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Dwayne Boyers, Moira Cruickshank, Mohammad Azharuddin, Paul Manson, Diane Swallow, Carl Counsell and Miriam Brazzelli

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Extended Research Article

Digitally enabled therapy for chronic tic disorders and Tourette Syndrome: a systematic review and economic evaluation

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This article

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Abstract

Background: Chronic tic disorders and Tourette syndrome typically present around age 5, with peak severity between ages 10 and 12. Treatment approaches vary by country and service availability and include psychoeducation, behavioural therapy, pharmacological therapies and deep brain stimulation. Digitally enabled interventions may improve outcomes.

Objectives: We evaluate the clinical and cost-effectiveness of two digital technologies, Online Remote Behavioural Treatment for Tics and Neupulse and identify evidence gaps for future research.

Methods: We searched major electronic databases (MEDLINE, EMBASE, Cochrane Library, Web of Science, and Cumulative Index to Nursing and Allied Health Literature) for published studies on clinical and cost-effectiveness. Data were extracted, assessed for bias using Cochrane risk-of-bias tool (version 2), and pooled using random-effects meta-analysis where appropriate. Cost-effectiveness was evaluated using a Markov cohort model with five tic severity states based on the Yale Global Tic Severity Scale – Total Tic Severity Score scale, from a United Kingdom National Health Service perspective. Model inputs were obtained from the Online Remote Behavioural Treatment for Tics study, company data, expert opinion and additional literature.

Results: We identified three trials reported across 14 publications: 2 comparing Online Remote Behavioural Treatment for Tics with online psychoeducation, and 1 comparing Neupulse with sham stimulation and a waitlist control. All were assessed as low risk of bias. Meta-analysis of the 2 Online Remote Behavioural Treatment for Tics studies (445 participants) showed significantly lower Yale Global Tic Severity Scale – Total Tic Severity Score at 3 and 12 months compared to online psychoeducation. Results of secondary outcomes were mixed. Neupulse showed significantly lower Yale Global Tic Severity Scale – Total Tic Severity Score, and improvements in motor and phonic tic scores at 4 weeks compared to sham, but no differences in Yale Global Tic Severity Scale-Impairment or Premonitory Urge for Tics Scale – Revised scores.

A definitive base-case incremental cost-effectiveness ratio could not be determined due to limited long-term data and uncertainty around long-term combinations of effectiveness and intervention costs in United Kingdom National Health Service practice. Probabilistic incremental cost-effectiveness ratios ranged from £642 per quality-adjusted life-year gained to Online Remote Behavioural Treatment for Tics being dominated. The probability of Online Remote Behavioural Treatment for Tics being cost-effective at a threshold value of £20,000 per quality-adjusted life-year ranged from 52% to 89% across a range of scenarios. Cost-effectiveness results for Neupulse were even more uncertain due to a lack of published data, only a 4-week follow-up and uncertainty surrounding the intervention cost.

Limitations: Evidence for Online Remote Behavioural Treatment for Tics and Neupulse was limited, with inconsistencies in the outcomes assessed. Comparators did not include face-to-face behavioural therapy and it was not possible to differentiate the effects of online delivery from those of exposure and response prevention. Cost-effectiveness results are uncertain due to a lack of long-term data.

Conclusions: Both Online Remote Behavioural Treatment for Tics and Neupulse appear to significantly reduce Yale Global Tic Severity Scale – Total Tic Severity Score, but there were no improvements in the Yale Global Tic Severity Scale-Impairment scores and mixed results across other secondary outcomes, meaning it is unclear to what extent improvements in tic severity scores can translate to improvements in quality of life. Cost-effectiveness estimates were highly uncertain due to a lack of long-term evidence.

Future studies: Replication studies are needed to confirm findings. Longer follow-up – particularly for Neupulse – is essential to understand sustained effects and long-term cost-effectiveness. More data on the natural course of tic severity and the sustainability of treatment effects would reduce uncertainty in economic modelling. Future research should also prioritise outcomes that reflect real-life impact on people's daily functioning.

Study registration: This study is registered as PROSPERO CRD42024508045.

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List of abbreviations

ADHD	attention deficit hyperactivity disorder
AE	adverse event
ASD	autism spectrum disorder
BiP	Barninternetprojektet (Child Internet Project; Swedish digital platform)
C&A-GTS-QOL	Child and Adolescent Gilles de la Tourette Syndrome Quality of Life scale
CBIT	Comprehensive Behavioural Intervention for Tics
CEA	cost-effectiveness analysis
CEAC	cost-effectiveness acceptability curve
CGAS	Children's Global Assessment Scale
CGI-I	Clinical Global Impression Improvement
CGI-S	Clinical Global Impression Severity
CHU-9D	Child Health Utility-9 Dimensions
CI	confidence interval
CINAHL	Cumulative Index to Nursing and Allied Health Literature
CTD	chronic tic disorder
CYPMHS	Children and Young People's Mental Health Services
DBS	deep brain stimulation
EAG	External Assessment Group
EQ-5D	EuroQol-5 Dimensions
ERP	Exposure and Response Prevention
HRQoL	health-related quality of life
HRT	Habit Reversal Training
HSUV	health state utility value
ICER	incremental cost-effectiveness ratio
MNS	median nerve stimulation
N/A	not applicable
NICE	National Institute for Health and Care Excellence
NMB	net monetary benefit
OCD	obsessive–compulsive disorder
ORBIT	Online Remote Behavioural Treatment for Tics
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
PSA	propensity score analysis
PTQ	Parent Tic Questionnaire
QALY	quality-adjusted life-year
QoL	quality of life
RCT	randomised controlled trial
TENS	transcutaneous electrical nerve stimulation
TS	Tourette syndrome
TTSS	Total Tic Severity Score
WTP	willingness to pay
YGTSS	Yale Global Tic Severity Scale
YGTSS-TTSS	Yale Global Tic Severity Scale – Total Tic Severity Score

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Note

This manuscript is based on the Technology Assessment Report produced for NICE. The full report contained a considerable number of data that were deemed confidential. The full report was used by the Appraisal Committee at NICE in their deliberations. The full report with each piece of confidential data removed and replaced by the statement 'confidential information (or data) removed' is available on the NICE website: www.nice.org.uk.

The present article presents as full a version of the report as is possible while retaining readability, but some sections, sentences, tables and figures have been removed. Readers should bear in mind that the discussion, conclusions and implications for practice and research are based on all the data considered in the original full NICE report.

Plain language summary

Tic disorders involve quick, repetitive muscle movements. Motor tics involve movements such as blinking and grimacing, while vocal tics involve sounds like grunting or sniffing. They usually start around age 5 and peak between ages 10 and 12. If tics persist over a year, the condition is called a chronic tic disorder. Tourette syndrome includes multiple motor tics and at least one vocal tic.

In the United Kingdom, tic disorder treatments include psychoeducation (giving information to encourage acceptance of the tic disorder), medication and behavioural therapy (training the person to recognise when a tic is looming and how to quell it). However, limited specialist access leads to long waiting times. Digital interventions may offer a solution. This work evaluates existing evidence for digitally enabled interventions with respect to clinical usefulness, cost and value for money.

We reviewed current evidence and found two technologies – Online Remote Behavioural Treatment for Tics and Neupulse – studied in three high-quality studies. Online Remote Behavioural Treatment for Tics is an online behavioural intervention for tics assessed in two trials (one in the United Kingdom and the other in Sweden) with participants aged 9–17. Neupulse is a wrist-worn device that uses mild electrical stimulation, assessed in one United Kingdom study among people aged 12 and older. Online Remote Behavioural Treatment for Tics showed greater reduction in tic severity than online psychoeducation at 3 and 12 months. Neupulse also reduced tic severity after 4 weeks. However, neither showed consistent pattern of improvements in other areas of people's lives.

When we looked at value for money, it was unclear whether these treatments lead to long-term improvements in quality of life, and the long-term costs remain uncertain. Longer-term studies of Neupulse are needed to determine its value for money to the National Health Service. For Online Remote Behavioural Treatment for Tics, more evidence on the duration of positive treatment effects after treatment discontinuation would help clarify its value compared to psychoeducation.

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Scientific summary

Background

Tic disorders are neurodevelopmental conditions characterised by fast, irregular and repetitive muscle movements that can manifest in any part of the body. Tics can affect body movements (known as motor tics), while involuntary repetitive sounds are known as vocal or phonic tics. Persistent or chronic tic disorders (CTDs) refer to single or multiple motor or vocal tics (but not both) that have persisted for more than 12 months since the first tic onset. Tourette syndrome (TS) refers to multiple motor tics and one or more vocal tics that have been present at the same time (but not necessarily concurrently) during the course of the disease and have persisted for more than 12 months since the first tic onset. The mean age of onset for tic disorders is around 5 years, with severity typically worsening between 10 and 12 years of age and then improving through adolescence into early adulthood. People with CTDs commonly experience psychiatric comorbidities, such as attention deficit hyperactivity disorder and obsessive–compulsive disorder. Tic disorders can vary in severity and impact various aspects of people's lives, contributing to a reduced quality of life (QoL). Current practice varies between countries and according to the availability of local services, but, in general, treatment options for CTDs include psychoeducation, behavioural therapy, pharmacological therapy and deep brain stimulation. Digitally enabled interventions have the potential to improve access as well as equity of access to treatment for people with tic disorders.

Objectives

The specific objectives of this assessment were to:

- Evaluate the safety and effectiveness of digitally enabled non-pharmacological therapy for treating CTDs and TS in UK clinical practice [Online Remote Behavioural Treatment for Tics (ORBIT) and Neupulse].
- Develop an economic model to assess the cost-effectiveness of digitally enabled technologies for the non-pharmacological treatment of CTDs that are available or likely to become available in UK clinical practice.

Methods

This manuscript contains reference to confidential information provided as part of the NICE appraisal process. This information has been removed from the report and the results, discussions and conclusions of the report do not include the confidential information. These sections are clearly marked in the report.

Clinical effectiveness

Comprehensive searches of major electronic databases, including MEDLINE, EMBASE, Cochrane Library, Web of Science and Cumulative Index to Nursing and Allied Health Literature, were conducted to identify relevant reports of published studies. Evidence was considered from randomised controlled trials and non-randomised comparative studies published in English and assessing the relevant digitally enabled technologies. Data on the characteristics of the studies, participants' intervention and comparator were extracted along with relevant patient-reported, clinical and intermediate outcomes, as well as information relating to the use of digital technologies. The risk of bias of included studies was assessed using the Cochrane risk-of-bias tool (version 2). Where sufficient data were available and it was appropriate, data were pooled using random-effects meta-analyses.

Cost effectiveness

A systematic literature search for all full economic evaluation studies of interventions for tic disorders in adults or children was conducted. A decision-analytic, Markov cohort, model was developed, based on the ORBIT study, to assess the cost-effectiveness of ORBIT compared to online psychoeducation and Neupulse compared to a waiting list control. The model base case was run for a lifetime horizon and results reported as incremental cost per quality-adjusted life-

year (QALY) gained from a UK NHS perspective. Costs and outcomes occurring beyond the first year were discounted at 3.5% per annum. Five health states were included in the model. Health states were defined according to quintiles of the Yale Global Tic Severity Scale – Total Tic Severity Score (YGTSS-TTSS) (very mild, mild, moderate, severe and very severe tics). Transition probabilities between health states were obtained up to 18 months from the ORBIT study and up to 4 weeks from unpublished data obtained through personal communication with the company for Neupulse. Given uncertainty surrounding the long-term outcomes of Neupulse, the External Assessment Group (EAG) consider this comparison to be more in line with National Institute for Health and Care Excellence's early value assessment approach. Intervention costs were obtained from the published literature and directly from companies. Health state costs and Child Health Utility-9 Dimensions utilities were based on data reported within the ORBIT study. The model was fully probabilistic, and a range of scenario analyses were undertaken to explore uncertainty in the base-case conclusions.

Results

Nature, description and quality of the available evidence

The database search identified 379 unique publications, and three further reports were identified. Three trials reported in 14 publications were included in the review. Two studies compared ORBIT with psychoeducation (one in the UK and the other in Sweden) and one UK-based study Neupulse active stimulation with sham stimulation. The two ORBIT studies recruited people aged 9–17, and the Neupulse study recruited people aged at least 12 years. All three studies were assessed as being at low risk of bias according to the Cochrane risk-of-bias tool (version 2).

Summary of benefits and risks

We were able to combine results of two outcomes assessed at two time points across the two ORBIT studies (445 participants in total). Pooled results at 3 and 12 months for YGTSS-TTSS in the ORBIT studies showed statistically significantly lower scores for the intervention groups than the control groups. However, no significant improvements in tic-related impairment and distress measured using the impairment score of the YGTSS were observed between treatment groups. In each ORBIT study, secondary outcome measures did not show a consistently greater response in the exposure and response prevention (ERP) group compared to the psychoeducation group at all assessed time points. In the UK ORBIT study, Clinical Global Impressions Improvement showed a greater response in the ERP group at 3, 12 and 18 months but not at 6 months. In the Swedish ORBIT study, Clinical Global Impressions Severity showed a difference in favour of the ERP group at 3 months, but not at 6 months. In both studies, the Children's Global Assessment Scale showed no differences between intervention groups at 3 months and a positive difference in favour of the ECHURP group at 12 and 18 months in the UK ORBIT study. The estimated mean difference in the Parent Tic Questionnaire favoured the ERP group in the UK ORBIT study at 3, 6 and 12 months but not at 18 months and was not significant at 3 and 12 months in the Swedish ORBIT study. Similarly, in the UK ORBIT study, other measures evaluating anxiety and mood, emotional and behavioural functioning did not show a consistent pattern of response at all assessed time points. In general, participants' engagement with the interventions, adherence and dropouts were reported to be similar between intervention groups.

The Neupulse study reported statistically significantly lower YGTSS-TTSS scores at 4 weeks in the active stimulation group compared to the sham stimulation group. Greater reductions in YGTSS motor and phonic scores were also observed among participants receiving active stimulation than among those receiving sham stimulation. However, no significant differences between treatment groups were observed for the YGTSS-Impairment score or the Premonitory Urge for Tics Scale – Revised.

Summary of costs and cost-effectiveness

It was not possible to determine a definitive base-case incremental cost-effectiveness ratio (ICER) due to a lack of long-term follow-up data and uncertainty about the long-term intervention costs that might be required to maintain, if possible, intervention effectiveness at the observed trial follow-up time points. For the comparison of ORBIT versus online psychoeducation, transition probabilities were broadly similar in both groups, suggesting a lack of clear evidence of long-term benefit. This was reflected in substantial uncertainty surrounding the estimated ICERs. Probabilistic ICERs ranged from £642 per QALY gained to ORBIT being dominated. The probability of ORBIT being cost-effective at a threshold value of £20,000 per QALY ranged from 52% to 89% across a range of scenarios explored.

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Cost-effectiveness results for Neupulse were highly uncertain due to a lack of published transition probability data, short 4-week follow-up and uncertainty surrounding the most likely intervention device and subscription costs if the device were rolled out to the UK NHS. Transition probabilities were based on small counts, and longer follow-up is required to determine whether initially optimistic Neupulse improvements can be sustained in the longer term.

Conclusions

Two studies comparing ORBIT with psychoeducation (one each in the UK and Sweden) and one UK study comparing active stimulation with sham stimulation showed that tic severity in terms of YGTSS-TTSS scores was lower in the intervention groups as compared to the comparator groups at follow-up periods ranging from 4 weeks to 12 months. No improvements in the YGTSS-Impairment scores were evident, and secondary outcome measures showed a mixed response across time points and ORBIT studies. The EAG do not consider it possible to make any recommendations in favour, or against Neupulse, given the current evidence base for cost-effectiveness. The evidence base for ORBIT is stronger. ORBIT appears to be cost-effective over shorter modelling time horizons compared to psychoeducation, but there remains some uncertainties regarding the long-term trajectory of disease and long-term maintenance of treatment benefit beyond 18 months.

Strengths, limitations and uncertainties

Thorough and robust methods were used for this assessment. However, there was limited evidence available for the technologies of interest and inconsistencies in the outcomes assessed, and their timing and further meaningful analyses were hampered. The comparators of the included studies did not include face-to-face behavioural therapy and it is not possible to differentiate the effects of online delivery from those of ERP. The reason(s) for selection of only the YGTSS-TTSS score as the primary outcome in the included studies, rather than the YGTSS-Impairment score, is unclear. Currently, available data for Neupulse refer to stimulation delivered for a maximum period of 4 weeks.

Published transition probabilities were not available for Neupulse and the intervention cost that might be incurred if the device were used in NHS practice is unclear. Economic modelling required several major assumptions around the most appropriate long-term extrapolations of clinical benefit in the model and what, if any, intervention costs would be required to maintain observed treatment effectiveness over the longer term.

Key areas for future research

- Replication of studies is needed to confirm observed results.
- Future studies should be of longer duration and compare the clinical and cost-effectiveness of digitally enabled with face-to-face behavioural therapy. In addition, inclusion of a non-active intervention, such as waitlist, would allow the natural course of the disease to be monitored over time.
- Future studies should consider the impact of interventions on participants' daily lives as the primary outcome.
- Appropriate subgroup analyses according to sex and common comorbidities should be planned in future studies.
- Future studies should include economic evaluations and collect longitudinal data to improve long-term modelling of treatment effectiveness. Emphasis should be placed on determining the impact clinical outcomes on QoL and costs.

Study registration

This study is registered as PROSPERO CRD42024508045.

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Chapter 1 Background and definition of the decision problem

Tic disorders are neurodevelopmental conditions characterised by fast, irregular and repetitive muscle movements that can manifest in any part of the body. Tics that affect body movements (e.g. blinking, grimacing, head jerking, head banging, finger clicking) are known as motor tics, while involuntary repetitive sounds, such as grunting, sniffing or throat clearing, are known as vocal or phonic tics. Tic disorders manifest more often in boys than girls with a ratio between 3 : 1 and 4 : 1.[1–4] There are several types of tic disorders according to their manifestation and frequency. Transient or provisional tic disorders refer to single or multiple motor and/or vocal tics that have been present for < 12 months since the first tic onset. Persistent or chronic tic disorder (CTD) refer to single or multiple motor or vocal tics (but not both) that have persisted for more than 12 months since the first tic onset. Tourette syndrome (TS) refers to multiple motor tics and one or more vocal tics that have been present at the same time (but not necessarily concurrently) during the course of the disease and have persisted for more than 12 months since the first tic onset. In all cases, onset is before the age of 18 years, and the tics are not attributable to the physiological effects of a substance (e.g. cocaine) or other medical conditions (e.g. Huntington's disease, post-viral encephalitis).[5]

The mean age of onset for tic disorders is approximately 5 years, although it can be lower in up to 40% of patients.[4,6] Typically, the severity of tic disorders worsens between 10 and 12 years of age and improves naturally during adolescence and early adulthood.[7,8] In children and young people, tics tend to come and go, while in adults, they show a more persistent pattern.[9] Psychiatric comorbidities are common among people who suffer from CTDs.[10] People with TS or CTDs often experience associated psychiatric conditions, such as attention deficit hyperactivity disorder (ADHD) (30–54% of people) and obsessive–compulsive disorder (OCD) (10–50% of people).[11] Other common comorbidities which are highly associated with comorbid OCD and ADHD in people with CTDs include mood disorders, disruptive behaviour and anxiety (30% of people).[6,11] Comorbid mood disorders tend to be observed more frequently in adolescents and adults than in children.[12] Independent of ADHD and OCD comorbidities, TS has also been reported to be associated with an increased risk of anxiety.[6]

Most prevalence studies of TS have focused specifically on children and young people, with few or less reliable data on adults. Internationally, the prevalence of TS in young people in the community has been reported to be between 0.4% and 3.8%.[2] In the UK, TS is identified in 1 per 100 school children.[13] A meta-analysis published in 2012 reported a pooled prevalence rate of 0.77% [95% confidence interval (CI) 0.39% to 1.51%] in children (13 studies) and of 0.05% (95% CI 0.03% to 0.08%) in adults (2 studies).[14] A more recent meta-analysis suggested that the adulthood prevalence of TS is around 118 cases per million adults (95% CI 19 to 751 cases per million adults) but with considerable heterogeneity between prevalence studies.[15]

Tic disorders can vary in severity and impact various aspects of people's lives, contributing to a reduced quality of life (QoL). It is not uncommon for people with tic disorders, particularly when the illness is more severe, to experience serious social issues, such as extensive stigma, public avoidance and discrimination.[10,16] Severe long-lasting tic disorders are also associated with a fourfold increased risk of suicide.[17]

The clinical pathway, management and treatment options are the same for all tic disorders.

Current management and clinical pathway

At present, in the UK, there are specific national guidelines for the assessment, management and referral of neurodevelopmental conditions such as AHDH and autism.[18–20] However, a comprehensive clinical guideline for the diagnosis and management of tic disorders in children and young people does not exist. The National Institute for Health and Care Excellence (NICE) guideline 127 on 'Suspected neurological conditions: recognition and referral' contains some information on tic disorders and indicates that (1) children or young people with tic disorders, that significantly interfere with their ability to function in their daily lives, should be referred to specialist mental

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health services, neurodevelopmental teams or for neurological assessment; (2) adults with tic disorders should be considered for neurological assessment if their symptoms are severe and the disorder continues to cause distress.[21] Current international guidelines and recommendations include the European clinical guidelines for Tourette and other tic disorders, the Canadian guidelines for the evidence-based treatment of tic disorders, practice guideline recommendations summary for TS and CTDs from the American Academy of Neurology, and BMJ Best Practice Tic disorders.[12,13,22–24]

Symptoms of tic disorders may be reported by people themselves or for children or young people identified by their parents/carers or school educators. In the UK, people with tic disorders attend an initial appointment with a general practitioner working in primary care. When the presence of a tic disorder is recognised to have a significant impact on people's QoL, a referral is usually made to appropriate secondary or tertiary care services (depending on the presentation, comorbidities, and local specialist clinics).[17,24]

For children and young people, referrals may be made to mental health services [including the Children and Young People's Mental Health Services (CYPMHS)] neurodevelopmental teams, paediatric or neurology teams dependent on local services. For adults, referrals are usually made to neurological services.

As tics may improve with time, the NICE guideline 127 indicates that for individuals presenting in primary care a watch-and-wait approach is considered acceptable, especially for those who do not experience any functional impairment.[21]

Current practice varies between countries and according to the availability of local services but, in general, treatment options for CTDs include psychoeducation, behavioural therapy, pharmacological therapy, and deep brain stimulation (DBS).

Psychoeducation for patients, their families, teachers, and peers, which aims to reduce stigma and distress and increase awareness of the illness, is regarded as the initial approach to treating all tic disorders. This includes information on the natural waxing and waning course of the disorder, which is favourable in most cases, on what can worsen tics, such as stress, anxiety and excitement, and on the importance of avoiding focusing on the presence of tics. An assessment of concomitant psychiatric and mood disorders [e.g. ADHD, OCD, autism spectrum disorder (ASD), anxiety] should also be considered, as these may further aggravate the patients' emotional, behavioural and social functioning.[13] In many cases, people with tic disorders may not require further treatment aside from psychoeducation and observation (watch and wait approach).[24]

However, it has been reported that in the UK psychoeducation is rarely provided by general practitioners in the first appointment, and many people with tic disorders do not receive advice on how to manage their tics or information on treatment options.[17,24]

Current international guidelines recommend the use of *behavioural therapy* as the first-line intervention for tic disorders in both children and young people and adults.[12,22,23,25] The behavioural approaches with more robust evidence of efficacy are habit reversal training (HRT), comprehensive behavioural intervention for tics (CBIT) and the efficacy of exposure and response prevention (ERP).[12] With HRT the patient is trained to perform a voluntary movement, which is physically incompatible with the performance of the tic until the urge (unpleasant internal stimulus) to perform the tic goes away. The CBIT utilises the same components of HRT alongside relaxation training and functional interventions to tackle factors that may provoke or exacerbate tics.[24] The ERP aims to break the association between the urge and the tic by asking the patient to suppress the tics for prolonged periods using various cognitive tools.[23] However, due to a shortage of trained therapists, behavioural therapy is only available in a small number of specialist centres, and only about 20% of people with tic disorders have access to it.[17] Therefore, digitally enabled interventions have the potential to improve access as well as equity of access to treatment for people with tic disorders.

Concerning *pharmacological therapy*, there is some evidence that α2-adrenergic receptor agonists (e.g. clonidine, guanfacine) and antipsychotic drugs (e.g. risperidone, haloperidol) are effective in the short term.[26–28] Antipsychotic drugs, due to their adverse effect profile, are mostly considered for the treatment of severe tics when α2-adrenergic receptor agonists are not effective or not tolerated. The decision about the type and dosage of pharmacological therapy

should be provided by a health professional with experience in the management of tic disorders after taking into consideration the presence of comorbidities, which may affect the patient's treatment response.[24]

Deep brain stimulation in specialised centres has been proposed for patients with severe tics that are refractory to behavioural and pharmacological interventions.[12,13] There is, however, little information on the effects of DBS in children and young people with CTDs to support its use in clinical practice.[23,24] The largest DBS randomised cross-over trial published in 2015 indicated some possible benefits for adults with TS but also highlighted several methodological challenges in the design of brain stimulation studies.[12,29,30] Similarly, the prospective International DBS Database and Registry published in 2018, which included 185 patients with medically refractory TS who underwent DBS implantation, showed that DBS was associated with improvement in patients' symptoms but also with important adverse events (AEs).[31]

Alternative treatments such as dietary supplements, fish oils, acupuncture and antibiotics have also been proposed for tic disorders, but the rationale and evidence of their efficacy is still unclear or insufficient.[24]

Novel treatment options such as median nerve stimulation (MNS) are currently under investigation. Results from a recent open-label comparative study assessing 27 people (15–64 years of age) with CTDs suggest that MNS may improve the frequency and intensity of tics with minimal side effects.[24,32]

Description of the technologies of interest

The technologies considered for this appraisal are digital technologies that enable the remote/online delivery of therapeutic intervention to people with CTDs or TS. These interventions should only be considered provided the person (and parent or carer where appropriate) have had access to a form of psychoeducation. If the tic disorder continues to cause difficulties, a clinician may consider referring people for these proposed interventions. These technologies should have received or are likely to receive appropriate regulatory approval (e.g. Conformité Européenne or European Conformity [CE] mark/UK Conformity Assessed [UKCA] mark and Digital Technology Assessment Criteria [DTAC] compliance), should be available or likely to be soon available to the NHS and should have online guided contact with a practitioner as part of the programme, or clinician oversight with the intervention for user safety. We have identified two digitally enabled technologies (*Table 1*) for the treatment of people with CTDs: *Online Remote Behavioural Treatment for Tics (ORBIT)* and *Neupulse*.[24]

The *ORBIT (MindTech)* is an online therapeutic intervention which aims to reduce tic severity in children and young people with tic disorders. The ORBIT treatment programme was developed from an existing research platform Barninternetprojektet (Child Internet Project; Swedish digital platform) in Sweden, which was designed to be age-appropriate in appearance for use by children and their parents and included animations and interactive scripts. The platform has been used to deliver internet-based therapy for conditions such as phobia, anxiety and OCD. ORBIT provides a form of behavioural therapy called exposure and response prevention, which is supported by an online therapist across a 10-week programme. It is delivered on a secure internet platform and includes 10 self-help guided chapters followed by ERP tasks. Through the ORBIT programme, patients practise controlling their tics for increasingly long periods and then deliberately provoke urges while not releasing any tics. Related interventions are delivered to the patient's parent/supporter on the same time scale. The therapist has 10–20 minutes of contact time with the family each week and promotes engagement with the intervention as well as answering any questions rather than delivering therapeutic content.[33–35] ORBIT has been studied as part of NIHR-funded UK-based trials which have reported it to be a clinically and cost-effective intervention at up to 18 months.[34,35] ORBIT does not require CE marking as it is not considered a medical device. At present, the investigators are working towards DTAC compliance.[24]

Neupulse (developed by Neurotherapeutics Ltd) is a wearable wrist-worn neuromodulation device with a corresponding phone app which provides a novel approach to reduce tic frequency and severity. The device addresses the imbalances in neural activity which are associated with tics and premonitory urges by modulating neural oscillations within the brain's sensorimotor networks. No active effort is required of the user to reduce these symptoms (besides turning on the device), which delivers low-intensity electrical pulses to the median nerve (MNS). Currently, the device has been

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TABLE 1 Summary of the characteristics of the devices considered for this assessment

Device name	ORBIT (MindTech)	Neupulse (neurotherapeutics) clinical trial	Neupulse (neurotherapeutics) current medical device
Platform	Delivered remotely via the BiP (*Barninternetprokektet*, Swedish for *Child Internet Project*; www.bup.se/BIP/) technical platform, a Swedish web-based platform specifically designed for use by children and their parents with an age-appropriate appearance, animations and interactive scripts. The platform can be accessed via the internet using a smartphone, desktop computer or laptop	Wrist-worn stimulation device designed and approved for a home use trial by the Medicines and Healthcare products Regulatory Agency	Wrist-worn wearable device with hydrogel pad to provide MNS. An accompanying mobile phone app is used to setup and adjust the device
Type of behavioural therapy	Exposure with response prevention (ERP). ERP aims to break the urge-tic-relief cycle of reinforcement while promoting tolerance of premonitory urges and tic suppression. The intervention is delivered in 10 chapters split into child intervention and parent/supporter intervention: 1. Learn about tics/introduction 2. More about tics/thoughts and behaviours of supporters 3. Practising stopping your tics/praise 4. Making the practice more challenging/prompts 5. Continued practice/situations and reactions 6. School/troubleshooting 7. Talk about your tics/continued practice 8. Continued practice/continued practice 9. The final sprint/continued practice 10. Plan for the future/plan for the future	Neuromodulation of the brain's sensorimotor networks using low intensity (1–19 mA) 10 Hz TENS delivered to the median nerve (MNS)	TENS to the MNS at a frequency of 10 Hz with intensity levels (1–14 mA) adjustable via a mobile phone app
Aim of therapy	ERP aims to break the urge-tic-relief cycle of reinforcement while promoting tolerance of premonitory urges and tic suppression	Immediate reduction in tic frequency and complexity during device use and reduction of tic severity after 4 weeks of use	Immediate reduction of urge to tic and tic intensity
Duration	10 weeks	The therapy aims to address the imbalances in neural activity which are associated with tics and premonitory urges by modulating neural oscillations within the brain's sensorimotor networks. The trial device was pre-programmed to deliver once a day rhythmic trains of low intensity electrical stimulation in bursts of 2 minutes of stimulation followed by 1 minute of no stimulation for 14 minutes. Users were instructed to use the device at home for 5 days a week for a month	Intermittent on demand (1 hour session) up to 8 hours depending on battery life Stimulation can be activated "on demand" by users with a maximum individual session time of 1 hour. Session parameters can be adjusted via the app. The default session provides burst stimulation comprising 2 minutes of stimulation followed by 1 minute of no stimulation
Contact with therapist	Remote contact; at least once a week via messages sent inside the treatment platform (resembling an e-mail). The therapist's role is to encourage uptake and adherence to the programme plus troubleshooting and technical support rather than delivering therapeutic content	Remote video: Weekly contact. The therapist completed weekly clinical assessments	Over the counter – no prescription required. No contact with the therapist is required. App can collate symptom monitoring data for review by an HCP Technical support available Change to the pathway is required – as people with TS find it hard to access HCPs

HCP, healthcare professional; TENS, transcutaneous electrical nerve stimulation.

Note
This table includes content reproduced from the research protocol.[24]

assessed for children and young adults aged 12 and over with suspected or diagnosed TS or a chronic (motor or vocal) tic disorder.[24]

Median nerve stimulation is a type of transcutaneous electrical nerve stimulation (TENS) delivered to the wrist. TENS has a long history of therapeutic use and TENS machines are widely available over the counter for use within the community. The Neupulse device produces low-intensity electrical stimulation up to a maximum of 14 mA. It has been shown within a UK double-blind sham control trial to reduce tic frequency when the stimulation is turned on and to be clinically effective with 4 weeks of once-a-day 14-minute use.[36] The rhythmic pattern of medial nerve stimulation used by Neupulse has been shown to increase brain activity associated with movement suppression, without impairing intentional movement or cognitive function.[36,37] The device currently under development for over-the-counter sale will be supported by written and video-based guidance and a technical support helpline. Neupulse is working towards CE and UKCA marking, and it is estimated that the device will be available in 2026.[24]

Population and relevant subgroups

The population of interest is people with a diagnosed primary tic disorder who have had access to psychoeducation; however, their tics continue to be bothersome to them.

Where data permit, the following subgroups were considered:

- Children and young people with diagnosed comorbidities, including ADHD, OCD, ASD, mood disorders and anxiety.
- Adults with CTDs.[24]

Aim and objectives

This assessment aims to establish whether digitally enabled therapy for people with CTDs and TS represents a clinically and cost-effective use of NHS resources.

The specific objectives are:

- to evaluate the safety and effectiveness of digitally enabled non-pharmacological therapy for treating CTDs and TS in UK clinical practice
- to develop an economic model to assess the cost-effectiveness of digitally enabled technologies for the non-pharmacological treatment of CTDs that are available or likely to become available in UK clinical practice.[24]

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Chapter 2 Assessment of clinical effectiveness

Systematic review methods

An objective synthesis of the evidence to evaluate the safety and effectiveness of digitally enabled non-pharmacological therapy as compared to standard care for treating CTDs and TS in UK clinical practice. This assessment was conducted according to current methodological standards. The methods were pre-specified in a research protocol (www.crd.york.ac.uk/prospero/display_record.php?ID=CRD42024508045).

Identification of studies

An Information Specialist developed a comprehensive literature search strategy to identify relevant published peer-reviewed studies. Major electronic databases were searched, including MEDLINE, EMBASE, Cochrane Library, Web of Science, and Cumulative Index to Nursing and Allied Health Literature (CINAHL). The focus of the search initially was on the approved devices listed in the NICE final scope; search facets defining the population of interest were included. There were no restrictions on the date or language of publication at the time of the search. The reference lists of studies selected for full-text appraisal were screened for additional studies. Major clinical trial registries were searched to identify relevant ongoing trials. Websites of manufacturers of appropriate technologies, professional organisations and regulatory bodies were searched to identify additional relevant reports. Any further information on potentially relevant evidence provided by the manufacturers of the technologies of interest was also considered. All references were exported to Endnote for recording and deduplication. A draft MEDLINE search is detailed in *Appendix 1*. The MEDLINE search was adapted to search other electronic databases.[24]

Inclusion and exclusion criteria

The eligibility criteria for the review of clinical effectiveness evidence are summarised in *Table 2*.

Study selection and data extraction

One reviewer, Moira Cruickshank (MC), screened all citations identified by the search strategies. A second reviewer, Miriam Brazzelli (MB), independently screened a random 20% sample (selected using a random number generator, random.org, with selection based on numerical position in the list of citations). Two reviewers (MC, MB) independently assessed each full-text article for eligibility. Reasons for exclusion were documented. The research protocol specified that data extraction had to be conducted by two independent reviewers. However, due to time and resource constraints, one reviewer MC extracted data, which was subsequently cross-checked by a second reviewer MB. A customised Excel data extraction spreadsheet was developed for this assessment. The following information was recorded from each study:

1. Characteristics of studies: first author, year of publication, country, language, setting, inclusion and exclusion criteria.
2. Characteristics of study participants: age, sex, tic typology, comorbidities, number of enrolled participants, number of participants analysed, number of dropouts and reasons for withdrawal, setting.
3. Characteristics of the intervention: digital platform, details of the technology, content of therapy, structure and number of sessions to be completed, duration, type and frequency of contact with a therapist, and therapist's level of expertise.
4. Characteristics of the comparator/control intervention: nature and mode of delivery, duration, type and frequency of contact with a therapist, and therapist's level of expertise.
5. Relevant patient-reported, clinical and intermediate outcome measures, and information related to the use of digital technologies.

At all stages, disagreements were resolved through discussion.[24]

Data synthesis

The findings of each included study were tabulated and summarised narratively for each outcome of interest. We combined results from two of the included studies that were considered sufficiently similar in terms of intervention/comparator, participants and outcome measures.[34,38] We conducted random-effects model meta-analyses to pool

TABLE 2 Eligibility criteria for the review of clinical effectiveness evidence

Population of interest	Children/young people and adults diagnosed with a confirmed primary, CTD
Clinical condition	Primary, CTDs, including TS Transient and secondary tic disorders and functional tic-like behaviours were not considered eligible for inclusion
Technologies under investigation	• ORBIT (MindTech) • Neupulse (Neurotherapeutics)
Comparator intervention	Standard care, including psychoeducation and face-to-face behavioural therapy
Outcome measures	**Intermediate outcome measures** • Intervention-related AEs • Treatment satisfaction and engagement • Intervention adherence, rates of attrition and completion **Clinical outcome measures** • Measures of symptom severity (self, parental or practitioner reported) using validated instruments such as the Yale Global Tic Severity Scale (YGTSS) • Tools for depression and anxiety such as Patient Health Questionnaire for adolescents, Children's Depression Inventory and Beck Depression Inventory • Social, behavioural, and functional outcomes • Suicidal thoughts and behaviour **Patient-reported outcome measures** • Health-related quality of life (HRQoL) • Patient's experience and patient's satisfaction • Rates and reasons for attrition
Study design	Clinical studies assessing the efficacy or effectiveness of non-pharmacological treatment delivered remotely or online using digital technologies We included randomised controlled trials (RCTs), and comparative non-randomised studies published in English. Articles available in their pre-publication version and relevant reports submitted by the manufacturers of the technologies under investigation were considered for inclusion. Crossover studies (phase before crossover) and evidence from uncontrolled studies (in the absence of evidence from comparative studies) were also considered eligible. Conference abstracts were excluded because they were not considered to provide sufficient information
Healthcare setting	Secondary care settings (e.g. CYPMHS) Tertiary care settings (e.g. neurology or neurodevelopmental teams – including neurologists, neuropsychologists, psychiatrists, psychologists, specialist nurses, speech and language therapists)

Note
This table includes content reproduced from the research protocol.[24]

unadjusted mean differences and 95% CIs for the Total Tic Severity Score (TTSS) and the impairment score of the YGTSS using the inverse variance method. It is worth noting that the TTSS score of the YGTSS ranges from 0 to 50 and measures the severity of the tic disorders (where 50 indicates higher severity). The YGTSS impairment score (YGTSS-Impairment) also ranges from 0 to 50. A score of 0 indicates that the presence of TS has no negative impact on a person's daily life. In contrast, a score of 50 indicates considerable interference and disability associated with the presence of TS. Heterogeneity between studies was assessed using the I^2 statistic. Statistical analyses were conducted using the Cochrane software for systematic reviews and meta-analysis (RevMan Web). When appropriate, the following subgroups were considered: children with diagnosed comorbidities (ADHD, OCD, ASD, mood disorders, anxiety) and adults with CTDs.

Assessment of risk of bias

The Cochrane risk-of-bias tool (version 2) was used to assess the risk of bias for the primary outcome measured by the Yale Global Tic Severity Scale – Total Tic Severity Score (YGTSS-TTSS) in the randomised controlled trials (RCTs) included in the review.[39] One reviewer (MC) assessed each included study, and a second reviewer (MB) cross-checked the assessments. Disagreements were resolved by consensus.

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Results of the assessment of clinical effectiveness

Results of the literature searches

The literature searches identified 379 titles/abstracts. Three further studies were identified: one[40] was identified from a reference list,[36] one was provided by the corresponding author of the Maiquez 2023 study[41] and the third[42] was identified from the website search. A total of 40 publications were selected for full-text screening, of which 14 met our inclusion criteria, reporting a total of 3 studies. The Andrén 2024 study was out with our search dates but was included as a secondary publication to Andrén 2022[38] for completeness. A Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram detailing the process of study selection is presented in *Figure 1*.

Characteristics of included studies

A total of 3 RCTs reported in 14 publications were included in the review of clinical effectiveness evidence. Characteristics of the included studies are presented in *Table 27*, *Appendix 2*. Two studies compared ORBIT with psychoeducation; one was conducted in the UK[34] and the other in Sweden.[38] The third study was UK-based and compared Neupulse active stimulation with sham stimulation; this trial also included an open-label waitlist (treatment as usual) control condition, which is reported here for completeness.[36] All three were published in English and full-text form. The two ORBIT studies recruited children and young people aged 9–17 years.[34,38] The Neupulse study recruited people aged 12 years upwards.[36] A total of 566 participants were randomised (UK ORBIT: 224, Swedish ORBIT: 221; Neupulse: 121).[34,36,37] Longest follow-up periods in the ORBIT studies were 18 months (UK ORBIT)[34] and 12 months (Swedish ORBIT).[37]

Evidence gap: evidence was not available to compare the interventions under investigation and face-to-face behavioural therapy, the current standard of care. The comparator in the two ORBIT studies was psychoeducation, while the Neupulse active stimulation arm was compared to sham stimulation and a waitlist group. Both ORBIT trials did not include a non-active control group (e.g. waitlist).

Characteristics of participants

Baseline characteristics of participants in the included studies are reported in *Table 3*. The mean age of participants was between 12.0 years and 12.4 years in the two ORBIT studies[34,38] and between 23.5 years and 24.4 years in the Neupulse study.[36] The proportion of male participants ranged from 64.0% to 80.4% in the ORBIT studies and 59.0% to 63.4% in the Neupulse study. Regarding tic typology, most participants in the UK ORBIT study had both motor and vocal tics (92% and 95% in the intervention and comparator groups, respectively), while 8% and 5%, respectively, had motor tics only, and none had only vocal tics.[34] In the Swedish ORBIT study, most participants had TS (93.7% and 89.1% in the intervention and comparator groups, respectively).[38] A further 6.3% and 8.2%, respectively, had chronic motor tic disorder and 2.7% of participants in the comparator group had chronic vocal tic disorder. Tic typology in the Neupulse study was not reported. Comorbidities reported by the studies included ADHD (ranging from 12.7% to 24.4%),[36,38] anxiety disorder (ranging from 13.6% to 30.8%)[36,38] and OCD (ranging from 3% to 41.5%).[34,36]

Evidence gap: the Neupulse study was the only study included in the review to recruit adults. The maximum age of participants in the two ORBIT trials was 17 years and the materials were developed accordingly. However, with adaptation, ORBIT may be suitable for adults.

Uncertainty: the proportion of participants with TS in the UK ORBIT trial was not reported. The mean baseline tic severity measured using the YGTSS-TTSS scores was slightly higher in the UK ORBIT study than in the Swedish study; however, both trials described the participants' severity of tic disorders as moderate to severe.

Uncertainty: it was unclear whether the participants in the two ORBIT trials had access to psychoeducation prior to recruitment into the trials. Access to psychoeducation was not an inclusion criterion for either trial.

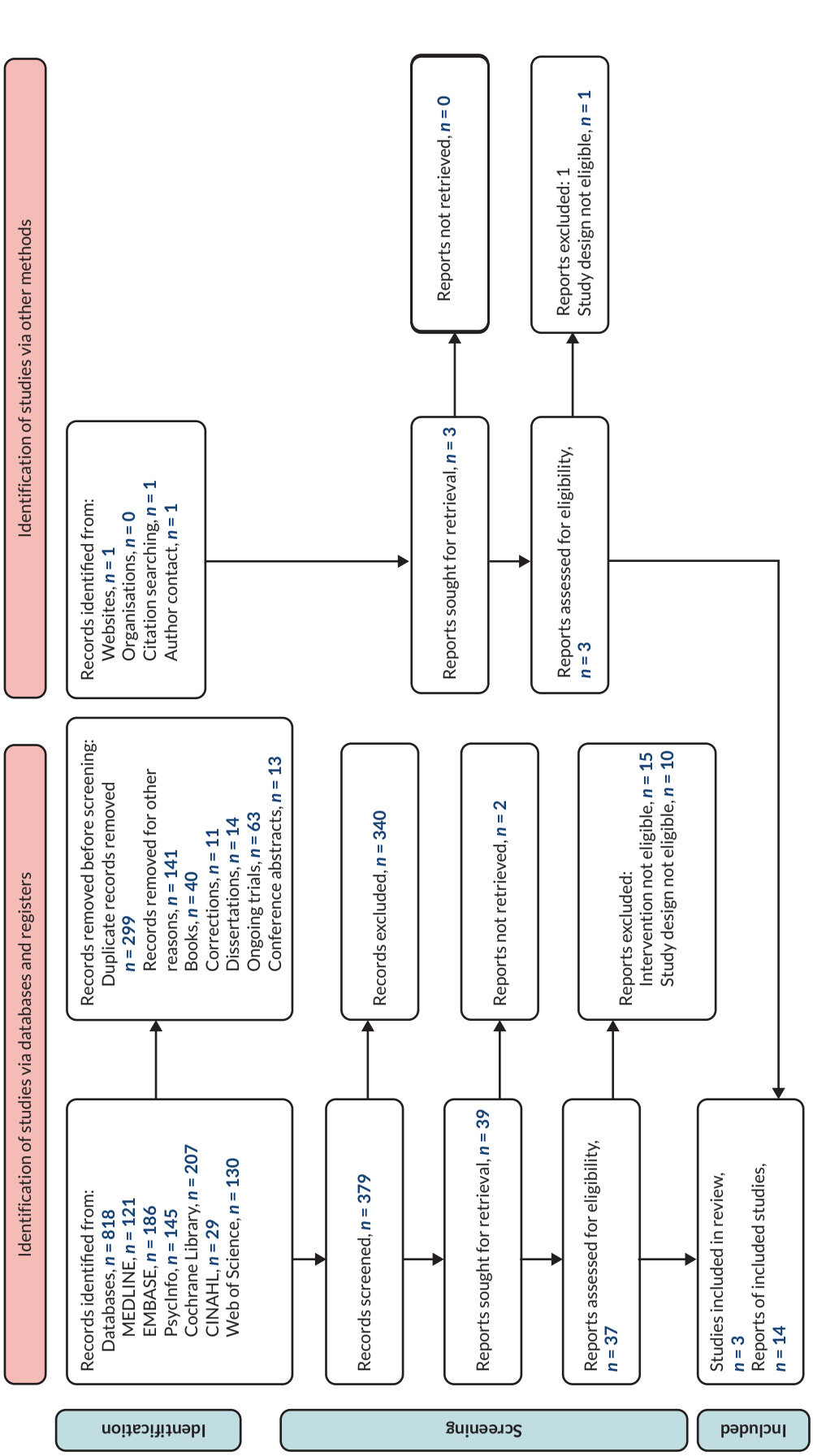

FIGURE 1 Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow diagram.

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TABLE 3 Baseline characteristics of participants in included studies

Study ID	Intervention group (*n* analysed)	Age, years, mean (SD)	Male sex, %	White ethnicity, %	Tic typology, *n* (%)	Comorbidities, *n* (%)
Hollis 2021[34] (ORBIT UK)	ERP (*n* = 112)	12.2 (2.0) (age of tic onset: NR)	80.4	86	Both motor and vocal tics: 103 (92) Motor tics only: 9 (8) Vocal tics only: 0 (0)	Anxiety disorder: 34 (30) ADHD: 26 (23) Oppositional defiant disorder: 26 (24) (*n* = 110) ASD: 9 (8) (*n* = 111) OCD: 8 (7) Major depression: 2 (2) Conduct disorder: 3 (3) (*n* = 110)
	Psychoeducation (*n* = 112)	12.4 (2.1) (age of tic onset: NR)	77.7	88	Both motor and vocal tics: 106 (95) Motor tics only: 6 (5) Vocal tics only: 0 (0)	Anxiety disorder: 27 (24) ADHD: 25 (22) Oppositional defiant disorder: 23 (21) (*n* = 111) ASD: 4 (4) OCD: 2 (3) Major depression: 6 (5) Conduct disorder: 2 (2) (*n* = 111)
Andrén 2022[38] (ORBIT Sweden)	ERP (*n* = 111)	12.0 (2.3) (age of tic onset: 5.7)	64.0	NR	TS: 104 (93.7) CTD motor: 7 (6.3) CTD vocal: 0	Any: 44 (39.6) ADHD: 20 (18.0) Anxiety disorder: 16 (14.4) OCD: 11 (9.9) Depression: 1 (0.9) Other: 7 (6.3)
	Education (*n* = 110)	12.1 (2.3) (age of tic onset: 6.2)	73.6	NR	TS: 98 (89.1) CTD motor: 9 (8.2) CTD vocal: 3 (2.7)	Any: 40 (36.0) ADHD: 14 (12.7) Anxiety disorder: 15 (13.6) OCD: 6 (5.5) Depression: 3 (2.7) Other: 3 (2.7)
Maiquez 2023[36] (Neupulse)	Active stimulation (*n* = 41)	23.5 (12.6) (age of tic onset: 7.0)	63.4	NR	NR	ADHD: 10 (24.4) OCD: 17 (41.5) ASD: 8 (19.5) Anxiety disorder: 9 (22.0)
	Sham stimulation (*n* = 39)	24.0 (13.4) (age of tic onset: 8.4)	59.0	NR	NR	ADHD: 9 (23.1) OCD: 8 (20.5) ASD: 9 (23.1) Anxiety disorder: 12 (30.8)
	Waitlist (*n* = 41)	24.4 (12.6) (age of tic onset: 7.5)	63.4	NR	NR	ADHD: 8 (19.5) OCD: 12 (29.3) ASD: 2 (4.9) Anxiety disorder: 11 (26.8)

NR, not reported; SD, standard deviation.

Note
The waitlist group on the Neupulse study is not included in the clinical effectiveness review but is reported for completeness.

Risk-of-bias assessments

Figure 2 presents a summary of the risk-of-bias assessments of the three included studies for the YGTSS-TTSS primary outcome.

Risk-of-bias assessments of individual studies is presented in *Figure 3*.

According to the Cochrane risk-of-bias tool (version 2), the overall risk of bias was low for the three trials.[34,36,38] All three were appropriately randomised, there was no evidence of deviations from the intended interventions, missing outcome data were low, accounted for and balanced across groups, the outcome and its assessment were appropriate and there was no evidence of selected reporting.

Clinical effectiveness results

Clinical outcomes

The primary outcome of all three studies was total tic severity assessed by the TTSS of the YGTSS scale in the two ORBIT studies[34,38] and by the TTSS of the YGTSS revised in the Neupulse study.[36] *Tables 4* and *5* present the YGTSS-TTSS outcome data from the two ORBIT studies and the Neupulse study, respectively. The improvements in tic severity in the intervention group in the Hollis 2021 study were described by the authors as clinically important, considering an average of 0.5 of a standard deviation (SD) between the intervention and comparator as being clinically important.[34] The authors of the Neupulse study defined a clinically meaningful reduction in tic severity as reduction of 25 percentiles or greater in YGTSS-TTSS scores, and reported a substantially greater proportion of the active stimulation group (59.0%) as responders than the sham stimulation group [33.3%; odds ratio (OR) 2.9, 95% CI 1.1 to 7.2].

Tables 6 and *7* report further clinical outcomes from the two ORBIT studies and the Neupulse study, respectively.

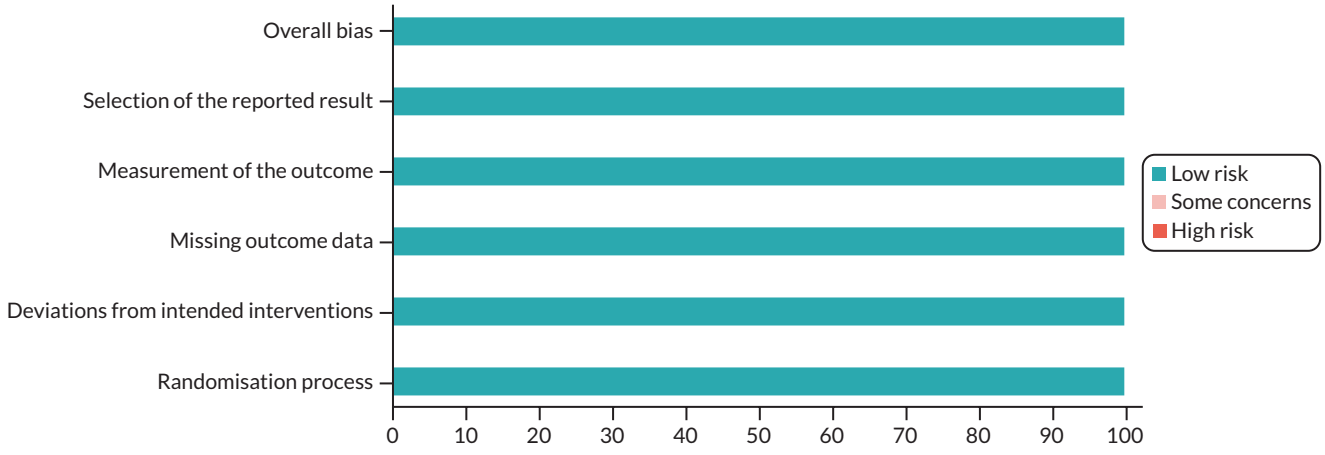

FIGURE 2 Summary of risk-of-bias assessments for the three included studies.

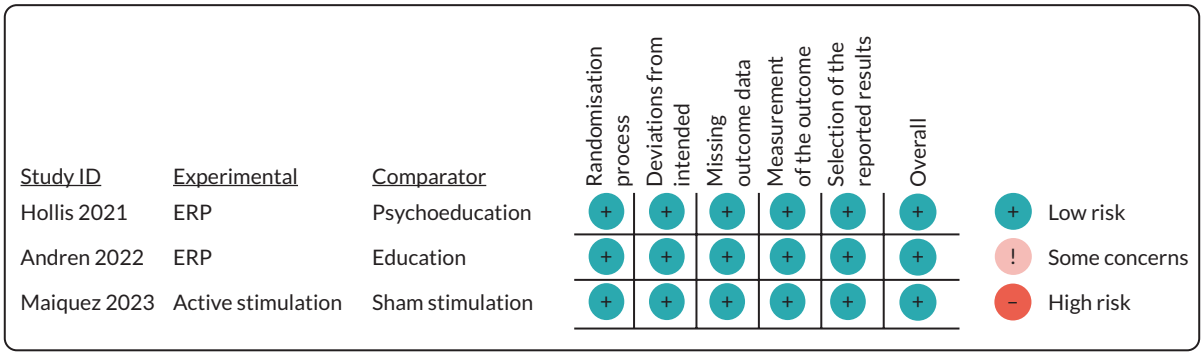

FIGURE 3 Risk-of-bias assessments of individual studies.

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TABLE 4 Yale Global Tic Severity Scale - Total Tic Severity Score data reported in the two ORBIT studies

Study ID	Time point	ORBIT	Psychoeducation	Difference between groups at time point
Orbit				
Hollis 2021[34]	Baseline	28.4 (7.7)	28.4 (7.1)	N/A (not applicable)
	3 months	23.9 (8.2)	26.8 (7.3)	Estimated difference: −2.29 (95% CI −3.86 to −0.71) Effect size −0.31 (−0.52 to −0.10)
	6 months	21.5 (8.8)	25.0 (7.6)	Estimated difference: −2.64 (95% CI −4.56 to −0.73) Effect size −0.36 (−0.62 to −0.10)
	12 months	21.7 (8.8)	24.9 (7.3)	Estimated difference −2.64 (95% CI −4.48 to −0.79) Effect size −0.36 (95% CI −0.61 to −0.11)
	18 months	21.5 (9.0)	23.9 (8.4)	Estimated difference −2.01 (95% CI −3.86 to −0.15) Effect size −0.27 (95% CI −0.52 to −0.02)
Andrén 2022[38]	Baseline	22.25 (5.60)	23.01 (5.92)	N/A
	3 months	16.17 (6.82)	17.72 (7.11)	Intention-to-treat linear quantile mixed-model coefficient −0.53 (95% CI −1.28 to 0.22) Effect size 0.11 (95% CI −0.09 to 0.30), p = 0.17
	6 months	16.06 (6.98)	17.23 (8.18)	NR (not reported)
	12 months	14.93 (7.70)	16.73 (8.30)	Interaction between treatment and time coefficient −0.38 (95% CI −1.11 to 0.35), p = 0.30 Effect size 0.13 (95% CI −0.12 to 0.37)

Note
Data reported as mean (SD).

TABLE 5 Yale Global Tic Severity Scale – Total Tic Severity Score data reported in the Neupulse study

Study ID	Time point	Active stimulation	Sham stimulation	Waitlist	Difference between groups at time point
Neupulse					
Maiquez 2023[36]	Baseline	40.1 (7.0)	39.5 (6.3)	38.9 (6.9)	N/A (not applicable)
	4 weeks	Mean (SD) reduction 7.13 (1.1)	Mean (SD) reduction 2.13 (0.32)	Mean (SD) reduction 2.26 (0.34)	Active vs. sham: Observed difference −5, effect size −0.47 (95% CI −0.94 to −0.02), p = 0.02 Active vs. waitlist: Observed difference −5, effect size −0.48 (95% CI −0.97 to −0.04), p = 0.02

Note
The waitlist group is not included in the clinical effectiveness review but is reported for completeness. Data reported as mean (SD) unless otherwise specified.

Patient-reported outcomes

Health-related quality-of-life (HRQoL) outcomes in terms of Child and adolescent Gilles de la Tourette syndrome quality of life scale (C&A-GTS-QOL) scores reported by the two ORBIT trials are presented in *Table 8* and those from the Neupulse study are presented in *Table 9*.

Intermediate outcomes

Adverse events

The two ORBIT studies reported AEs. AEs were not reported in the Neupulse study. In the UK study, 78.6% of the intervention group and 84.8% of the comparator group experienced an AE.[34] It was unclear if they were related to the relevant intervention. In addition, two participants of the comparator group experienced a serious AE (one collapse and one tic attack), both of which were deemed unrelated to trial participation. In the Swedish study, 44 treatment-related AEs were reported: depressed mood (n = 11), irritability (n = 8), anxiety/worry/stress (n = 8), conflicts with family/peers

TABLE 6 Clinical outcomes from the two ORBIT studies

Study ID	Time point	ORBIT	Psychoeducation	Difference between groups at time point
YGTSS-Impairment, mean (SD)				
Hollis 2021[34]	Baseline	23.8 (10.3)	22.9 (9.9)	N/A
	3 months	16.7 (10.4)	19.1 (10.9)	Estimated difference (95% CI) −2.24 (−4.82 to 0.33) Effect size −0.22 (−0.48 to 0.03)
	6 months	14.7 (10.7)	17.0 (10.5)	Estimated difference (95% CI) −1.95 (−4.68 to 0.78) Effect size −0.19 (−0.46 to 0.08)
	12 months	14.8 (11.6)	17.5 (11.1)	Estimated difference (95% CI) −2.41 (−5.35 to 0.53) Effect size −0.24 (−0.53 to 0.05)
	18 months	15.8 (11.5)	16.9 (12.1)	Estimated difference (95% CI) −0.97 (−3.93 to 1.99) Effect size −0.10 (−0.39 to 0.20)
Andrén 2022[38]	Baseline	18.38 (7.08)	18.73 (7.79)	N/A
	3 months	7.68 (8.82)	8.70 (8.10)	ITT linear quantile mixed model coefficient −0.26 (−1.70 to 1.18), $p = 0.72$ Effect size (95% CI) 0.05 (−0.34 to 0.44)
	6 months	6.85 (7.81)	7.84 (8.97)	NR
	12 months	6.54 (8.14)	6.14 (8.12)	Interaction between treatment and time coefficient 0.16 (95% CI −0.55 to 0.86), $p = 0.67$ Effect size 0.03 (95% CI −0.14 to 0.20)
Parent Tic Questionnaire				
Hollis 2021[34]	Baseline	54.7 (29.9)	53.1 (26.1)	N/A
	3 months	34.7 (26.4)	45.7 (25.5)	Estimated difference (95% CI) −9.44 (−15.37 to −3.51) Effect size −0.34 (−0.55 to −0.13)*
	6 months	31.1 (21.6)	40.6 (24.3)	Estimated difference (95% CI) −8.60 (−14.43 to −2.77) Effect size −0.31 (−0.51 to −0.10)*
	12 months	30.7 (23.8)	43.0 (25.3)	Estimated difference (95% CI) −9.89 (−16.01 to −3.77) Effect size −0.35 (−0.57 to −0.13)*
	18 months	28.1 (19.1)	35.9 (25.6)	Estimated difference (95% CI) −2.15 (−8.83 to 4.53) Effect size −0.08 (−0.31 to 0.16)
Andrén 2022[38]	Baseline	34.33 (19.06)	38.04 (23.27)	N/A
	3 months	19.84 (17.92)	23.51 (18.14)	ITT linear quantile mixed model coefficient 0.13 (95% CI −1.43 to 1.68) Effect size (95% CI) −0.01 (−0.22 to 0.19) $p = 0.87$
	6 months	18.17 (16.18)	24.18 (20.08)	NR
	12 months	16.76 (15.97)	20.76 (17.04)	Interaction between treatment and time coefficient −0.10 (95% CI −1.63 to 1.44), $p = 0.90$, effect size 0.02 (95% CI −0.22 to 0.26)
Clinical Global Impressions – Improvement Scale (CGI-I)				
Hollis 2021[34]	Baseline	NR	NR	N/A
	3 months	2.96 (1.1)	3.37 (1.1)	Estimated difference (95% CI) −0.41 (−0.71 to −0.11) Effect size −0.37 (−0.64 to −0.10)*
	6 months	2.8 (1.3)	3.1 (1.1)	Estimated difference (95% CI) −0.31 (−0.66 to 0.03) Effect size −0.29 (−0.61 to 0.03)
	12 months	2.67 (1.09)	3.07 (0.9)	Estimated difference (95% CI) −0.43 (−0.75 to −0.10) Effect size −0.43 (−0.74 to −0.12)*
	18 months	2.49 (1.36)	2.86 (1.1)	Estimated difference (95% CI) −0.38 (−0.71 to −0.05) Effect size −0.35 (−0.66 to −0.04)*

continued

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TABLE 6 Clinical outcomes from the two ORBIT studies (*continued*)

Study ID	Time point	ORBIT	Psychoeducation	Difference between groups at time point
Clinical Global Impression Severity scale (CGI-S)				
Andrén 2022[38]	Baseline	4.08 (0.74)	4.19 (0.72)	N/A
	3 months	3.24 (0.92)	3.49 (0.90)	ITT linear quantile mixed model coefficient −0.36 (95% CI −0.67 to −0.04), p = 0.03 Effect size (95% CI) 0.71 (0.05 to 1.37)*
	6 months	3.10 (0.93)	3.32 (1.11)	NR
	12 months	2.97 (0.96)	3.25 (1.13)	Interaction between treatment and time coefficient 0.03 (95% CI −0.16 to 0.21), p = 0.28 Effect size −0.11 (95% CI −0.80 to 0.58)
CGAS				
Hollis 2021[34]	Baseline	70.7 (13.7)	72.1 (11.8)	N/A
	3 months	75.9 (12.6)	75.2 (12.6)	Estimated difference (95% CI) 0.96 (−1.48 to 3.41) Effect size 0.08 (−0.12 to 0.27)
	6 months	77.5 (14.7)	76.8 (12.3)	Estimated difference (95% CI) 0.60 (−2.24 to 3.44) Effect size 0.05 (−0.17 to 0.27)
	12 months	77.4 (13.3)	75.0 (12.9)	Estimated difference (95% CI) 2.85 (0.15 to 5.56) Effect size −0.22 (−0.43 to −0.01)*
	18 months	79.3 (13.5)	77.3 (12.6)	Estimated difference (95% CI) 3.18 (0.47 to 5.90) Effect size −0.25 (−0.46 to −0.04)*
Andrén 2022[38]	Baseline	60.60 (6.59)	60.71 (6.46)	N/A
	3 months	66.83 (8.64)	65.72 (7.44)	Intention to treat linear quantile mixed model coefficient 0.67 (95% CI −0.15 to 1.49), p = 0.11, effect size 0.12 (−0.05 to 0.29)
Strengths and difficulties questionnaire				
Hollis 2021[34]	Baseline	18.0 (6.5)	16.3 (6.2)	N/A
	3 months	14.7 (6.1)	14.2 (6.3)	Estimated difference (95% CI) −0.38 (−1.62 to 0.85) Effect size −0.06 (−0.25 to 0.13)
	6 months	15.3 (6.2)	13.3 (6.1)	Estimated difference (95% CI) 0.57 (−0.93 to 2.07) Effect size 0.09 (−0.15 to 0.32)
	12 months	14.4 (5.6)	14.6 (6.4)	Estimated difference (95% CI) −0.86 (−2.31 to 0.58) Effect size −0.13 (−0.36 to 0.09)
	18 months	13.6 (6.1)	13.8 (5.4)	Estimated difference (95% CI) −0.71 (−2.26 to 0.84) Effect size −0.11 (−0.35 to 0.13)
Mood and feelings questionnaire				
Hollis 2021[34]	Baseline	16.3 (11.3)	15.9 (1.5)	N/A
	3 months	10.7 (11.1)	12.6 (11.1)	Estimated difference (95% CI) −1.36 (−3.75 to 1.02) Effect size −0.12 (−0.33 to 0.09)
	6 months	11.4 (12.1)	11.4 (11.2)	Estimated difference (95% CI) −0.61 (−3.85 to 2.64) Effect size −0.05 (−0.34 to 0.23)
	12 months	11.4 (10.4)	14.3 (11.6)	Estimated difference (95% CI) −2.93 (−5.77 to −0.09) Effect size −0.26 (−0.51 to −0.01)*
	18 months	10.9 (10.0)	16.0 (14.6)	Estimated difference (95% CI) −4.87 (−8.00 to −1.75) Effect size −0.43 (−0.70 to −0.15)*

TABLE 6 Clinical outcomes from the two ORBIT studies (*continued*)

Study ID	Time point	ORBIT	Psychoeducation	Difference between groups at time point
Spence child anxiety scale				
Hollis 2021[34]	Baseline	32.9 (20.0)	30.5 (17.9)	N/A
	3 months	27.2 (19.0)	28.2 (18.3)	Estimated difference (95% CI) −2.80 (−6.52 to 0.93) Effect size −0.15 (−0.34 to 0.05)
	6 months	25.7 (19.6)	25.9 (18.7)	Estimated difference (95% CI) −5.10 (−9.70 to −0.50) Effect size −0.27 (−0.51 to −0.03)*
	12 months	25.3 (17.1)	29.9 (19.1)	Estimated difference (95% CI) −6.11 (−10.41 to −1.81) Effect size −0.31 (−0.53 to −0.08)*
	18 months	24.3 (18.6)	32.6 (20.4)	Estimated difference (95% CI) −9.41 (−14.11 to −4.70) Effect size −0.49 (−0.74 to −0.25)*

* $p < 0.05$.
ITT, intention to treat; N/A, not applicable; NR, not reported.

Note
For the study by Hollis 2021, linear regression models were fitted with the study group as the main explanatory variable. The statistical model for CGI-I did not adjust for baseline as it is a model of change. For the Andrén 2022 study, outcomes were analysed with linear quantile mixed models, complementary linear mixed models, quantile regression, logistic regression and chi-squared tests. The magnitude of the effects is presented as between-group differences in median relative to the interquartile range (for median differences) and as standardised between-group effect sizes (for mean differences, *Cohen's d*). Data reported as mean (SD).

TABLE 7 Clinical outcomes from the Neupulse study

Study ID	Time point	Active stimulation, mean (SD)	Sham stimulation, mean (SD)	Waitlist, mean (SD)	Difference between groups at time point
YGTSS-Impairment					
Maiquez 2023[36]	Baseline	25.5 (13.7)	29.8 (13.5)	30.1 (12.9)	N/A
	4 weeks	NR	NR	NR	Active vs. sham: Observed difference 1.07, effect size 0.06 (95% CI −0.39 to 0.52); $p = 0.6$ Active vs. waitlist: Observed difference 1.86, effect size 0.11 (95% CI −0.35 to 0.58); $p = 0.7$
YGTSS-motor					
Maiquez 2023[36]	Baseline	21.1 (3.2)	20.4 (3.5)	20.8 (3.1)	N/A
	4 weeks	NR	NR	NR	Active vs. sham: Observed difference −2.03, effect size −0.4 (95% CI −0.85 to 0.04); $p = 0.04$* Active vs. waitlist: Observed difference −2.15, effect size −0.45 (95% CI −0.88 to −0.01); $p = 0.03$*
YGTSS-phonic					
Maiquez 2023[36]	Baseline	19.0 (4.7)	19.1 (4.7)	18.1 (4.7)	N/A
	4 weeks	NR	NR	NR	Active vs. sham: Observed difference −3, effect size −0.42 (95% CI −0.87 to 0); $p = 0.04$* Active vs. waitlist: Observed difference −2.72, effect size −0.42 (95% CI −0.85 to 0.02); $p = 0.04$*
Premonitory Urge for Tics Scale – Revised (PUTS-R)					
Maiquez 2023[36]	Baseline	17.9 (8.8)	19.3 (8.5)	17.6 (8.6)	N/A
	4 weeks	NR	NR		Active vs. sham: Observed difference at 4w active vs. sham: −0.59, effect size −0.05 (95% CI −0.5 to 0.39); $p = 0.4$ Active vs. waitlist: Observed difference −2.98, effect size −0.24 (95% CI −0.72 to 0.19); $p = 0.14$

* $p < 0.05$, ** indicates statistical significance; N/A, not applicable; NR, not reported.

Note
Data reported as mean (SD).

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TABLE 8 The C&A-GTS-QOL scores from the two ORBIT studies

Study ID	Time point	ORBIT, mean (SD)	Psychoeducation, mean (SD)	Difference between groups at time point
Hollis 2021[34]	Baseline	36.6 (16.4)	35.0 (17.2)	N/A
	3 months	25.7 (18.0)	31.8 (17.7)	Estimated difference (95% CI) −4.81 (−8.79 to −0.83) Effect size −0.29 (−0.52 to −0.05)*
	6 months	27.4 (16.5)	28.9 (18.3)	Estimated difference (95% CI) −2.91 (−7.60 to 1.78) Effect size −0.17 (−0.45 to 0.11)
	12 months	25.5 (16.8)	32.2 (16.8)	Estimated difference (95% CI) −5.79 (−10.28 to −1.30) Effect size −0.34 (−0.61 to −0.08)*
	18 months	26.0 (16.6)	36.8 (21.1)	Estimated difference (95% CI) −9.00 (−13.98 to −4.01) Effect size −0.53 (−0.83 to −0.24)*
Andrén 2022[38]	Baseline	29.1 (15.1)	30.5 (16.5)	N/A
	3 months	19.8 (16.3)	20.1 (15.7)	Coefficient 0.46 (95% CI −1.63 to 2.55), effect size −0.04 (−0.24 to 0.16), $p = 0.67$
	6 months	18.3 (15.2)	21.2 (16.7)	NR
	12 months	20.7 (17.5)	20.0 (15.2)	Coefficient 0.18 (95% CI −0.98 to 1.33), effect size −0.04 (−0.31 to 0.23), $p = 0.77$

* $p < 0.05$.

TABLE 9 The C&A-GTS-QOL scores from the Neupulse study

Study ID	Time point	Neupulse, mean (SD)	Sham stimulation, Mean (SD)	Waitlist, mean (SD)
Maiquez 2023[36]	Baseline	54.9 (24.6)	52.8 (22.4)	56.7 (24.1)
	3 months	46.7 (25.2)	40.3 (23.6)	52.1 (24.0)
Difference within group at time point		$t = 2.64$, $p < 0.015$ (baseline vs. 3 months)	$t = 3.9$, $p < 0.0005$ (baseline vs. 3 months)	$t = 1.6$, $p = 0.13$ (baseline vs. 4 weeks)

Note
All QoL data for the Maiquez 2023 study were obtained through personal correspondence with Stephen Jackson.

($n = 5$), increased tics ($n = 4$), pain ($n = 3$), tiredness/fatigue/drowsiness ($n = 2$), increased isolation ($n = 1$), restless ($n = 1$), other ($n = 1$).[38] Twenty-one AEs were reported in the comparator group: depressed mood ($n = 7$), anxiety/worry/stress ($n = 4$), increased tics ($n = 2$), irritability ($n = 2$), other ($n = 2$), bullying ($n = 1$), conflicts with family/peers ($n = 1$), physical harm/injury ($n = 1$), hopelessness ($n = 1$). One serious AE unrelated to treatment was reported in the comparator group (meningitis requiring hospitalisation).

Evidence gap: Reporting of safety data was limited in the ORBIT trials, particularly with respect to long-term AEs. Additionally, the Neupulse study did not report any AEs. Collecting long-term safety data would be valuable to better assess the overall risk profile of these interventions.

Treatment satisfaction/engagement

The two ORBIT studies reported indicators of treatment satisfaction or engagement. In the intervention arm of one study, the median number of logins by the young person was 19 as compared to 9 in the comparator group.[34] The median score for the young person's perception of treatment suitability and credibility was 7 in the intervention group and 6 in the comparator group. Mean child satisfaction scores with the ORBIT intervention were 24.8 out of 32, with higher scores indicating higher levels of satisfaction. In the other study, both children and parents were more satisfied with the ORBIT intervention than the comparator treatment (children: coefficient 3, 95% CI 1.13 to 4.87, $p = 0.003$; parents: coefficient 4, 95% CI 2.33 to 5.66, $p < 0.001$).[38] The treatment credibility score was identical for children and parents (coefficient 1, 95% CI 0.38 to 1.62, $p = 0.002$).

Intervention adherence

In the study by Andrén 2022, treatment adherence, as measured by the internet intervention Patient Adherence Scale, showed no differences between the groups [mid + post-treatment summarised to one score: quantile regression 1 (95% CI −1.28 to 3.28, $p = 0.39$)].[38] The Neupulse study did not report adherence data.[36]

Rates and reasons for attrition

In the intervention arm of the UK ORBIT study, 23/112 (20.5%) of participants were lost to follow-up at 18 months (13 withdrew, 10 were uncontactable).[34] In the comparator group, 22/112 (19.6%) were lost to follow-up at 18 months (10 withdrew, 12 were uncontactable). In the Swedish ORBIT study, at the 3-month follow-up, three in the intervention arm and two in the comparator arm were lost to follow-up; no reasons were reported.[38] In the Neupulse study, a total of ten participants withdrew during the initial training as they found the stimulation uncomfortable.[36] Reasons for other withdrawals from the study were not requested for ethical reasons but some were volunteered, such as insufficient time to complete the study or because they were planning to be away during the period of the trial and could not commit to participation (*personal communication with Stephen Jackson from Neupulse*).

Intervention completion

In the two ORBIT studies, treatment completion was defined as completion of at least the first four child chapters. As such, in the UK study, 88.4% of the intervention group and 93.8% of the comparator group were classed as treatment completers.[34] In the Swedish study, 100% of the intervention group and 94.6% of the comparator group were treatment completers.[38]

Evidence gap: although there were statistically significant improvements in YGTSS-TTSS scores over time in the intervention groups as compared to the control groups, changes in the reported secondary outcomes and QoL scores were less consistent. In particular, the YGTSS-Impairment scores did not show any improvement. Therefore, it is unclear if improvements in tic severity scores translate into improvements in people's daily lives.

Evidence gap: published evidence was not available for all outcomes specified in the scope (*Table 10*), namely, behavioural outcomes, functional outcomes, suicidal thoughts and behaviour, and information about digital technology. Clinical measures were reported by all three included studies, albeit using various outcomes and time points, precluding a more extensive pooling of outcomes.

Relevant subgroups

There were insufficient data available to conduct statistical analyses of the specified subgroups. The UK ORBIT study conducted an unplanned post hoc analysis of the effect of the intervention on the primary outcome by common comorbidities (anxiety disorder, ADHD). The number of participants with ADHD in each intervention group was 22 while the number of participants without ADHD in the ERP group and psychoeducation group were 79 and 78, respectively. The number of participants with anxiety disorder in the ERP group and psychoeducation group was 30 and 23, respectively, and that without anxiety disorder was 71 and 77, respectively. There was no difference in the effect of the intervention on participants with or without ADHD ($p = 0.906$) or anxiety disorder ($p = 0.204$).

The Swedish ORBIT study conducted post hoc analyses on the impact of age and sex on the primary outcome. The median age of 11 years was used to split the sample; in the 9–11 years age group, there were 124 participants and there were 97 participants in the 12–17 years group. There was an interaction effect between group (ERP and

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TABLE 10 Summary of reporting of outcomes specified in scope

Outcome specified in scope	Study/ies in which reported
Intermediate outcomes	
Intervention-related AEs	ORBIT UK,[34] ORBIT Sweden[38]
Treatment satisfaction and engagement	ORBIT UK,[34] ORBIT Sweden[38]
Intervention adherence, rates of attrition and completion	ORBIT Sweden[38] ORBIT UK,[34] ORBIT Sweden,[38] Neupulse[36] ORBIT UK,[34] ORBIT Sweden[38]
Clinical outcome measures	
Measures of symptom severity (self, parental or practitioner reported)	ORBIT UK,[34] ORBIT Sweden,[38] Neupulse[36]
Social, behavioural, and functional outcomes	ORBIT UK[34] Not reported Not reported
Suicidal thoughts and behaviour	Not reported
Patient-reported outcome measures	
HRQoL	ORBIT UK,[34] ORBIT Sweden,[38] Neupulse[36]
Patient's experience and patient's satisfaction	ORBIT UK,[34] ORBIT Sweden[38]
Rates and reasons for attrition	ORBIT UK,[34] ORBIT Sweden,[38] Neupulse[36]
Digital technology information	Not reported

comparator) and time (baseline to 3-month follow-up) on the older group [coefficient (95% CI) −1.21 (−2.14 to −0.02); $p = 0.05$] but not the younger group. More participants in the older group responded to ERP ($n = 26$; 51%) than the comparator ($n = 10$; 23%). The equivalent analysis in the younger group showed no difference between the groups. The sample was also split by gender, with 152 boys and 68 girls (and one participant not included in the analysis due to identifying as non-binary). There was a significant interaction effect for boys [coefficient (95% CI) −1.06 (−2.09 to −0.03); $p = 0.04$] but not for girls. Significantly more boys responded to ERP ($n = 35$; 51%) than the comparator ($n = 21$; 26%) at the 3-month follow-up [OR 2.94 (95% CI 1.48 to 5.84); $p = 0.002$]. The equivalent analysis among girls showed no between-group difference.

Meta-analysis: Yale Global Tic Severity Scale – Total Tic Severity Score

The two ORBIT trials at low risk of bias reported YGTSS-TTSS scores at 3 and 12 months and were combined in a meta-analysis.[34,38] The Neupulse study was not included in the meta-analyses as it is a different type of technology than ORBIT. Furthermore, the Neupulse study used sham stimulation and waitlist as comparator interventions, whereas the ORBIT studies used psychoeducation as the comparator intervention. The Swedish ORBIT study did not report comparison data at 6 months and, therefore, a meta-analysis at that time point was not possible.[37] *Figures 4* and *5* show that the TTSS scores of the YGTSS were significantly lower for the ERP group as compared to the psychoeducation

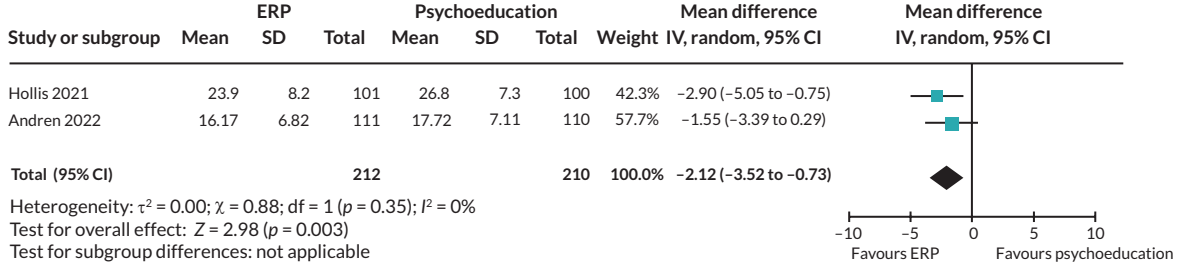

FIGURE 4 Meta-analysis for YGTSS-TTSS at 3 months.

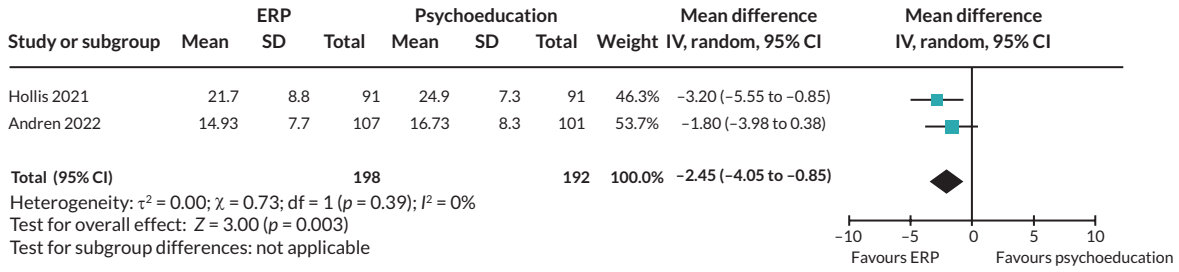

FIGURE 5 Meta-analysis for YGTSS-TTSS at 12 months.

group at 3 months (mean difference −2.12, 95% CI −3.52 to −0.73, p = 0.0003) and 12 months (mean difference −2.45, 95% CI −4.05 to −0.85, p = 0.0003). In both meta-analyses, there was no evidence of heterogeneity between studies (I^2 = 0%).

Meta-analysis: Yale Global Tic Severity Scale-Impairment

The mean difference in the impairment score of the YGTSS at 3 and 12 months were pooled from the same two ORBIT trials. The YGTSS-Impairment score indicates whether the presence of tic disorders had a negative impact on people's personal life. The YGTSS-Impairment summary score was lower for the ERP group as compared to the psychoeducation group at 3 months (mean difference −1.53, 95% CI −3.32 to 0.26, p = 0.09) and 12 months (mean difference −0.90, 95% CI −3.90 to 2.10, p = 0.56), but the differences were not statistically significant (*Figures 6* and *7*). There was no evidence of heterogeneity between studies in the 3-month meta-analysis (I^2 = 0%) and a moderate degree of heterogeneity (I^2 = 57%) in the 12-month meta-analysis. The Swedish ORBIT study did not report comparison data at 6 months, and, therefore, a meta-analysis at that time point was not possible.[37]

Summary of clinical effectiveness section

A total of three RCTs investigating two types of digitally enabled therapy, namely ORBIT and Neupulse, for CTDs and TS in children, young people and adults were included in the review of clinical effectiveness. Meta-analysis results of the two ORBIT studies showed that tic severity in terms of YGTSS-TTSS scores was significantly lower in children and

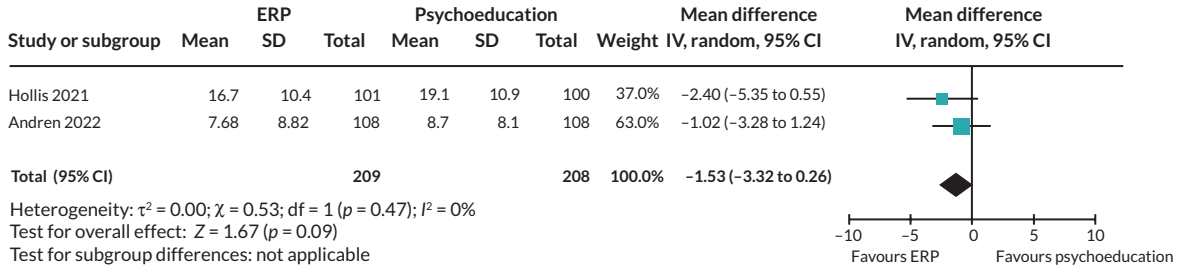

FIGURE 6 Meta-analysis for YGTSS-Impairment at 3 months.

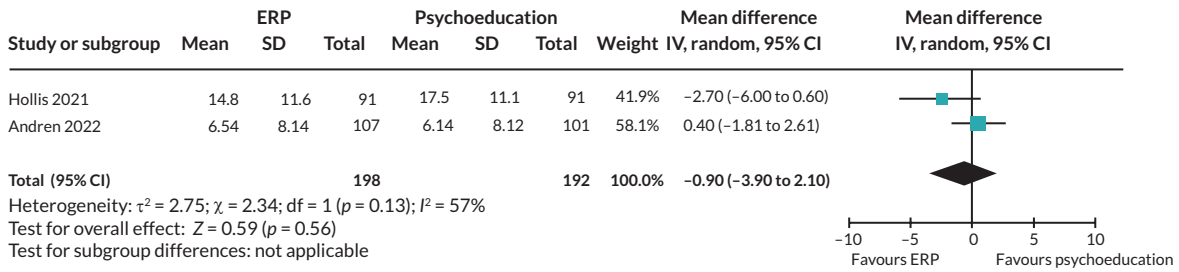

FIGURE 7 Meta-analysis for YGTSS-Impairment at 12 months.

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young people in the ERP groups than those in the psychoeducation groups at 3 months and 12 months. However, no significant improvements in tic-related impairment and distress measured using the impairment score of the YGTSS were observed between treatment groups. In each ORBIT study, secondary clinical outcome measures such as the CGAS, the Clinical Global Impression Improvement (CGI-I), and the Clinical Global Impression Severity (CGI-S) did not show a consistently greater response in the ERP group compared to the psychoeducation group at all assessed time points. In the UK ORBIT study, CGI-I showed a greater response in the ERP group at 3, 12 and 18 months but not at 6 months. In the Swedish ORBIT study, CGI-S showed a difference in favour of the ERP group at 3 months, but not at 6 months. In both studies, the CGAS showed no differences between intervention groups at 3 months and a positive difference in favour of the ERP group at 12 and 18 months in the UK ORBIT study. The estimated mean difference in the Parent Tic Questionnaire (PTQ) favoured the ERP group in the UK ORBIT study at 3, 6 and 12 months but not at 18 months and was not significant at 3 and 12 months in the Swedish ORBIT study. Similarly, in the UK ORBIT study, other measures evaluating anxiety and mood, emotional, and behavioural functioning did not show a consistent pattern of response at all assessed time points. It is worth noting that in Phase 2 of the UK ORBIT study (the naturalistic follow-up beyond 6 months), a substantial proportion of data were missing for most secondary outcome measures – including the PTQ, Mood and Feeling Questionnaire, Spence Child Anxiety Scale, Strengths and Difficulties Questionnaire and GTS-QoL at both 12- and 18-month follow-ups. Missing data rates ranged from 41% to 61%, significantly limiting the reliability and interpretability of these findings. Notably, the YGTSS-TTSS and YGTSS-Impairment scales had considerably lower rates of missing data (19–21%).

The Neupulse study reported significantly lower YGTSS-TTSS scores at 4 weeks in the active stimulation group compared to the sham stimulation group. Greater reductions in YGTSS motor and phonic scores were also observed among participants receiving active stimulation than among those receiving sham stimulation. No significant differences between treatment groups were observed for the YGTSS-Impairment score or the Premonitory Urge for Tics Scale – Revised. In general, participants' engagement with the interventions was reported to be good.

Chapter 3 Assessment of cost-effectiveness

Review of existing economic model evaluations

Methods for systematic review of economic evaluations

The initial protocol sought to conduct a systematic search to identify full economic evaluations of digitally enabled therapies for people with tic disorders. Given the lack of anticipated evidence, searches were expanded to include full economic evaluations of any intervention for people with tic disorders. The following databases were searched, with no time, language, or publication type restriction:

- Ovid MEDLINE
- Ovid EMBASE
- Ovid PsycInfo® (American Psychological Association, Washington, DC, USA)
- NHS Economic Evaluations Database
- International HTA Database (INAHTA)
- Proquest EconLit Cost-Effectiveness Analysis (CEA) Registry.

Detailed search strategies are provided in *Appendix 1*. The websites of relevant professional organisations [e.g. International Society for Pharmacoeconomics and Outcomes Research (ISPOR) Scientific Presentations Database] and health technology agencies [e.g. the National Institute for Health and Care Excellence (NICE), the Canadian Agency for Drugs and Technologies in Health (CADTH), the Pharmaceutical Benefits Advisory Committee, the Institute for Clinical and Economic Review (ICER)] were screened for supplementary reports. Reference lists of all incorporated studies were manually reviewed to identify additional relevant studies. Additional data and information provided by the companies was assessed for relevance to the decision problem and included in results summaries where appropriate.[24]

The review included full economic evaluations of any intervention for people with tic disorders. For the purposes of the review, full economic evaluations are defined as comparative analyses of costs and outcomes within the framework of cost-utility, cost-effectiveness, cost-benefit, or cost-minimisation analyses. Economic evaluations conducted alongside single effectiveness studies or decision-analytic models were included.[24]

The key findings from included economic evaluations were summarised in tabular format and narratively synthesised. All included studies were appraised with respect to the NICE reference case checklist for economic evaluations.[44] Reporting quality of studies was assessed using the Consolidated Health Economic Evaluation Reporting Standards[45] checklist, and any decision models were quality assessed using the Philips *et al.* (2004) checklist.

Results for systematic review of economic evaluations

The search identified 1242 potentially relevant articles. One further study was provided by one of the companies post search date, leading to a total number of articles of 1243.[41] An initial screen by the study information specialist excluded 1171 irrelevant titles and abstracts and duplicates. The remaining 72 abstracts were reviewed by a health economist reviewer Dwayne Boyers (DB), of which 10 were retained for full text screening. The final list of studies included four publications describing three studies.[35,41,46,47] Further details of the screening results are provided in the PRISMA flow chart in *Figure 8*.[48]

Summary of existing systematic review of economic evaluations

Tables 11 and *12* summarise the characteristics and results of the included studies.

The quality assessment of the included studies is summarised in *Table 13*. Full details of quality assessment scores for decision modelling studies are presented in *Table 28*, *Appendix 3*. AQ2

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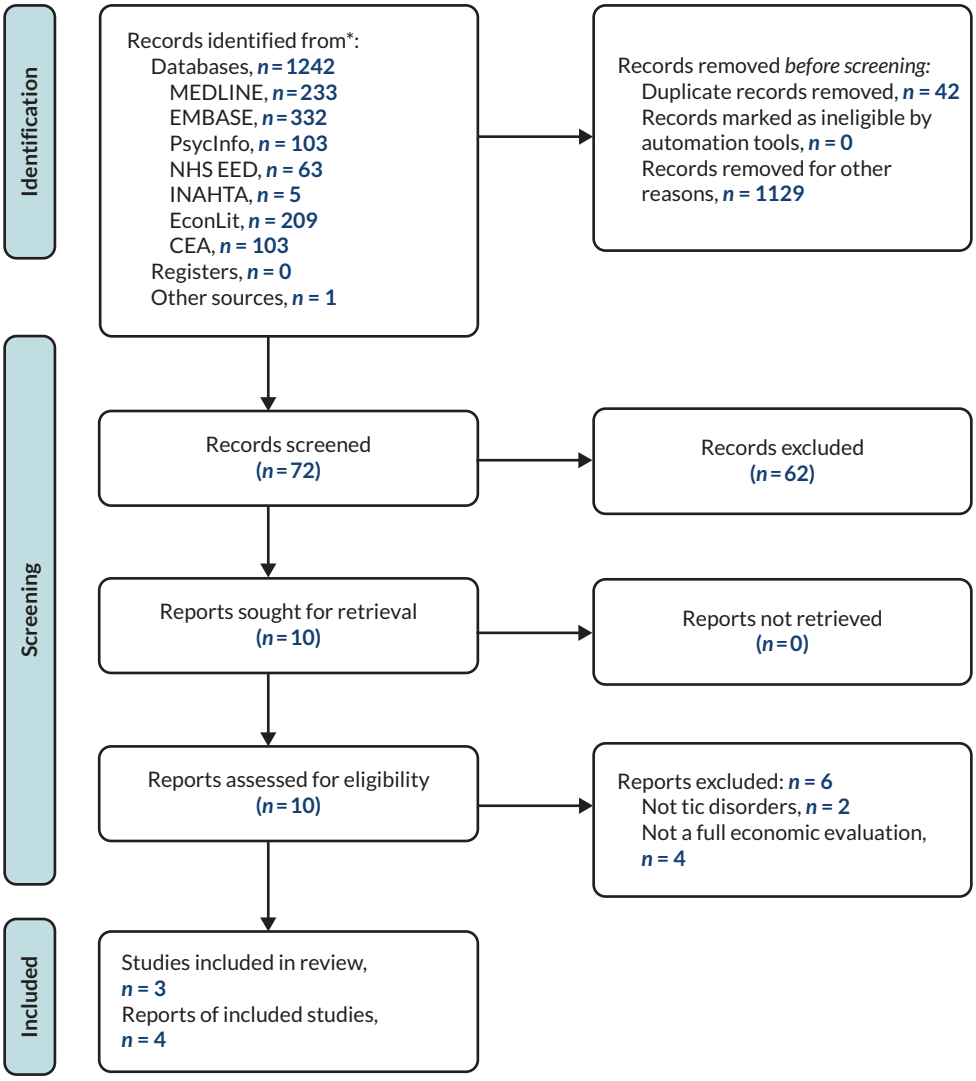

FIGURE 8 Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow chart for economic evaluation studies.

Economic model overview

A Markov cohort model was constructed in TreeAge Pro 2023 software (TreeAge Software, Inc., Williamstown, MA, USA) to assess the expected costs and quality-adjusted life-years (QALYs) of different treatments for managing tics and TS in children and young adults. Model outputs are used to calculate the expected net monetary benefit (NMB) for each strategy at a range of cost-effectiveness thresholds. As demonstrated in the review of economic evaluation studies, there were few examples of cost-effectiveness models for tic disorders and the model structure was therefore based on the model developed alongside the recently published RCT by Hollis *et al.*, which compared online ERP with online psychoeducation for tics in children.[47] Two separate comparisons of cost-effectiveness are presented in this chapter:

1. Online ERP therapy compared to online psychoeducation in children and adolescents. Despite some uncertainties in modelled parameters, the External Assessment Group (EAG) is satisfied that the evidence base on cost-effectiveness for ORBIT is sufficient to enable decision-making. It should however be noted that the online psychoeducation comparator does not align directly with the NICE scope, where face-to-face psychoeducation was stated as the preferred comparator. Comparisons against this standard of care remain an area of future research need.

TABLE 11 Summary characteristics of included economic evaluation studies

Study	Population	Country	Setting	Intervention	Comparator	EE framework	EE type	DM type/health states	Perspective	Time horizon	Discounting
Andrén 2024[41]	Diagnosis of TS or CTDs, mean age 12.1; 69% male	Sweden	Research clinic	Therapist supported, internet delivered, ERP	Therapist supported, internet delivered, psychoeducation	CEA; CUA	EE alongside RCT	N/A	Provider; health system; societal	12 months	N/A
Dang 2019[46]	Severe TS (undefined); int (*N* = 17): mean age 28, 82% M Comp: mean age 35, 75% M	Australia	NR	DBS	Best medical treatment	CUA	DM based on SES, before and after	Alive dead	NR, assume Healthcare payer.	10 years	5% p.a.
Hollis 2023[35]	Moderate/severe tic disorder (TS or CTD); mean age 12, 79% M	UK	CAMHS	Online therapist supported ERP	Online, therapist supported, psychoeducation	CEA, CUA	EE alongside RCT + decision model	Type: Markov cohort model. States: very mild, mild, moderate, severe, very severe	Health and social care; societal	Trial: 18 M DM: 10 years.	3.5% p.a.

CAMHS, Child and Adolescent Mental Health Services; CUA, cost–utility analysis; N/A, not applicable; NR, not reported.

TABLE 12 Summary results of the included economic evaluation studies

Study	Currency, year	Incremental costs	Incremental Benefits	Base-case ICER	Uncertainty from PSA
Andrén 2024[41]	SEK converted to USD, 2021	Healthcare: − $84.48 (−$440.20 to + $977.60) Societal: + $127.66 (−$1061.62 to + $2562.26)	Treatment response (proportion): + 0.051 (−0.085 to + 0.187) QALYs: + 0.007 (−0.013 to + 0.027)	Treatment response (proportion) Dominant (NR) QALYs: Dominant (NR)	≈ 75% at US$50,000 (healthcare perspective)
Dang 2019[46]	Multiple cost and year inputs, converted to 2018 AUD for outputs/results	Non rechargeable IPG AU$64,084 (NR) Rechargeable IPG AU$29,054 (NR)	Non rechargeable IPG 1.83 QALY IPG 1.83 QALY	ICER: non rechargeable IPG AU$34,959 per QALY gained Rechargeable IPG AU$15,856 per QALY gained	≈ 40–80% across scenarios @ threshold = AU$70,000 per QALY
Hollis 2023[35]	GBP, 2019–20	Trial (18 million) + £662 (−£59 to £1384) Decision model (10 years) £70.76 (NR)	Trial (18 million) + 0.040 (−0.004 to + 0.083) QALY Decision model (10 years) + 0.009	Trial: £16,708 per QALY gained Model: £8276 per QALY gained	Trial (base case) ≈ 65% @ £20,000 ≈ 79% @ £30,000 Model: ≈ 50% @ £10,000 threshold ≈ 60% @ £30,000 threshold

ICER, incremental cost-effectiveness ratio; IPG, Implantable Pulse Generator; NR, not reported; PSA, probabilistic sensitivity analysis; QALY, quality-adjusted life-year; SEK, Swedish Krona.
Note on currency:
US$1 = £0.74 (date of conversion 1 September 2025).
AU$1 = £0.48 (date of conversion 1 September 2025).

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TABLE 13 Summary of quality assessment of the included economic evaluation studies

Study	EAG interpretation of relevance against NICE reference case and scope for this assessment	Quality assessment criteria for decision modelling studies
Andrén 2024[41]	Moderate relevance. relevant interventions (ERP), in a Swedish setting, but does not explore long-term costs and consequences	**N/A**
Dang 2019[46]	**N/A,** intervention and comparators do not meet the scope, does not explore long-term outcomes. Included for completeness from literature review	**N/A**
Hollis 2023 (a);[35] Hollis 2023 (b)[47]	High relevance. detailed assessment of relevant intervention and includes a decision-analytic model with an appropriate model structure parameterised using trial data from a UK NHS perspective. Note that the comparator may not necessarily reflect UK clinical practice	Moderate quality. well-conducted study, with appropriate parameterisation using clinical data. Further scenario analyses and discussion around long-term extrapolation assumptions and intervention costing would have been helpful

N/A, not applicable.

2. Neupulse stimulation compared to a waitlist control (i.e. no stimulation) in young adults. The EAG notes that there is no evidence regarding the cost-effectiveness of Neupulse. The only existing clinical evidence (transition probabilities) to populate the economic model comes from short-term (4-week), non-published data that were provided to the EAG through personal communication with the company. The EAG are, therefore, of the view that there is currently insufficient evidence to decide on the cost-effectiveness case for Neupulse at the moment, and longer-term follow-up data were required. Further evidence generation is required to identify medium and long-term trajectory of clinical outcomes, to provide transition probabilities for extrapolation beyond 4 weeks, and to understand the full costs of intervention delivery and support. The EAG therefore consider the assessment of Neupulse to remain highly uncertain and more appropriate for an early value assessment.

For comparison 1, data are available from the ORBIT study, and this study has been used to replicate the model structure for the current assessment. We use a 5-state Markov model describing different severity of tics and TS classified according to quintiles of the YGTSS-TTSS score. An option for an absorbing state of 'no tics' is included to explore the impact on results of an assumption that some people may gain complete control of tics and TS over time, into adulthood, without treatment. The cohort can die from any state during the model according to all-cause age and sex adjusted mortality probabilities. There is no excess mortality associated with tics and TS included in the model.

The cohort can progress through different severity levels of tics in either 6-monthly cycles (ORBIT) or 4-weekly cycles (Neupulse), according to a set of transition probabilities obtained from the respective RCT data and personal communication with the manufacturer of Neupulse.[36,47] A range of alternative assumptions are explored to illustrate the impact of different assumptions on tics progression over the longer term, post treatment, including extrapolation in the longer term based on last observed health state transitions, fixing the cohort in their last observed health state longer term, and switching ERP transitions to the online psychoeducation arm of ORBIT longer term. Intervention cost data are obtained from the literature, though the current price of Neupulse, if it were to be implemented in NHS practice, is not publicly available. Mean Child Health Utility-9 Dimensions (CHU-9D) based utilities and NHS perspective costs associated with each YGTSS-TTSS defined health state were determined using data reported in the ORBIT study.

In line with the NICE reference case, we take a UK NHS perspective, over a modelled lifetime time horizon. Costs and outcomes accruing beyond the first year were discounted at the recommended rate of 3.5% per year.[49] A summary of the model characteristics is provided in *Table 14*.

Model structure

After conducting a rapid literature review of existing economic evaluations of any intervention, in any population for CTDs or TS, we identified one published Markov decision-analytic model that extended the analysis of cost-effectiveness from the ORBIT trial for treating tics in children aged 9–17 years.[35] Full details of the ORBIT trial are

TABLE 14 Summary of the economic model

Factor	Chosen values	Justification
Time horizon	Lifetime (ORBIT: 88 years for starting age 12; Neupulse: 76 years for starting age 24). Shorter time horizons, 10 years, 5 years and 2 years explored in scenario analyses	According to NICE guidelines, the time horizon should be extended enough to adequately capture all important differences in costs and health outcomes[49] The mean age of patients in the ORBIT trial was 12 years (14 at the end of the trial follow-up). Therefore, a lifetime time horizon of 88 years (86 years post-trial) is appropriate to capture all costs and outcomes, based on the assumption that all patients will be dead by the age of 100[34] Shorter time horizons are explored to reduce the impact of highly uncertain long-term extrapolations
Cycle length	ORBIT: 6 months Neupulse: 4-weekly	This aligns with the ORBIT trial, where the primary outcome measure (YGTSS-TTSS) was assessed at 6 months. Also aligns with reported transition probabilities and health state costs This aligns with the trial, where the primary outcome measure (YGTSS-TTSS) was assessed at 4 weeks and transition probabilities were provided up to 4 weeks only[36]
Intervention(s)	• ORBIT (MindTech) • Neupulse (Neurotherapeutics)	This aligns with the NICE final scope.
Comparators	• ORBIT: Standard care represented as online psychoeducation (ORBIT) • Neupulse: wait list control, no intervention	The comparators differ to the NICE scope, which stated psychoeducation, delivered in a face-to-face format was the ideal comparator. However, the EAG were unable to find any evidence comparing the interventions to face-to-face psychoeducation and definitions of psychoeducation across other studies were too heterogeneous to enable any form of indirect comparison to be performed
Discount rate for costs and outcomes	3.5%	This aligns with the NICE reference case.[49]
Perspective	UK NHS and PSS	This aligns with the NICE reference case, which considers all direct health effects for patients and, carers (if applicable)[49]
Half-cycle correction	A half cycle correction was applied to all modelled costs and outcomes	Aligns with best practice modelling methods
Source of clinical efficacy	ORBIT study informed the clinical efficacy for online therapist-supported ERP and online psychoeducation up to 18 months. Neupulse study informed the clinical efficacy for active Neupulse stimulation, and waitlist (no stimulation) up to 4 weeks. Transition probabilities provided through personal communication with the company. Long-term effectiveness of all interventions is unknown	Head-to-head data for online ERP and online psychoeducation is informed by transition matrices published in the ORBIT trial[47] Data for Neupulse obtained from company upon request because published data on transition probabilities were not available from the published literature in a manner suitable for informing the economic model structure
Source of utilities	Parent proxy reported responses to the CHU-9D, obtained from the ORBIT study, applied to all modelled health states, regardless of age. Assumed that utility of very mild and mild states was equivalent. Assumed that utility of severe and very severe states was equivalent. All HSUVs age and sex adjusted to UK general population norms (based on EQ-5D general population utilities)	These were the only HSUVs available from the literature. Children self-reported responses to the CHU-9D in the study but parent proxy reports were used to calculate HSUVs. CHU-9D utilities were applied into adulthood for all health states because of a lack of data from adult generic HRQoL measures for tics and TS.[47] An assumption about equivalence between mild/very mild states and severe/very severe states was required due to a lack of data

continued

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TABLE 14 Summary of the economic model (*continued*)

Factor	Chosen values	Justification
Source of costs	• Intervention costs, including BiP platform costs and therapist support costs for ORBIT and online psychoeducation obtained from the ORBIT study • Confidential Neupulse intervention costs obtained from personal communication with company, including upfront device cost and monthly software subscription costs *(Personal communication, NeuPulse, July 2024)* • Health state costs obtained from the ORBIT study, validated with clinical experts • All costs were adjusted to 2023 values using the UK NHS Cost Inflation Index (NHSCII), available from https://kar.kent.ac.uk/105685	ORBIT study provides the best available costing information for the intervention. It was not possible to re-cost all aspects of the intervention as sufficient information to do this was not available from the source study; therefore, costs were inflated to current prices instead. Variation in intervention delivery costs, particularly whether ongoing costs of the BiP platform are required in either or both model arms for the ORBIT comparison. Scenario analyses explore the impact of different throughput values on the platform to determine the impact on average per person costs
Outcomes	• Total costs • Incremental costs • Total QALYs • Incremental QALYs • ICERs	Consistent with the final NICE scope and the NICE reference case
Uncertainty	• Univariate sensitivity analysis • Scenario analysis • Probabilistic sensitivity analysis • Evidence gaps highlighted in italics throughout the chapter.	Consistent with NICE reference case. A particular focus is placed on scenario, two-way scenario analyses, probabilistic analyses and highlighting of evidence gaps to inform key priorities for future research questions

EQ-5D, EuroQol-5 Dimensions; HSUV, health state utility value; NHS CII, National Health Service Cost Inflation Index; UK NHS and PSS: United Kingdom National Health Service and Personal Social Services.

provided in *Table 3*, with results of the clinical effectiveness outcomes detailed in *Tables 4*, *6* and *8*. As the ORBIT study model was the only decision modelling study that closely meets the scope for this project, we have built the current model structure around the health states defined in that study. The EAG's clinical expert advisor confirmed that the model structure from the ORBIT was appropriate for decision-making as it captured disease severity using the most used outcome measure for patients with tics and TS, the YGTSS score. The Markov cohort model structure is illustrated in *Figure 9*.

The model comprises five mutually exclusive health states that describe the severity of tics and TS, defined as quintiles of the YGTSS-TGSS score as depicted in the schematic above. The cohort can move through the model states, according to a set of transition probabilities that allow for progression, stability or regression of symptoms in each model cycle. Two different cycle lengths are considered depending on the comparison being evaluated: a 6-month cycle length for ORBIT and a 4-week cycle length for Neupulse. The 4-week cycle length was required for Neupulse due to it being the only available data. Cycle lengths were chosen given the limited availability of data, especially for Neupulse.

Health states are defined according to the level of tic severity as measured using the YGTSS, TTSS.[50] The classification was based on the severity structure proposed by Bloch and Leckman, which was also applied in the ORBIT modelling, where tics are classified according to quintiles of the TTSS on the YGTSS: very mild (0–9), mild (10–19), moderate (20–29), severe (30–39), and very severe (40–50).[9] An additional, semi-absorbing, tics-free health state was considered for scenario analysis. The purpose of the scenario analysis was to allow for a proportion of patients to become permanently tics-free over time, into adulthood. However, based on clinical expert advice, this was not considered appropriate for the base-case analysis. Definitions of each health state are summarised in *Table 15*.

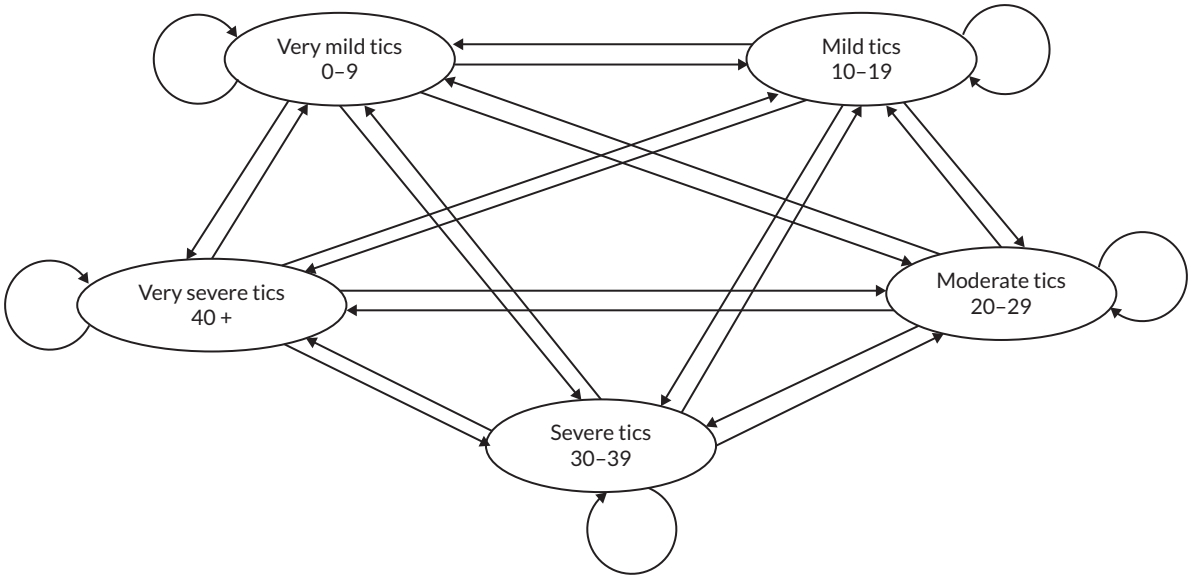

FIGURE 9 Schematic diagram of the Markov model structure of the economic model. In each model cycle, the cohort are also exposed to a risk of all-cause mortality where they enter the 'death' state from any other model state. Death is an absorbing state in the model, based on age-specific mortality rates reported for males and females in the UK life tables.[51]

TABLE 15 Health states categorised using TTSS on the YGTSS

Health states	YGTSS-TTSS
No tics (completely tic free), scenario analysis only	0
Very mild	0–9
Mild	10–19
Moderate	20–29
Severe	30–39
Very severe	40–50

An important evidence gap relating to the model structure is that the long-term potential for people with CTDs or TS to become tic-free over time, into adulthood is unclear. Scenario analyses explore the potential for this based on one small study, but caution is required regarding heterogeneity in the underlying severity of that study compared to the studies included in our review.

Population

The modelled populations were different for comparison 1 (ORBIT) and comparison 2 (Neupulse). This reflects the likely different populations in which these treatments would be used in UK clinical practice (e.g. Neupulse in an older population and with more severe tics and TS). The modelled starting cohort's characteristics are therefore obtained from the key clinical trials of both interventions as described below.

Online Remote Behavioural Treatment for Tics

The population entering the model for ORBIT and online psychoeducation consists of children and young people, diagnosed with CTDs who continue to report bothersome tics after initial psychoeducation, which is in line with the

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NICE scope.[52] The specific participant characteristics were obtained as the mean age and gender proportion across the full study population in the ORBIT trial. The detailed proportion of participants starting in each severity health state undergoing online ERP and psychoeducation treatment was based on data from the ORBIT trial. Most participants entered the model in the moderate, severe or very severe states, with comparatively fewer starting with mild or very mild tics according to the YGTSS.

Neupulse

For Neupulse, the population is restricted to individuals aged 12 and older with confirmed or suspected TS and CTD, with moderate to severe tics. The starting population in the model for the Neupulse and waiting list control arms of the model was therefore based on the mean characteristics across the Neupulse and waitlist control groups from the Maiquez, 2023 trial.[36] The Neupulse trial included participants with comparatively more severe tics and TS and significantly higher YGTSS-TGSS score compared to the ORBIT trial population. This necessitated separate comparisons of different populations for CEA. Data for the distribution of the cohort starting in each modelled state at baseline were not available from the published literature. Starting proportions according to our modelled definitions were provided through personal communication with a coauthor from the Maiquez study *(Personal communication, Neupulse, May 2024)*. Modelled population characteristics for both comparisons are summarised in *Table 16*.

A key evidence gap for the Neupulse comparison relates to a lack of available data in the public domain regarding the starting distribution of the cohort across Markov model states. However, information was helpfully provided by the company. It was not possible to conduct a fully incremental analysis, including a comparison or Neupulse with ORBIT as the clinical trials were conducted in different population groups. Importantly, there was no evidence to enable a cost-effectiveness assessment of any of the interventions compared to current UK standard of care, as defined in the NICE scope (online/face-to-face psychoeducation). The online psychoeducation arm of ORBIT uses the BiP platform and may therefore be a more active comparator than current UK clinical practice. Due to the lack of available data, the assessment therefore relies on the comparisons considered in the key clinical trials.

Perspective, time horizon and discounting

The base-case analysis reports incremental cost per QALY gained over a lifetime time horizon (up until age 100) from a UK NHS and Personal Social Services perspective. All costs and QALYs beyond 12 months were discounted at a rate of 3.5% per year in line with the NICE reference case.[49] Shorter time horizons (2, 5 and 10 years) are explored in scenario analyses to reduce the uncertainty associated with longer-term tics and TS progression. For the ORBIT comparison, the model starting point is 18 months, as the model includes the costs and QALY payoffs reported in the clinical trial up to 18 months' follow-up. Discounting formulae are adjusted accordingly. A 2-year time horizon therefore refers to 18 months plus 2 years of extrapolation for the ORBIT comparison. No cost-effectiveness trial data are available for the Neupulse; therefore, the model is started at time zero.

A key evidence gap relates to long-term extrapolations beyond 18 months for the ORBIT comparison and beyond 4 weeks for the Neupulse comparison. This is a significant source of uncertainty, and it may therefore be appropriate to consider shorter time horizons given the lack of robust long-term data on tic/TS progression with and without treatment.

Model parameters: transition probabilities

Transition probabilities based on observed data

For the ORBIT study, costs and QALYs from the trial are used directly within the economic model as payoffs up to 18 months (first three model cycles). The starting proportions for the Markov cohort were taken as the distribution of health state occupancy at the end of the ORBIT study follow-up at 18 months. Beyond that time point, baseline transition probabilities were derived from the online psychoeducation arm of the ORBIT trial follow-up, calculated from observed transitions between 6 and 18 months, aiming to assess the natural course of tic progression post intervention.[34,47] Specific transitions between 6–12 and 12–18 months were not reported. The calculation of transition

TABLE 16 Modelled population characteristics for ORBIT and Neupulse evaluations

	ORBIT		Neupulse		
	Psychoeducation	**ERP**	**Active simulation**	**Waitlist**	**Distribution**
Participant demographics					
Mean age	12		24		Fixed
Proportion male	*N* = 177/224 (79%)		Active: *N* = 26/41 (63%) Waitlist: *N* = 26/41 (63%)		Fixed
	ORBIT		**Neupulse**		**Distribution**
	Psychoeducation	**ERP**	**Active simulation**	**Waitlist**	
Disease severity [model health state starting proportions (i.e. reported at 18 months ORBIT trial follow-up)]					
	% Alpha	% Alpha	% Alpha	% Alpha	
Very mild	4% 4	12% 11	0 0	0 0	DT
Mild	18% 16	19% 17	0 0	3% 1	DT
Moderate	37% 33	33% 29	11% 4	6% 2	DT
Severe	21% 19	14% 12	18% 7	43% 15	DT
Very severe	20% 18	22% 20	71% 27	49% 17	DT
No tics	0 0	0 0	0 0	0 0	0

DT, Dirichlet distribution.

probabilities in the ORBIT study excluded transitions between baseline and 6 months to remove the initial steeper improvement in tics in both arms of the trial from the calculation of long-term extrapolation transition probabilities. The 6-monthly transitions calculated from the observed data between 6 and 18 months were applied in the model from cycle 3 onwards in the base-case analysis. Transition probabilities for ERP were also obtained directly from the ORBIT study, using a similar approach for data from the intervention arm of the trial.

For Neupulse and waiting list control, a similar approach was taken to deriving transition probabilities. There was no trial-specific cost nor QALY data available to inform the model; therefore, the starting point for the cohort was time zero. Transition probabilities were not available from the published literature. Instead, 4-week transitions were obtained through personal communication with the company. The EAG provided a pre-specified transition matrix form, in which count data from the study were entered and returned to the EAG for use in the model.

All transition probabilities are incorporated into the model using Dirichlet distributions using alpha values reflecting transition counts back calculated from transition probabilities reported in *Table 17* of the ORBIT NIHR report, assumed to reflect 6-monthly transitions, though it is not explicitly stated in the report how these were derived. For Neupulse, the Dirichlet distributions are parameterised using 4-week alpha counts provided through personal communication with the company. Data underpinning these distributions are provided in *Table 17*.

Evidence gaps: it should be noted that Neupulse transition probabilities were not available from the published literature and were instead sourced through personal communication with the company. Data were provided up to 4 weeks, which the EAG considers a short time horizon. These data are insufficient to make any strong predictions of longer-term outcomes and clinical effectiveness data up to 6 months, anticipated to be published in future, will help reduce the uncertainty somewhat. Transition probabilities for all comparisons (ORBIT and Neupulse) are derived from very small counts. This leads to substantial uncertainty regarding treatment effect sizes in the longer term. For example, transition probabilities derived from < 10 observations should be interpreted particularly cautiously as they may lead to misleading deterministic base-case results. Larger studies of the interventions are required, with longer-term follow-up, particularly for Neupulse required to improve modelling projections.

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TABLE 17 Transition probabilities

	To very mild	To mild	To moderate	To severe	To very severe	*n*
6-monthly transition probabilities for ORBIT and online psychoeducation						
Online psychoeducation						
From very mild	0.500	0.500	0.000	0.000	0.000	4
From mild	0.074	0.817	0.036	0.036	0.036	16
From moderate	0.019	0.060	0.827	0.092	0.000	33
From severe	0.000	0.051	0.134	0.680	0.134	19
From very severe	0.000	0.000	0.021	0.115	0.863	18
Online ERP						
From very mild	0.788	0.105	0.105	0.000	0.000	11
From mild	0.147	0.609	0.174	0.022	0.046	17
From moderate	0.011	0.150	0.754	0.035	0.047	29
From severe	0.000	0.000	0.113	0.886	0.000	12
From very severe	0.000	0.021	0.044	0.021	0.912	20
4-week cycle-specific transition probabilities for Neupulse and waiting list control						
Active Neupulse stimulation						
From very mild	1[a]	0.00	0.00	0.00	0.00	0
From mild	0.00	1[a]	0.00	0.00	0.00	0
From moderate	0.00	0.50	0.25	0.25	0.00	4
From severe	0.00	0.00	0.14	0.86	0.00	7
From very severe	0.04	0.00	0.11	0.33	0.52	27
Waitlist (no stimulation)						
From very mild	1[a]	0.00	0.00	0.00	0.00	0
From mild	0.00	0.00	1.00	0.00	0.00	1
From moderate	0.00	0.00	1.00	0.00	0.00	2
From severe	0.00	0.00	0.13	0.60	0.27	15
From very severe	0.00	0.00	0.00	0.29	0.71	17

a Where no data were available for any given transition out of a health state, it was assumed that people remained in that state if they entered the state in subsequent model cycles.

Source

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Transition probabilities to the absorbing 'tics free' state in scenario analyses

Inclusion of a semi-absorbing state of 'tics free' is explored in a scenario analysis. The intention of this state is to model a proportion of people who may 'grow out' of tics in the longer term, returning to a QoL assumed equal to that of the general population. The proportion of the cohort entering the absorbing 'tics free' state in the scenario analysis is derived from a study reporting that, over one-third (37%) of a combined sample of across two studies of $N = 82$ children with TS were completely tic-free. We use the median follow-up from Bloch *et al.*, of 7.3 years to fit an exponential distribution to the median to determine a linear progression into the tics free state over time for this scenario analysis.[9]

Since cycle-specific transitions into the tics-free state were unavailable, we used an exponential formula based on the median time to an event to estimate the proportion of individuals who become tic-free in each 6-monthly cycle. Transitions to the tic-free state were applied from each modelled tic severity state at an equal rate due to a lack of evidence to support a tic severity adjustment.

The cycle-specific transition into the tics-free state was calculated as:

$P(t) = \exp(\ln(0.5)/\text{median number of cycles} \times \text{current cycle})$

Where:

- $P(t)$ is the probability of being disease-free at time t.
- ln is the natural logarithm.
- 0.5 represents the 50th percentile (median).
- The median number of cycles is the time at which 50% of the cohort remains disease-free.
- The current cycle is the specific time point for which we are calculating the probability.

Evidence gap: the long-term trajectory towards a tic-free state, that is the potential for people to have completely resolved tics over time, into adulthood is not well understood. There appears to be limited long-term data, and it is unclear how the time to achieve tics-free would depend on the underlying severity of chronic tics of TS. Further evidence is required to better inform modelling of any potential possibility for transition to a tics-free state over time and whether different intervention types might have differential impacts on these outcomes. Our simplistic scenario analysis assumes that transitions occur at the same rate from any state of the model. This assumption is likely to lack face validity, given that people become tics gradually over time. However, in the absence of alternative data, this was deemed the most appropriate approach in which to conduct the scenario analysis.

Longer-term transition probabilities beyond the end of the observed period from trial data

The EAG note that there is significant uncertainty and a lack of data to describe the long-run transitions between model health states beyond the observed periods in the respective trials. The tentative base-case analysis is formulated on the assumptions which the EAG consider potentially plausible, and in line with the clinical expert advice we have received, but a range of different assumptions are applied in scenario analyses. For online psychoeducation and ORBIT, we assume that the transition probabilities between 6 and 18 months can be extrapolated over a lifetime horizon. These transitions exclude the initial improvement in both arms seen up to 6 months in the study. We assume that, to achieve these outcomes, ongoing use of the BiP platform would be required in both arms of the model. However, the costs of ongoing therapist support would not be incurred. This assumes that both ERP and online psychoeducation are successful in the longer term and that learnt behaviours can be implemented indefinitely.

For Neupulse, the mechanism of action is electrical stimulation. It is therefore assumed that the intervention is effective only so long as it is used. For the base-case analysis, we assume, similarly, to ORBIT that transition probabilities from 4 weeks can be extrapolated longer term. Again, this would require that Neupulse treatment is continued indefinitely. However, it may be more appropriate to assume that full effectiveness for Neupulse is achieved at 4 weeks and that ongoing treatment would not lead to further improvement in symptoms, with the cohort instead being held in their observed state at 4 weeks.

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All these assumptions are surrounded by considerable uncertainty, and it is not possible to derive a clear base-case set of assumptions. For that reason, we have reported several scenario analyses as follows:

- Assuming that longer-term transition probabilities switch from the active intervention to comparator transitions beyond the observed time points. This would be a pessimistic assumption for Neupulse. However, it would be optimistic for ORBIT given that there is some evidence that transition probabilities may be favourable to psychoeducation longer term with initial gains potentially being reversed.
- Assuming that each cohort is held in their last observed state for the remainder of the economic model.
- Given that none of these scenarios for long-term modelling are supported by robust evidence and are, at best, speculative, the model time horizon has been reduced to 10, 5 and 2 years in scenario analyses to minimise the impact of long-term extrapolation assumptions on results.

Evidence gaps: long-term transition probabilities are unknown for all the interventions. It is unclear how transition probabilities for Neupulse would change beyond the study intervention phase (4 weeks). There is some suggestion that transition probabilities for online psychoeducation may be slightly favourable to psychoeducation longer term suggesting that gains in the ERP arm might not be sustained longer term. However, all these data are highly uncertain, and it is more appropriate to consider the balance of uncertainty around model outcomes using probabilistic analyses, with the uncertainty captured through small counts informing the Dirichlet distributions of transitions. Future, longer-term follow-up studies are required to better understand the long-term impact of interventions on chronic tics and TS.

Model parameters: costs and resource use

Intervention costs: Online Remote Behavioural Treatment for Tics and online psychoeducation

All cost items for ERP and online psychoeducation were sourced directly from the ORBIT trial. It was not possible to identify each item of resource use in sufficient detail to enable a recalculation of costs using current Personal Social Services Research Unit costs of staff time. Therefore, costs reported in the ORBIT study are inflated to 2023 values for application in the model. The Neupulse device cost was obtained from the company upon request. A summary of intervention costs, inflated from those reported in the ORBIT study is provided in *Table 18*. The costs for consideration include:

- The BiP platform costs (fixed cost of setting up platform and variable cost per text sent from the platform, based on usage). The BiP platform was used in both arms of the study in the ORBIT trial, with an assumed throughput for calculation of per person costs of $N = 222$ (combined sample across both arms of the ORBIT study). However, the ORBIT study only included costs in the ERP arm for their economic modelling. The EAG consider it appropriate to include the costs of the platform in both arms of the study to align the resource use incurred with the benefits derived. The throughput is varied between 100 and 1000 for sensitivity analyses.
- Costs of therapist support time, including a fixed component for training and a variable component of service delivery and patient support.

For the EAG analyses, costs were split into an 'upfront' initial cost, as described above, plus and ongoing cycle-specific cost based on variable cost of platform usage. The ongoing cycle-specific costs are applied to both arms in the base-case analysis, on the assumption that long-term transition probabilities can only be achieved if use of the platform is continued indefinitely over time. These assumptions are tested in scenario analyses. Full details of the intervention costing are provided in *Table 18*.

Evidence gaps: The ORBIT study used the BiP platform in both study arms, but costs in the ORBIT economic evaluation only included costs in the ERP arm. The EAG preferred to include the costs in both arms because this reflects the potential resource use incurred in the trial. However, it is unclear how the availability of the BiP platform would have impacted on the effectiveness of the online psychoeducation arm of the study, but it is plausible that it would have overestimated effectiveness in the comparator arm relative to standard care where the platform was not available. Similarly, the exact throughput for the BiP platform is unclear, and this impacts on costs. For the longer-term

TABLE 18 Intervention costs for ORBIT and online psychoeducation

Cost per participant	Initial up-front costs		Ongoing costs per cycle	
	Psychoeducation (£)	ERP (£)	Psychoeducation (£)	ERP (£)
Fixed cost of BiP platform per participant[a]	43.05	43.05	0	0
Fixed cost of therapist support (training and supervision)[a]	75.38	75.38	0	0
Variable platform costs[b]	6.32	7.73	6.32[c]	7.73[c]
Variable cost of therapist support[b]	42.76	48.38	0	0
Total intervention cost	167.51	174.54	6.32	7.73
Scenario analysis 1, include only variable cost of therapist support for psychoeducation	42.76	174.54	0	7.73
Scenario analysis 2, apply approach from ORBIT study (include only variable costs of platform and therapist support for psychoeducation and remove all ongoing costs)	49.08	174.54	0	0
Scenario analysis 3, only include variable therapist support costs, include ongoing costs + platform throughput (*n* = 100)	42.76	227.06	6.32	7.73
Scenario analysis 4, only include variable therapist support costs, include ongoing costs + platform throughput (***n*** = 1000)	42.76	141.05	6.32	7.73
Scenario analysis 5, remove ongoing costs from both arms	167.51	174.54	0	0

a Fixed platform costs calculated as SEK96,000, converted to 2022/3 GBP £9556.96 and divided by the assumed throughput on the platform (*N* = 222, combined ORBIT trial sample). The fixed therapist support includes costs of training and supervision, based on weekly 1-hour supervision sessions with therapists during 10-week intervention delivery. Total costs divided by total patient numbers in the study (*N* = 222) to obtain per person costs. Costs were reported in Table 1 of the Results Appendix document in Hollis *et al.*, fixed cost of therapist support inflated to 2022-3 values for use in the model.[34]

b Each time a participant accesses the BiP platform, a text message is sent to them. The average cost of sending a text message across various UK network providers has been calculated in the ORBIT study and multiplied by the number of total system logins per study arm and divided by the sample size to estimate per person costs. A patient-level variable cost of therapist support is also calculated for each participant based on the reported therapist time and the therapist's grade with whom they interacted. Further details available from: Hollis *et al.*, Table 6 of Appendix results, variable cost.[34]

c Costs are per year, adjusted to 6-monthly cycles and discounted in model.

extrapolation, the EAG includes some ongoing costs of platform access for the model time horizon because we also extrapolate short-term transition probabilities over the longer-term time horizon. However, it is unclear which combination of intervention costs and long-term extrapolations is most appropriate.

Intervention costs: Neupulse

The cost for Neupulse consists of two components: an initial device purchase cost and a monthly subscription cost (*Table 19*). A definitive purchase and subscription cost to the NHS was not available, but the company confidentially provided tentative prices that could be used to inform the committee's decision-making. Given the uncertainty of the definitive price that would be applicable in UK clinical practice, if rolled out on the NHS, the economic model explored the impact of a range of different prices on cost-effectiveness results. The model assumed that the intervention cost would need be incurred indefinitely to maintain the intervention's effectiveness. An ongoing monthly subscription cost is also applied in each model cycle. The monthly subscription includes access to an app for controlling the device, daily disposable hydrogel pads, storage of medical data associated with the therapy, and access to both digital and human product support resources. It was assumed that there were no intervention costs assigned to the waiting list control arm of the model and that no additional costs would be incurred associated with training or therapist support as Neupulse is intended as a self-administered device, with all required patient training provided within the company provided materials.

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TABLE 19 Neupulse intervention costs

Cost item	Fixed
Neupulse device cost	Varied between £0 and £1000 in scenario analyses
Subscription cost/month	Varied between £0 and £100 per month in scenario analyses

Evidence gap: the costs of Neupulse are not currently publicly available and have been provided to the EAG through personal communication with the company. It is unclear how the costs provided would translate to costs in UK NHS practice if the device was made available to the NHS. However, it is feasible that a combination of factors, including additional costs of sales to the NHS, or reductions due to economies of scale, would be relevant, meaning that the cost to the NHS may not be accurately represented by the costs used in the economic modelling. While the company suggest that there are no training or staff costs associated with the use of the device, there are, as yet, no data to support or refute this assumption.

Health state costs

The EAG's understanding of UK clinical practice is that management of children with tics and TS is most likely to take place in paediatrics, or CAMHs services, with management of adults typically occurring in community mental health teams of neurology clinics. Within the ORBIT study, the authors compared resource use and costs between ERP and online psychoeducation across several different categories of costs (specialist tic services, community services, hospital services, accident and emergency and medication costs). They found no clear differences between groups for any of the cost categories, despite potential clinical benefits. The authors also explored the impact of tic severity on these cost categories. The only cost category identified as being significantly determined by tic severity was the use of specialist tic services. Therefore, the model used health state costs that were informed by a regression analysis to determine health state-specific costs (defined as use of specialist tic services), with adjustment for age, comorbidities using the development and wellbeing assessment, and gender.

The EAG's base-case analysis uses the cost data from the trial on the grounds that it is a conservative estimate of the potential cost-savings of moving between different health states but acknowledging that it might not capture the full range of services utilised by patients with chronic tics and TS. The EAG's clinical expert and one response to a survey of specialist committee members for this topic suggested that improvements in tic severity might also reduce the need for medication. The EAG therefore explored a scenario analysis where an additional medication cost was added to the moderate and severe YGTSS health states, but not to the mild/very mild states. Medication usage also likely varies across UK clinical practice, both in terms of the proportion of patients receiving medication and the distribution of medications among those who do. For the scenario analysis, the EAG applied 6-month costs of Clonidine (assumed 50%) and Haloperidol (assumed 50%) in the moderate state with a cost of Clonidine (45%), Risperidone (10%) and Haloperidol (45%) applied in the severe and very severe tics states. Costs of medications for the scenario analysis were sourced from eMIT 2023 prices as:

- Clonidine 25 mcg, dose up to 150 mcg per day, unit cost £2.95 per pack size of 112 tablets, 10 packs required per 6-month model cycle, cost per cycle: £29.50.
- Haloperidol 5 mg, dose of up to 5 mg per day, unit cost £0.84 per pack size of 28 tablets, 6 packs required per 6-month model cycle, cost per cycle: £5.04.
- Risperidone 1 mg, average dose of approximately 5 mg per day, unit cost £0.77 per pack size of 60 tablets, 16 packs required per 6-month cycle, cost per cycle: £12.32.

Based on the weightings above, an additional cost of £17.27 and £16.78 is added to the severe and very severe tic states respectively.

All cost parameters were incorporated into the model probabilistically using gamma distributions. Where a measure of spread was not available for any of the cost parameters, the standard error (SE) was assumed to be 10% of the mean. All cost parameters are summarised in *Table 20*.

TABLE 20 Summary of health state costs applied in the model

Parameters		Mean (£)	SE (£)	Alpha	Lambda	Dist.	Source
6-month health state costs							
Very mild	Base case	145.14	17.11	71.96	0.50	Gamma	ORBIT
	Scenario	145.14	17.11	71.96	0.50	Gamma	ORBIT
Mild	Base case	145.14	17.11	71.96	0.50	Gamma	ORBIT
	Scenario	145.14	17.11	71.96	0.50	Gamma	ORBIT
Moderate	Base case	149.64	14.21	110.89	0.74	Gamma	ORBIT
	Scenario[a]	166.91	16.69			Gamma	ORBIT + assumption
Severe	Base case	218.28	21.40	104.04	0.48	Gamma	ORBIT
	Scenario[a]	235.06	23.51			Gamma	ORBIT + assumption
Very severe	Base case	218.28	21.40	104.04	0.48	Gamma	ORBIT
	Scenario[a]	235.06	23.51			Gamma	ORBIT + assumption
No tics		0	N/A	N/A	N/A	Fixed	Assumption

a SE was calculated as 10% of the mean.

Evidence gap: There is limited evidence external to the clinical trial with regards to the most appropriate health state costs to apply in the economic model. A survey of clinical experts for this assessment failed to provide any additional information to reflect variation in UK clinical practice. The EAG are also aware tha4t many people may not have access to services specifically to treat their tics/TS and that in some cases, these services may be embedded within other services for other comorbid conditions. Care is required to avoid double-counting of health state costs, and further research is needed to better understand the care pathways followed by patients with tics and TS in UK clinical practice. Similarly, there are no data from the ORBIT study regarding the health state costs to apply for adults. This is an added uncertainty, particularly for the Neupulse assessment.

Model parameters: health state utility values

Health state utility values were obtained from the ORBIT study. In the ORBIT study, utilities were calculated from responses to the CHU-9D.[53,54] Responses within the trial were provided by a mix of patient (young person) and proxy (assumed parent) reports at baseline and at 3, 6, 12 and 18 months' follow-up. It is unclear whether child self-reports, parent proxy-report or a combination of both were used to derive health state utility values (HSUVs) for application in the model. Responses to the CHU-9D were converted to utilities using a preference-based algorithm.[55] As with costs above, mild and very mild states incurred the same utility as did severe/very severe states. The estimation approach for HSUVs was not described in the study, and, therefore, it was unclear whether these were based on regression estimates or descriptive data. For the scenario analysis that includes the semi-absorbing tics free state, utility is assumed to be equal to the very mild/mild health state, acknowledging that people with tics and TS often have multiple comorbidities and it would likely be inappropriate to assign UK general population norms, despite the absence of tics.

Table 21 summarises the HSUVs obtained from the ORBIT trial data and applied in the model. All utilities are incorporated using beta distributions. When applied to health states, QALY payoffs were halved to accommodate the 6-monthly cycle duration. The utility of the death state is set to zero. All utility inputs to the model are age and sex adjusted, allowing for reduced HSUVs in all health states as the cohort ages through the model. Adjustment multipliers were calculated as general population EuroQol-5 dimensions (EQ-5D) based utility at each stage/general population utility at the start age of the model cohort. At any given time, the UK general population norm is calculated using the method described by Ara and Brazier.[56]

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TABLE 21 Utilities associated with each health state

Parameters	Mean	SE	alpha	Beta	Dist.	Notes/source
Mild	0.867	0.006	2776.21	425.88	Beta	ORBIT
Moderate	0.839	0.004	7082.37	1359.07	Beta	ORBIT
Severe	0.814	0.005	4928.90	1126.26	Beta	ORBIT
No tics	0.867	0.006	2776.21	425.88	Fixed	Assumed equal to utility of the mild state

Evidence gaps: As demonstrated in the clinical-effectiveness review, the relationship between tic severity and HRQoL is unclear. Changes in the clinical outcome do not necessarily lead to changes in QoL or HSUVs. This is an important area for future research. While some evidence is available from the ORBIT study for children, there are no studies reporting the relationship between tic severity and EQ-5D in adult patients. The EAG understands the rationale for pooling very mild/mild and very severe/severe states for calculating HSUVs. However, if a true relationship between tic severity and generic HRQoL exists, the approach may underestimate the QALY benefits of effective treatments. It is unclear if the lack of statistical significance of health state in the ORBIT study is due to small sample sizes, or a true lack of effect. Further studies are required to better understand the relationship between tic severity and QALY benefits. The lack of evidence is particularly acute in an adult population.

Model analysis

Results are presented as incremental cost per QALY gained from a UK NHS perspective. ICERs were determined for pairwise comparisons of ERP versus psychoeducation and active Neupulse stimulation versus waitlist control.

The cost-effectiveness of each intervention versus comparators was evaluated at an indicative threshold value of £20,000–30,000 per QALY gained.[57]

The model is constructed to be fully probabilistic. Probabilistic analyses were performed for each modelling scenario, using Monte Carlo simulation with 50,000 iteration runs (the minimum number of runs required to achieve convergence of probabilistic ICERs), to construct the cost-effectiveness acceptability curves (CEACs). This involved varying the inputs by randomly assigning parameter values from predefined uncertainty distributions as described in the model input parameter tables. A probability distribution was assigned to each model input parameter, reflecting the degree of uncertainty due to sampling variation. Gamma distributions were applied to represent uncertainty surrounding cost inputs, beta distributions were used for utility parameters, and Dirichlet distributions[58] were applied for transition probabilities. When SEs for parameters were unknown, they were assumed to be 10% of the parameter value to define the PSA distributions. The CEACs show the probability of an intervention being cost-effective compared to comparators for a range of cost-effectiveness threshold values. Results are also presented as iterations of simulations for intervention versus comparator on the cost-effectiveness plane to illustrate the impact of parameter uncertainty on results.

Scenario analysis

There are multiple points of residual uncertainty surrounding many of the key assumptions and model inputs, both for the comparison of ORBIT versus online psychoeducation and Neupulse versus waitlist control. This makes it difficult for the EAG to define a clear set of base-case assumptions. However, we have selected a set of assumptions that, on balance, appear plausible as a starting point and conduct extensive scenario analyses around these. *Table 22* summarises some of the key assumptions, residual uncertainties and EAG scenarios conducted to illustrate that uncertainty.

Model validation and face validity checks

One health economist built and parameterised the economic model. Model formulae and parameter inputs were verified against source by a second health economist, who also conducted a range of face validity checks, changing one

TABLE 22 Base-case assumptions, residual uncertainties and EAG scenario analyses

Assumption/parameter	Base case	Residual uncertainty	Scenario analyses completed
All parameter inputs	Sampled from probabilistic distributions	Parameters are highly uncertain, in particular transition probabilities	Parameter uncertainty incorporated through probabilistic analyses
Potential for some people to become permanently 'tics free' longer term	Assumed not possible	Some people may 'grow out' of tics longer term, into adulthood, but it is unclear to what extent this can be assumed for the modelled population. Duration to achieve 'tics free' and potential to do so are key residual uncertainties	Inclusion of a tics free semi-absorbing health state in the model
Long-term transition probability extrapolation assumptions	Last observed transition carried forward for the full model time horizon	Long-term transition probabilities beyond observed periods are unknown and it is unknown what level of resource use would be required to maintain effectiveness	Cohort fixed in last observed health state; intervention arm transferred to control group transitions beyond observed time period; shorter time horizons of 2,5 and 10 years explored
ERP and psychoeducation intervention costs	BiP platform costs included in both study arms; ongoing platform usage would be required to maintain effectiveness longer term	It is unclear to what extent the costs incurred in the trial for the BiP platform would be incurred in the psychoeducation arm in routine clinical practice, or whether longer-term resource use would be required to maintain effectiveness	BiP platform costs removed from psychoeducation arm, costs of ongoing use of the platform removed, platform throughput varied between 100 and 1000 for 'per person' cost calculations
Health state costs	Obtained from the ORBIT study, includes only the costs of using specialist tic services	The ORBIT economic model may not have captured all the variability in health state costs due to exclusion of other services (e.g. medication costs)	Additional medication costs included as a scenario analysis in the moderate and severe health states based on clinical expert advice

model parameter at a time and re-running results to assess consistency. Adaptations were made where issues were identified. The EAG were unable to identify any longer-term data against which the model outputs could be externally validated. The model outputs were instead presented and discussed among the team and clinical expert did not identify any issues of concern regarding the plausibility of the outputs. However, they did flag that the highly uncertain evidence base meant that caution should be exercised when interpreting the results of a lifetime horizon model, given the lack of longer-term follow-up beyond 18 months for ORBIT and lack of published transition probability data for Neupulse.

The EAG has undertaken a range of further verification tests, based on an adaption of those proposed by Tappenden *et al.*[59] The results of these verification checks are provided in *Table 23*, applied to the EAG's preferred base-case analysis. No further issues were identified with the final version of the EAG's model.

TABLE 23 'Black box' verification checks conducted on the EAG base-case model

Model component	Model test	Unequivocal criterion for verification	Issues
Model component Clinical trajectory	**Model test**	**Unequivocal criterion for verification**	**Issues**
	Apply online psychoeducation probabilities to the ERP, equalise starting proportions and apply equal QALY gains from the trial to both arms	All treatments produce equal estimates of mean total QALYs	None
	Sum health state occupancy at any model time point	Total probability equals 1.0	None
Long-term extrapolation	Fix cohort in last observed state from the ORBIT trial	ICER reduced, NMB increased	None
Discounting	Set discount rate to 0	Costs and QALYs in both arms increase.	None
QALY estimation	Set discount rate to a large number	Costs and QALYs in both arms tend to 0	None

continued

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TABLE 23 'Black box' verification checks conducted on the EAG base-case model (*continued*)

Model component	Model test	Unequivocal criterion for verification	Issues
QALY estimation Cost estimation	Set all HSUVs for living states = 1; set probability mortality to 0; remove QALY discounting; Set trial QALYs = 1.5 years	QALY gains equal to modelled time horizon + 1.5 years	None
	Set intervention costs to 0	ICER is reduced, NMB increased, probability of cost-effectiveness increased	None
Input parameters	Increase intervention cost	ICER is increased, NMB reduced, probability of cost-effectiveness reduced	None
Input parameters General	Produce *n* samples of each model parameter	Range of sampled parameter values does not violate characteristics of statistical distribution	None
	Set all treatment-specific parameters equal for all treatment groups (implemented by removing all re-definitions from the ERP node in the model)	Costs and QALYs equal for all treatments	None

NMB: net monetary benefit; QALY: quality-adjusted life-year.

Results: Online Remote Behavioural Treatment for Tics

Markov cohort traces

Figures 10 and *11* illustrate the base-case Markov cohort traces for online psychoeducation and ORBIT respectively over a lifetime horizon. The cohort traces are very similar, particularly after the first few model cycles. This is due to differences up to 18 months being quite quickly offset by slightly favourable, but highly uncertain transition probabilities for online psychoeducation.

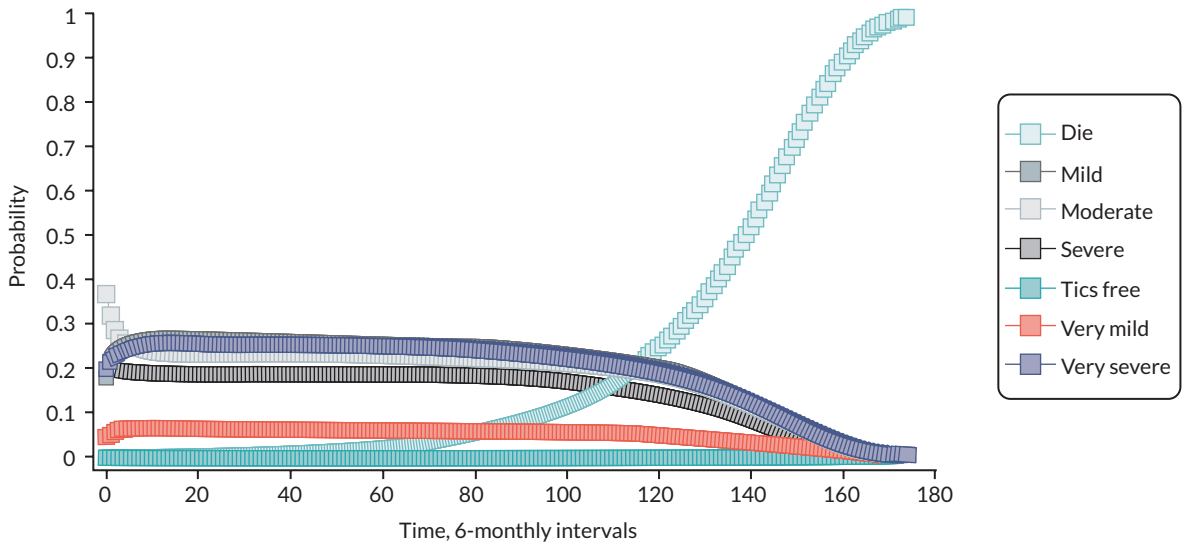

FIGURE 10 Markov cohort trace – online psychoeducation.

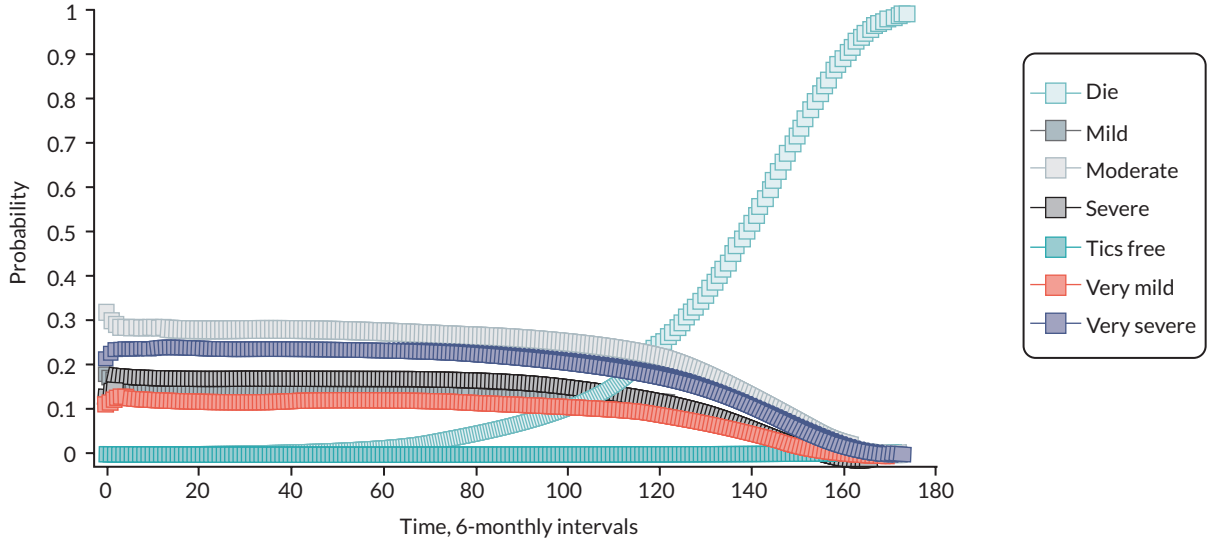

FIGURE 11 Markov cohort trace – ORBIT.

Base-case analysis

It was not possible to determine a definitive base-case set of assumptions. However, a set of assumptions, as outlined in *Table 22* are used as a starting point for exploring uncertainty. It is important to consider the full range of scenario analyses carried out and note that some scenarios have a major impact on the reported ICERs and probability of cost-effectiveness. Probabilistic and deterministic ICERs are reported in *Table 24*. The deterministic analysis suggests a low ICER of £9289 for ORBIT compared to online psychoeducation, whereas the probabilistic ICER shows ORBIT to be, on average, more costly with minimal differences in effectiveness (i.e. dominated by online psychoeducation). While these results may appear significantly different to each other, they should be interpreted in the context of the uncertainty surrounding the results output. The magnitude of QALY gains and losses are small in the context of a lifetime horizon, driven by broadly similar transition probabilities for both arms of the model, slightly favouring online psychoeducation, offsetting early QALY gains observed in the trial.

TABLE 24 Base-case incremental analysis (ORBIT vs. online psychoeducation)

Technologies	Total costs (£)	Total QALY	Incremental costs (£)	Incremental QALYs	ICER (£)	INMB
Deterministic ICER						
Psychoeducation	12,755	20.916	–	–	–	
ERP	12,974	20.939	218	0.024	9289	+ £502
Probabilistic ICER						
Psychoeducation	12,731	20.928	–	–	–	
ERP	13,085	20.921	354	−0.007	Dominated	− £564

INMB: incremental net monetary benefit with lambda assumed equal to £30,000.

The results should be interpreted considering the uncertainty surrounding the model outputs. Observation of the spread of iterations from the 50,000 iterations from the probabilistic analysis on the cost-effectiveness plane (*Figure 12*) indicates substantial uncertainty. An approximately equal proportion of iterations lie above and below the £20,000 per QALY threshold line, indicating that neither strategy is clearly optimal under base-case assumptions. Furthermore, many of the simulated cost and effect pairs lie in the northwest quadrant of the plane, indicating that we cannot rule out ERP being more costly and less effective over a lifetime horizon. CEACs, provided in *Figure 13* also illustrate that the uncertainty persists across all threshold values of willingness to pay (WTP) for a QALY gain.

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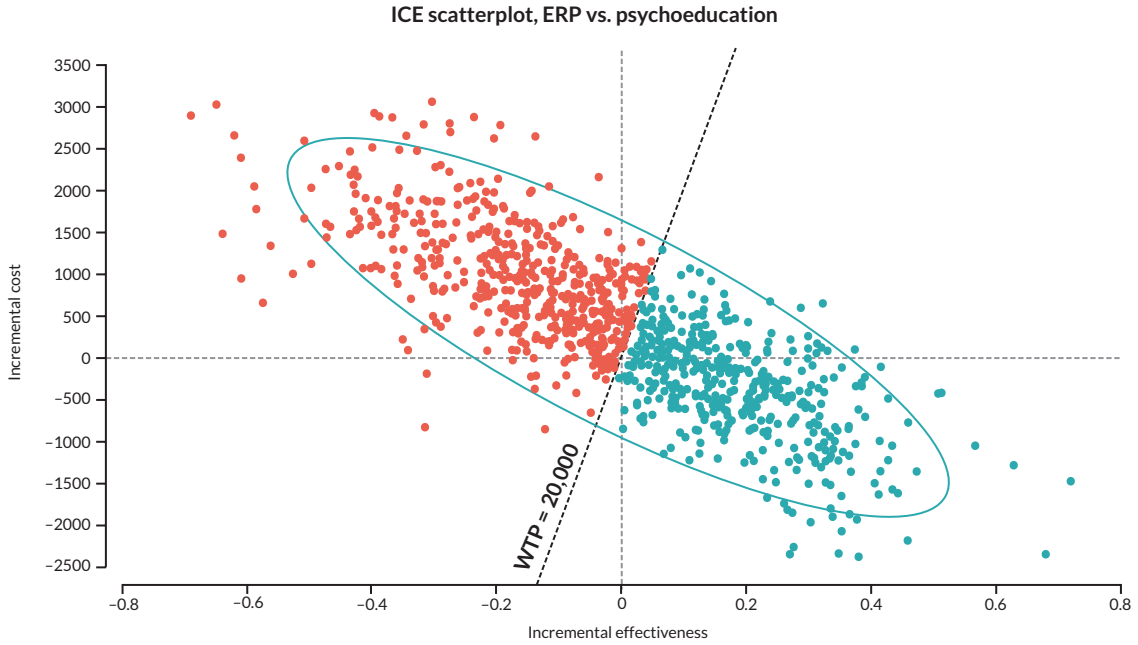

FIGURE 12 Base-case incremental scatter plot of simulations on the cost-effectiveness plane for ORBIT vs. online psychoeducation.

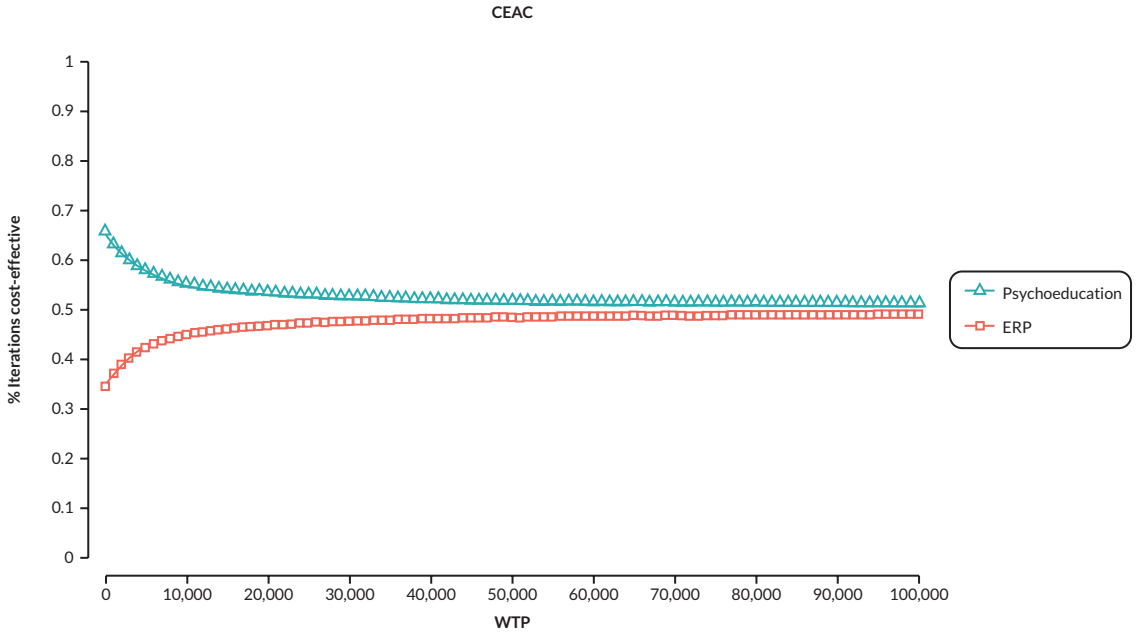

FIGURE 13 Base-case CEACs for ORBIT and online psychoeducation.

Scenario analysis

The results of a range of scenario analyses described throughout the report and summarised in *Table 22* are provided to further explore uncertainty surrounding key modelling assumptions, including intervention costing, long-term extrapolation of transition probabilities and the potential for inclusion of a tics free semi-absorbing state in the model. Results of the scenario analyses are reported in *Table 25*. All analyses are probabilistic, based on 50,000 iterations, and probabilities of cost-effectiveness at a £20,000 and £30,000 threshold value of WTP for a QALY gain are reported for completeness, and to illustrate the residual decision uncertainty. Accompanying deterministic results are provided in *Appendix 4*, *Table 29*. In general, results were most sensitive to assumptions about the costs of psychoeducation,

TABLE 25 Scenario analyses for comparison of ORBIT vs. online psychoeducation (probabilistic)

S. No	Technologies	Total costs (£)	Total QALYs	Incremental costs (£)	Incremental QALYs	ICER (£)	INMB @ lambda = £30,000	Probability cost-effective @ various values of lambda	
								£20,000	£30,000
0	***Base case***								
	Psychoeducation	12,731	20.928	–	–	–		0.53	0.52
	ERP	13,085	20.921	354	−0.007	Dominated	− £564	0.47	0.48
1	***Time horizon = 10 years from end-of-trial follow-up (18 months + 10 years)***								
	Psychoeducation	5123	7.741	–	–	–		0.45	0.42
	ERP	5417	7.763	294	0.023	£12,867	+ £396	0.55	0.58
2	***Times horizon = 5 years from end-of-trial follow-up (18 months + 5 years)***								
	Psychoeducation	3422	4.593	–	–	–		0.37	0.32
	ERP	3707	4.622	285	0.029	£9936	+ £585	0.63	0.68
3	***Time horizon = 2 years from end-of-trial follow-up (18 months + 2 years)***								
	Psychoeducation	2253	2.413	–	–	–		0.32	0.25
	ERP	2541	2.443	289	0.030	£9611	+ £611	0.68	0.75
4	***Include transitions into the absorbing 'tics free' health state, set utility tics free = mild***								
	Psychoeducation	5947	21.311	–	–	–		0.50	0.48
	ERP	6254	21.324	306	0.013	£22,979	+ £84	0.50	0.52
5	***Include only variable cost of therapist support for psychoeducation***								
	Psychoeducation	12,495	20.928	–	–			0.55	0.54
	ERP	13,088	20.921	593	−0.007	Dominated	− £803	0.45	0.46
6	***Apply approach from ORBIT study (include only variable platform costs and therapist support for psychoeducation; remove all ongoing costs)***								
	Psychoeducation	12,489	20.928	–	–			0.54	0.53
	ERP	12,936	20.922	447	−0.006	Dominated	− £627	0.46	0.47
7	***Only include variable therapist support costs, include ongoing costs + platform throughput (n = 100)***								
	Psychoeducation	12,615	20.927	–	–	–		0.55	0.53
	ERP	13,145	20.920	530	−0.007	Dominated	− £740	0.45	0.47

continued

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TABLE 25 Scenario analyses for comparison of ORBIT vs. online psychoeducation (probabilistic) (*continued*)

S. No	Technologies	Total costs (£)	Total QALYs	Incremental costs (£)	Incremental QALYs	ICER (£)	INMB @ lambda = £30,000	Probability cost-effective @ various values of lambda	
								£20,000	£30,000
8	***Only include variable therapist support costs, include ongoing costs + platform throughput (n = 1000)***								
	Psychoeducation	12,603	20.928	–	–	–		0.54	0.53
	ERP	13,054	20.920	451	−0.008	Dominated	− £691	0.46	0.47
9	***Remove ongoing costs from both arms***								
	Psychoeducation	12,619	20.928	–	–	–		0.53	0.52
	ERP	12,946	20.922	327	−0.006	Dominated	− £507	0.47	0.48
10	***Remove long-term transition probabilities (retain in state beyond 18 months), assumes 18-month benefit retained indefinitely***								
	Psychoeducation	12,647	20.871	–	–	–		0.10	0.11
	ERP	12,723	20.989	76	0.119	£642	+ £3494	0.90	0.89
11	***ERP transition probabilities revert to online psychoeducation arm after 18 months***								
	Psychoeducation	12,730	20.928	–	–	–		0.29	0.22
	ERP	13,010	20.962	281	0.033	£8419	+ £709	0.71	0.78
12	***Apply additional medication costs to moderate and severe health states***								
	Psychoeducation	13,416	20.929	–	–	–		0.54	0.53
	ERP	13,830	20.921	415	−0.008	Dominated	− £655	0.46	0.47

INMB, incremental net monetary benefit.

Note
Lambda, Society's threshold value of WTP for a QALY gained.

including whether the variable costs of the platform are included. When combined with uncertainty around the most appropriate extrapolation assumptions, uncertainty increased further. The results show an improving cost-effectiveness case for ORBIT over shorter-term time horizons. This is because long-term transition probabilities are extrapolated from the 18-month observed trial data. Transition probabilities between 12 and 18 months tended for favour the comparator, psychoeducation group (despite the overall profile of effectiveness at 18 months favouring ORBIT). Extrapolating these transitions over a lifetime horizon therefore favours the psychoeducation group. The maintenance of a treatment effect over the longer term is a key driver of cost-effectiveness results and different assumptions lead to substantial variation in the ICER. This also explains why re-setting transition probabilities to the psychoeducation arm might be anticipated to increase the ICER substantially for ERP but this is not observed in the model outputs. The probability of ORBIT being cost-effective at a WTP threshold of £20,000 per QALY gained varies between 45% up to 90% in a highly optimistic scenario where it is assumed that the cohort remain in their last observed health state at the end of the trial follow-up period.

In terms of overall findings, it should also be acknowledged that the psychoeducation comparator delivered as part of the ORBIT study was potentially more beneficial than the treatment options widely available to patients in UK NHS practice. In such scenarios, estimates of cost-effectiveness of ORBIT compared to usual care may lead to lower ICERs, and this is an area for future research.

Results: Neupulse

Markov cohort traces

Figures 14 and *15* show the modelled Markov cohort traces for waiting list control and Neupulse (assumed standard of care) respectively.

The Markov cohort traces show a clear difference between the Neupulse arm, with most of the cohort in the mild health state over time, compared to the waiting list control arm, with the majority in the moderate health state. These cohort traces reflect the optimistic transition probabilities provided by the company to the EAG. However, it is crucial to note that these are based on one set of transitions, between baseline and 4 weeks only, and are based on very small samples. It is therefore likely that the relative effectiveness of the intervention is overestimated in the longer term as it is highly unlikely that the level of effectiveness seen up to 4 weeks would be maintained over a full lifetime horizon.

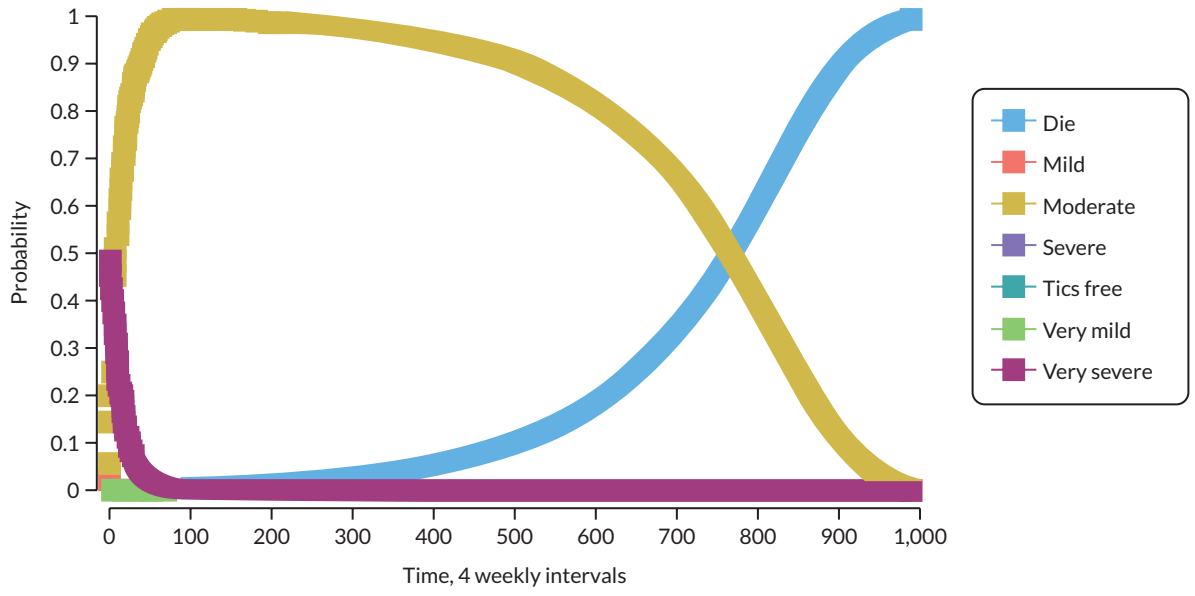

FIGURE 14 Base-case Markov cohort traces for wait list control.

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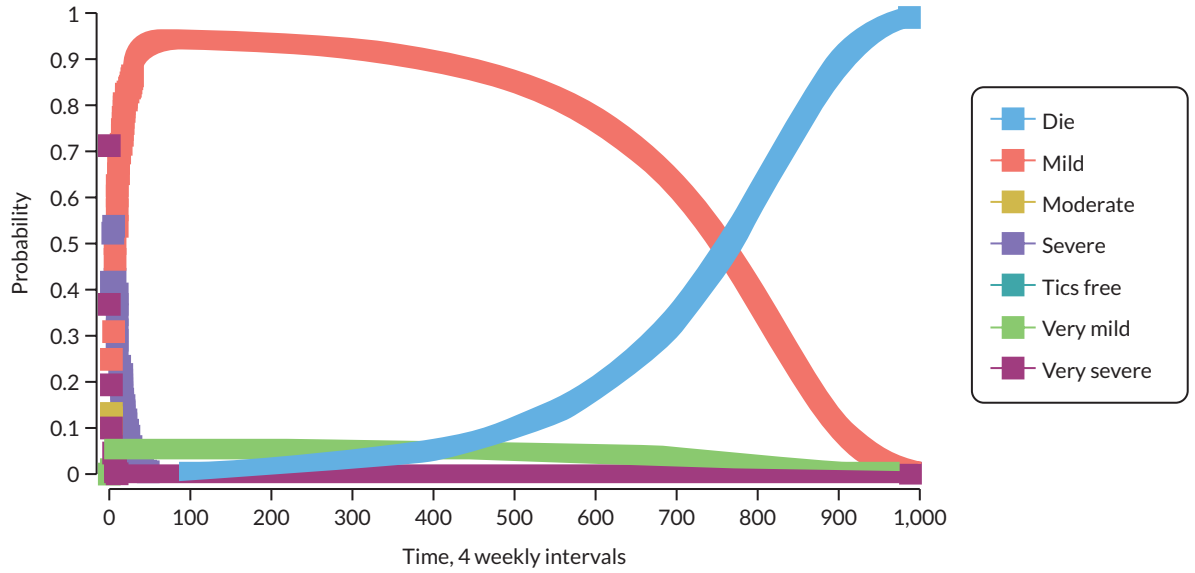

FIGURE 15 Base-case Markov cohort traces for Neupulse.

Base-case analysis

Given the lack of available data to populate the Neupulse model, it is not reasonable to derive a definitive base-case analysis. Instead, the potential uncertainty surrounding results should be interpreted across the range of scenario analyses presented. Neupulse was more costly than the waiting list control at the prices provided by the company. The additional costs are driven by the costs of device replacement and ongoing subscription which would be the minimum costs required to allow extrapolation of highly optimistic 4-weekly transition probabilities over a lifetime horizon. This scenario likely represents the maximum feasible QALY gain that could be achieved if an intervention could almost entirely resolve all tics to the 'mild tics' health state. Whether this is achievable in the longer term is unclear. Full details of total Neupulse costs are confidential in nature and so were provided only to the committee to aid in decision-making.

Scenario analysis

The results of scenario analyses conducted to explore the sensitivity of the base-case results to a range of modelling assumptions were provided confidentially to decision-makers. Results, in terms of the probability of cost-effectiveness under various scenarios are detailed in *Table 26*. All analyses are probabilistic, with the probability of cost-effectiveness indicated. Results were most sensitive to assumptions about the long-term extrapolation from 4 weeks onwards, clearly demonstrating the need for future research around long-term effectiveness. Different assumptions cause wide variation in the ICER between just over £10,000 per QALY gained in an optimistic scenario analysis that extrapolates 4-weekly transitions for a lifetime (probability of cost-effective = 87%) to over £300,000 per QALY in the less optimistic scenario analysis (probability cost-effective = 0%) where transitions are crossed over to the waitlist control group after the observed 4-week period. Deterministic analyses are provided in Table 30, *Appendix 4*.

Given the confidential nature of initial and ongoing Neupulse intervention costs, two-way scenario analyses are conducted to illustrate the impact of varying intervention and subscription costs on results. These scenarios are applied to two alternative assumptions about long-term transition probabilities (4-weekly transitions are carried forward, and the cohort fixed in state after 4 weeks, assuming maximum effectiveness achieved at 4 weeks). Analyses are based on NMBs with a WTP = £20,000 per QALY. Results are reported in *Figures 16* and *17*. Results of these analyses further emphasise the substantial residual uncertainty regarding intervention costs and long-term extrapolation assumptions.

TABLE 26 Scenario analyses for comparison of Neupulse vs. wait list control (probabilistic)

S. no	Technologies	Total QALYs	Incremental QALYs	Probability cost-effective @ various values of lambda	
				£20,000	£30,000
0	***Base case***				
	Wait list control	19.118	-	0.14	0.07
	Neupulse	19.69	0.572	0.88	0.93
1	***Time horizon = 10 years***				
	Wait list control	6.924		0.24	0.16
	Neupulse	7.11	0.186	0.76	0.84
2	***Time horizon = 5 years***				
	Wait list control	3.742		0.33	0.23
	Neupulse	3.835	0.092	0.67	0.77
3	***Time horizon = 2years***				
	Wait list control	1.535		0.56	0.39
	Neupulse	1.566	0.031	0.44	0.61
4	***Include transitions into the absorbing 'tics free' health state, set utility tics free = mild***				
	Wait list control	19.475	-	0.17	0.1
	Neupulse	19.721	0.247	0.83	0.9
5	***Long-term transition probabilities: set equal to zero, assumes no further improvement of regression of tics and TS after 4 weeks***				
	Wait list control	18.659	-	0.99	0.91
	Neupulse	18.763	0.104	0.01	0.09
6	***Long-term transition probabilities: assume that Neupulse cohort reverts to 'no treatment' transition matrix after 4 weeks***				
	Wait list control	19.119	-	1	1
	Neupulse	19.141	0.022	0	0
7	***Apply additional medication costs to moderate and severe health states***				
	Wait list control	19.119	-	0.11	0.93
	Neupulse	19.69	0.572	0.89	0.07

lambda, Society's threshold value of WTP for a QALY gained.

Note
Cost data cannot be reported due to the confidential nature of Neupulse prices provided to aid committee decision-making.

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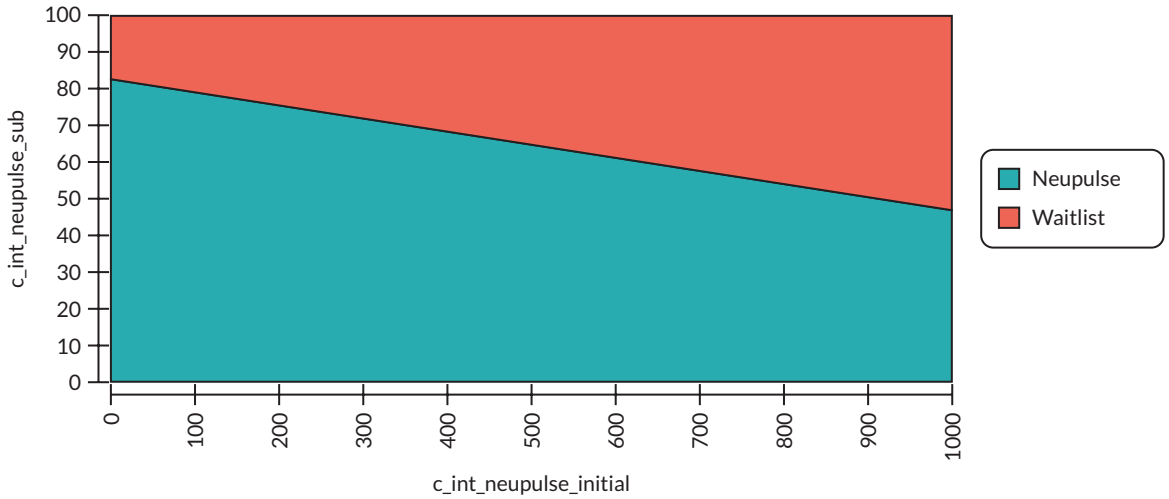

FIGURE 16 Two-way scenario analysis of initial and subscription costs for Neupulse (assumes long-term transition probabilities extrapolated).

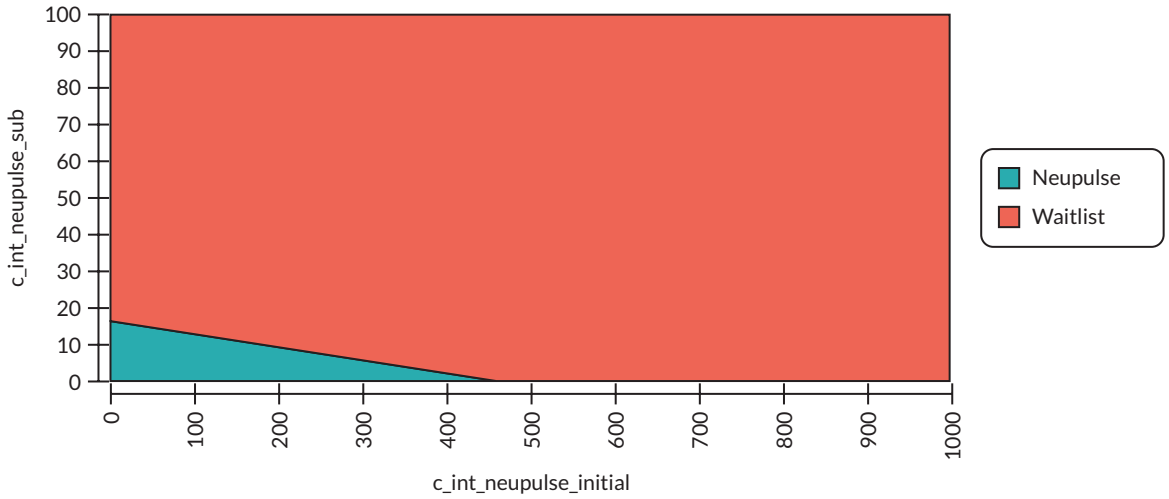

FIGURE 17 Two-way scenario analysis of initial and subscription costs for Neupulse (assumes cohort held in last observed state).

Chapter 4 Interpretation of the evidence and conclusions

Statement of principal findings

Following comprehensive searches of the current literature, two studies comparing ORBIT with psychoeducation (one each in the UK[34] and Sweden[38]) and one UK study comparing active stimulation with sham stimulation[36] were included in the review of clinical effectiveness. All were assessed as being at low risk of bias. However, there were important differences between study size and follow-up duration across the comparisons. ORBIT studies had larger sample sizes and longer follow-up than for Neupulse. Additionally, all ORBIT data used in economic modelling were available in the public domain and published in peer-reviewed articles, whereas the economic modelling for Neupulse relied on company-provided data through personal communication, with a shorter follow-up duration for transition probability model inputs.

The majority of intermediate, clinical and patient-reported outcomes specified in the scope were reported across the three studies, but the actual measures utilised and time points they were administered were not consistent across studies. In general, tic severity scores measured using the YGTSS-TTSS (primary outcome) were lower in the respective intervention groups at follow-up periods ranging from 4 weeks (Neupulse)[36] to 12 months (the two ORBIT studies).[34,38] However, no improvements were observed in all three studies concerning the YGTSS-Impairment score. Responses to secondary outcome measures were mixed, and participants did not consistently show a better response to the intervention compared with the control at all assessed time points and across studies. In general, the level of engagement, adherence to treatment and dropouts were similar between intervention groups. The Neupulse study lacked reporting of AEs.

Economic modelling shows that there remains substantial residual uncertainty in the assessment of cost-effectiveness, particularly for the Neupulse intervention. Key areas of remaining uncertainty for Neupulse include:

- non-publicly available Neupulse pricing information
- short follow-up of only 4 weeks for Neupulse
- a lack of evidence on longer-term effectiveness and safety for economic modelling.

For the economic modelling of ORBIT, there were some uncertainties regarding long-term intervention costs for ORBIT that would be required to deliver sustained trial observed benefits over the longer term.

For model population more generally, there was uncertainty about the most appropriate link between tic severity score and health state costs and utilities, in particular whether small improvements in YGTSS scores have a direct impact on generic QoL measures such as EQ-5D or CHU-9D.

Despite longer-term follow-up available for ORBIT than Neupulse, economic modelling results over a lifetime horizon were uncertain because of a lack of information about the maintenance of long-term effectiveness beyond the trial follow-up periods to inform economic modelling

Strengths and limitations of the assessment and uncertainties

This assessment was conducted using thorough and robust methods. The main limitation of the systematic review of clinical effectiveness was the paucity of evidence for the technologies of interest. The limited amount of evidence and inconsistencies in the outcomes measured and the timing of these measurements also hampered efforts to conduct further meaningful analyses.

The identified studies did not involve a comparison with face-to-face behavioural therapy, which is the current standard of care. Therefore, for the ORBIT studies, it was not possible to separate the effects of online delivery from

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those of ERP. Moreover, both ORBIT studies did not include a non-active control treatment (e.g. waitlist) to evaluate the natural course of the disease over time, especially in young children. For the ORBIT studies in particular, the comparator, psychoeducation, may be a more active, beneficial comparator than is routinely available in UK clinical practice. Therefore, results of cost-effectiveness modelling might under-estimate cost-effectiveness compared to usual NHS care.

While a reduction of tic severity measured by the YGTSS-TTSS score was greater among participants receiving the intervention (digitally enabled ERP in the ORBIT studies and home-administered MNS in the Neupulse study), the fact that there were no improvements in the YGTSS-Impairment score casts some doubt on whether a reduction in tic severity translates into an improvement in daily life, including self-esteem, social interactions and school/work performance. Similarly, the inconsistent improvements in quality-of-life measures (i.e. C&A-GTS-QOL) over follow-up times and across studies reinforce this doubt.

It is also unclear why only the YGTSS-TTSS score was selected as the primary outcome in the included studies, but not the YGTSS-Impairment score.

Both ORBIT studies included participants with moderate to severe tic disorders, who had a low rate of common comorbidities and modest use of medications for tics. Therefore, the reported findings cannot be generalisable to more severe tic disorder populations. Similarly, most participants in at least one of the ORBIT studies (the UK study) were White, which limits the generalisation of findings to other ethnic groups.

The longest follow-up period in the UK ORBIT study and the Swedish ORBIT study was 18 and 12 months, respectively. The current data for Neupulse, which has been designed to control tic symptoms on demand, refer to stimulation delivered for a maximum of 4 weeks. There are no data on longer durations of stimulation or longer-term outcomes to inform economic modelling.

The assessment of cost-effectiveness relied on several major, but highly uncertain assumptions about longer-term intervention costs that might be required to maintain the intervention's effectiveness as well as the most appropriate long-term extrapolation assumptions. Scenario and probabilistic sensitivity analyses show that there is substantial residual uncertainty, making it difficult to define the most plausible ICERs for either comparison.

Key areas for future research

- As the included studies are the first published adequately powered randomised studies to assess the technologies under investigation, future replication is needed to confirm the observed results.
- Future studies of longer duration should compare digitally enabled therapy for tics versus face-to-face behavioural therapy and should also consider including a non-active intervention (e.g. waitlist) to monitor the natural course of the disease over time.
- In addition to tic severity, future studies should measure the impact of digitally enabled therapy on participants' daily lives as their primary outcome.
- To assess differences in treatment response among participants, future studies should plan appropriate subgroup analyses according to the participants' sex distribution (males vs. females) and common comorbidities.
- Future studies should include economic evaluations and should consider collection of longitudinal data to improve long-term modelling of treatment effectiveness with a focus on determining the impact of changes in clinical outcomes on QoL and costs.

Patient and public involvement

We did not involve patient and public involvement partners in the preparation of our report. However, we shared our findings with NICE, whose appraisal committees include representatives from patient organisations and networks, ensuring that the patient perspective is considered in the decision-making process.

Equality, diversity and inclusion considerations

This project involves an evidence synthesis and economic evaluation. The scope was defined by the NICE, which is committed to promoting equality of opportunity, eliminating unlawful discrimination and fostering good relations between people with particular protected characteristics and others.

- Tic disorders are more common in boys than girls at a ratio of 4 : 1.
- Patient-facing digital health technologies may be unsuitable for people with cognitive impairment, problems with manual dexterity, learning disabilities, and visual and/or hearing impairments. Carer or advocate assistance may be required to utilise the digital platform, and consideration of this should be made by the referring practitioner when considering appropriate intervention for the child or young person.
- Children and young people, or their families/carers, with English as a second language may have difficulties navigating digital technologies provided in English.
- People's ethnic, religious and cultural background may affect their views of digital health interventions. HCPs should discuss the language and cultural content of digital health interventions with users before provision.
- Specific groups may particularly benefit from improved access to online behavioural therapy, for example:
  - Those living in areas not currently served by specialist clinical centres might have difficulty travelling to face-to-face appointments if public transport is unreliable, costly and if parents are unable to drive them.
  - Adolescents may have an increased engagement with this format of intervention.
  - Children and young people with more chaotic home lives may lack the family support required to ensure that they attend face-to-face sessions. These families may also be less likely to seek help in the first place and or be less able to navigate the healthcare system.
- However, accessibility would not be improved for those who are unable to engage with a digital service due to a lack of equipment, unavailability of internet connection or lack of experience with computers or lack the privacy needed to complete this intervention. Additional support and resources may be needed for these individuals.

Chronic tic disorders and TS can significantly affect people's daily lives. Under the Equality Act 2010, a person has a disability if they have a physical or mental impairment that has a substantial and long-term effect on their ability to do typical day-to-day activities. Age, sex, disability, race and religion are protected characteristics under the Equality Act (2010).

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Additional information

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Moira Cruickshank (https://orcid.org/0000-0002-5182-884X): Data curation, Formal analysis, Writing – original draft.

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Diane Swallow (https://orcid.org/0000-0001-6622-7839): Supervision, Writing – reviewing and editing.

Miriam Brazzelli (https://orcid.org/0000-0002-7576-6751): Conceptualisation, Project administration, Supervision, Writing – original draft, Writing – reviewing and editing.

Data-sharing statement

This is an evidence synthesis and economic evaluation; all quantitative data are presented in the text or contained within tables, figures, and appendices. No new data, suitable for data sharing have been created in the preparation of this synthesis. All queries should be submitted to the corresponding author for consideration.

Ethics statement

This report focuses on secondary research evidence. No primary research data were collected as part of this project, and ethics approval was not required.

Information governance statement

The University of Aberdeen is committed to handling all personal information in line with the UK Data Protection Act (2018) and the General Data Protection Regulation (EU GDPR) 2016/679. However, no personal data (information that can identify a living individual) were accessed or processed during the course of this project.

Disclosure of interests

Full disclosure of interests: Completed ICMJE forms for all authors, including all related interests, are available in the toolkit on the NIHR Journals Library report publication page at https://doi.org/10.3310/QLAS8524.

Primary conflicts of interest: Dwayne Boyers reports receiving grants from the National Institute for Health and Care Research (NIHR) for conducting clinical trials.

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References

1. Centers for Disease Control and Prevention. Prevalence of diagnosed Tourette syndrome in persons aged 6–17 years: United States, 2007. *MMWR: Morb Mortal Wkly Rep* 2009;**58**:581–5.
2. Robertson MM. The prevalence and epidemiology of Gilles de la Tourette syndrome. Part 1: the epidemiological and prevalence studies. *J Psychosom Res* 2008;**65**:461–72.
3. Apter A, Pauls DL, Bleich A, Zohar AH, Kron S, Ratzoni G, *et al*. An epidemiologic study of Gilles de la Tourette's syndrome in Israel. *Arch Gen Psychiatry* 1993;**50**:734–8.
4. Szejko N, Robinson S, Hartmann A, Ganos C, Debes NM, Skov L, *et al*. European clinical guidelines for Tourette syndrome and other tic disorders-version 2.0. Part I: assessment. *Eur Child Adolesc Psychiatry* 2022;**31**:383–402.
5. American Psychiatric Association. *Diagnostic and Statistical Manual of Mental Disorders*. 5th edn. Washington, DC: American Psychiatric Publishing; 2022.
6. Hirschtritt ME, Lee PC, Pauls DL, Dion Y, Grados MA, Illmann C, *et al*.; Tourette Syndrome Association International Consortium for Genetics. Lifetime prevalence, age of risk, and genetic relationships of comorbid psychiatric disorders in Tourette syndrome. *JAMA Psychiatry* 2015;**72**:325–33.
7. Bloch MH, Peterson BS, Scahill L, Otka J, Katsovich L, Zhang H, Leckman JF. Adulthood outcome of tic and obsessive-compulsive symptom severity in children with Tourette syndrome. *Arch Pediatr Adolesc Med* 2006;**160**:65–9.
8. Groth C, Mol Debes N, Rask CU, Lange T, Skov L. Course of Tourette syndrome and comorbidities in a large prospective clinical study. *J Am Acad Child Adolesc Psychiatry* 2017;**56**:304–12.
9. Bloch MH, Leckman JF. Clinical course of Tourette syndrome. *J Psychosom Res* 2009;**67**:497–501.
10. Yang C, Cheng X, Zhang Q, Yu D, Li J, Zhang L. Interventions for tic disorders: an updated overview of systematic reviews and meta analyses. *Psychiatry Res* 2020;**287**:112905.
11. Kurlan R, Como PG, Miller B, Palumbo D, Deeley C, Andresen EM, *et al*. The behavioral spectrum of tic disorders: a community-based study. *Neurology* 2002;**59**:414–20.
12. Pringsheim T, Okun MS, Müller-Vahl K, Martino D, Jankovic J, Cavanna AE, *et al*. Practice guideline recommendations summary: treatment of tics in people with Tourette syndrome and chronic tic disorders. *Neurology* 2019;**92**:896–906.
13. BMJ Best Practice. *Tic Disorders*. 2022. URL: https://bestpractice.bmj.com/topics/en-gb/970 (accessed 13 January 2024).
14. Knight T, Steeves T, Day L, Lowerison M, Jette N, Pringsheim T. Prevalence of tic disorders: a systematic review and meta-analysis. *Pediatr Neurol* 2012;**47**:77–90.
15. Levine JLS, Szejko N, Bloch MH. Meta-analysis: adulthood prevalence of Tourette syndrome. *Prog Neuropsychopharmacol Biol Psychiatry* 2019;**95**:109675.
16. Conelea CA, Woods DW, Zinner SH, Budman CL, Murphy TK, Scahill LD, *et al*. The impact of Tourette syndrome in adults: results from the Tourette Syndrome Impact Survey. *Community Ment Health J* 2013;**49**:110–20.
17. Marino C, Khan K, Groom MJ, Hall SS, Anderson S, Mcnally E, *et al*. Patients' experience of accessing support for tics from primary care in the UK: an online mixed-methods survey. *BMC Health Serv Res* 2023;**23**:788.
18. National Institute for Health and Care Excellence. *Attention Deficit Hyperactivity Disorder: Diagnosis and Management (NG87)*. 2018. URL: www.nice.org.uk/guidance/ng87 (accessed 13 January 2024).
19. National Institute for Health and Care Excellence. *Autism Spectrum Disorder in under 19s: Recognition, Referral and Diagnosis (CG128)*. 2011. URL: www.nice.org.uk/Guidance/CG128 (accessed 13 January 2024).

20. National Institute for Health and Care Excellence. *Autism Spectrum Disorder in under 19s: Support and Management (CG170)*. 2013. URL: www.nice.org.uk/guidance/cg170 (accessed 13 January 2024).
21. National Institute for Health and Care Excellence. *Suspected Neurological Conditions: Recognition and Referral (NG127)*. 2019. URL: www.nice.org.uk/guidance/ng127 (accessed 13 January 2024).
22. Müller-Vahl KR, Szejko N, Verdellen C, Roessner V, Hoekstra PJ, Hartmann A, Cath DC. European clinical guidelines for Tourette syndrome and other tic disorders: summary statement. *Eur Child Adolesc Psychiatry* 2022;**31**:377–82.
23. Steeves T, McKinlay BD, Gorman D, Billinghurst L, Day L, Carroll A, *et al*. Canadian guidelines for the evidence-based treatment of tic disorders: behavioural therapy, deep brain stimulation, and transcranial magnetic stimulation. *Can J Psychiatry* 2012;**57**:144–51.
24. Aberdeen Health Technology Assessment Group. *Digitally Enabled Therapy for Chronic Tic Disorders and Tourette Syndrome in Children and Young People (GID-MT605): Final Protocol*. University of Aberdeen: Aberdeen Centre for Evaluation; 2024. URL: www.nice.org.uk/guidance/hte25/documents/final-protocol-2 (accessed 15 June 2024).
25. Andrén P, Jakubovski E, Murphy TL, Woitecki K, Tarnok Z, Zimmerman-Brenner S, *et al*. European clinical guidelines for Tourette syndrome and other tic disorders-version 2.0. Part II: psychological interventions. *Eur Child Adolesc Psychiatry* 2022;**31**:403–23.
26. Hollis C, Pennant M, Cuenca J, Glazebrook C, Kendall T, Whittington C, *et al*. Clinical effectiveness and patient perspectives of different treatment strategies for tics in children and adolescents with Tourette syndrome: a systematic review and qualitative analysis. *Health Technol Assess* 2016;**20**:1–450, vii.
27. Whittington C, Pennant M, Kendall T, Glazebrook C, Trayner P, Groom M, *et al*. Practitioner review: treatments for Tourette syndrome in children and young people – a systematic review. *J Child Psychol Psychiatry* 2016;**57**:988–1004.
28. Roessner V, Plessen KJ, Rothenberger A, Ludolph AG, Rizzo R, Skov L, *et al*.; ESSTS Guidelines Group. European clinical guidelines for Tourette syndrome and other tic disorders. Part II: pharmacological treatment. *Eur Child Adolesc Psychiatry* 2011;**20**:173–96.
29. Kefalopoulou Z, Zrinzo L, Jahanshahi M, Candelario J, Milabo C, Beigi M, *et al*. Bilateral globus pallidus stimulation for severe Tourette's syndrome: a double-blind, randomised crossover trial. *Lancet Neurol* 2015;**14**:595–605.
30. Jimenez-Shahed J. Design challenges for stimulation trials of Tourette's syndrome. *Lancet Neurol* 2015;**14**:563–5.
31. Martinez-Ramirez D, Jimenez-Shahed J, Leckman JF, Porta M, Servello D, Meng FG, *et al*. Efficacy and safety of deep brain stimulation in Tourette syndrome: the International Tourette Syndrome Deep Brain Stimulation Public Database and Registry. *JAMA Neurol* 2018;**75**:353–9.
32. Iverson AM, Arbuckle AL, Song DY, Bihun EC, Black KJ. Median nerve stimulation for treatment of tics: a 4-week open trial with ecological momentary assessment. *J Clin Med* 2023;**12**:2545.
33. Hall CL, Davies EB, Andrén P, Murphy T, Bennett S, Brown BJ, *et al*.; ORBIT Trial team. Investigating a therapist-guided, parent-assisted remote digital behavioural intervention for tics in children and adolescents – 'Online Remote Behavioural Intervention for Tics' (ORBIT) trial: protocol of an internal pilot study and single-blind randomised controlled trial. *BMJ Open* 2019;**9**:e027583.
34. Hollis C, Hall CL, Jones R, Marston L, Novere Marie Le, Hunter R, *et al*. Therapist-supported online remote behavioural intervention for tics in children and adolescents in England (ORBIT): a multicentre, parallel group, single-blind, randomised controlled trial. *Lancet Psychiatry* 2021;**8**:871–82.
35. Hollis C, Hall CL, Khan K, Le Novere M, Marston L, Jones R, *et al*. Online remote behavioural intervention for tics in 9- to 17-year-olds: the ORBIT RCT with embedded process and economic evaluation. *Health Technol Assess* 2023;**27**:1–120.

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36. Maiquez BM, Smith C, Dyke K, Chou CP, Kasbia B, McCready C, *et al*. A double-blind, sham-controlled, trial of home-administered rhythmic 10-Hz median nerve stimulation for the reduction of tics, and suppression of the urge-to-tic, in individuals with Tourette syndrome and chronic tic disorder. *J Neuropsychol* 2023;**17**:540–63.
37. Neurotherapeutics Ltd. *Improving the Lives of People with Tourettes*. URL: www.neupulse.co.uk/ (accessed 9 January 2024).
38. Andrén P, Holmsved M, Ringberg H, Wachtmeister V, Isomura K, Aspvall K, *et al*. Therapist-supported Internet-delivered exposure and response prevention for children and adolescents with Tourette Syndrome: a randomized clinical trial. *JAMA Netw Open* 2022;**5**:e2225614.
39. Sterne JAC, Savović J, Page MJ, Elbers RG, Blencowe NS, Boutron I, *et al*. RoB 2: a revised tool for assessing risk of bias in randomised trials. *BMJ* 2019;**366**:l4898.
40. Morera Maiquez B, Sigurdsson HP, Dyke K, Clarke E, McGrath P, Pasche M, *et al*. Entraining movement-related brain oscillations to suppress tics in Tourette syndrome. *Curr Biol* 2020;**30**:2334–42.e3.
41. Andrén P, Sampaio F, Ringberg H, Wachtmeister V, Warnström M, Isomura K, *et al*. Internet-delivered exposure and response prevention for pediatric Tourette Syndrome: 12-month follow-up of a randomized clinical trial. *JAMA Netw Open* 2024;**7**:e248468.
42. Canadian Agency for Drugs and Technologies in Health. *Telehealth Services for the Treatment of Psychiatric Issues: Clinical Effectiveness, Safety, and Guidelines (Rapid Review)*. Ottawa: CADTH; 2015. URL: www.cadth.ca/telehealth-services-treatment-psychiatric-issues-clinical-effectiveness-safety-and-guidelines (accessed 13 January 2024).
43. Philips Z, Ginnelly L, Sculpher M, Claxton K, Golder S, Riemsma R, *et al*. Review of guidelines for good practice in decision-analytic modelling in health technology assessment. *Health Technol Assess* 2004;**8**:iii–v, ix.
44. National Institute for Health and Care Excellence. *Developing NICE Guidelines: The Manual (PMG20). Appendix H: Appraisal Checklists, Evidence Tables, GRADE and Economic Profiles*. 2014. URL: www.nice.org.uk/process/pmg20/resources/appendix-h-appraisal-checklists-evidence-tables-grade-and-economic-profiles-pdf-8779777885 (accessed 13 January 2024).
45. Husereau D, Drummond M, Petrou S, Carswell C, Moher D, Greenberg D, *et al*.; CHEERS Task Force. Consolidated Health Economic Evaluation Reporting Standards (CHEERS) statement. *J Med Econ* 2013;**16**:713–9.
46. Dang TTH, Rowell D, Liddle J, Coyne T, Silburn P, Connelly LB. Economic evaluation of deep-brain stimulation for Tourette's syndrome: an initial exploration. *J Neurol* 2019;**266**:2997–3008.
47. Hollis C, Hall CL, Khan K, Jones R, Marston L, Le Novere M, *et al*. Long-term clinical and cost-effectiveness of a therapist-supported online remote behavioural intervention for tics in children and adolescents: extended 12- and 18-month follow-up of a single-blind randomised controlled trial. *J Child Psychol Psychiatry* 2023;**64**:941–51.
48. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, *et al*. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ* 2021;**372**:n71.
49. National Institute for Health and Care Excellence. *NICE Health Technology Evaluations: The Manual (PMG36)*. 2022. URL: www.nice.org.uk/process/pmg36/chapter/introduction-to-health-technology-evaluation (accessed 15 June 2024).
50. Leckman JF, Riddle MA, Hardin MT, Ort SI, Swartz KL, Stevenson J, Cohen DJ. The Yale Global Tic Severity Scale: initial testing of a clinician-rated scale of tic severity. *J Am Acad Child Adolesc Psychiatry* 1989;**28**:566–73.
51. Office for National Statistics. *National Life Tables: UK*. 2024. URL: www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/lifeexpectancies/datasets/nationallifetablesunitedkingdomreferencetables (accessed 15 June 2024).

52. National Institute for Health and Care Excellence. *GID-MT605 Digitally Enabled Therapy for Chronic Tic Disorders and Tourette Syndrome Final Scope – Updated*. London; Manchester: NICE; 2024. URL: www.nice.org.uk/guidance/hte25/documents/final-scopewww.nice.org.uk/guidance/gid-mt605/documents/final-scope (accessed 15 June 2024)
53. Furber G, Segal L. The validity of the Child Health Utility instrument (CHU9D) as a routine outcome measure for use in child and adolescent mental health services. *Health Qual Life Outcomes* 2015;**13**:22.
54. Stevens K. The Child Health Utility 9D (CHU9D) A new paediatric preference based measure of health related quality of life. *PRO Newsletter* 2010;**43**:11–2.
55. Stevens K. Assessing the performance of a new generic measure of health-related quality of life for children and refining it for use in health state valuation. *Appl Health Econ Health Policy* 2011;**9**:157–69.
56. Ara R, Brazier JE. Populating an economic model with health state utility values: moving toward better practice. *Value Health* 2010;**13**:509–18.
57. National Institute for Health and Care Excellence. *The Guidelines Manual: Process and Methods (PMG6)*. London; Manchester: NICE; 2012. URL: www.nice.org.uk/process/pmg6/resources/the-guidelines-manual-pdf-2007970804933 (accessed 15 June 2024).
58. Briggs AH, Ades AE, Price MJ. Probabilistic sensitivity analysis for decision trees with multiple branches: use of the Dirichlet distribution in a Bayesian framework. *Med Decis Making* 2003;**23**:341–50.
59. Tappenden P, Chilcott JB. Avoiding and identifying errors and other threats to the credibility of health economic models. *PharmacoEconomics* 2014;**32**:967–79.
60. Hall CL, Sanderson C, Brown BJ, et al. Opportunities and challenges of delivering digital clinical trials: lessons learned from a randomised controlled trial of an online behavioural intervention for children and young people. Trials. 2020;21(1):1011.
61. Hollis C, Hall CL, Khan K, et al. Long-term clinical and cost-effectiveness of a therapist-supported online remote behavioural intervention for tics in children and adolescents: extended 12- and 18-month follow-up of a single-blind randomised controlled trial. J Child Psychol Psychiatry. 2023;64(6):941-51.
62. Khan K, Hollis C, Hall CL, et al. Protocol for the process evaluation of the Online Remote Behavioural Intervention for Tics (ORBIT) randomized controlled trial for children and young people. Trials. 2020;21(1):6.
63. Khan K, Hollis C, Hall CL, et al. Fidelity of delivery and contextual factors influencing children's level of engagement: process evaluation of the Online Remote Behavioral Intervention for Tics Trial. J Med Internet Res. 2021;23(6):e25470.
64. Khan K, Hollis C, Hall CL, et al. Factors influencing the efficacy of an online behavioural intervention for children and young people with tics: Process evaluation of a randomised controlled trial J Behav Cogn Ther. 2022;32(3):197-206.
65. Andrén P, Aspvall K, De La Cruz LF, Wiktor P, Romano S, Andersson E, Murphy T, Isomura K, Serlachius E, Mataix-Cols D. Therapist-guided and parent-guided internet-delivered behaviour therapy for paediatric Tourette's disorder: a pilot randomised controlled trial with long-term follow-up. BMJ open. 2019 Feb 1;9(2):e024685.
66. Andrén P, Fernandez de la Cruz L, Isomura K, et al. Efficacy and cost-effectiveness of therapist-guided internet-delivered behaviour therapy for children and adolescents with Tourette syndrome: study protocol for a single-blind randomised controlled trial. Trials. 2021;22(1):669.

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Appendix 1 Literature search strategies

Clinical

Ovid MEDLINE(R) and Epub Ahead of Print, In-Process, In-Data-Review and Other Non-Indexed Citations, Daily and Versions <1946–5 February 2024>

1 Tics/ or exp Tic Disorders/ or (tic or tics or Tourette?).tw,kw.14781
2 exp Behavior Therapy/ or psychotherapy/145391
3 (((psycho* or behavio* or cognitive) adj5 (therap* or intervention? or treatment or program* or training)) or psychotherapy).tw,kw.259594
4 ("Habit Reversal Training" or HRT or "Comprehensive Behavio?ral Intervention for Tics" or CBIT or "Exposure and response prevention" or ERP).tw,kw.31475
5 2 or 3 or 4367217
6 Internet/ or Online Systems/ or Internet-Based Intervention/ or Mobile Applications/ or Cell Phone/ or Smartphone/ or telemedicine/ or videoconferencing/149679
7 (digital or remote or online or web or internet or technology or app? or computer or mobile or smart phone or smartphone or virtual or tele* or video*).tw,kw.1860466
8 Wearable Electronic Devices/ or ((wearable adj7 (technolog* or device?)) or wearables).tw,kw.19151
9 (ORBIT or Mindtech or Neupulse or Neurotherapeutics).af.55382
10 (6 or 7 or 8 or 9) not "Telephone Interview for Cognitive Status".tw.1954578
11 1 and 5 and 10121
12 from 11 keep 1-121121

EMBASE <1974–2024 week 5>

1 exp Tic/ or (tic or tics or Tourette?).tw,kw.24974
2 exp Behavior Therapy/ or exp cognitive therapy/ or psychotherapy/195463
3 (((psycho* or behavio* or cognitive) adj5 (therap* or intervention? or treatment or program* or training)) or psychotherapy).tw,kw.346715
4 ("Habit Reversal Training" or HRT or "Comprehensive Behavio?ral Intervention for Tics" or CBIT or "Exposure and response prevention" or ERP).tw,kw.42982
5 2 or 3 or 4472798
6 Internet/ or Online Systems/ or web-based intervention/ or mobile application/ or mobile phone/ or Smartphone/ or telemedicine/ or telepsychology/ or teletherapy/ or video consultation/ or videoconferencing/258798
7 (digital or remote or online or web or internet or technology or app? or computer or mobile or smart phone or smartphone or virtual or tele* or video*).tw,kw.2390370
8 Wearable computer/ or ((wearable adj7 (technolog* or device?)) or wearables).tw,kw.16895
9 (ORBIT or Mindtech or Neupulse or Neurotherapeutics).af.71797
10 (6 or 7 or 8 or 9) not "Telephone Interview for Cognitive Status".tw.2526602
11 1 and 5 and 10239
12 conference abstract.pt.5038585
13 11 not 12186

APA PsycInfo <1967–January week 5 2024>

1 Tics/ or exp Tic Disorders/ or (tic or tics or Tourette?).tw,id.7117
2 exp Behavior Therapy/ or psychotherapy/165748
3 (((psycho* or behavio* or cognitive) adj5 (therap* or intervention? or treatment or program* or training)) or psychotherapy).tw,id.350593

4 ("Habit Reversal Training" or HRT or "Comprehensive Behavio?ral Intervention for Tics" or CBIT or "Exposure and response prevention" or ERP).tw,id.17786
5 2 or 3 or 4420407
6 Internet/ or Digital Interventions/ or Mobile Phones/ or Smartphones/ or Mobile Applications/ or exp Telemedicine/54857
7 (digital or remote or online or web or internet or technology or app? or computer or mobile or smart phone or smartphone or virtual or tele* or video*).tw,id.522816
8 Wearable Devices/ or ((wearable adj7 (technolog* or device?)) or wearables).tw,id.1909
9 (ORBIT or Mindtech or Neupulse or Neurotherapeutics).af.21883
10 (6 or 7 or 8 or 9) not "Telephone Interview for Cognitive Status".tw.544776
11 1 and 5 and 10145

CINAHL

S1 (MH "Tic")862
S2 TX tic or tics or Tourette?586
S3 S1 OR S21,176
S4 (MH "Behavior Therapy+") OR (MH "Psychotherapy")64,275
S5 TX ((psycho* OR behavio* OR cognitive) N5 (therap* OR intervention? OR treatment OR program* OR training)) OR TX psychotherapy213,705
S6 TX "Habit Reversal Training" OR HRT OR "Comprehensive Behavioral Intervention for Tics" OR CBIT OR "Exposure and response prevention" OR ERP6,117
S7 S4 OR S5 OR S6225,804
S8 (MH "Internet") OR (MH "Online Systems") OR (MH "Internet-Based Intervention") OR (MH "Mobile Applications") OR (MH "Cellular Phone") OR (MH "Smartphone") OR (MH "Telemedicine") OR (MH "Videoconferencing")90,713
S9 TX digital OR remote OR online OR web OR internet OR technology OR app? OR computer OR mobile OR "smart phone" OR smartphone OR virtual OR tele* or video*1,043,445
S10 TX (wearable N7 (technolog* OR device?)) OR TX wearables7,325
S11 TX (ORBIT OR Mindtech OR Neupulse OR Neurotherapeutics)5,416
S12 (S8 OR S9 OR S10 OR S11) NOT TX "Telephone Interview for Cognitive Status"1,057,789
S13 S3 AND S7 AND S1229

Web of Science Core Collection

1: tic or tics or Tourette$ (Topic)32284
2: (psycho* or behavio* or cognitive) Near/5 (therap* or intervention$ or treatment or program* or training) (Topic)220662
3: psychotherapy (Topic)32198
4: "Habit Reversal Training" or HRT or "Comprehensive Behavioral Intervention for Tics" or CBIT or "Exposure and response prevention" or ERP (Topic)41037
5: #2 OR #3 OR #4278222
6: digital or remote or online or web or internet or technology or app$ or computer or mobile or "smart phone" or smartphone or virtual or tele* or video* (Topic)4119359
7: wearable Near/7 (technolog* or device$) (Topic)24576
8: wearables (Topic)3888
9: ORBIT or Mindtech or Neupulse or Neurotherapeutics (Topic)179034
10: #6 OR #7 OR #8 OR #94291494
11: #1 AND #5 AND #10130

NIHR

Search: "tics", "tic disorders", Tourette: 2, 0 additional

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SIGN

Browse list: 0

NICE

Search: “tics”, “tic disorders”, Tourette
Suspected neurological conditions: recognition and referral NICE guideline [NG127] (Previously supplied)

AHRQ Evidence Reports

Search: “tics”, “tic disorders”, Tourette: 0

CADTH

Search: “tics”, “tic disorders”, Tourette
Telehealth Services for the Treatment of Psychiatric Issues: Clinical Effectiveness, Safety, And Guidelines

HIQA

Search: “tics”, “tic disorders”, Tourette: 0

IHTA

MeSH ‘Tic Disorders’; ‘Tourette Syndrome’, “tics”, “tic disorders”, Tourette: 3, 0 additional

Royal College of Psychiatrists

Search: “tics”, “tic disorders”, Tourette: 1, 0 additional

Royal College of Paediatrics and Child Health

Search: “tics”, “tic disorders”, Tourette: 0

Health economics

Ovid MEDLINE(R) and Epub Ahead of Print, In-Process, In-Data-Review and Other Non-Indexed Citations, Daily and Versions <1946–4 March 2024>

1 Tics/ or exp Tic Disorders/ or (tic or tics or Tourette?).tw,kw.14848
2 exp “costs and cost analysis”/269094
3 *economics/10813
4 economics, hospital/11281
5 exp economics,medical/14425
6 economics,pharmaceutical/3126
7 exp models, economic/16267
8 exp decision theory/13578

9 monte carlo method/32688
10 markov chains/16084
11 exp technology assessment, biomedical/12284
12 (cost$ adj2 (effective$ or utilit$ or benefit$ or minimis$)).ab.198457
13 economics model$.tw.78
14 (economic$ or pharmacoeconomic$).tw.386784
15 (price or prices or pricing).tw.53571
16 budget$.tw.36953
17 (value adj1 money).tw.41
18 (expenditure$ not energy).tw.38373
19 markov$.tw.32744
20 monte carlo.tw.60753
21 (decision$ adj2 (tree? or analy$ or model$)).tw.40544
22 ec.fs.443096
23 or/2-221170130
24 1 and 23233

EMBASE <1974–2024 week 9>

1 exp Tic/ or (tic or tics or Tourette?).tw,kw.25056
2 exp economic evaluation/364230
3 exp *economics/29531
4 health economics/36299
5 exp health care cost/349378
6 pharmacoeconomics/11677
7 exp decision theory/1861
8 Monte Carlo method/52760
9 Markov chain/11114
10 exp biomedical technology assessment/17894
11 (cost$ adj2 (effective$ or utilit$ or benefit$ or minimis$)).ab.267789
12 economics model$.tw.147
13 (price or prices or pricing).tw.73206
14 (value adj2 money).tw.3091
15 (expenditure$ not energy).tw.51916
16 markov$.tw.41120
17 monte carlo.tw.63148
18 (decision$ adj2 (tree? or analy$ or model$)).tw.54253
19 or/2-18998976
20 1 and 19431
21 conference abstract.pt.5065495
22 20 not 21332

APA PsycInfo <1967–February week 5 2024>

1 Tics/ or exp Tic Disorders/ or (tic or tics or Tourette?).tw,id.7144
2 exp Health Care Costs/ or exp “Costs and Cost Analysis”/50267
3 *economics/ or health care economics/19726
4 pharmacoeconomics/293
5 decision theory/1379
6 Markov Chains/1960
7 (cost$ adj2 (effective$ or utilit$ or benefit$ or minimis$)).ab.26687
8 economics model$.tw.52
9 (economic$ or pharmacoeconomic$).tw.135615

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10 (price or prices or pricing).tw.21221
11 budget$.tw.10255
12 (value adj1 money).tw.47
13 (expenditure$ not energy).tw.9592
14 markov$.tw.5346
15 monte carlo.tw.5643
16 (decision$ adj2 (tree? or analy$ or model$)).tw.11458
17 or/2-16237133
18 1 and 17103

CRD Databases (NHS EED, DARE, HTA)

Tics (MeSH): 2/ 0
Tic disorders (MeSH): 19/ 1
Title: Tic* or Tourette*: 61/ 1
Proquest EconLit
noft(tic OR tics OR tourette*)

CEA

Keyword: Tourette or tic or tics

Disease: mental, behavioural and neurodevelopmental disorders/diseases of the nervous system

NICE

Search: “tics”, “tic disorders”, Tourette: 2, 0 additional

NIHR

Search: “tics”, “tic disorders”, Tourette: 2, 0 additional

AHRQ Evidence Reports

Search: “tics”, “tic disorders”, Tourette: 0

CADTH

Search: “tics”, “tic disorders”, Tourette

HIQA

Search: “tics”, “tic disorders”, Tourette: 0

IHTA

Tics (MeSH): 1
Tic disorders (MeSH): 4

Appendix 2 Characteristics of included studies

TABLE 27 Characteristics of included studies

Study details	Inclusion criteria	Exclusion criteria
First author, year: Hollis 2021[34] **Secondary reports:** Hall 2019[33] Hall 2020[60] Hollis 2023[35] Hollis 2023[61] Khan 2020[62] Khan 2021[63] Khan 2022[64] **Language:** English **Publication type:** Full text **Setting:** home **Study design:** RCT **Intervention device:** ORBIT **Comparator:** Psychoeducation	1. Aged 9–17 years 2. Suspected or confirmed TS or CTD. – Including moderate/severe tics: TTSS > 15 on the YGTSS; TTSS score > 10 if motor or vocal tics only 3. Competent to provide written, informed consent (parental consent for children aged < 16 years) 4. Broadband internet access and regular PC/laptop/Mac (Apple Inc.Cupertino, CA, USA) user, with mobile phone Short Message Service	1. Receipt of/engaged in structured behavioural intervention for tics (e.g. HRT/CBIT or ERP) within the last 12 months 2. Change to medication for tics (start or stop) within the previous 2 months 3. Diagnoses of alcohol/substance dependence, psychosis, suicidality or anorexia nervosa 4. Moderate/severe intellectual disability 5. Immediate risk to self or others 6. Parent or child not able to speak or read/write English
First author, year: Andrén 2022[38] **Secondary reports:** Andrén 2019[65] Andrén 2021,[66] Andrén 2024[41] **Language:** English **Publication type:** full text **Setting:** home **Study design:** RCT **Intervention device:** ORBIT **Comparator:** psychoeducation	Eligible participants were 9–17-year-old children with a DSM-5 diagnosis of TS or CTD1 who had a YGTSS TTSS > 15 (or > 10 if only motor or vocal tics had been present during the last week), had at least one parent available to participate in the treatment, and had access to at least one computer and one mobile phone per family	Participants were excluded if they had received ≥ 8 sessions of BT for tics with a qualified therapist within the past year, were receiving simultaneous psychological treatment for TS/CTD, had initiated or adjusted any psychotropic medication for TS/CTD within the past 8 weeks, had a diagnosis of organic brain disorder, intellectual disability, ASD, psychosis, bipolar disorder, anorexia nervosa or alcohol/substance dependence, were an immediate risk for themselves or others requiring urgent medical attention (e.g. suicidality or self-injurious tics), were not able to read and communicate in Swedish or had a close relative already enrolled in the trial
First author, year: Maiquez 2023[36] **Secondary reports:** Maiquez 2020[40] **Language:** English **Publication type:** full text **Setting:** home **Study design:** RCT **Intervention device:** Neupulse **Comparators:** sham stimulation; waitlist (not considered for review of clinical effectiveness)	1. Age 12 years upwards 2. Confirmed or suspected TS/CTD. With moderate to severe tics indicated by a total tic score > 15 on the YGTSS, or total tic score > 10 if only motor/vocal tics are present 3. No change in medication for tics or tic-related treatment in the last 2 months. Participants were to confirm this during telephone screening 4. Broadband internet access and electronic device for completion of online materials. For a subset of participants, a device with a camera will also be required 5. Ability to travel to the University of Nottingham for one onsite visit 6. Participant is willing and able to give informed consent for participation in the clinical investigation 7. Able (in the investigator's opinion) and willing to comply with all clinical investigation requirement. 8. Resident in the UK	1. Current diagnosis of epilepsy. 2. Participant or participant's guardian (if under 16) unable to read/write in English. 3. Participants will be excluded from the trial if they find the stimulation too uncomfortable during the in-person baseline assessment visit 4. Individuals with implanted electronic devices (e.g. pacemakers, insulin pump, implantable cardioverter defibrillator, neurostimulators) 5. Individuals sharing the household with an individual with implanted electronic devices (e.g. pacemakers, insulin pump, implantable cardioverter defibrillator, neurostimulators) 6. Individuals with a current/recent diagnosis or symptoms of SARS-CoV-2 were not invited to visit the university until it was safe for them to do so (2 weeks following positive test) 7. Diagnosis of non-verbal autism or similar condition which would affect the ability to give informed consent to take part in the study 8. Pregnant women 9. Participants who have participated in previous research studies involving MNS 10. Participants aged over 90 years old

HRT: habit reversal therapy.

Source

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Appendix 3 Completed quality assessment forms for included studies

TABLE 28 Philips checklist[43] quality assessment of ORBIT study

Dimension of quality	Questions for critical appraisal	Assessment	Reviewer comments
Statement of decision problem/objective	*Is there a clear statement of the decision problem?*	Y	None
	Is the objective of the evaluation and model specified and consistent with the stated decision problem?	N	The objective of the evaluation is clearly described and relevant to the context of the decision problem for the study. However, the comparator for the evaluation (online psychoeducation, including use of the BiP intervention platform) may not align closely with the decision problem for the NICE medtech assessment (face-to-face behavioural therapy)
	Is the primary decision-maker specified?	Y	
Statement of scope/ perspective	*Is the perspective of the model stated clearly?*	Y	
	Are the model inputs consistent with the stated perspective?	Y	
	Has the scope of the model been stated and justified?	Y	
	Are the outcomes of the model consistent with the perspective, scope and overall objective of the model?	Y	
Rationale for structure	*Has the evidence regarding the model structure been described?*	Y	
	Is the structure of the model consistent with a coherent theory of the health condition under evaluation?	Y	Yes, but there is uncertainty surrounding the link between YGTSS-TTSS score and health state utility values that requires further investigation. That being said, the model structure is coherent and plausible.
	Have any competing theories regarding model structure been considered?	N	No alternatives (such as linear relationship between tic severity and utility) have been proposed. Similarly, no discussion around whether the categorisation based on YGTSS_TTSS is the most appropriate definition. Clinical expert validation would have been helpful
	Are the sources of data used to develop the structure of the model specified?	Y	Briefly mentioned
	Are the causal relationships described by the model structure justified appropriately?	Y	Yes, however there is some uncertainty
Structural assumptions	*Are the structural assumptions transparent and justified?*	Y	
	Are the structural assumptions reasonable given the overall objective, perspective and scope of the model?	Partly	Structural assumptions imply that transition probabilities can be extrapolated indefinitely beyond the trial observation end point. There is no evidence to support or refute this assumption and further scenario analyses would have been useful

TABLE 28 Philips checklist quality assessment of ORBIT study (*continued*)

Dimension of quality	Questions for critical appraisal	Assessment	Reviewer comments
Strategies/ comparators	*Is there a clear definition of the options under evaluation?*	Y	
	Have all feasible and practical options been evaluated?	Y	
	Is there justification for the exclusion of feasible options?	N/A	
Model type	*Is the chosen model type appropriate given the decision problem and specified causal relationships within the model?*	Y	
Time horizon	*Is the time horizon of the model sufficient to reflect all important differences between options?*	N	A time horizon of 10 years was used, but this may be appropriate given uncertainties surrounding long-term extrapolations
	Are the time horizon of the model, the duration of treatment and the duration of treatment effect described and justified?	N	The duration of treatment effect is assumed to be indefinite, despite no ongoing intervention costs being incurred. Further justification of this assumption would have been helpful
	Has a lifetime horizon been used? If not, has a shorter time horizon been justified?	N	Not explicitly justified but may be appropriate given the uncertainty in long-term extrapolations beyond the trial observation follow-up
Disease states/ pathways	*Do the disease states (state transition model) or the pathways (decision tree model) reflect the underlying biological process of the disease in question and the impact of interventions?*	Y	
Cycle length	*Is the cycle length defined and justified in terms of the natural history of disease?*	Y	
Data identification	*Are the data-identification methods transparent and appropriate given the objectives of the model?*	Partly	The model was informed by trial data, though it was not always possible to follow what methods were used to derive model input parameters (e.g. were annual transitions appropriate converted to 6-month cycle-specific transitions, data to support the exclusion of particular health state costs categories would have been helpful)
	Where choices have been made between data sources, are these justified appropriately?	N	No details provided
	Has particular attention been paid to identifying data for the important parameters in the model?	Y	data obtained from the trial (best available data)
	Has the process of selecting key parameters been justified and systematic methods used to identify the most appropriate data?	N	Systematic methods have not been clearly documented
	Has the quality of the data been assessed appropriately?	N	There is a lack of quality assessment of the input data, in particular small counts for transition probabilities from the trial
	Where expert opinion has been used, are the methods described and justified?	N	
Premodel data analysis	*Is the data analysis (premodel) methodology based on justifiable statistical and epidemiological techniques?*	Y	

continued

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TABLE 28 Philips checklist quality assessment of ORBIT study (*continued*)

Dimension of quality	Questions for critical appraisal	Assessment	Reviewer comments
Baseline data	*Is the choice of baseline data described and justified?*	Y	
	Are transition probabilities calculated appropriately?	Unclear	However, it is unclear how annual transitions were converted to 6-month cycle-specific transitions
	Has a half-cycle correction been applied to both cost and outcome?	N	Use of a half cycle correction has not been reported. Assume not applied
	If not, has this omission been justified?	N	
Treatment effects	*If relative treatment effects have been derived from trial data, have they been synthesised using appropriate techniques?*	Y	Data from one trial applied in the model. Raw data parameterised in each arm is appropriate but does not include exploration of correlated draws for each arm
	Have the methods and assumptions used to extrapolate short-term results to final outcomes been documented and justified? Have alternative assumptions been explored through sensitivity analysis?	N	The methods are not clearly described, though it appears that the last observed transition probabilities are carried forward. This assumption is not well justified, particularly given that intervention costs do not appear to be applied beyond 18 months (trial observation period). No sensitivity or scenario analyses have been conducted to explore this uncertainty
	Have assumptions regarding the continuing effect of treatment once treatment is complete been documented and justified? Have alternative assumptions been explored through sensitivity analysis?	N	As described above
QoL weights (utilities)	*Are the utilities incorporated into the model appropriate? Is the source for the utility weights referenced?*	Partly	It is unclear whether parent-reported proxy or child self-reported responses to the CHU-9D are used
	Are the methods of derivation for the utility weights justified?	Y	Based on published literature. Unclear if utilities are age adjusted in the model, though this likely would have minimal impact for a cohort at starting age 12 over 10 years
Data incorporation	*Have all data incorporated into the model been described and referenced in sufficient detail?*	Y	
	Has the use of mutually inconsistent data been justified (i.e. are assumptions and choices appropriate)?	Unclear	
	Is the process of data incorporation transparent?	Y	
	If data have been incorporated as distributions, has the choice of distribution for each parameter been described and justified?	Y	
	If data have been incorporated as distributions, is it clear that second order uncertainty is reflected?	Y	
Assessment of uncertainty	*Have the four principal types of uncertainty been addressed?*	N	Long-term extrapolation (continuing treatment effect beyond intervention delivery) is not explored in scenario analyses. Similarly, any long-term intervention costs required to generate effectiveness are not explored
	If not, has the omission of particular forms of uncertainty been justified?	N	

TABLE 28 Philips checklist quality assessment of ORBIT study (*continued*)

Dimension of quality	Questions for critical appraisal	Assessment	Reviewer comments
Methodological	*Have methodological uncertainties been addressed by running alternative versions of the model with different methodological assumptions?*	N	
Structural	*Is there evidence that structural uncertainties have been addressed via sensitivity analysis?*	N	
Heterogeneity	*Has heterogeneity been dealt with by running the model separately for different subgroups?*	N	Although it is difficult to see how to appropriately parameterise subgroups in this case
Parameter	*Are the methods of assessment of parameter uncertainty appropriate?*	Y	
	Has probabilistic sensitivity analysis been done? If not, has this been justified?	Y	
	If data are incorporated as point estimates, are the ranges used for sensitivity analysis stated clearly and justified?	Y	
Internal consistency	*Is there evidence that the mathematical logic of the model has been tested thoroughly before use?*	N	
External consistency	*Are the conclusions valid given the data presented?*	Y	Although uncertainty is likely understated
	Are any counterintuitive results from the model explained and justified	N/A	
	If the model has been calibrated against independent data, have any differences been explained and justified?	N	
	Have the results of the model been compared with those of previous models and any differences in results explained?	N/A	First model in this area

N/A, not applicable.

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Appendix 4 Additional cost-effectiveness results for Online Remote Behavioural Treatment for Tics versus online psychoeducation

TABLE 29 Scenario analyses for comparison of ORBIT vs. online psychoeducation (deterministic)

S. no	Technologies	Total costs (£)	Total QALYs	Incremental costs (£)	Incremental QALYs	ICER (£)
0	***Base case***					
	Psychoeducation	12,755	20.916	–	–	–
	ERP	12,974	20.939	218	0.024	9289
1	***Time horizon = 10 years from end-of-trial follow-up (18 months + 10 years)***					
	Psychoeducation	5128	7.738	–	–	–
	ERP	5397	7.767	269	0.028	9490
2	***Times horizon = 5 years from end-of-trial follow-up (18 months + 5 years)***					
	Psychoeducation	3422	4.593	–	–	–
	ERP	3702	4.623	280	0.03	9451
3	***Time horizon = 2 years from end-of-trial follow-up (18 months + 2 years)***					
	Psychoeducation	2253	2.413	–	–	–
	ERP	2540	2.443	287	0.03	9584
4	***Include transitions into the absorbing 'tics free' health state, set utility tics free = mild***					
	Psychoeducation	5955	21.305	–	–	–
	ERP	6219	21.327	264	0.022	12,254
5	***Include only variable cost of therapist support for psychoeducation***					
	Psychoeducation	12,513	20.916	–	–	–
	ERP	12,974	20.939	460	0.024	19,582
6	***Apply approach from ORBIT study (include only variable platform costs and therapist support for psychoeducation; remove all ongoing costs)***					
	Psychoeducation	12,520	20.916	–	–	–
	ERP	12,830	20.939	311	0.024	13,216
7	***Only include variable therapist support costs, include ongoing costs + platform throughput (n = 100)***					
	Psychoeducation	12,631	20.916	–	–	–
	ERP	13,026	20.939	396	0.024	16,831
8	***Only include variable therapist support costs, include ongoing costs + platform throughput (n = 1000)***					
	Psychoeducation	12,631	20.916	–	–	–
	ERP	12,940	20.939	310	0.024	13,172
9	***Remove ongoing intervention costs from both arms (i.e. no variable costs applied for each cycle)***					
	Psychoeducation	12,638	20.916	–	–	–
	ERP	12,830	20.939	192	0.024	8177

TABLE 29 Scenario analyses for comparison of ORBIT vs. online psychoeducation (deterministic) (*continued*)

S. no	Technologies	Total costs (£)	Total QALYs	Incremental costs (£)	Incremental QALYs	ICER (£)
10	***Remove long-term transition probabilities (retain in state beyond 18 months), assumes 18-month benefit retained indefinitely***					
	Psychoeducation	12,646	20.87	–	–	–
	ERP	12,722	20.989	76	0.119	640
11	***ERP transition probabilities revert to online psychoeducation arm after 18 months***					
	Psychoeducation	12,755	20.916	–	–	–
	ERP	13,040	20.948	284	0.033	8747
12	***Apply additional medication costs to moderate and severe health states***					
	Psychoeducation	13,466	20.916	–	–	–
	ERP	13,717	20.939	251	0.024	10,695

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