning disability which would interfere with the young person's ability to use the app; (3) young people with active suicidal plans; or (4) safeguarding concerns where the young person had suffered abuse within the last 6 months or was the subject of a safeguarding investigation.

The BASH trial was registered prospectively on the ISRCTN Registry (ISRCTN10541045). Informed consent was obtained from all adolescents aged 16 or older and from parents for those aged 12–15 years. The study had NHS Research Ethics approval (South Central – Oxford B NHS Research Ethics Committee (19/SC/0212) and was overseen by an independent trial steering committee.

2.3. Randomisation & sample size

Computer-generated randomisation was undertaken by an independent researcher at Exeter Clinical Trials Unit who had no ongoing involvement with the rest of the trial. Participants were randomised in a 1:1 ratio to either UC or UC+BI, minimising for sex assigned at birth, age (<16 vs ≥ 16), self-harm frequency in last 4 weeks (0–2 or ≥ 3 times) and severity of depression (Mood and Feelings Questionnaire <27 vs ≥ 27).

The study was powered to detect a 2-point difference on the self-harm scale of the RTSHIA. 69 participants per group were needed with a SD of 3.6, 90 % power and a 2-sided alpha set at 0.05. To allow for 20 % attrition a total cohort of 170 was required.

By the nature of the intervention participants were not blind to their allocation. Researchers assessing outcomes remained blind throughout the trial.

2.4. Interventions

Usual Care (UC): Young people received mental healthcare from specialist CAMHS clinicians, either face-to-face or, remotely via telephone or Microsoft teams. Care involved a combination of mental health and/or risk assessments; psychological therapy delivered individually or in groups, face to face or digitally, to young people and/or their carers; pharmacological interventions; multi-disciplinary team review and discussion; liaison with other services and professionals.

Usual Care plus BlueIce (UC+BI). BlueIce is a smartphone app for android and apple smartphones codesigned and produced with young people with a lived experience of self-harm. The app is passcode protected, contains a diary to monitor mood, a personalised toolbox of mood lifting strategies available 24/7, and automatic routing to emergency contact numbers in case of a crisis. The mood lifter incorporates ideas from Cognitive Behaviour Therapy (CBT) and Dialectical Behaviour Therapy for Adolescents (DBT-A), promising interventions for the treatment of self-harm (Witt et al., 2021), and is designed to prevent urges to self-harm (Grist et al., 2018).

3. Data collection

3.1. Health related outcomes

Health outcome data were collected at baseline (considering 1–6 months before enrolment), 12-weeks and 6-months post-enrolment. The primary clinical outcome was assessed by self-report on the self-harm scale of the Risk-Taking and Self-Harm Inventory for Adolescents (RTSHIA) (Vrouva et al., 2010). The self-harm scale consists of 18 items and assesses the presence and frequency of a range of intentional self-injuries (e.g., cutting, burning, self-hitting, self-poisoning). In addition, self-report on the Child Health Utility 9 Dimension (CHU-9D) preference-based questionnaire was used to obtain utility scores (Stevens, 2011) for estimating Quality Adjusted Life Years (QALYs). The CHU-9D contains nine dimensions (worried, sad, pain, tired, annoyed, schoolwork/homework, sleep, daily routine and activities), each with five levels of functioning rated for 'today'. RTSHIA and QALY scores were adjusted for gender, age (<16 vs ≥ 16), self-harm frequency in last 4 weeks (0–2 or ≥ 3), and severity of depression (Mood and Feelings Questionnaire <27 vs ≥ 27) at baseline. QALYs were additionally adjusted for a baseline utility.

3.2. Intervention costs and mental health resource use utilisation

The per participant intervention cost included the cost of delivering the BlueIce app alongside healthcare resource use. For mental healthcare resources, these included the use of CAMHS direct and indirect services, Emergency Department attendances, hospital admissions and medication prescriptions. Data for each participant were extracted from clinical records (i.e. CareNotes) by two research assistants (RAs), blind to treatment allocation. Extracted data were jointly reviewed by the RAs and any discrepancies identified, checked and resolved. Individual-level healthcare resource use data were combined with unit costs taken from the Unit Costs of Health and Social Care (Jones et al., 2023) or NHS Reference Costs (NHS England, 2023) to calculate the total cost of mental healthcare for each participant. All costs were inflated to 2022 prices costs using the NHSCII inflation rate and are presented in UK sterling (£). Unit costs are presented in Table 1.

CareNotes data and medication prescriptions were available for time points 4–6 months pre-enrolment, 1–3 months pre-enrolment, 1–3 months post-enrolment, and 4–6 months post-enrolment. For total cost analysis all pre-enrolment CareNotes costs were added for each participant to obtain a baseline value.

Table 1
CareNote unit costs.

Service	Unit cost (£)	Unit	Source	Page	Comment
CAMHS core professionals					
Assistant psychologist	£37.00	Working hour	PSSRU 2022	60	Band 4 (psychology)
Mental health support worker	£37.00	Working hour	PSSRU 2022	60	Band 4 (psychology)
Mental health practitioner	£42.00	Working hour	PSSRU 2022	60	Band 5 (psychology)
Professionals in training	£42.00	Working hour	PSSRU 2022	60	Band 5 (psychology)
Psychological wellbeing	£42.00	Working hour	PSSRU 2022	60	Band 5 (psychology)
Clinical nurse specialist	£53.00	Working hour	PSSRU 2022	97	Band 6 (hospital-based nurses)
Senior mental health practitioner	£55.00	Working hour	PSSRU 2022	60	Band 6 (psychology)
Other (dietician, OT, etc.)	£55.00	Working hour	PSSRU 2022	60	Mostly OT, band 6 community-based scientific and professional staff
Dialectical behaviour therapy lead	£66.00	Working hour	PSSRU 2022	60	Band 7 (psychology)
Clinical psychologist	£75.00	Working hour	PSSRU 2022	60	Band 8a (psychology)
Child psychotherapist	£75.00	Working hour	PSSRU 2022	60	Band 8a (psychology)
Family therapist	£75.00	Working hour	PSSRU 2022	60	Band 8a (psychology)
Child and adolescent psychiatrist	£113.00	Working hour	PSSRU 2022	101	Consultant psychiatric (hospital-based doctors)
Multi-disciplinary team meeting	£279.97	Meeting	NHS ref costs 21/22	MH sheet	Other Mental Health Specialist Teams, Children and Adolescents
CAMHS interaction with other services					
Social care	£47.25	Working hour	PSSRU 2021	123	Social worker unit cost without qualifications (£46). Additional info: social worker (children's services) cost per case is £3809 based on 17.4 average caseload. Inflated to 2022 using NHSCII inflation rate
SEND	£55.92	per person	Hinze (2022) 'Service use and costs in adolescents with pain and suicidality: a cross-sectional study'	Table S4	Average service cost for teaching support.
School	£55.92	per person	Hinze (2022) 'Service use and costs in adolescents with pain and suicidality: a cross-sectional study'	Table S4	Average service cost for teaching support.
GP	£120.00	Hour	PSSRU 2022	70	Per hour of GMS activity, excluding direct care staff costs, without qualification costs
Police	£320.03	Occurrence (police attendance for those who were not arrested or put under a Section 136)	Heslin (2017) 'Costs of the police service and mental healthcare pathways experienced by individuals with enduring mental health needs'	Table DS1	Cost based on the mean number of minutes of total police attendance per incident for those who were not arrested or put under a Section 136 but did have police attend the incident: 275.54 min multiplied by the unit cost per minute for a police officer of £0.97 = £267 in 2013. Costs estimated through direct communication with Devon and Cornwall police - July 2013. Costs inflated from 2013 to 2022 using NHSCII inflation rate
Other (wider services e.g. private therapists, voluntary sector etc.)	£70.15	per person	Hinze (2022) 'Service use and costs in adolescents with pain and suicidality: a cross-sectional study'	Table S4	Average service cost for community health and social care services.
Accident, emergency, and hospital					
Emergency department visit	£386.05	Visit/admission	NHS ref costs 21/22	MH sheet	A&E Mental Health Liaison Services, Children and Adolescents
Ambulance trip to hospital	£390.08	See and treat and convey	NHS ref costs 21/22	AMB sheet	Ambulance see and convey
General hospital night	£1404.59	Night	NHS ref costs 21/22	MH sheet	Children and Adolescent Mental Health Services, Admitted Patients
Inpatient mental health hospital	£2971.82	Night	NHS ref costs 21/22	MH sheet	CAMHS psychiatric ITU

Medication unit costs available from authors on request.

3.3. Cost-effectiveness analysis

Descriptive statistics provide mean, standard deviation, and range of the RTSHIA scores, utility values derived from the CHU-9D, and total costs. Data are presented for each arm and data collection point. Any cost outliers were excluded in the primary analysis. Mean difference and 95 % confidence intervals between arms at 12 weeks from baseline and at 6 months from baseline are presented.

Primary analysis is conducted according to intention-to-treat (ITT) principle. No discount is applied within trial analysis due to the length of the follow-up. Cost-utility analysis is based upon the QALYs estimated from the CHU-9D utilities. Cost per RTSHIA score change are also presented. Costs and QALYs were adjusted using a generalised linear model (GLM) with gamma distribution and log link (Faria et al., 2015). The GLM included covariates: treatment allocation, baseline gender, baseline age (<16 vs ≥16), baseline self-harm frequency in last 4 weeks (0–2 vs ≥3), baseline severity of depression (<27 vs ≥27), baseline utility score. A nonparametric bootstrap method addressed the uncertainty around incremental cost-effectiveness ratio (ICER) point estimates (Briggs et al., 1997). The probabilities of the intervention being cost-effective are estimated using both bootstrap and incremental net benefit approaches (Glick et al., 2014). Primary analysis is based on complete case data. Loss to follow-up at data collection points is presented for both the primary outcome and QALYs. The CHEERS

(Husereau et al., 2022) reporting standards were followed according to current practice in economic evaluation. Analyses are conducted using Stata/SE version 17.

3.4. Sensitivity analysis

Sensitivity analysis first considered the impact of including long-term hospital stay outliers in the total costs recorded by CareNotes. These long-term hospital stays are defined as over 21 days (NHS, online), and considered as outliers in this population due to them being low frequency high cost events. Sensitivity analysis also included analysis of the full area under the curve from baseline to 6 months. Here QALYs are calculated for the full period from baseline to 6 months using the Simpson's rule. Total costs include baseline, 12 weeks, and 6-months health care resource use and medication, plus the additional intervention cost in the intervention arm. These costs are combined yielding total cost across the 6-months post-intervention and including baseline to match the QALY calculation. Additionally, sensitivity analysis estimated between arm difference in costs and QALYs at 6-months using 12 weeks as the baseline time point. Finally, sensitivity analysis reported the unadjusted scores and costs including long-term hospital stay outliers.

4. Results

4.1. Demographics

There were 85 young people recruited to each treatment arm (170 in total). Demographic detail can be seen in *Appendix 1*. Young people included in the BASH study were majority female (91 %; (78/85 BlueIce, 76/85 usual care), majority white British (89 %; 75/85 BlueIce, 76/85 usual care), and 82 % (72/85 BlueIce, 67/85 usual care) reported mood disorder and/or anxiety disorder. This was consistent across both arms at baseline.

4.2. BlueIce intervention costs

The cost of developing the app was not included in this study since the app is free of charge and available in the NHS. The intervention costs considered here include recruitment for the trial and maintenance costs (see *Appendix 2*). The cost of making the app available to study participants through text message exchanges took 5 min per young person conducted by a clinical psychologist (band 8d, £125 per hour) totalling £10.42 per recruitment message. Downloading the app was free for the young person. In addition, the cost of maintaining the app was estimated to be £0.84 per week (£10.08 per 12 weeks and £21.84 for six months). The cost of updating or useful lifespan of app smartphone technology were not considered in this costing.

4.3. Self-harm assessment

Adjusted RTSHIA self-harm scores are presented in Table 2. Higher RTSHIA scores indicate greater self-harm. The RTSHIA score declined over time, providing evidence of improvement (fewer instances of self-harm), this decline was reported in both the BlueIce and usual care arms, at 12-weeks and 6-months. At each time point there is greater self-harm in the usual care arm, than BlueIce, although this difference was not statistically significant at any time point (Stallard et al., 2024).

Table 2
Per person adjusted costs and effects.

	12 weeks*			6 months*		
CareNote cost per person	UC+BI	UC	(UC+BI) – (UC)	UC+BI	UC	(UC+BI) – (UC)
CAMHS core professionals	715.26 (111.73) [496.28, 934.23]	795.90 (120.03) [560.65, 1031.15]	-£80.65 (165.40) [−404.83, 243.54]	1184.34 (181.86) [827.90, 1540.77]	1453.33 (213.65) [1034.58, 1872.08]	-£269.00 (282.51) [−822.70, 284.70]
CAMHS interaction with other services	93.04 (19.98) [53.89, 132.19]	129.33 (28.01) [74.42, 184.24]	-£36.29 (33.50) [−101.95, 29.36]	153.65 (43.82) [−67.76, 239.53]	261.67 (79.02) [106.79, 416.54]	-£108.02 (89.81) [−284.05, 68.01]
Accident, emergency, and hospital (excl. long-term stays)	816.69 (1830.16) [−2770.35, 4403.74]	3517.77 (7281.39) [−10,753.50, 17,789.03]	-£2701.07 (6151.39) [−14,757.57, 9355.43]	560.45 (668.26) [−749.31, 1870.22]	1929.14 (2258.41) [−2497.26, 6355.54]	-£1368.69 (1836.46) [−4968.08, 2230.70]
Medications	39.84 (12.01) [16.31, 63.37]	21.73 (5.48) [11.00, 32.47]	£18.10 (13.13) [−7.64, 43.84]	73.58 (18.81) [36.71, 110.46]	46.43 (10.55) [25.75, 67.10]	£27.16 (21.61) [−15.19, 69.51]
Intervention cost	20.50	0.00	20.50	32.26	0.00	32.26
Total cost	1109.80 (228.02) [662.89, 1556.70]	1359.67 (258.72) [852.60, 1866.75]	**-£249.88** (342.96) [−922.06, 422.31]	1750.63 (329.15) [1105.52, 2395.75]	2472.73 (428.99) [1631.93, 3313.53]	**-£722.09** (539.16) [−1778.84, 334.65]
Health related outcomes						
RTSHIA	14.75 (1.58)	16.37 (1.42)	**−1.62**	13.23 (1.81)	13.42 (1.61)	**−0.19**
CHU-9D utility – youth	0.695 (0.017) [0.662, 0.728]	0.659 (0.015) [0.629, 0.689]	0.036 (0.023) [−0.010, 0.081]	0.696 (0.016) [0.665, 0.727]	0.687 (0.015) [0.658, 0.715]	0.009 (0.022) [−0.033, 0.052]
QALY (CHU-9D) - youth	0.156 (0.002) [0.152, 0.159]	0.151 (0.002) [0.148, 0.155]	**0.004** (0.003) [−0.001, 0.010]	0.337 (0.004) [0.329, 0.345]	0.335 (0.004) [0.327, 0.342]	**0.003** (0.006) [−0.005, 0.017]

Total cost includes: health service professionals and intervention costs (intervention cost 20.50 at 12 weeks, 20.50+11.76 at 6 months).

* Mean (SE) [95 %CI].

† Adjusted A-B reports Average Marginal Effects. Adjusted using GLM with gamma distribution and log link. Covariates: treatment allocation, baseline gender, baseline age (<16 vs ≥16), baseline self-harm frequency in last 6 months (0–2 vs ≥3), baseline severity of depression (<27 vs ≥27), baseline utility score (youth score unless costs given by parents).

4.4. Youth reported health-related quality of life

Complete case analysis for youth reported utility derived from the CHU-9D questionnaire is presented in Table 2. Loss to follow up is reported in *Appendix 3.* For the BlueIce arm loss to follow up was 32 % at 12 weeks and an additional 5 % at 6 months, in the usual care arm loss to follow up was 26 % at 12 weeks and an additional 2 % at 6 months. Also reported in *Appendix 3*, utility increased for both arms at 12 weeks, and again at 6 months. At each of the follow up time points reported utility was slightly higher in the BlueIce arm with the greatest difference between arms being reported at 12 weeks. However, the differences between means were not statistically significant.

QALYs obtained from CHU-9D questionnaires completed by young people are reported in Table 2. Mean QALYs, reported in *Appendix 3*, were higher at 6 months than 12 weeks for both BlueIce and usual care suggesting improved quality of life in both arms over time. Results indicate higher QALYs following BlueIce compared to usual care with adjusted difference in mean 0.004 at 12 weeks and 0.003 at 6 months although these differences were not statistically significant (Table 2).

4.5. CareNotes recorded use and cost of CAMHS services

As reported in Table 2, the BlueIce arm had fewer hours of contact with CAMHS core professionals, CAMHS interactions with other services, and accident and emergency visits, compared to the usual care arm at both 12 weeks and 6-months post-enrolment. Resulting total CAMHS service costs were lower in the BlueIce intervention arm than the usual care arm from 1 to 3 months pre-enrolment onwards. Thus, at 12 weeks the overall between arm difference in costs was -£249.88. CareNotes recorded particularly high costs for the usual care arm at 4–6 months post-enrolment driven by three long-term hospital stays. Including these outliers increases the magnitude of the difference in means at 6 months from -£722.09 (Table 2) to -£4467.89 (Table 3). While the CareNotes reported costs at 6 months show a firmly negative confidence interval, upon removing long-term hospital stay outliers (our primary analysis) the confidence interval straddles zero reducing confidence in the cost reduction. The difference in cost at both 12 weeks and 6 months is driven in magnitude by accident, emergency, and hospital use, as illustrated in Table 2, though is also supported by consistently lower costs in the BlueIce intervention arm associated to CAMHS core professionals and CAMHS interaction with other services.

4.6. Cost of mental health medications

Mental health prescriptions were costed (Table 2) with the BlueIce arm consistently spending more than usual care on medications. The difference is small and statistically non-significant. Both arms presented lower medication costs post intervention.

4.7. Cost effectiveness

Intervention costs and medication costs were added to the CareNotes service costs for the BlueIce arm to derive a total mental health cost. Total costs were lower in the BlueIce arm than the usual care at both 12 weeks (£1109.80 vs £1359.67) and 6 months (£1750.63 vs £2472.73), even after adding the intervention cost.

At 12 weeks, total cost was lower in the BlueIce intervention arm with a mean difference of -£249.88 (95 % CI: −922.06, 422.31) whilst quality of life was higher with a mean difference of 0.036 (95 % CI: −0.010, 0.081). Results clustered predominantly in the south-east quadrant of the cost-effectiveness plane (Fig. 1) suggesting the BlueIce intervention alongside usual care is more effective and saves money compared to usual care alone. Results are also displayed on the cost-effectiveness acceptability curve (CEAC) show in Fig. 2. At 6 months the difference in mean costs totalled -£722.09 (95 % CI: −1998.84, 334.65) and difference in mean quality of life 0.009 (95 %CI; −0.033, 0.052), both in favour of the intervention arm (Fig. 3). Thus, at both time points, costs were lower, and benefits measured by the CHU-9D higher in the BlueIce arm, indicating that the intervention remains dominant. When incremental net monetary benefit (NMB) was calculated using the £20,000 cost-effectiveness threshold using the youth derived QALYs this yields to a NMB of £329.88 at 12 weeks and £782.09 at 6 months. The probability of the intervention being cost-effective at 12 weeks was over 75 % and at 6 months almost 70 % (Figs. 2 and 4).

5. Sensitivity analysis

5.1. Including long-term hospital stay outliers

No long-term hospital stays were recorded in the first 12-weeks post-intervention. At 6 months, including these outliers increased the size of the difference in mean costs from -£722 Table 2 to -£4468 Table 3.

5.2. Total change baseline to 6 months

Analysis of the total change from baseline to 6 months is presented in Table 3. QALYs were greater under the BlueIce intervention than usual care and CareNotes costs were recorded as higher in the usual care arm than the BlueIce arm across the 6-month period making the intervention arm dominant.

5.3. 12-week to 6-month period

Considering only the 12-week to 6-month period, utilising the 12-

Table 3
Sensitivity analyses.

	12 weeks*			6 months*		
	Δ Cost	Δ QALY	ICER	Δ Cost	Δ QALY	ICER
CareNote cost including long term hospital stays	n/a	n/a	n/a	-£4467.89 (2133.38) [−8649.24, −286.55]	0.003 (0.006) [−0.005, 0.017]	DOMINANT
Total change at 6 months - all non-outlier costs	n/a	n/a	n/a	-£1839.12 (1121.95) [−4038.10, 359.85]	0.013 (0.010) [−0.006, 0.032]	DOMINANT
Period of time 12 weeks to 6 months	n/a	n/a	n/a	-£475.07 (267.39) [−999.15, 49.00]	0.006 (0.006) [−0.005, 0.017]	DOMINANT
Unadjusted base case	-£385.38 (333.47) [−1038.97, 268.22]	0.004 (0.004) [−0.004, 0.013]	DOMINANT	-£975.52 (516.70) [−1988.23, 37.19]	0.001 (0.010) [−0.018, 0.021]	DOMINANT

* Mean (SE) [95 %CI].
DOMINANT = lower cost and higher utility.

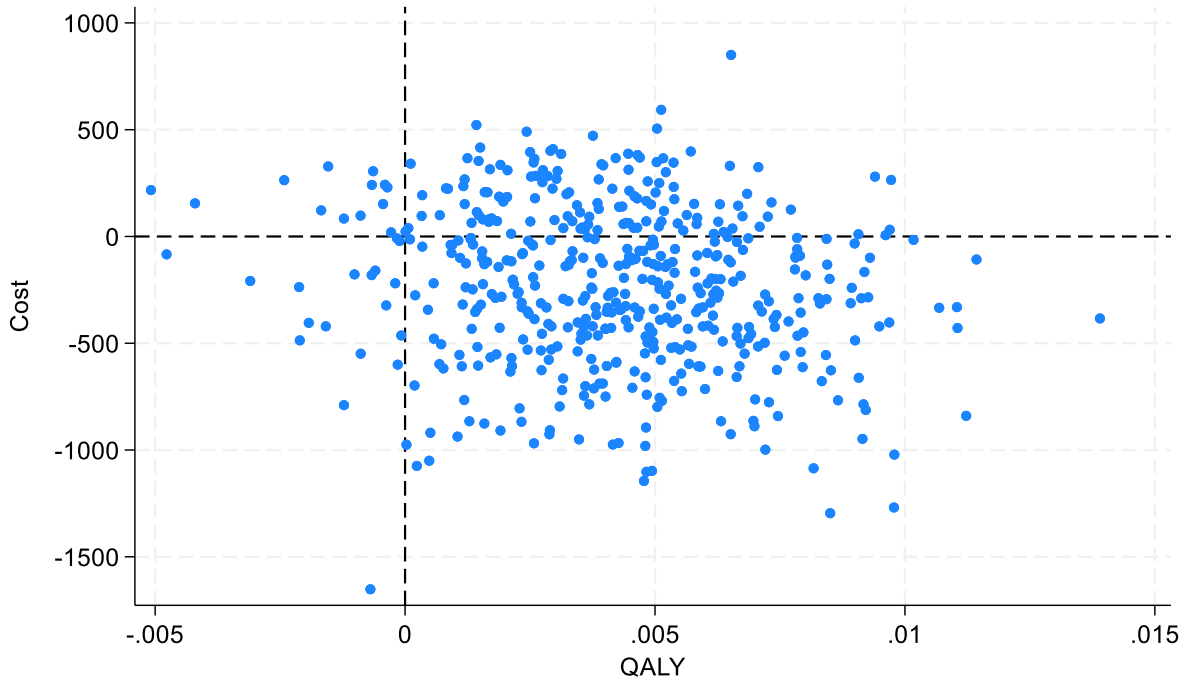

Fig. 1. Cost-effectiveness plane base case 12 weeks.

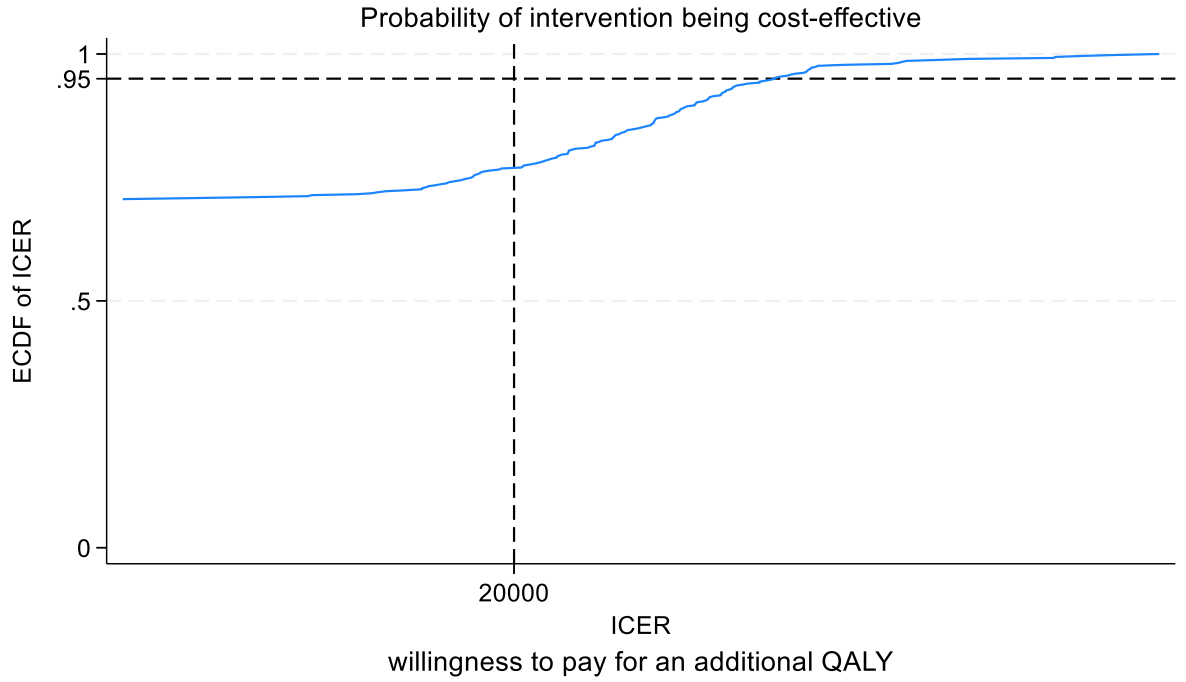

Fig. 2. Cost-effectiveness acceptability curve base case 12 weeks.

week data as baseline, revealed lower costs and higher quality of life in the BlueIce arm at 6 months (Table 3).

5.4. Unadjusted base case results

Unadjusted results are reported in Table 3, *Appendix 3*, and *Appendix 5*. Difference in QALYs remained the same when adjusted as when unadjusted at 12 weeks. Meanwhile the unadjusted difference in QALYs at 6 months was smaller than the adjusted value. Difference in cost was greater in magnitude when unadjusted while directionality remained the same with the BlueIce intervention costing less than the usual care arm.

6. Discussion

To our knowledge, this is the first economic evaluation to assess the addition of a smartphone app to specialist mental healthcare for youth who repeatedly self-harm. Our findings show a reduction in self-harm (adjusted RTSHIA) and an increase in HRQoL but no significant statistical between arm difference. Using youth derived QALYs the incremental net monetary benefit (NMB) was £329.88 at 12 weeks and £782.09 at 6 months with an over 75 % probability of the intervention

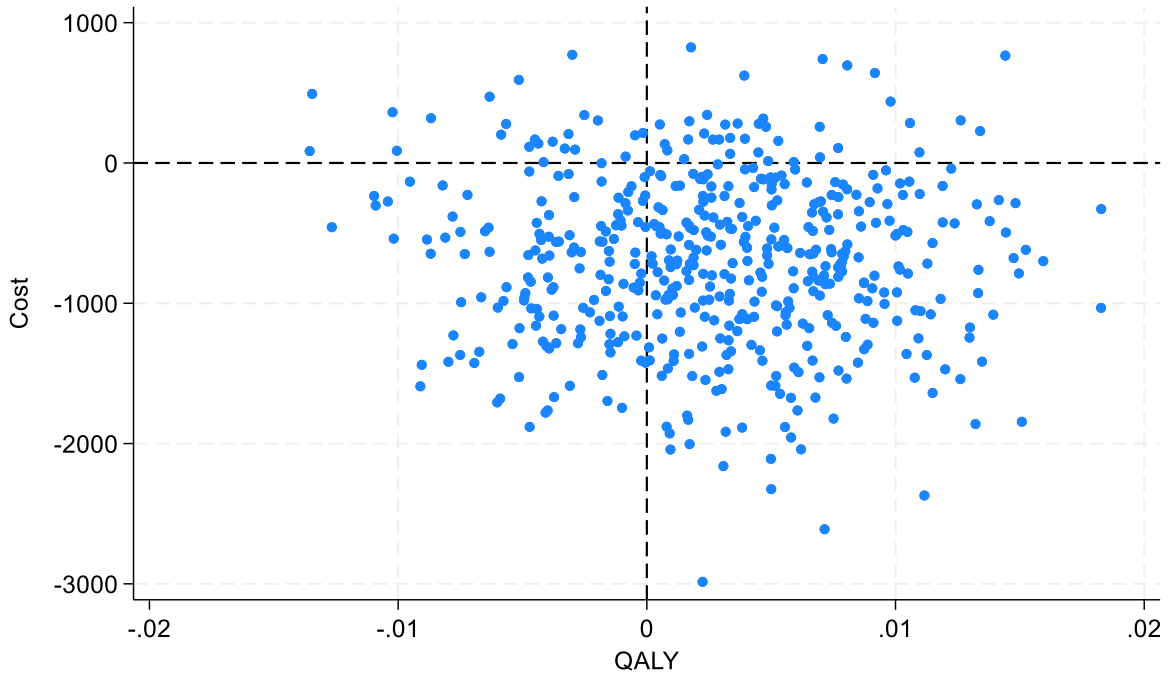

Fig. 3. Cost-effectiveness plane base case 6 months.

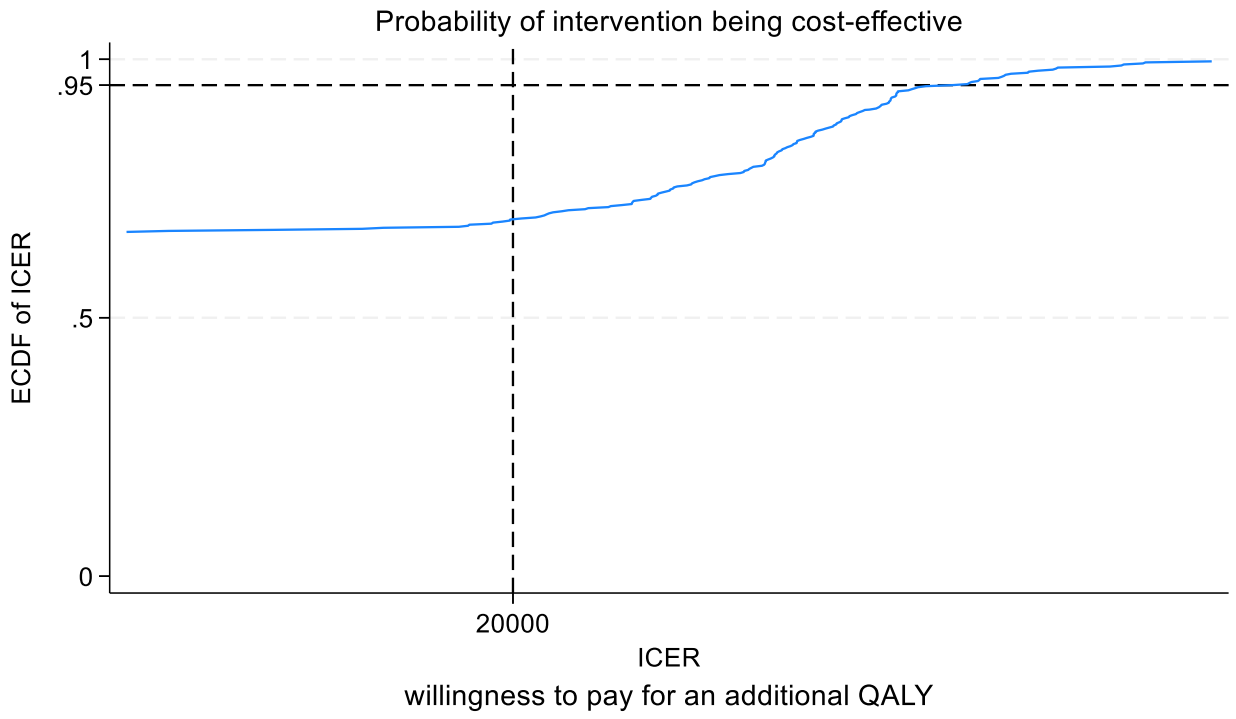

Fig. 4. Cost-effectiveness acceptability curve base case 6 months.

being cost-effective at 12 weeks and almost 70 % at 6 months.

The costs associated with providing specialist mental health care over 6 months for this group of youth who repeatedly self-harm ranged from £1750 to £2472. Costs were driven by low frequency high cost events requiring hospital attendance or admission. Reducing the need for emergency department attendance or length of hospital stay are important goals for this population (Ougrin et al., 2021). In our trial, there were fewer adverse or serious adverse events (i.e. escalations in self-harm and/or Emergency Department attendance and hospital admissions) in those who received BlueIce compared to treatment as usual (25 vs 47) (Stallard et al., 2024). Similarly, all 3 young people admitted to a psychiatric inpatient unit because of escalations in their self-harm were randomised to treatment as usual. Qualitative feedback revealed that youth liked BlueIce and used it at times of crises (Stallard et al., 2024b). Whilst we are unable to directly relate the lower rates of emergency attendances and admissions to BlueIce, this cumulative data tentatively suggests that the app may have helped some young people during some crises.

The cost of providing the app for 6 months were £32.26 per person, less than a one-hour contact with a Band 4 Assistant Psychologist or

Mental Health Support Worker. One-third-of these costs (£10.42) were associated with trial recruitment and ensuring that those assigned to BlueIce downloaded the app. The cost of the intervention in everyday practice could be less if this role was undertaken by a professional from a lower band.

In terms of strengths, no studies to our knowledge have evaluated the cost-effectiveness of adding a self-help digital app to usual mental healthcare for adolescents who are repeatedly self-harming. Our data has been collected from a randomised controlled trial and is one of the few to involve young adolescents aged 12–17 years. Our methodology for resource extraction was comprehensive and robust and involved an independent review and extraction of data from specialist mental healthcare records rather than relying on patient recall. We do however acknowledge a number of limitations which need to be considered when interpreting these results. Firstly, this study was powered to detect changes on clinical not economic outcomes. Our sample may not have been sufficient to fully capture low frequency high cost events associated with hospital attendance and admissions. Secondly, the 6-month time frame for the economic analysis was relatively short. Though we observed clinical improvements over the course of this trial, a longer time frame is required to determine whether these benefits are sustained. Finally, although this study recruited from a large geographical area our sites were served by a single Mental Health Trust. The specialist mental health services provided by this Trust cannot be assumed to be representative of other CAMHS across the UK.

This study supports the addition of the BlueIce app to the specialist mental healthcare provided for adolescents who repeatedly self-harm to reduce healthcare resources and to improve health benefits. Participants in the BlueIce arm had fewer emergency department attendances and admissions, lower rates of self-harm, fewer symptoms of anxiety and depression (Stallard et al., 2024) and was used and positively evaluated by users (Stallard et al., 2024b), suggesting that BlueIce could be a positive addition to mental healthcare. Further evidence of the longer term clinical and economic benefits with a diverse population in different settings is required.

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Author contributions

PS was the chief investigator and conceived the study design. PS, GT, AM-L and SR designed and obtained funding for the study GT provided statistical oversight, wrote the statistical analysis plan and undertook the analysis. AM-L led the economic evaluation, wrote the health economic analysis plan and provided oversight of the analysis. NM undertook the economic analysis. SR advised on trial management and patient randomisation. EM and KW were involved in recruiting participants, undertook assessments, entered and cleaned data. BC recruited participants and undertook post-use interviews. All authors were involved with, and approved the final version of this paper and decision to submit for publication. PS is guarantor of the study.

Data sharing

The study investigators own and have complete control of the research data which can be accessed at any time. For statistical and economic analyses, the data will be stored on a computer system maintained by the University of Exeter. Deidentified participant data and a data dictionary will be made publicly available after publication upon reasonable request to the chief investigator according to NIHR policy.

Role of funding source

The funders of this study had no role in study design, data collection, analysis, interpreting data, writing reports or decisions to publish findings.

CRediT authorship contribution statement

Nia Morrish: Formal analysis, Writing – original draft. **Paul Stallard:** Conceptualization, Funding acquisition, Methodology, Project administration, Supervision, Writing – original draft. **Kathryn Whittle:** Investigation, Writing – review & editing. **Emma Moore:** Investigation, Writing – review & editing. **Shelley Rhodes:** Funding acquisition, Project administration, Writing – review & editing. **Gordon Taylor:** Data curation, Formal analysis, Funding acquisition, Methodology, Writing – review & editing. **Antonieta Medina-Lara:** Formal analysis, Funding acquisition, Methodology, Writing – original draft.

Declaration of competing interest

BlueIce is the intellectual property of PS., the creator of the app. He has no financial benefits from the app The remaining authors have no competing or potential conflicts of interest to declare.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.psychres.2024.116186.

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