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Research paper

Appropriate use criteria for endotracheal suction interventions in mechanically ventilated children: The RAND/UCLA development process

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ABSTRACT

Objectives: Endotracheal suction is an invasive airway clearance technique used in mechanically ventilated children. This article outlines the methods used to develop appropriate use criteria for endotracheal suction interventions in mechanically ventilated paediatric patients.

Methods: The RAND Corporation and University of California, Los Angeles Appropriateness Method was used to develop paediatric appropriate use criteria. This included the following sequential phases of defining scope and key terms, a literature review and synthesis, expert multidisciplinary panel selection, case scenario development, and appropriateness ratings by an interdisciplinary expert panel over two rounds. The panel comprised experts in the fields of paediatric and neonatal intensive care, respiratory medicine, infectious diseases, critical care nursing, implementation science, retrieval medicine, and education. Case scenarios were developed iteratively by interdisciplinary experts and derived from common applications or anticipated intervention uses, as well as from current clinical practice guidelines and results of studies examining interventions efficacy and safety. Scenarios were rated on a scale of 1 (harm outweighs benefit) to 9 (benefit outweighs harm), to define appropriate use (median: 7 to 9), uncertain use (median: 4 to 6), and inappropriate use (median: 1 to 3) of endotracheal suction interventions. Scenarios were than classified as a level of appropriateness.

Conclusions: The RAND Corporation/University of California, Los Angeles Appropriateness Method provides a thorough and transparent method to inform development of the first appropriate use criteria for endotracheal suction interventions in paediatric patients.

1. Introduction

Endotracheal suction (ETS) is a mainstay secretion management technique for mechanically ventilated children worldwide. Despite its importance and frequency of application, ETS is an invasive and potentially harmful intervention. Observational studies in critically ill children have demonstrated that approximately 25% of ETSs[1] contribute to postsuction complications including oxygen

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desaturation,[2,3] cardiovascular interactions,[4–6] and ventilator-associated infection.[3,7,8] Although many of these complications are transient, more serious complications such as atelectasis and infection may be associated with significant sequelae for the patient and healthcare system. Such complications can contribute to a protracted duration of ventilation[8–10] and prolonged paediatric intensive care unit (PICU) admission which in turn increase the likelihood of PICU-acquired complications and impact survivorship.[11,12]

Internationally, ETS practice lacks standardisation, with the variable use of ETS interventions (e.g., normal saline instillation, preoxygenation, postoxygenation) likely contributing to the high incidence of complications.[2,5,13] However, clinical decision-making regarding ETS intervention use in the PICU is complex. The heterogeneous nature of the PICU population and the high-acuity environment mean decisions must be made quickly, often in high-stake situations by nurses with relatively little critical care experience (i.e., < 12–24 months). These decisions are further complicated by a lack of clear guidelines, to help inform the decision-making process. This results in a heavy reliance on a clinician's own clinical experience and judgement.[14] Use of historical ETS practices such as ad hoc use of saline or lung recruitment may not be the best way to optimise ventilation strategies, improve oxygenation, or to prevent suction-related complications. Given the widespread variability and uncertainty regarding ETS best practice in the PICU, clinicians and patients would benefit from improved clinical guidance regarding the appropriateness (and inappropriateness) of ETS interventions. This guidance could be used to support clinical decision-making at the bedside, reduce variation in care and harmful practices, and improve outcomes for children and their families.

In response to the need for improved guidance regarding the use of ETS interventions in the delivery of high-quality care, we undertook a process to determine the appropriate use of ETS interventions for paediatric patients. The resulting resource will be referred to as The Paediatric AirWay Suction (PAWS) appropriateness guide for ETS interventions.

2. Methods

2.1. Design

Using the RAND Corporation/University of California, Los Angeles (RAND/UCLA) Appropriateness Method,[15] we developed appropriate use criteria for ETS interventions in mechanically ventilated children across Australia and New Zealand. Appropriateness refers to the relative weight of the benefits and harms of an intervention.[15] The method balances the best available scientific evidence with the collective judgement of experts to form a statement regarding the appropriateness of using a procedure.[15] The appropriate procedure is evidence based, is individualised to the patient, is cost-effective, and achieves expert consensus. This method is valuable for the current study given the limited availability of high-quality evidence surrounding paediatric ETS interventions.[16] The Appropriateness Method has been used to develop appropriate use criteria internationally and across health disciplines,[17–19] with a number of apropirate use criteria implemented in clinical practice, including for advanced diagnostic imaging[20] and transthoracic echocardiography.[21] The RAND/UCLA Appropriateness Method involves sequential phases, detailed in Fig. 1. Ethical approval to undertake the study was obtained from Griffith University Human Research Ethics Committee (GU REF: 2019/916). All expert panel members provided written informed consent before panel participation.

2.2. Context and applicability

The PAWS guideline focused on defining the appropriateness of interventions that are most commonly applied during ETS in mechanically ventilated children in intensive care, across Australia and New Zealand. These geographical locations were chosen to reflect current collaborations and the need to generate recommendations that would take into account varying care contexts across these locations. The PAWS included critically ill paediatric patients from birth to 18 years of age. We did not seek to provide appropriate recommendations for preterm neonates admitted to neonatal intensive care units or special care after birth as this cohort requires a specialist approach and consideration of differing lung pathology and mechanics. Included patient populations (e.g., general, cardiovascular, severe traumatic brain injury, respiratory and specialist patient populations) were included to represent the diversity amongst key PICU service users across Australia and New Zealand.[22]

ETS interventions included in the PAWS are representative of the most common adjunct interventions used within Australia and New Zealand; as such we intentionally excluded practices that are not specifically utilised in these healthcare settings (e.g., lignocaine installation).[23,24] This decision was made with the support of the expert panel. We also sought to provide guidance on important clinical questions surrounding ETS practice that were current areas of uncertainty, irrespective of evidence availability or quality.

2.3. Definition of key terms

ETS: The artificial aspiration of respiratory secretions from the distal end of an endotracheal tube to maintain airway patency and facilitate ventilation and oxygenation.[16,25]

Invasive mechanical ventilation: Ventilatory support (assistance to breathing) delivered by invasive means (oral or nasal endotracheal tube) including conventional mechanical ventilation and high-frequency oscillation ventilation. For the purposes of following the PAWS guideline, this included positive pressure ventilation modes and continuous positive airway pressure.[26] We excluded children receiving mechanical ventilation via a tracheostomy tube owing to their unique considerations.

Populations: Population definitions including age and subspecialty populations are outlined in Table 1.

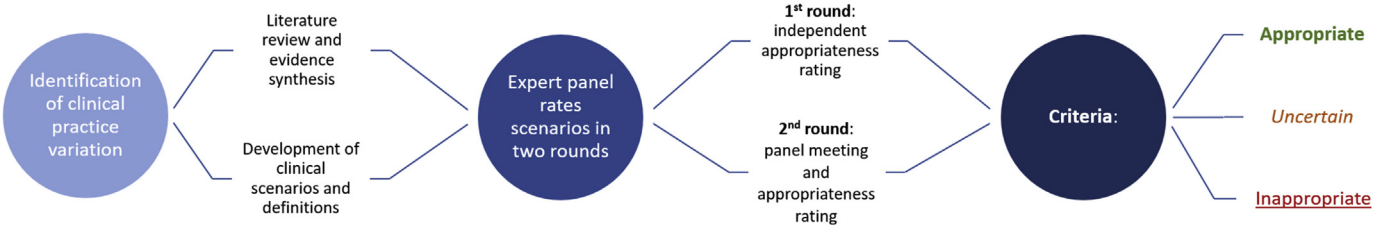

Fig. 1. RAND/UCLA Appropriateness Method phases.

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Table 1
Population categories.

Demographic item	Definition
Age[27,28]	
Neonate	From full-term to less than ≤30 days of age
Infant	Aged between >31 days and 12 months
Child	Aged between >12 months and 11 years
Adolescent	Aged between >11 years and 18 years
Patient population	
Critically ill	Paediatric patients receiving care in an intensive care setting.
General paediatric[28]	Includes patients admitted for the following reasons: neurologic or neuromuscular diagnosis, gastrointestinal, metabolic, malignancy, technology dependency, renal or urologic, haematologic or immunologic, other congenital or genetic defect, transplantation, mental health/behavioural
Specialty population	
i. Systemic therapeutic anticoagulation,[29] patients receiving anticoagulation therapy for treatment or prevention of thromboembolic disorders	
Cardiovascular[28]	A patient who has been admitted for medical or surgical treatment of an underlying congenital cardiac condition or acquired cardiovascular disease.
Subspecialty populations[30,31]	
i. Low-risk and stable haemodynamics after cardiac surgery, e.g., low risk: atrial septal defect, ventricular septal defect, coarctation repair, stage II and III single-ventricle pathway;	
ii. High-risk and/or unstable haemodynamics after cardiac surgery, e.g., high risk: stage 1 single-ventricle pathway, systemic-to-pulmonary artery shunts, pulmonary artery band, neonatal repair of truncus arteriosus, transposition of the great arteries;	
iii. High-risk cardiovascular conditions, patients with severe cardiac conditions with a high degree of instability, e.g., known cardiac dysfunction, cardiomyopathy;	
iv. Pulmonary hypertension, high blood pressure that affects the arteries in your lungs and the right side of the heart; and	
v. Extracorporeal membrane oxygenation is a technique that involves oxygenation of blood outside the body and provides support to selected patients with severe respiratory or cardiac failure.	
Specialty population	
Severe traumatic brain injury[32]	Including the following primary reasons for admission: Primary TBI (skull fractures and intracranial injury) or secondary TBI (diffuse cerebral swelling), e.g., severe TBI (these are the ones we intubate for neurological reasons not because of other injuries)
Subspecialty populations	
i. Raised intracranial pressure,[33] defined as patients with sustained ICP elevations requiring tier two management	
ii. Hypoxic brain injury,[32] defined as a patient with brain injuries formed due to a restriction in oxygen delivery to the brain	
iii. Post neurovascular procedure/neurosurgery,[34] e.g., arteriovenous malformations	
iv. Neurological determination of death,[35] defined as a patient with a permanent loss of brain function requiring clinical and physiological support for organ donation preservation.	
Specialty population	
Respiratory[28]	A pathological condition that effects the lungs and other parts of the respiratory system that facilitate gas exchange and respiration
Subspecialty populations	
i. Paediatric acute respiratory distress syndrome (PARDS),[36] as per PARDS definition for mild, moderate, and severe	
ii. Highly infectious respiratory disease,[37] a highly infectious respiratory pathogen which may be transmitted via airborne or droplet routes	
Additional patient populations[38–40]	
a. ***Patients requiring long-term ventilation***: any child who, when medically stable, continues to require a mechanical aid for breathing (3 months after the institution of ventilation), after an acknowledged failure to wean, or a slow wean, 3 months after the institution of ventilation. Including children who require invasive ventilation in the home	
b. ***Patients requiring ventilation for palliative support***: ventilatory support provided with a focus on palliation of symptoms and to facilitate quality of life in children with a life-limiting condition.	
c. ***Patients requiring ventilation for transport***: ventilatory support provided with a focus on the transportation of the patient to another location or healthcare facility.	

TBI = traumatic brain injury; ICP = intracranial pressure.

Clinical indications for ETS were categorised into two classifications:[41–43] nonrespiratory indications such as routine or proactive/preprocedural indications (e.g., pre-extubation, before transfer) and respiratory indications, that is a change in the patient's respiratory status (e.g., decreased air entry, visible/audible secretions, change in tidal volume, peak inspiratory pressure, or end tidal CO_2).

ETS interventions: A range of ETS treatments which are used to support secretion clearance via the endotracheal tube are defined in Table 2.

2.4. Evidence review and synthesis

An integrative review of the literature[16] was undertaken to summarise the available scientific evidence surrounding ETS interventions in mechanically ventilated children. The review was undertaken using high-quality methods[44] including an extensive, systematic search of electronic databases (Cochrane Central Register of Controlled Trials, Ovid MEDLINE, Ovid EMBASE, EBSCO, CINAHL, and clinical trial registries). Search strings were developed with the assistance of a health librarian and included Medical Subject Heading and key words. After the integrative review, a review and critical appraisal of current ETS clinical guidelines[45] was undertaken. A systematic search for ETS clinical practice guidelines[46,47] in children (aged <18 years) was conducted in CINAHL, Medline, PubMed, Embase, and Google Scholar. Two independent assessors evaluated each included guideline, using the Appraisal of Guidelines for Research Evaluation (AGREE) II instrument.[48,49] Results of the integrative review and critical appraisal were synthesised, summarised, and provided to expert panellists before undertaking appropriateness ratings in round 1.

2.5. Panel of clinical experts

Australian and New Zealand experts were invited to be a part of a panel to assess and rate potential ETS interventions. Acknowledged lead researchers in the field of respiratory medicine/PICU as well as clinical experts (currently practising) in paediatrics, intensive care medicine, anaesthetics, physiotherapy, nursing, neonatology, neuro and cardiac intensive care, and infectious disease as

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Table 2
Endotracheal suction interventions.[3,30–36]

Intervention	Definition
Presuction	Interventions to facilitate optimisation of the endotracheal suction event, typically applied immediately preceding the suction
Preoxygenation	The deliberate increase in the FiO_2 before the endotracheal suction.
Prebagging	Disconnection of ETT from ventilator circuit to anaesthetic bag and ventilation delivered using anaesthetic bag, also referred to a bag-ETT ventilation.
MAP manipulation	Increase in mean airway pressure before endotracheal suction in children receiving HFOV.
Suction procedure	Breaking of the ventilator-ETT circuit or the intention to commence suction using a closed system.
Normal saline instillation	0.9% saline solution (sodium chloride) instilled into the endotracheal tube during the suction.
Open suction	Open-suction system requiring the disconnection of the patient from the mechanical ventilator to mechanically aspirate secretions.
Closed suction[a]	The mechanically aspiration of secretions occurring while patient remains connected to the mechanical ventilator using an inline suction system.
Deep suction	Suction to the point of resistance (i.e., carina)
Postsuction	Interventions to facilitate optimisation of the endotracheal suction event, typically applied immediately after the suction
Postoxygenation	The deliberate increase in FiO_2 after the completion of the endotracheal suction
Postbagging	Disconnection of ETT from ventilator circuit to anaesthetic bag and ventilation delivered using anaesthetic bag, also referred to a bag-ETT ventilation.
PEEP manipulation	A deliberate treatment to increase pulmonary pressure and maximise alveolar recruitment and gas surface exchange area. For this project, PEEP manipulation refers to increasing the baseline PEEP, for example, by a factor of 2 (e.g., 5–10 cm H_20) or incremental PEEP where incremental increases in PEEP are involved followed by incremental decreases to return to baseline.

FiO2 = fraction of inspired oxygen; MAP = mean airway pressure; HFOV = high-frequency oscillation ventilation; PEEP = positive and spiritual pressure; H_2O = centimetres of water; ETT = endotracheal tube.
[a] Inline suction system.

voting panellists (n = 12), thus ensuring the resulting criteria were applicable across diverse range of PICU populations. A parent representative[50,51] (parent of three children with Australian PICU experience, providing a parent perspective) was also invited as a nonvoting panellist member to ensure the consumer voice was central to all discussions. In addition, the parent representative led a discussion on the lived experience of a PICU family at the beginning of the panel. As per RAND/UCLA methods, nonvoting attendees, including panel facilitators (methodologist Professor Amanda Ullman, Australia) and support staff were also present. Panel representation is outlined in Table 3.

2.6. Clinical scenario development

Fig. 2 outlines the conceptual framework used to develop the clinical scenarios and appropriate use criteria. The conceptual framework utilised patient and clinical characteristics to inform the iterative development of clinical scenarios for specific patient and subspecialty populations. The clinical scenarios were informed by the results of the integrative review, appraisal of the guidelines, and the expertise of panellists, within the boundaries and scope of the project. Clinical scenarios were divided into the following sections: patient population, mode of ventilation, clinical indication for ETS, and patient age. Suction interventions were categorised into presuction, the suction event, and postsuction interventions. Subspecialty populations were also included. Developed clinical scenarios underwent a process of internal review by the investigators and expert panellists and external review by independent international PICU experts to ensure the scenarios reflected the predefined aims of the project.

2.7. Round 1 appropriateness rating

As per the RAND/UCLA Appropriateness Method, round 1 appropriateness rating involved independent review of the document without interaction with other panel members. Voting

Table 3
Panel representatives.

Name	Paediatric specialty	Location	Hospital and/or university affiliations
Voting panellists			
P1		Victoria, Australia	
P2		Victoria, Australia	
P3		Tasmania, Australia	
P4		Western Australia, Australia	
P5		Western Australia, Australia	
P6		Auckland, New Zealand	
P7		Queensland, Australia	
P8		Queensland Australia	
P9		New South Wales, Australia	
P10		New South Wales, Australia	
P11		Western Australia, Australia	
P12		Queensland, Australia	
Nonvoting panellists			
NV 1		Queensland, Australia	
NV 2		Queensland, Australia	
NV 3		Queensland, Australia	
NV4		Queensland, Australia	
Parent representative		Queensland, Australia	

RN = registered Nurse; PhD = Doctor of Philosophy; PICU = paediatric intensive care unit; MD = medical doctor; CNC = clinical nurse consultant; NEd = nurse educator; PT = physiotherapist; [+]mixed population.

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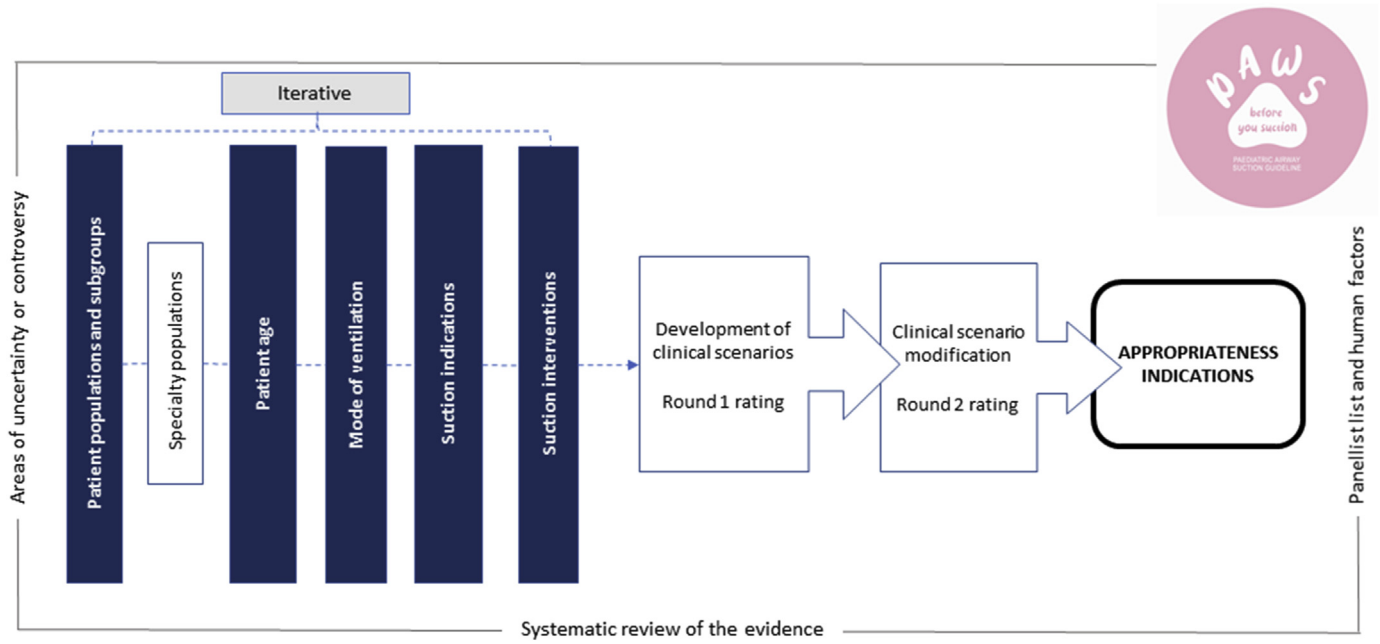

Fig. 2. Conceptual framework for the development of clinical scenarios of appropriateness and preference. The conceptual framework developed for the Paediatric AirWay Suction (PAWS) guideline was based on existing conceptual frameworks developed by The Michigan Appropriateness Guide for Intravenous Catheters[52] and Michigan Appropriateness Guide for Intravenous Catheters in Pediatrics appropriate use criteria.[53]

panellists received the literature review, clinical scenarios, definition of terms, and guide for rating scenarios via email. Panellists were instructed to familiarise themselves with the literature review and the process of rating clinical scenarios using a Microsoft Excel® spreadsheet. For each scenario, panel members were asked to rate the appropriateness by considering the benefit-to-harm ratio on a scale of 1–9, where 1 indicates harms outweighs benefit and 9 signifies that benefits outweigh harm. The ratings were completed and distributed electronically and returned to their investigator group via email. A maximum of three follow-up emails were sent to ascertain missed ratings. The overall ratings for round 1 for each indication were summarised descriptively as a median, frequency, range, and interquartile range (IQR). As recommended by the RAND/UCLA method, indications were classified into three levels of appropriateness:

1. Appropriate: panel median score of 7–9, without disagreement;
2. Uncertain/neutral: panel median score of 4–6, or with disagreement regardless of median; and
3. Inappropriate: panel median score of 1–3, without disagreement.

Disagreement existed if ≥ four panelists rated in each extreme (1–3 and 7–9).[15]

2.8. Round 2 appropriateness rating

After round 1 appropriateness ratings, panellists were invited to a face-to-face meeting at the Centre for Children's Health Research, Brisbane, Queensland, Australia. Owing to COVID-19 restrictions, the round 2 meeting was also offered online using Microsoft Teams®. The panel discussion was moderated by a RAND/UCLA methodology expert (Professor Ullman) and scientific content experts (Dr Schults, Associate Professor Long), without voting. Sessions were structured to encourage discussion and debate regarding uncertain clinical practices and ratings where disagreement occurred. Clinical scenarios that were rated neutral or uncertain were also revisited. During this discussion, panellists recommended modifications to indications and definitions resulting in a reduction in the final number of clinical scenarios and improvement in the clarity of ratings. After this discussion, clinical scenarios were rerated independently by voting panellists using the Microsoft Excel® document. Round 2 data were then analysed and reclassified into the three levels of appropriateness with disagreement and agreement (≥10 panellists rating in the three-point median) described. A maximum of three follow-up emails were made in an attempt to ascertain missing responses after round 2 ratings.

3. Discussion

This study is the first of its kind to be undertaken across Australia and New Zealand and will translate evidence and clinical expertise into ETS intervention appropriate use criteria for PICU clinicians. Although many steps are being taken to establish research as a standard of care in the PICU,[54] many routine practices, such as ETS, lack clinical trial data to support the safe and effective use of associated interventions. In the absence of this evidence, the RAND/UCLA Appropriateness Method represents a reliable method to systematically assess variation in the use of procedures, by defining the appropriateness of these procedures, within clinical situations.[55] The new appropriateness guidelines can inform large-scale collaborative and bedside efforts to reduce inappropriate ETS intervention use and related adverse events. It will also support the appropriate use of suction interventions, as well as identify areas of clinical practice requiring further research. Future research could explore the acceptability, application, and efficacy of the developed appropriate use recommendations across varying health contexts.

4. Limitations

The current COVID-19 pandemic required a modification to the RAND/UCLA methods to accommodate round 2 appropriateness

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ratings via an online platform. This may impact the result of the study, both in recommendations (e.g., increased use of closed suction) and panellist participation (the online platform may lead to reduced panellist discussion when compared with in-person meetings).[15]

5. Conclusion

Using the outlined, rigorous methodology, the resulting appropriate use criteria may be a valuable clinical resource to support practice decisions across a broad range of contexts. Such guidance can be used to reduce suction intervention variation across diverse paediatric critical care practice settings.

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CRediT authorship contribution statement

Jessica A Schults: Conceptualisation, Funding acquisition, Methodology, Investigation, Writing – original draft, Visualisation. **Karina Charles:** Methodology, Investigation, Resources, Data curation, Writing – original draft, Visualisation, Project administration. **Debbie Long:** Conceptualisation, Funding acquisition, Methodology, Writing – review & editing. **Simon Erikson:** Investigation, Validation, Writing – review & editing. **Georgia Brown:** Investigation, Validation, Writing – review & editing. **Michaela Waak:** Investigation, Validation, Writing – review & editing. **Lyvonne Tume:** Conceptualisation, Methodology, Validation, Writing – review & editing. **Lisa Hall:** Conceptualisation, Funding acquisition, Methodology, Writing – review & editing. **Amanda J Ullman:** Conceptualisation, Funding acquisition, Methodology, Validation, Writing – review & editing.

Conflict of Interest

The authors have no conflicts of interest to declare.

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