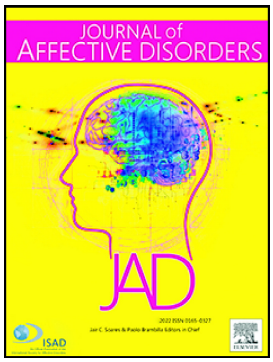

Cost-effectiveness of an online personalised parenting intervention to prevent affective disorders in high-risk adolescents compared to a standard educational package

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Title page

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Abstract

Background

Adolescent depression is associated with substantial health and economic burden. Preventive interventions that strengthen parenting skills show promise in reducing depressive symptoms and improving adolescent well-being. However, evidence on the cost-effectiveness of scalable online parenting interventions remains limited.

Objectives

To evaluate the cost-effectiveness of an online personalised parenting (PP) programme – Partners in Parenting- designed to prevent affective disorders in high-risk adolescents, compared with a standard educational package.

Methods

This trial-based economic evaluation was conducted alongside a randomised controlled trial of 512 parent–adolescent dyads (256 per arm). Analyses adopted UK public sector and societal perspectives over 15 months. Costs (2022–2023 GBP) were collected prospectively. Utilities from EQ-5D-Y and CHU9D were used to estimate quality-adjusted life-years (QALYs). The base case used bivariate regression of costs and QALYs with multiple imputation under intention-to-treat. Incremental cost-effectiveness ratios, net monetary benefits, and cost-effectiveness acceptability curves were estimated. Sensitivity analyses assessed robustness.

Results

In the adjusted multiply imputed base-case analysis, mean incremental public-sector costs were £639 (95% CI £272 to £988) and mean incremental QALYs were 0.013 (95% CI −0.021 to 0.042), corresponding to a 13%-27% probability of cost-effectiveness at willingness-to-pay thresholds of £20,000-£30,000 per QALY. Complete-case analysis suggested lower costs and higher QALYs but with substantial uncertainty.

Conclusions

Over the 15-month trial horizon, the personalised parenting programme was associated with higher costs, a small and uncertain gain in QALYs, negative incremental net monetary benefit, and a low probability of being cost-effective at NICE-recommended willingness-to-pay thresholds.

Keywords

Economic evaluation, cost-utility analysis, health-related quality of life, cost-effectiveness, affective disorders, adolescents, depression prevention, parenting intervention

Introduction

Approximately half of lifetime mental disorders emerge before mid-adolescence and three-quarters by the mid-twenties (Kessler et al., 2007). In the UK, annual mental health treatment costs are projected to exceed £10 billion by 2026, with the highest costs incurred among young people (McCrone et al., 2008). Depression in adolescence is of particular concern (Whiteford et al., 2015); approximately one in seven (14.4%) young people aged 11–16 have a mental health disorder, with almost one in ten experiencing an affective disorder (Sadler et al., 2018).

Adolescent depression and anxiety put young people at risk of developing more severe affective disorders (Sadler et al., 2018; Shankman et al., 2009), long-term psychosocial and vocational impairments, and increased risk of suicide as they mature (Lawrence et al., 2015; Rao et al., 1995), even when symptoms are sub-threshold (Balázs et al., 2013). Early identification and indicated interventions for those with low-level symptoms have been associated with positive outcomes with meta-analyses showing a typical reduction in depression incidence of around 20% in the 3–24 months post-intervention (Cuijpers et al., 2008; van Zoonen et al., 2014).

Beyond health impacts, adolescent depression carries substantial economic consequences across healthcare, education, and productivity. It is associated with poorer academic attainment, higher dropout rates, reduced employment prospects, and increased healthcare utilisation (Beddington et al., 2008; Kessler, 2011). Wider societal costs include absenteeism, reduced workforce productivity, and greater engagement in risky behaviours. Depression also disproportionately affects disadvantaged groups, exacerbating inequalities and perpetuating cycles of poor health and poverty (Friedrich, 2017; Patel, 2013). Strategies for preventing depression in adolescence are therefore a global priority (Andrews et al., 2004; Shafran et al., 2014).

Evidence identifying modifiable psychosocial risk and protective factors provides a foundation for prevention (Cairns et al., 2014; Patel et al., 2007). Although school- and individual-level psychological interventions show sustained effects at 12 months (Merry et al., 2012), they rarely include family components (Patel et al., 2007; Stockings et al., 2016). However, a meta-analysis found that interventions targeting parents/carers of children aged 0–18 produced lasting benefits for anxiety (up to 11 years) and depression (up to 5.5 years), with numbers-needed-to-treat of 10 and 11 respectively comparable to adolescent-focused interventions (Merry et al., 2012; Yap et al., 2016).

Parents are well placed to detect early changes and initiate help-seeking (Jorm et al., 2007), yet many report limited knowledge of effective preventive strategies (Yap and Jorm, 2012). Most evidence-based parenting programmes are delivered face-to-face in groups, making them costly and vulnerable to engagement barriers such as scheduling and privacy concerns (Finan et al., 2018; Heinrichs et al., 2005).

Digital interventions may address these limitations by offering confidentiality, flexibility, scalability, and personalisation (Andrews et al., 2010; Finan et al., 2018; Kreuter et al., 2013). Tailored web-based programmes can target empirically derived risk and protective factors, enhancing relevance and effectiveness (Wildeboer et al., 2016; Yap et al., 2017). However, few tailored online parenting interventions for preventing adolescent depression and anxiety exist. A 2019 review identified only one: “Partners in Parenting” (PiP) (Hansen et al., 2019; Yap et al., 2017). In an Australian randomised controlled trial of 359 parent–adolescent dyads, PiP improved parenting practices (Cohen’s d=0.51) and reduced depressive symptoms among adolescents with elevated baseline symptoms (Yap et al.,

2014a; Yap et al., 2018; Yap et al., 2014b). However, PiP has not been tested outside Australia, and its cost-effectiveness remains unknown.

We adapted the Australian online PiP programme for use in a UK setting and conducted an RCT to test its effectiveness, cost-effectiveness and usability compared to a standard educational package. This paper focuses on the health economic evaluation of the adapted programme, whilst the main clinical results are discussed in full in a separate paper.

Methods

Trial background

The online Parenting Intervention to Prevent affective disorders in high-risk Adolescents (PIPA) was a two-arm, superiority, intention-to-treat randomised controlled trial comparing a UK-adapted Partners in Parenting (PiP) programme with an active control to reduce risk of affective disorders in young people at high risk (Connor et al., 2022). Eligible family dyads (parent/carer and child aged 11–15) included children screening positive for elevated depressive symptoms. The target sample size was 433 dyads; 512 were recruited between 9 February 2021 and 1 May 2023.

Recruitment was primarily via 164 UK schools, with 28 additional families recruited through community and social media advertising. Participants were randomised 1:1 to the personalised programme (PP) or standard educational package (SEP). Follow-up assessments were completed online at 6 and 15 months.

The treatment intervention, the personalised programme for parents (PP), was delivered online via the PiP website (Yap et al., 2017). After assessment of current parenting practices using the Parenting to Reduce Adolescent Depression and Anxiety Scale (PRADAS (Cardamone-Breen et al., 2017)), parents/carers received individually tailored feedback and were recommended up to nine modules. Modules offered a range of specific actionable parenting strategies drawn from evidence- and expert-consensus-based parenting guidelines (Yap et al., 2014a). Participants had the option of accepting the recommended modules or selecting their own, with one module released per week until all selected had been released. The active control, a standard educational package (SEP), was also delivered via the PiP website and consisted of five factsheets about adolescent development and wellbeing with general parenting tips that were not individually tailored for parents/carers and released in a set order on a weekly basis.

The primary outcome was the change in parent/carer-reported adolescent depression score between entry to trial and 15 months post-randomisation using the Short Mood & Feelings Questionnaire – Parent reported; SMFQ-PR (Angold et al., 1995). Other important outcomes included parenting practices, parental wellbeing, child emotion regulation, child depression, and the economic outcomes described below.

Overview of economic analyses

We conducted an economic evaluation that involved an assessment of economic costs, health-related quality of life (HRQoL) outcomes and cost-effectiveness of PP versus SEP where cost-effectiveness was expressed in terms of incremental cost per quality adjusted life year (QALY) gained. The base-case economic evaluation took the form of an intention-to-treat, imputed analysis conducted from a UK public sector perspective in line with guidance for evaluation of public health interventions (Health and Excellence, 2012). This reflected a

cross-sectoral public-health decision context and included intervention costs, NHS and personal social service costs, and education sector costs. This perspective is broader than the narrower NHS/PSS perspective commonly used in some NICE technology appraisal contexts. A broader societal perspective, including private healthcare costs, family-borne costs, travel costs, and productivity losses, was explored in sensitivity analysis. The economic evaluation adopted a 15-month time horizon from randomisation, mirroring the trial follow-up period. Costs and QALYs accrued within the first 12 months were undiscounted, and a 3.5% annual discount rate was applied only to the portions accruing between 12 and 15 months, in line with the National Institute of Health and Care Excellence (NICE) reference case (National Institute for and Care, 2022). Reporting of this economic evaluation follows the Consolidated Health Economic Evaluation Reporting Standards (CHEERS) 2022, and the completed CHEERS checklist is provided in the Supplementary Material.

Costs

Costs were grouped according to the analytic perspective: (i) intervention costs, including platform management and maintenance; (ii) NHS, personal social services (PSS), and education-sector costs; and (iii) broader non-public-sector costs included only in the societal sensitivity analysis. Public-sector costs comprised intervention, NHS/PSS, and education-sector costs. Societal costs comprised public-sector costs plus private healthcare costs, family-borne costs, travel costs, and productivity losses. All costs were valued in 2022–23 GBP using the NHS Cost Inflation Index where required (Jones and Burns, 2022).

The platform, hosted by Monash University (Australia), was costed per participant using infrastructure, maintenance, communication and personnel information, assuming scalable delivery (Supplementary Table S7). Sensitivity analyses varied maintenance and eligible population assumptions. The reported costs represent average per-participant estimates rather than total trial expenditure. These estimates were intended to reflect scalable intervention delivery costs and were derived from projected infrastructure, maintenance, communication, and security-testing requirements spread across the estimated eligible population. They do not represent a full implementation costing exercise and therefore exclude research and development costs, trial-specific activities, and potentially organisation-specific implementation costs that may arise during routine adoption.

In accordance with NICE guidance, we captured NHS and PSS costs for participants in both arms of the trial (NICE, 2022). This included inpatient care, outpatient care, accident and emergency admissions, community health and social care, and medication use. We also collected information on school support. The methods for capturing resource use and the sources for unit costs are described in Supplementary Table S8. All resource inputs were collected through parent-completed questionnaires completed at six and 15 months post-randomisation. The identified resource inputs were valued using unit costs (Supplementary Table S9) identified through national cost compendia in accordance with NICE's Guide to the Methods of Technology Appraisal (NICE, 2022). Unit cost data were derived based on NHS England's National schedules of NHS costs 2021-22 (England, 2022), the Personal Social Services Research Unit (PSSRU) Unit Costs of Health and Social Care 2023 compendium (Jones and Burns, 2022), 2021-22 volumes of the British National Formulary (NICE), the NHS Supply Chain Catalogue 2021-22 (Digital, 2022), and the 2021-22 National Health Service Business Service Authority (NHSBSA) Prescription Cost Analysis (PCA) schedules (NHSBSA, 2022). Analyses from a societal perspective additionally encompassed economic values for work absences (by parents/carers), days off school, travel costs and privately incurred health expenditures. The economic values associated with these broader impacts were self-reported by parent participants.

Health-related quality of life outcomes

Health-related quality of life outcomes were assessed using the EQ-5D-Y-3L child self-report, EQ-5D-Y-3L proxy-report (Ravens-Sieberer et al., 2010; Stevens, 2010), Child Health Utility 9D (CHU9D) child self-report (Stevens, 2009, 2012; Stevens, 2010), EQ-5D-5L parent self-report (Foundation, 2019), and Short Warwick-Edinburgh Mental Wellbeing Scale (SWEMWBS) parent self-report (Haver et al., 2015). The primary HRQoL outcome for the economic evaluation was the EQ-5D-Y-3L child self-report instrument, which defines HRQoL in terms of five dimensions (mobility, self-care, usual activities, pain/discomfort, anxiety/depression), each with three levels of severity (Foundation, 2019). The EQ-5D-Y-3L was selected as the primary HRQoL measure in line with NICE guidance, which recommends the use of generic preference-based measures to generate QALYs for cost-effectiveness analyses. It provides comparability across studies and supports policy decision-making (National Institute for and Care, 2022). Although the EQ-5D-Y-3L may have limited sensitivity for detecting changes in mental health in children, it has acceptable psychometric properties (Kwon et al., 2023). HRQoL was assessed at baseline, six and 15 months post-randomisation using the EQ-5D-Y-3L child self-report responses. In the absence of a UK-specific EQ-5D-Y value set available at the time of analysis, EQ-5D-Y health states were valued using the UK adult EQ-5D-3L tariff. We acknowledge that health-state values may differ when elicited for children rather than adults, and therefore conducted a sensitivity analysis using the CHU9D, an alternative child-specific preference-based measure. In addition, a post hoc sensitivity analysis using the German EQ-5D-Y value set was undertaken to explore the impact of alternative valuation approaches. Participant-level QALYs were estimated using the area under the curve approach, assuming linear interpolation between the utility scores, i.e., the preference-based values attached to the health states generated from the EQ-5D-Y-3L descriptive system.

Handling of missing data

Missing cost and health utility data were imputed under the missing at random (MAR) assumption at each time point using fully conditional multiple imputation by chained equations (MICE) implemented in Stata 18 (StataCorp, 2023). Because MAR is not empirically testable from observed data alone, logistic regression was used to identify observed predictors of missingness and inform specification of the imputation model (Faria et al., 2014). Robustness to departures from MAR was subsequently assessed through prespecified missing-not-at-random (MNAR) sensitivity analyses using a reference-based pattern-mixture multiple-imputation framework. Imputation was achieved using predictive mean matching, which has the advantage of preserving nonlinear relationships and correlations between variables within the data (Faria et al., 2014). Fifty imputed datasets were generated to inform the base-case and subsequent sensitivity and subgroup analyses. Parameter estimates were pooled across the imputed datasets using Rubin's rules to account for between- and within-imputation components of variance terms associated with parameter estimates (Little and Rubin, 2019). The adequacy of the imputation procedure was assessed using multiple-imputation diagnostics, including the fraction of missing information (FMI), relative efficiency, and Monte Carlo error. Further details on missing-data handling are provided in the Supplementary Information, including missingness diagnostics, the complete imputation model specification, arm-specific imputation procedures, passive derivation of analysis variables, Stata commands and settings, the MI-SUR-bootstrap

workflow used for cost-effectiveness uncertainty estimation, and detailed descriptions of the MAR and MNAR sensitivity analyses.

Cost-effectiveness analyses

Mean resource use, cost and health utility values were compared between the trial arms using two sample t-tests. Mean incremental costs and mean incremental QALYs were estimated using seemingly unrelated regression (SUR) methods that accounted for the correlation between costs and outcomes (Zellner and Huang, 1962). Differences between groups, along with their confidence intervals (CIs), were estimated using non-parametric bootstrap estimates (5,000 replications) of regression models. The primary economic analysis used prespecified adjusted models. The cost equation was adjusted using pre-baseline costs, primary parent sex and number of parents/carers involved at baseline. The QALY equation was adjusted using baseline utilities, primary parent sex and number of parents/carers involved at baseline. Following imputation, bootstrapping was used to generate the joint distribution of costs and outcomes and to populate a cost-effectiveness plane. The incremental cost-effectiveness ratio (ICER) for PP was estimated from the joint distribution of incremental costs and QALYs generated through the non-parametric bootstrap procedure. Mean ICER values were compared against cost-effectiveness threshold values (i.e. society's willingness to pay for an additional QALY) ranging between £20,000 and £30,000 per QALY gained in line with NICE guidance (NICE, 2022). ICER values lower than this threshold are considered cost-effective for use in the UK public sector. The incremental net monetary benefit (INMB) of switching from SEP to PP was also calculated at each of these cost-effectiveness threshold values. The net monetary benefit is the economic benefit of an intervention (expressed in monetary terms) net of all costs. A positive incremental NMB, for example, suggests that, on average, PP is cost-effective compared with SEP, at the given cost-effectiveness threshold. All health economic analyses, including the multiple imputation, seemingly unrelated regression (SUR), bootstrapping, and cost-effectiveness analyses, were conducted in Stata version 18 (StataCorp, College Station, TX, USA).

Sensitivity and subgroup analyses

Pre-specified sensitivity analyses included complete-case analysis, societal perspective, alternative HRQoL measures (CHU9D; EQ-5D-Y proxy), and alternative intervention cost assumptions. Subgroup analyses were conducted by parental education (GCSE or below vs above) and ethnicity (White vs non-White). A scenario analysis estimated incremental cost per PRADAS parenting score reduction.

Results

Study population and data completeness.

Of 512 randomised participants, two withdrew and requested data removal. Baseline characteristics were balanced between groups (Table 1). Completeness rates for the health-related quality of life outcome and wellbeing measures at the different follow-up points are presented in Table 2. Complete QALY profiles were available for 138 (27%) participants based on the EQ-5D-Y-3L child self-report measure. Completeness rates for the resource use categories at the different follow-up points are presented in Table 3.

Total costs for the period between randomisation and 15 months were calculable for 140 (27%) participants. There was complete information on both costs and QALYs for 40 (8%) participants. There were no significant differences in the sociodemographic characteristics between participants with or without complete data (Supplementary Table S2).

Resource utilisation

For health, personal social service and education sector services, shown in Supplementary Tables S10a-c, there were non-significant differences between the two groups in utilisation of resources at all follow up points.

Cost of intervention

Mean total intervention costs per participant are presented for each group in Supplementary Table S7 and varied between £8.20 (PP) and £0.05 (SEP) for the primary analysis. Scenario analyses explored variation in eligible population size and maintenance of the online platform, which produced a range of per-participant costs from £4.47 to £15.67 for PP and £0.04 to £0.05 for SEP. Information on how these costs were estimated can be found in Supplementary Table S7.

Economic costs

For the base-case (imputed) analysis, mean total UK public sector costs, comprising intervention, NHS/PSS, and education-sector costs, were £2398 for the PP arm versus £1759 for the SEP arm (Table 4 and Supplementary Table S13).

Mean total societal costs, which additionally included private healthcare costs, family-borne costs, travel costs and productivity losses, were £4179 for the PP arm compared with £3079 for the SEP arm (Table 4 and Supplementary Table S13). The estimates of total economic costs for non-imputed (observed) cases are shown in Supplementary Table S11a and follow the same pattern as the imputed base case analysis. Estimates of observed costs by cost category for the different follow-up points are presented in Supplementary Tables S11b-d.

Health related quality of life outcomes

Mean (standard deviation [SD]) observed QALYs were estimated at 0.84 (0.32) for the PP arm versus 0.82 (0.33) for the SEP arm (MD: 0.02, p=0.740) (Supplementary Table S12). For the base-case imputed analysis, mean (SE) participant-reported QALY estimates for the entire period were 0.781 (0.02) for the PP arm versus 0.769 (0.02) for the SEP arm; the mean between-group difference was 0.0126 QALYs (Table 4: Supplementary Table S13). Estimates of observed HRQoL outcomes using the different HRQoL measures used in the study are presented in Supplementary Table S12.

Cost-effectiveness results: base-case analysis

The base-case economic evaluation (public sector perspective, imputed costs and QALYs and adjusted for covariates) indicated that PP was associated with significantly higher total public sector costs (£639, 95% CI £272 to £988) and a non-significant improvement in QALYs (0.013, 95% CI -0.021 to 0.042) (Table 4: Supplementary Table S13). The mean ICER derived from the bootstrap-based cost-effectiveness analysis was £59,734 per QALY gained and fell in the northeast quadrant of the cost-effectiveness plane, meaning that the intervention is, on average, more effective than the comparator but also more costly. This suggests that each additional QALY gained through PP would require a cost exceeding the commonly cited £20,000 per QALY willingness-to-pay threshold used by the UK National Institute for Health and Care Excellence (NICE) to inform reimbursement decisions. The

corresponding mean INMB values at cost-effectiveness thresholds of £20,000 and £30,000 per QALY were -£419 and -£314, respectively (Supplementary Table S13). The base-case mean INMB was less than zero, suggesting that the use of PP would result in an average net economic loss. The probability of cost-effectiveness for PP was estimated as 13% and 27% at cost-effectiveness thresholds of £20,000 and £30,000 per QALY, respectively (Supplementary Table S13). The joint distribution of costs and outcomes for the base-case analysis is presented graphically in Fig. 1, with axes labelled for incremental costs and incremental QALYs and the four quadrants of the cost-effectiveness plane labelled to aid the interpretation of the results. The figure displays the results of 5,000 bootstrap simulations, with two reference lines representing willingness to pay thresholds of £20,000 and £30,000 per QALY. A higher proportion of bootstrap simulations falling below these threshold lines indicates a greater probability that the PP intervention is cost-effective. The cost-effectiveness acceptability curve is shown in Fig. 2, with a horizontal line at 50% probability dividing the curve into two sections. Points above this line indicate that the intervention is more likely than not to be cost-effective at the corresponding cost-effectiveness threshold, whereas points below indicate a low probability. For PP, the curve remains below the 50% line across commonly cited cost-effectiveness thresholds, reinforcing the low probability that PP is cost-effective. When the analysis for the base-case was conducted on the basis of the MNAR assumption (Table 4); PP was associated with non-significantly higher total public sector costs (£414, 95% CI -£374 to £1201) and a non-significant reduction in QALYs (0.001, 95% CI -0.061 to 0.030).

Sensitivity and subgroup analyses

For the sensitivity analysis conducted from a societal perspective, the probability that PP was cost-effective ranged between 0% and 10% across cost-effectiveness thresholds (Table 4 and Supplementary Table S13). The sensitivity analysis based on complete cases showed that the cost and QALY differences were non-significant, but the probability of cost-effectiveness could not be calculated due to insufficient data. Changing the source of HRQoL outcomes for QALY estimation (to the CHU9D or EQ-5D-Y proxy), applying the German EQ-5D-Y value set, changing intervention cost assumptions (increasing positive screening rate, adjusting platform maintenance costs), or removing discounting, did not materially affect the results or conclusions.

The pre-planned subgroup analyses showed variation in cost-effectiveness estimates according to parental education and participant ethnicity. However, interaction terms in the underlying regression models were not statistically significant, providing no evidence of differential cost-effectiveness between subgroups (Table S13).

The scenario analysis that estimated the incremental cost per unit change in PRADAS parenting score indicated that PP was associated with increased costs from randomisation to 15 months (£705, 95% CI -£109 to £1518) and an increase in PRADAS score (4.84, 95% CI 2.03 to 7.65). The incremental cost per unit change in PRADAS score was £146 (Table S9).

Discussion

Principal Results

This economic evaluation found that the personalised parenting programme (PP) did not significantly improve adolescent health-related quality of life over 15 months, while increasing costs. The ICER exceeded the NICE threshold (£20,000–£30,000 per QALY)

commonly applied by the UK National Institute for Health and Care Excellence (NICE) to inform reimbursement decisions, and societal analyses similarly showed no evidence of cost-effectiveness. These results align with the main trial outcome, which found no difference in parent-reported adolescent depression in the PP arm compared to the SEP arm.

Exploratory subgroup estimates varied according to parental education and ethnicity; however, interaction tests did not support evidence of differential cost-effectiveness between subgroups. These analyses were not powered to detect subgroup differences and should be interpreted cautiously. Consequently, the findings should not be used to inform targeting decisions, and the primary conclusions are based on the overall trial population.

We used a pragmatic approach to sampling, and hence our findings should be generalisable. To the best of our knowledge there is no comparable evidence for cost-effectiveness of online personalised parenting programmes to reduce the risk of affective disorders in young people at high risk in the broader literature.

The PP intervention was not costly and resulted in some improvement in parenting (the primary and direct target of the Partners in Parenting intervention) compared to a standard education package for parents. We estimated the incremental cost per unit improvement in the parenting measure (PRADAS) as £146. This result should be interpreted descriptively. In the absence of an established willingness-to-pay threshold or validated minimally important difference for the PRADAS, the estimated cost per unit improvement cannot be used to determine cost-effectiveness.. Nevertheless, the PRADAS assesses parenting behaviours that have previously been identified as modifiable risk and protective factors for adolescent depression and anxiety (Yap et al., 2014a; Yap et al., 2014b). Further research is required to establish the clinical and economic significance of changes in PRADAS scores and to determine how improvements in parenting practices translate into longer-term mental health and quality-of-life outcomes.

Comparison with Prior Work

There have been no previous economic evaluations of the PP intervention. During the COVID-19 pandemic, a UK based group developed “parent positive”, an online parenting intervention, and tested this in a RCT versus treatment as usual. Participants were parents or carers of children aged 4 to 10 years. The outcomes were child conduct and emotional problems and family well-being at one, two and three months and an economic analysis was performed. The intervention was found to be cost-effective (but only once four outliers with extremely high health care costs were excluded (Palmer et al., 2023)). It is difficult to directly compare our results with this study, as parent positive was not personalised and the primary outcome was parent-reported child conduct problems using the conduct subscale of the Strengths and Difficulties Questionnaire and not an internalising outcome.

Strengths and Limitations

The strengths of the study are that it was based on a prospectively designed trial for a cost-effectiveness analysis using individual-level data to reach a confirmatory conclusion, and our approaches to collecting economic data disentangled resource inputs associated with mental health or emotional problems from resource inputs associated with broader factors.

A first limitation is that utility measurements were collected at only two time-points post-randomisation. Evidence suggests that the timing of assessment can significantly influence cost-effectiveness results when using the EQ-5D-Y, particularly when participants experience recurrent health fluctuations. (Schilling et al., 2016) In such cases, linear interpolation of utility data may fail to reflect HRQoL fluctuations over short periods and the

uncertainty is compounded by missing data. In addition, the EQ-5D-Y may not be an appropriate measure to use to generate QALYs in mental health settings as it only has one dimension/question related to mental health. Furthermore, in the absence of a UK-specific EQ-5D-Y value set at the time of analysis, EQ-5D-Y health states were valued using the UK adult EQ-5D-3L tariff. As preferences for child and adult health states may differ, this introduces additional uncertainty into the utility estimates. However, this study also estimated QALYs using the CHU9D and undertook an additional post hoc sensitivity analysis using the German EQ-5D-Y value set. The findings were consistent across valuation approaches, with no meaningful differences in the conclusions regarding cost-effectiveness.. Secondly, resource use data were retrospectively recalled by participants over a substantial period of time, and this could have led to recall bias, though we cannot predict the direction of this bias. Findings from the literature are mixed, suggesting that resource use may be under-reported or over-reported, or may show good agreement with data extracted from medical records, depending on how well the resource use measures are structured.(Ridyard and Hughes, 2015) Because the recall periods and questionnaires were standardised across randomised groups, retrospective recall is probably unlikely to have biased results in favour of one group. Thirdly, there were very high levels of missingness in the study data. However, we handled missingness within the health economic data through recommended multiple imputation techniques that address the inherent biases associated with estimating effects on the basis of complete data. Fourthly, the study had a relatively short (15-month) follow-up period, which limits conclusions about long-term cost-effectiveness. Future research could use decision-analytic modelling to extrapolate outcomes over a longer period, incorporating evidence on the natural history of adolescent depression and the persistence of intervention effects on parenting behaviours. Such models could simulate trajectories of mental health outcomes, health and broader resource use, educational attainment, and productivity into adulthood, allowing estimation of lifetime cost-effectiveness. Building on our current findings, a model-based economic evaluation could therefore help quantify whether modest short-term effects translate into meaningful long-term benefits and cost savings from both public sector and societal perspectives in a disorder that often has lifelong consequences. The intervention costing reflected scalable delivery assumptions rather than a full implementation costing exercise. As a result, some costs that may be incurred during adoption within routine services, such as governance activities, workforce training, technical support, system integration, platform redevelopment, and other organisation-specific implementation activities, were not explicitly included. However, extensive sensitivity analyses varying key intervention cost assumptions had minimal impact on the estimated ICERs and did not alter the overall conclusions regarding cost-effectiveness.

There were particular challenges when analysing the trial data, including persistent missingness at both follow up points and a highly right-skewed cost distribution in both treatment arms. Although the primary analysis used a prespecified SUR framework with non-parametric bootstrapping to characterise uncertainty, alternative modelling approaches may perform differently when cost distributions are highly skewed and should be explored in future research. There were few participants for whom we had complete cost and QALY data (40). The results for the complete cases showed no differences in costs or QALYs, but they should be interpreted with caution as they account for less than 10% of the trial population. When looking at observed unadjusted public sector costs at each time point for those with complete information to calculate costs, the results suggested higher public sector costs in the PP arm at both six months and 15 months, with a larger difference at the six-month timepoint. In the six-month data, outpatient care costs seem to be driving the cost difference, but there were no significant differences in resource use for this resource use category. When looking at 15-month data, inpatient hospital costs and school support costs seem to

drive cost differences, but there were no significant differences in resource use for these resource categories. A regression of total public sector costs at six months that adjusted for baseline costs, primary parent's sex and number of parents showed the same pattern of higher costs for the PP arm.

One possible, but untested, explanation for the higher healthcare costs observed in the PP arm is that the professional help-seeking module increased access to services. However, module-level exposure, the appropriateness of service use, and potential mediation through help-seeking behaviours were not evaluated in the present study. This interpretation should therefore be regarded as speculative.

To address missing data, multiple imputation was carried out in accordance with the pre-specified health economic analysis plan, under the assumption that data were missing at random. The imputation model included a wide range of baseline covariates and outcome variables to reduce potential bias associated with systematic missingness. The results of our imputed analyses of cost-effectiveness outcomes showed an increase in cost that was marginally significant and no difference in QALYs, possibly reflecting some adjustment for the patterns of missingness. Exploratory imputed analyses for the six month and 15-month questionnaire data showed the same pattern of results as the observed (complete case) data, where higher costs were observed for the PP arm. An analysis based on the MNAR assumption also produced a consistent pattern, showing no significant differences in costs or QALYs. Taken together, these comparisons suggest that the conclusions are robust to alternative assumptions about missingness, though the high level of missing data warrants cautious interpretation.

Conclusions

Using data collected as part of a large RCT testing the effects of a personalised online parenting intervention versus standard educational material for parents, the PP online programme is unlikely to be cost-effective compared with the active educational control over a 15-month time horizon. While it improved parenting behaviours, no short-term health or economic benefits were observed. Longer-term effects remain uncertain, and further follow-up or model-based analyses are required to determine whether improvements in parenting behaviours translate into later health gains or economic benefits.

Declarations

Trial registration: ISRCTN63358736. Registered 18 September 2019.

Ethics Approval

The PIPA trial received ethical approval from the University of Warwick Biomedical Sciences Research Ethics Committee (BSREC).

Competing Interests

MY is the founder and lead investigator of the Partners in Parenting Programme (Monash University) but does not receive any financial benefits from the programme. SP receives support as an NIHR Senior Investigator (NF-SI-0616-10103) and from the NIHR Applied Research Collaboration Oxford and Thames Valley).

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Author Contributions

AT is the Chief Investigator and conceived the study. KAK drafted and led the paper including revisions. All other authors contributed to the conduct of the trial and the writing of this manuscript and read and approved the final version.

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Availability of Data and Materials

Fully anonymised individual participant data will be available 12 months after the main trial paper has been published and ending 10 years after trial closure. Data will only be shared under a formal Data Sharing Agreement and transferred in accordance with University of Warwick SOP 15 and relevant legislation. Applications should be made to the PIPA trial team (pipa@warwick.ac.uk).

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Table 1: Baseline characteristics of study participants by trial arm

	PP (n=254)	SEP (n=256)
Parent sex (n, %)		
Male	20 (7.9%)	21 (8.2%)
Female	234 (92.1%)	235 (91.8%)
Number of parents (n, %)		
1	191 (75.2%)	192 (75.0%)
2	62 (24.4%)	63 (24.6%)
3	1 (0.4%)	1 (0.4%)
Parent's highest qualification (n, %)		
GCSE and below	55 (21.7%)	51 (19.9%)
Above GCSE	199 (78.3%)	205 (80.1%)
Ethnicity (n, %)		
White	227 (89.4%)	235 (91.8%)
Non-white	27 (10.6%)	21 (8.2%)
Child school year (n, %)		
7	68 (26.8%)	72 (28.1%)
8	61 (24.0%)	52 (20.3%)
9	61 (24.0%)	58 (22.7%)
10	64 (25.2%)	74 (28.9%)
Child sex (n, %)		
Male	79 (30.9%)	79 (31.1%)
Female	175 (68.9%)	177 (69.1%)
Baseline EQ-5D-Y child self-report utilities (mean (SD))	0.5737 (0.34)	0.5506 (0.35)
Baseline CHU9D utilities (mean (SD))	0.6948 (0.13)	0.6899 (0.13)
GCSE; General certificate of secondary education No missing data were observed for the categorical baseline characteristics presented		

Table 2: Completeness rates for health-related quality of life and wellbeing measures across follow-up time points

Variable	Overall, N = 510[1]	PP, N = 254[1]	SEP, N = 256[1]
EQ-5D-Y-3L Baseline	416 (82)	214 (84)	202 (79)
EQ-5D-Y-3L 6 months	243 (48)	122 (48)	121 (47)
EQ-5D-Y-3L 15 months	187 (37)	96 (38)	91 (36)
CHU9D Baseline	415 (81)	214 (84)	201 (79)
CHU9D 6 months	239 (47)	118 (46)	121 (47)
CHU9D 15 months	190 (37)	97 (38)	93 (36)
EQ-5D-Y-3L proxy Baseline	484 (95)	240 (94)	244 (95)
EQ-5D-Y-3L proxy 6 months	232 (45)	114 (45)	118 (46)
EQ-5D-Y-3L proxy 15 months	191 (37)	97 (38)	94 (37)
EQ-5D-5L (parent self-report) Baseline	486 (95)	243 (96)	243 (95)
EQ-5D-5L (parent self-report) 6 months	230 (45)	114 (45)	116 (45)
EQ-5D-5L (parent self-report) 15 months	190 (37)	97 (38)	93 (36)
SWEMWBS (parent self-report) Baseline	495 (97)	246 (97)	249 (97)
SWEMWBS (parent self-report) 6 months	233 (46)	114 (45)	119 (46)
SWEMWBS (parent self-report) 15 months	191 (37)	95 (37)	96 (38)
Complete information to calculate QALY	138 (27)	74 (29)	64 (25)

[1]N (% not missing)

Table 3: Completeness rates for resource use data across follow-up time points

Variable	Overall, N = 510[1]	PP, N = 254[1]	SEP, N = 256[1]
Inpatient care (baseline[2])	487 (95)	244 (96)	243 (95)
Inpatient care (6 months)	225 (44)	111 (44)	114 (45)
Inpatient care (15 months)	188 (37)	92 (36)	96 (38)
Outpatient and day care (baseline[2])	489 (96)	244 (96)	245 (96)
Outpatient and day care (6 months)	225 (44)	111 (44)	114 (45)
Outpatient and day care (15 months)	186 (36)	90 (35)	96 (38)
Community-based health and social service (baseline[2])	485 (95)	241 (95)	244 (95)
Community-based health and social service (6 months)	222 (44)	109 (43)	113 (44)
Community-based health and social service (15 months)	180 (35)	86 (34)	94 (37)
Prescribed medication (baseline[2])	482 (95)	241 (95)	241 (94)
Prescribed medication (6 months)	222 (44)	109 (43)	113 (44)
Prescribed medication (15 months)	182 (36)	88 (35)	94 (37)
Private health care (baseline[2])	479 (94)	238 (94)	241 (94)
Private health care (6 months)	220 (43)	109 (43)	111 (43)
Private health care (15 months)	182 (36)	88 (35)	94 (37)
SEN support (baseline[2])	477 (94)	239 (94)	238 (93)
SEN support (6 months)	217 (43)	108 (43)	109 (43)
SEN support (15 months)	181 (35)	86 (34)	95 (37)
Lost productivity (baseline[2])	477 (94)	240 (94)	237 (93)
Lost productivity (6 months)	218 (43)	107 (42)	111 (43)
Lost productivity (15 months)	183 (36)	88 (35)	95 (37)
Other expenses (baseline[2])	475 (93)	238 (94)	237 (93)
Other expenses (6 months)	214 (42)	106 (42)	108 (42)
Other expenses (15 months)	180 (35)	88 (35)	92 (36)
Complete information to calculate Total costs	140 (27)	69 (27)	71 (28)

[1]N (% not missing)

[2] This relates to resource use for the 3 months prior to randomisation

SEN Special educational needs

Table 4: Cost-effectiveness results from primary and sensitivity analyses

Scenario	Treatment group, mean (SE) Cost		Incremental cost (95% CI)	Treatment group, mean (SE) QALY		Incremental QALYs (95% CI)	ICER*
	SEP	PP		SEP	PP		
Base case analysis							
Imputed costs and QALYs, adjusted[1] (N=510)	£1758.55 (246.47)	£2397.85 (299.21)	£639.30 (£272 to £988)	0.769 (0.02)	0.781 (0.02)	0.0126 (-0.0206 to 0.0417)	£59,734 (NE Quadrant)
Sensitivity analyses							
Inclusion of societal costs (N=510)	£3079.04 (348.82)	£4178.81 (440.46)	£1099.77 (£512 to £1642)	0.769 (0.02)	0.781 (0.02)	0.0126 (-0.0206 to 0.0417)	£102,023 (NE Quadrant)
Complete case analysis (N=40)	£1737.82 (747.47)	£641.42 (534.91)	-£1096.39 (-£2964 to £771)	0.747 (0.07)	0.868 (0.05)	0.1204 (-0.0527 to 0.2934)	-£9,106 (SE Quadrant)
Using QALYS based on CHU9D, imputed and adjusted[1] (N=510)	£1758.55 (246.47)	£2397.85 (299.21)	£639.30 (£272 to £988)	0.892 (0.01)	0.894 (0.01)	0.0019 (-0.0126 to 0.0157)	£409,254 (NE Quadrant)
Using QALYS based on EQ-5D-Y proxy, imputed and adjusted[1] (N=510)	£1758.55 (246.47)	£2397.85 (299.21)	£639.30 (£272 to £988)	0.887 (0.02)	0.866 (0.02)	-0.0210 (-0.0557 to 0.0197)	-£34,970 (NW Quadrant)
[2]Using QALYS based on EQ-5D-Y (German tariff), imputed and adjusted[1] (N=510)	£1,892.23 (274.35)	£2,443.49 (293.40)	£551.26 (-£189 to £1,291)	0.879 (0.02)	0.890 (0.01)	0.0106 (-0.0296 to 0.0508)	£61,545 (NE Quadrant)
30% chance of positive screening, imputed and adjusted[1] (N=510)	£1758.55 (246.47)	£2396.49 (299.21)	£637.95 (£275 to £982)	0.769 (0.02)	0.781 (0.02)	0.0126 (-0.0206 to 0.0417)	£60,260 (NE Quadrant)
0.25% FTE for platform maintenance, imputed and adjusted[1] (N=510)	£1758.55 (246.47)	£2394.12 (299.21)	£635.58 (£273 to £980)	0.769 (0.02)	0.781 (0.02)	0.0126 (-0.0206 to 0.0417)	£60,033 (NE Quadrant)
1 FTE for platform maintenance, imputed and adjusted[1] (N=510)	£1758.55 (246.47)	£2405.32 (299.21)	£646 (£284 to £991)	0.769 (0.02)	0.781 (0.02)	0.0126 (-0.0206 to 0.0417)	£61,106
Imputed (MNAR) costs and QALYs, adjusted[1] (N=510)	£1886.88 (372.86)	£2300.65 (310.64)	£413.77 (-£374 to 1201)	0.779 (0.03)	0.779 (0.02)	-0.0009 (-0.0605 to 0.0303)	£459,744

All models estimated using SUREG

*ICER: Incremental cost-effectiveness ratio (reported as mean bootstrap ICER). Dominance indicates average costs were less and average benefit greater for PP vs. standard educational package

[1]cost equation adjusted for baseline/pre-randomisation public sector costs, primary parent sex, and number of parents/carers involved at baseline. QALY equation adjusted for baseline utility, primary parent sex, and number of parents/carers involved at baseline. Primary parent sex and number of parents/carers were prespecified randomisation stratification/minimisation variables measured before randomisation.

[2] German tariff scenario used a different imputed dataset, so cost estimates are not directly numerically identical to base case.

Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Figure 1: Cost-effectiveness plane, base case (Imputed costs and QALYs, adjusted)

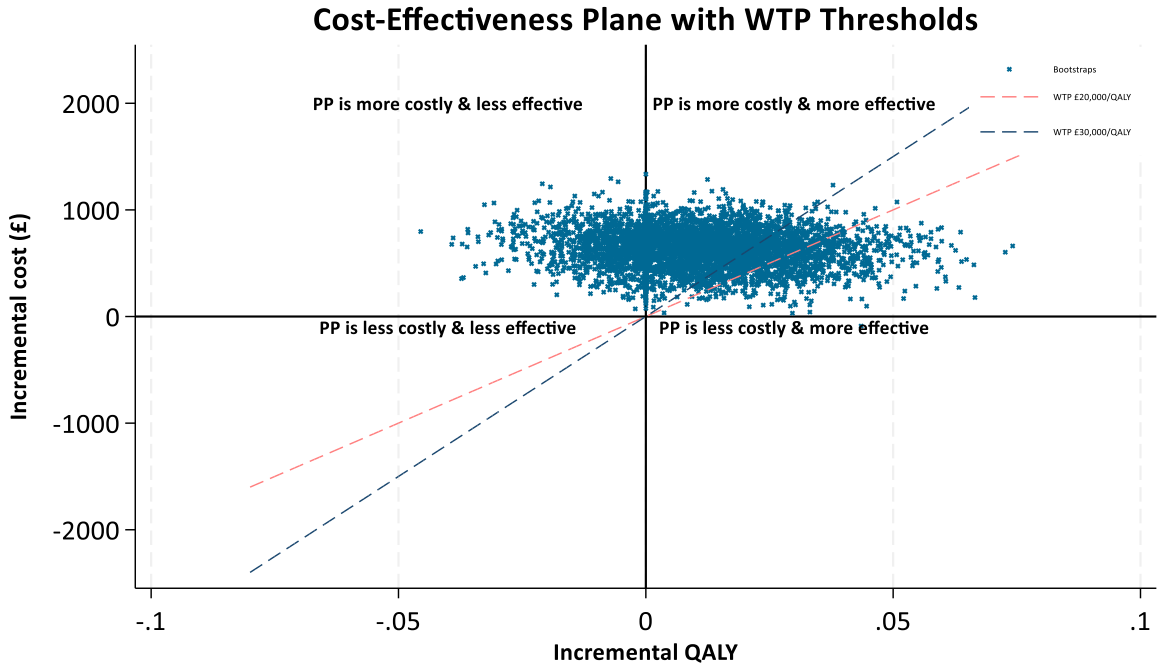
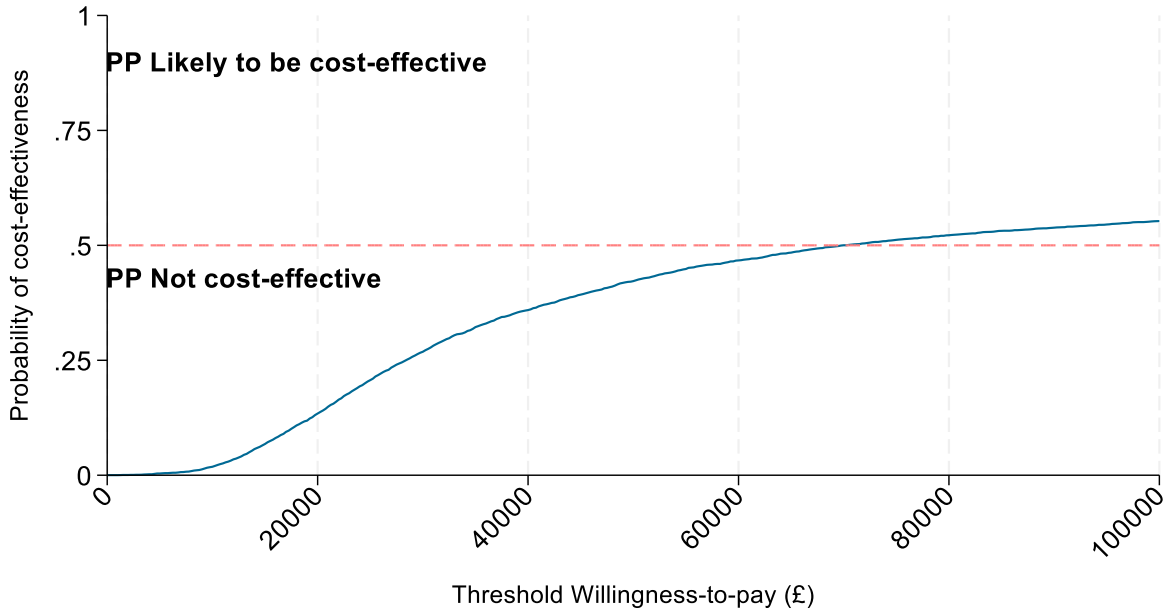


Figure 2: Cost-Effectiveness Acceptability Curve (CEAC), base case (Imputed costs and QALYs, adjusted)



Highlights

- Online parenting programme for high-risk adolescents evaluated
- Trial-based cost-utility analysis (512 families)
- Small QALY gain (0.013) with higher mean costs
- 13–27% probability of cost-effectiveness
- No statistically significant cost-effectiveness advantage