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RESEARCH ARTICLE

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Evaluating the impact of school-based rebound therapy on chest health in children and young people with neurodisability and respiratory issues: a series of single case studies

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ABSTRACT

Purpose: To evaluate feasibility and impact of an individualised rebound therapy programme on chest health in children with complex neurodisability.

Methods and materials: A single-case ABA design was conducted over 18 weeks with five children aged 5–15 years with complex neurodisability. Intervention involved twice weekly rebound therapy for six consecutive weeks in school. Summary outcomes included parent/carer-reported chest health, quality-of-life and clinician-observed motor ability. Serial weekly outcomes included chest health observations, usual care changes, adherence and adverse events. Parents completed a semi-structured interview after follow-up. Quantitative data were analysed descriptively and qualitative data were analysed using thematic analysis.

Results: Within-case and across-case findings indicated improvement in motor ability following rebound therapy intervention. Additional trends of improvement were noted in parent/carer-reported chest health and quality-of-life, but these changes were not specific to the intervention phase. Improvements in motor ability, chest health and quality-of-life indicators were verified through qualitative interview data.

Conclusion: Co-design successfully informed an inclusive, feasible intervention study for children with complex neurodisability. However, overall improvement in parent/carer-reported chest health, quality-of-life and observed motor ability were not limited to the intervention phase. Measurement tools lacked published thresholds to determine if changes were clinically significant.

IMPLICATIONS FOR REHABILITATION

- Rebound therapy is a feasible school-based intervention to promote rehabilitation through physical activity participation in children with complex neurodisability.
- Selected outcome measures require further psychometric testing to evaluate the impact of this rehabilitation approach effectively.
- Chest health education, monitoring and communication alongside rebound therapy may positively influence outcomes of rehabilitation, such as quality of life.
- Co-design and safety monitoring is necessary to address challenges of implementing rehabilitation research in children with complex neurodisability.

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Cerebral palsy; children; rebound therapy; chest health; respiratory health; quality of life; motor function

Introduction

Neurodisability represents one of the largest populations of childhood disability in the UK, encompassing congenital or acquired long-term conditions attributed to impairment of the brain and/or neuromuscular system [1]. This population is at a higher risk of respiratory impairments due to their underlying condition and/or associated co-morbidities, such as poor swallow, seizures, or motor impairments [2,3]. Within this paper, authors use the term "chest health" to represent the wide range of impairments affecting the respiratory system in childhood neurodisability.

Within childhood neurodisability, poor chest health is the most common reason to seek medical advice and emergency hospital care, accruing significant healthcare costs and impacting on quality-of-life (QoL) [4,5]. Moreover, it remains the primary cause of early death in this population [6,7]. Chronic and recurrent chest health problems demand long-term management beyond acute exacerbations, directing attention to prevention and

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community-based management strategies. A range of beneficial treatments have been identified, yet no high-quality evidence supports a gold-standard non-pharmaceutical intervention [8,9]. Further research is required to optimise chest health management and prevent illness.

A recent international consensus highlighted the importance of optimising physical activity (PA) for chest health management in neurodisability [10]. PA supports secretion clearance, thoracic mobility, lung volume, cardiovascular fitness, muscle strength and posture, while also benefiting psychological wellbeing and happiness in children with neurodisability [11–15]. The UK Department of Health and Social Care recommends daily PA for health improvements in children with disability [16,17]. However, many children face barriers to PA, particularly those with lower physical function, leaving them at greater risk of chest illness [3,4,18]. Addressing PA disparities is a research priority for children with neurodisability and forms part of the Global Action Plan On Physical Activity 2018–2030 [19,20].

Rebound therapy, a popular PA intervention in UK educational settings, uses trampolines for therapeutic exercise, positioning, communication and recreation [21]. Anecdotally, it is valued by clinicians, patients and families [22] and features in care standards for people with learning disabilities, to support postural management, exercise and respiratory care [23]. Research indicates rebound therapy can improve participation [24], muscle tone [25], balance [26], sitting posture [27], behaviour, and QoL [28] in children with neurodisability. Chest health benefits of rebound therapy have been established in children with cystic fibrosis [29,30] and asthma [31]. However, within the population of interest, potential chest health benefits have not been widely evaluated.

There is some evidence to suggest that rebound therapy could be advantageous for chest health in children with moderate to severe neurodisability, who cannot actively participate in traditional airway clearance techniques [32]. Small-scale studies have shown improved lung volumes through movement, vocalisation and laughing [33], and imitation of percussion and vibration techniques through the bounce of the trampoline [34]. This raises hypothesis-generating evidence that demands further exploration. This study aims to examine the feasibility and impact of a six-week individualised rebound therapy programme on chest health outcomes in children with neurodisability.

Methods

Study design

An 18-week single-case ABA design was selected to examine relationships between rebound therapy and outcomes. This method enabled within-case analysis of individual responses, acknowledging the variability within a heterogeneous cohort [35,36]. The use of replicated six-week phases, combined with weekly serial measures and summary assessments at weeks 0, 6, 12, and 18, enabled cross-case comparisons to broaden findings [37]. Reporting followed the Single-Case Reporting Guideline In Behavioural Interventions 2016 [38]. Study components were defined using the PICOT framework (see Supplementary Table 1).

Primary research questions

1. Is a six-week individualised rebound therapy programme feasible, considering factors of adherence and adverse events in children with neurodisability?
2. Does a six-week individualised rebound therapy programme improve chest health outcomes in children with neurodisability?

Secondary questions

3. Does a six-week individualised rebound therapy programme improve:
   a. parent/carer-reported QoL in children with neurodisability?
   b. clinician-observed motor ability in children with neurodisability?
4. How do parent/carer(s) perceive the feasibility of the study design, outcome measures and contact methods?

Public, patient involvement and engagement

This study was co-designed with a parent/carer advisory group (PCAG). Co-design activities included: (1) defining eligibility for participants with complex neurodisability, (2) choosing low-burden contact methods, (3) selecting meaningful, feasible outcome measure instruments, and (4) adapting public-facing materials, including a topic guide, to better address family needs, and (5) co-authors for dissemination.

Participants

Eligibility criteria were children aged 4–15 years, with a clinical diagnosis of neurodisability [1], a significant motor [39] and swallow impairment [40], a history of chest infections and weekly chest health symptoms [10] (see Table 1). Children were excluded if they had a progressive neurological diagnosis or a contraindication to a rebound therapy intervention (see Supplementary Tables 2a/b).

Procedure

Poster adverts and online forums were used to recruit children and their families through their local healthcare settings and school communities. Interested families received age-appropriate study information and a "consent to contact" form. On receipt of a "consent to contact" form, families were contacted by a researcher (RKL) *via* telephone and screened for eligibility. All contact information was securely recorded on a screening log and confirmed by their local named clinician.

Context

The study ran from March to November 2021 in two special schools with rebound therapy facilities in Southwest England. Outcome data collection was offered at the school or clinic, although all participants chose school to minimise travel and time burden.

Approvals

Ethics approval was granted by Health Research Authority Leeds West Research Ethics Committee (REC ref. 21/YH/0171) and University of Plymouth Faculty Research Ethics and Integrity Committee. Informed consent was documented by a legal guardian, with an option for children to assent. The study was registered with ClinicalTrials.gov (ID: NCT05495412).

Table 1. Participant eligibility criteria.

Component	Definition for inclusion
Population	Children up to 16 years, attending an educational setting, with access to a caregiver in a position of main custody, capable of giving consent on their behalf. Additional access to a caregiver in a position of main custody able to consent to participate in the study was also required.
Condition	Clinical diagnosis of neurodisability, defined as a congenital or acquired long-term condition attributed to impairment of the brain and/or neuromuscular system, impacting on function e.g., movement, cognition, hearing, vision, communication, emotion, and behaviour [1].
Motor characteristics	Physical impairment: GMFCS [39] level 3–5, defined as: • Level 3: Walks with aids. Uses wheelchair for long distances. • Level 4: Self-mobility with powered mobility • Level 5: Severely limited, unable to lift head and trunk or use powered mobility due to other comorbidities like vision impairment
Swallow characteristics	EDACS [40] Level 3–5, defined as: • Level 3: Eats and drinks with some limitations to safety; limitations to efficiency. • Level 4: Eats and drinks with significant limitations to safety. • Level 5: Unable to eat or drink safely – tube feeding may be considered to provide nutrition
Respiratory characteristics	Symptoms of respiratory impairment [10] experienced at least once a week, defined as one or more of the following: • Noisy breathing (wheezy, gurgling, rattily) • Weak/poor cough • Difficulty clearing secretions. And a history of chest infection(s) in the past three years requiring medication

Intervention

Trampoline and hoisting facilities were accessed in school. The intervention was performed individually, delivered by a rebound-trained physiotherapist (RKL) and supported by a familiar communicator. Starting at week 6 (Phase B), intervention was offered twice weekly for six consecutive weeks, with each session lasting 20–30 min, as per PA guidance [16]. No home programme component was included.

The intervention included passive and active-assisted limb and spine movement on the trampoline, during gentle rhythmical bouncing. This was followed by trampoline-assisted movements in long sitting, progressing to perch sitting, four-point and two-point kneeling over a roll. Supported standing was offered where appropriate to the child. Therapeutic support was tailored to the individual. Aerobic activity was encouraged through independent arms movement, rolling and bouncing. Additional communication strategies were used to support participant choice and motivation through rhythmical songs.

Programme starting levels were set in consultation with the participant's physiotherapist, considering their postural management plan and therapy goals. Progression of the intervention was determined by reduced dependence on therapist support and increased active movement such as head control. Ongoing assent and rest needs were monitored across each session, using Makaton, verbalising "more bouncing," facial expressions (smiling, laughing, nodding, shaking) and actively moving on/off the trampoline bed. Intervention adherence was measured by number of attendances and fidelity was assessed by rebound-trained staff through session observation and programme discussion. All intervention contraindications informed participant non-eligibility for the study and identified "precautions" were subject to risk assessment with the participant's named clinician at weeks 0 and 6. Ongoing risk assessment was monitored *via* weekly safety monitoring with parents *via* a telephone call, and by the treating physiotherapist and relevant school staff before, during and after each session. The intervention is reported in Supplementary Table 3 using the TIDieR checklist [41].

Summary outcome measures

Summary outcome measures were recorded after each phase (weeks 0, 6, 12, 18) as shown in Figure 1 and detailed in Supplementary Table 4. Where spirometry was not considered feasible [42], a composite of relevant measures was selected in consultation with the PCAG. These included the Modified Liverpool Respiratory Symptom Questionnaire (LRSQ-Neuro) [43,44], Chailey levels of Ability [45] and Caregiver Priorities and Child Health Index of Life with Disabilities (CPCHILD)[46] to measure chest health, motor ability and QoL, respectively.

The primary outcome, LRSQ-Neuro is a 15-item parent-reported questionnaire evaluating chest health across daytime, night-time and QoL domains, recalled over four-weeks. Though lacking published psychometric data, it has precedence for use in paediatric neurodisability [47–49]. Scores (0–4 Likert scale) were summed, with lower scores indicating better chest health.

The Chailey levels of Ability were used to measure clinician-observed motor ability, validated in children with low physical function [45]. Observations in sitting, supine and prone where possible, were scored by a trained physiotherapist (RKL) and fidelity was assessed through joint observation and discussion with local trained clinicians. Scores were summed, with higher scores indicating better motor ability.

The CPCHILD is a 37-item proxy/parent-reported QoL questionnaire evaluating six QoL domains, recalled over a two-week period. The questionnaire has established reliability and validity in non-ambulatory children with CP [46]. Scoring was recorded in line with the CPCHILD™ Manual, with higher scores indicating higher QoL.

Serial outcome measures

Serial weekly chest health measures included breaths per minute, cough frequency per minute, time spent completing a pre-established chest health care plan [10] and, where it was considered part of a child's usual care, oxygen saturations. Parent/carers received training to collect and record these observations, during a pre-specified time frame at home from weeks 0 to 18.

Feasibility measures

Weekly monitoring of adverse events was conducted *via* the telephone with parent/carers, recording any symptoms and care plan changes. The treating physiotherapist recorded any additional adverse events before, during and after sessions, and intervention adherence, including attendance, reason for absences, and exercise programme details for each session.

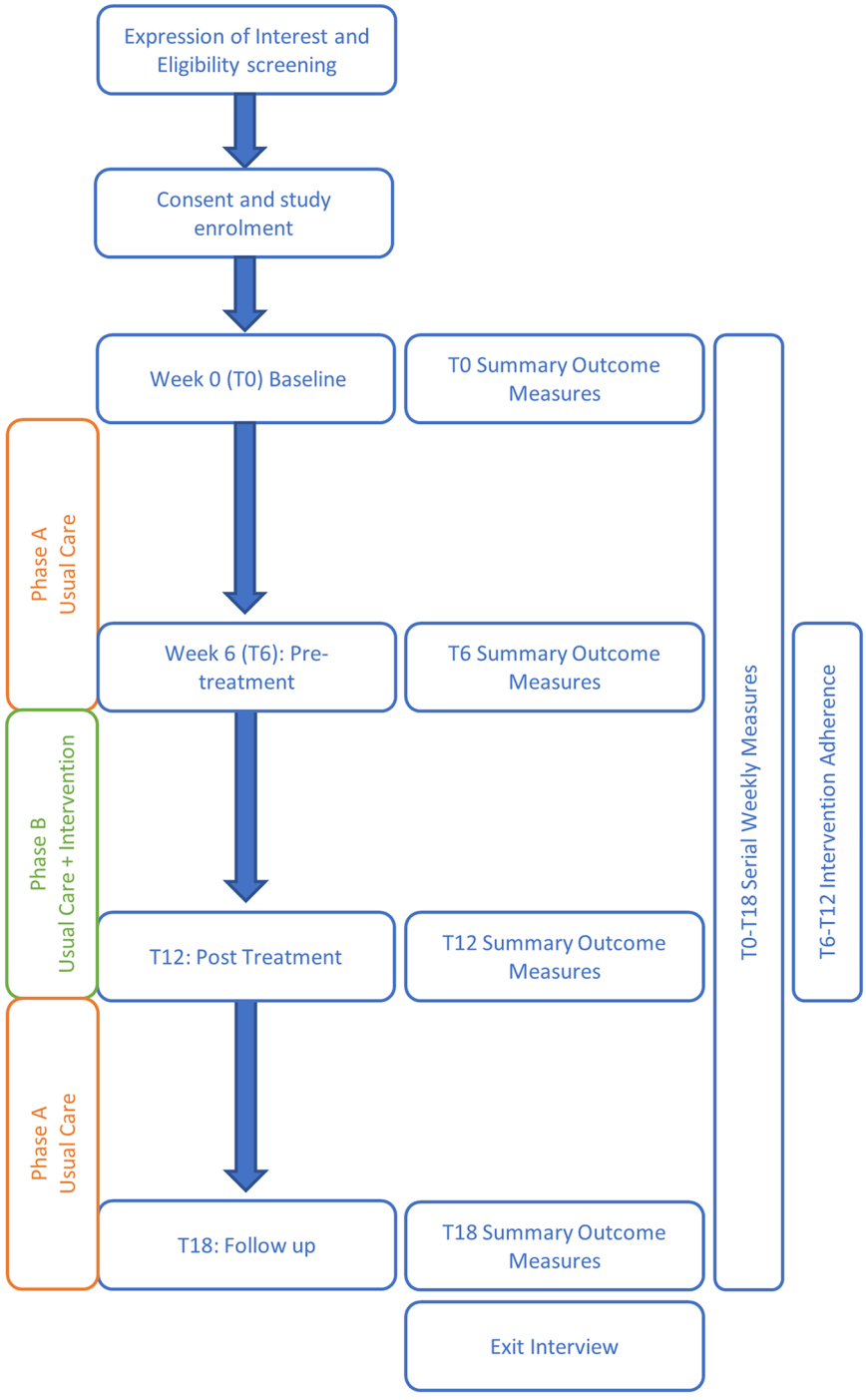

Figure 1. ABA single-subject design timeline and outcome measurements.

Qualitative measures

Families were invited to take part in a semi-structured interview after completing the study. Interviews were offered online or face-to-face at their child's special school. The topic guide explored health outcomes considered important to stakeholders [19], feasibility and acceptability of the study design, contacts and questionnaires and lasted between 20 and 30 min.

Data analysis

Summary outcome measures are presented as raw scores within-case, and as mean values across-case, differentiating between phases. These were visually inspected for trends.

Serial weekly measures are presented graphically within-case, differentiating between phases. Across-phase analysis incorporated visual and statistical analysis, consisting of an extended celeration line (ECL) to highlight trends, and percentage of overlapping data (PND) to quantify effectiveness of intervention. Baseline Phase (A) stability was established by calculating the percentage of data points within 15% of the phase median, implementing a criterion threshold of 85% [50]. Where within-phase (A) stability criterion was satisfied, a Two Standard Deviation Band Method (2SD) was used to identify clinically significant change [50–52]. See Supplementary Table 5 for definitions.

Qualitative data were transcribed (RKL) and analysed thematically. Codes were mapped across the case studies and conceptualised into themes [53].

Table 2. Participant characteristics and study activity participation.

Participant characteristics								Study participation					
								Attendance (total 12)		Adverse Events		Assessment completion	
ID	Sex	Age	Diagnosis	GMFCS	EDACS	Respiratory complications	Intervention precautions	n	%	SAE	AE	T0-18	Interview
Isla	F	15.8	Cerebral palsy seizure disorder	5	5	Laryngomalacia	Seizure plan. Movement of left hip	12	100	Nil	4	Full	✓
Evie	F	5.4	KCNG1 gene deletion epilepsy	5	5	Nocturnal BiPAP	Seizure plan. SpO_2 monitor	9	75	Nil	6	Full	✓
Nora	F	10.8	Cerebral palsy epilepsy	5	3	None	Seizure plan. Movement of hips	10	83	Nil	4	Full	✓
Sarah	F	5.3	1P36 gene deletion epilepsy	5	3	Cardiology sleep apnoea	Seizure plan. Movement of hips	9	75	Nil	5	Full	✓
Ryan	M	5.0	Undiagnosed global developmental delay	5	3	Asthma	Blood sugars review	8	67	Nil	4	Full	✓

Note: ID: participant pseudonym; F: female; M: male; y: age in years (recorded at week 0); GMFCS: Gross Motor Functional Classification System; EDACS: Eating and Drinking Ability Classification System; n: number; SAE: serious adverse event; AE: adverse event; T0: week 0 baseline assessment; T18: week 18 exist assessment.

Results

Six children were screened; one was ineligible due to insufficient chest health symptoms. Five children were enrolled (mean age 8.46 years, range 5–15 years) (see Table 2). Diagnoses included cerebral palsy, chromosomal deletion syndromes and global developmental delay. All had motor impairments equivalent to GMFCS level V, and swallow impairment equivalent to EDACS level III-V. Respiratory issues included laryngomalacia, sleep apnoea and asthma. No participant received therapy or surgery outside their usual care during the study. Participants are referred to using pseudonyms: Isla, Evie, Sarah, Nora and Ryan.

Feasibility measures

The intervention was delivered as planned, with attendance ranging from 8 to 12 sessions. Four of five children met the 75% adherence criteria. Non-attendance was due to reasons unrelated to the study, such as COVID-19, tonsillitis, chickenpox, diarrhoea, vomiting, pre-planned appointments, and/or seizures before an intervention session.

No serious adverse events were reported. Over 18 weeks, 23 adverse events were logged across all participants, with four to six events per child, across all phases. Sixteen new symptoms were reported, including respiratory ($n=8$), gastrointestinal ($n=3$), medical interventions ($n=1$), and other issues ($n=4$). Seven worsening symptom events, such as increased cough, secretions and fatigue. These events were considered unrelated to the intervention, attributed to allergies, seizures, chicken pox, COVID-19, tonsillitis, or upper respiratory infections. Four children required temporary chest care plan adjustments in response to an acute illness, including increased pharmaceutical and non-pharmaceutical treatments. Two children had changes in their general healthcare plan, such as seizure medication and vagal nerve stimulation settings. One child had a change in postural management care, introducing a muscle relaxant, which resulted in a new cough on feeding. The medication was immediately withdrawn by the paediatrician due to concerns of aspiration.

Summary outcome measures

Summary outcome measure results are displayed in Table 3 and visually in Figure 2.

LRSQ-Neuro

Within-case analysis of LRSQ-Neuro scores showed a decrease in respiratory symptoms during Baseline Phase A (weeks 0–6) and Intervention Phase B (weeks 6–12) for four of five children. Sarah was the exception, with an increase in symptoms during Phase B, coinciding with contracting COVID-19 at weeks 10–11. Follow-up Phase A (weeks 12–18) showed mixed results: two children had increased symptoms, two had further decreases, and one remained stable. Across-case analysis revealed a consistent mean decrease in respiratory symptoms across each phase, with the largest mean difference (5.4) in Baseline Phase A (weeks 0–6), suggesting that the decrease was not due to rebound therapy.

Chailey Levels of Ability

Within-case analysis of Chailey Level of Ability scores showed variability during Baseline Phase A (weeks 0–6). Two children had decreased motor ability, one of which was attribute to an acute illness, while three remained stable. During Intervention Phase B (weeks 6–12), all five children showed increased motor ability, either in sitting or prone. In Follow-up Phase A (weeks 12–18), one child showed a decrease, while others maintained their scores. Across-case analysis revealed a consistent mean increase in motor ability during Phase B, suggesting rebound therapy could have contributed to the improvement.

CPCHILD

Within-case analysis of CPCHILD scores showed an increase in overall QoL during Baseline Phase A (weeks 0–6) for all five children, with further improvement in Intervention Phase B (weeks 6–12) for four children, except Evie. Follow-up Phase A (weeks 12–18) showed a decrease in QoL for all children. Across-case analysis revealed a consistent mean increase at Baseline (0.06) and Intervention Phase B (0.06), followed by a decrease at Follow-up Phase A (−0.07). The largest improvements were in personal care, positioning, transferring, and mobility.

Serial measures

Across-phase visual analysis of ECL and PND methods showed no notable changes in weekly respiratory observations. Figures 3–6

Table 3. Total scores of summary outcome measure.

	Between case analysis mean scores																				
	LRSQ-neuro							Chailey levels of ability							CP-child						
	T0	T6		T12		T18		T0	T6		T12		T18		T0	T6		T12		T18	
Isla	31	34	↑	32	↓	33	↑	3	3	–	4	↑	4	–	.38	.40	↑	.42	↑	.40	↓
Evie	29	25	↓	22	↓	24	↑	12	12	–	15	↑	15	–	.60	.62	↑	.62	–	.58	↓
Nora	33	18	↓	14	↓	6	↓	7	6	↓	8	↑	8	–	.46	.46	–	.60	↑	.59	↓
Sarah	15	5	↓	11	↑	1	↓	17	17	–	18	↑	18	–	.47	.55	↑	.59	↑	.51	↓
Ryan	7	6	↓	4	↓	4	–	16	15	↓	16	↑	15	↓	.49	.69	↑	.81	↑	.60	↓
Across case analysis mean scores																					
Mean	23	17.6	↓	16.6	↓	13.6	↓	11	10.6	↓	12.2	↑	12	↓	.48	.54	↑	.61	↑	.54	↓
Mean Difference		5.4	↓	1	↓	3	↓		−0.4	↓	1.6	↑	−0.2	↓		.06	↑	.06	↑	.07	↓

A decrease in LRSQ-neuro raw score indicates improvement in chest health; An increase in Chailey levels of ability and CP-child raw score indicates improvement in motor function and quality of life respectively.

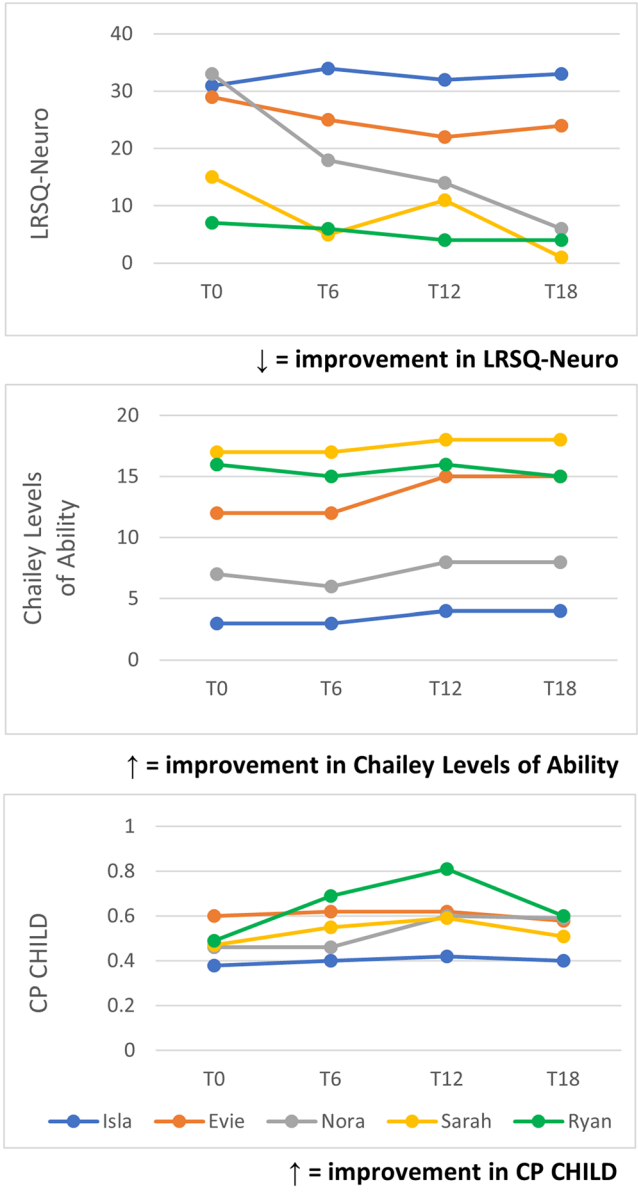

Figure 2. Visual across-case of summary outcome measure total scores.

display results for each measure. In Baseline Phase A (weeks 0–6), stability criteria were met variably. All five children met stability criterion for "time spent providing chest care." Sarah met additional stability criterion for "cough frequency," and Nora and Ryan met stability criterions for all three measures. Evie met stability criterion for all four measures, including oxygen saturation monitoring. Implementing the 2SD threshold showed no clinically significant changes in serial respiratory observations across study phases beyond two standard deviations.

Visual analysis compared respiratory-related adverse event timepoints with change in serial weekly measures. For Isla, reported cold symptoms correlated with increased "cough frequency," "breaths per minute," and "time spent doing chest care." Evie's reported tonsillitis linked to the highest "breaths per minute" recorded, though other observations remained unchanged. For Nora, a suspected aspiration event correlated with increased "breaths per minute," and a new cough impacted all three observations. Ryan and Sarah displayed no changes in serial measures during reported contractions of COVID-19.

Qualitative findings

Five exit interviews were conducted with primary parent/carers (RKL), lasting 15–25 min. Four parents chose in-person interviews at their child's school, and one opted for an online interview. Themes included child and family perceived impact (sub-themes: chest health, motor ability, and QoL) and study feasibility and acceptability (sub-themes: acceptance, learning, burden, and questionnaire responses). See Illustrative quotes in Supplementary Table 6.

"Child and family perceived impact" theme highlighted benefits not captured by outcome measures, including activities of daily living: "[Sarah] is able to climb more confidently and pull to stand against the sofa"(Sarah's mum); increased frequency and volume of verbal communication, improved sleep quality, mood and happiness: "She is much more happier in herself in general, she is more affectionate, particularly with daddy"(Evie's mum). Parents also reported a reduction in their child's symptoms of digestion discomfort and in caregiver burden: "[its] easier to put his t-shirt on, his arms are more active in helping"(Ryan's mum).

"Study feasibility and acceptance" theme showed positive participant study experiences, highlighting low travel burden, a familiar and supportive assessment environment, flexible and convenient contacts. All parents noted benefits of learning new skills and leading in their child's assessment: "it has been a good experience to lead the readings for breathing rate and I will continue to do this in the future"(Nora's mum). Whilst the questionnaires were low burden, some questions were perceived as inappropriate for children with lower levels of communication and functioning: "Some of the questions about understanding was not appropriate when child is non-verbal" (Evie's mum); "personal care questions can make you realise what she can't do" (Sarah's mum).

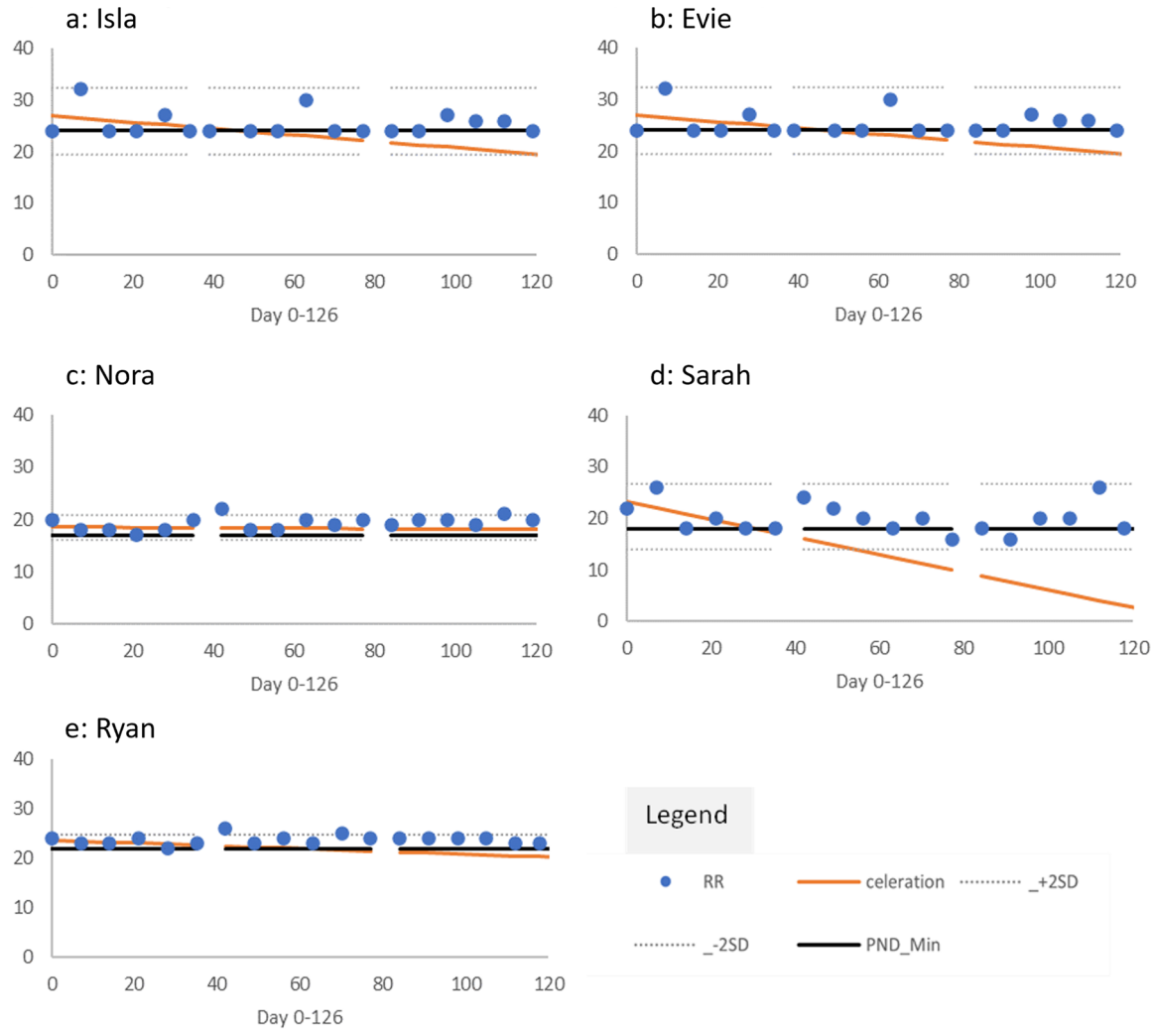

Figure 3. (a–e) Visual within-case of breathes per/minute.

Discussion

Findings of satisfactory adherence, no related adverse events, and qualitative data suggest that rebound therapy is a safe, enjoyable, and feasible intervention for children with complex neurodisability, confirming PCAG views. It addresses key facilitators to PA participation, including personal factors, e.g., enjoyment and environmental factors e.g., accessibility [18], which can be challenging for children with lower physical functioning. These results align with previous small-scale studies [14,15,24], warranting further attention in clinical research. Intervention sustainability could be achieved through integration into educational healthcare plans, forming part of a child's school day and aligning with wider physical education curriculum and PA guidelines [16]. Yet, despite its established practice in the UK, Australia, Malaysia, Canada, and the USA [21], delivery is limited by access to facilities globally.

Although some improvements in proxy-reported respiratory symptoms and QoL were noted following rebound therapy, these were comparable to or smaller than baseline improvements. As proxy-reported measures, Hawthorne effect and social desirability bias may have been introduced through parents' awareness of the study's purpose and positive study experience [54,55]. Study-related monitoring, communication, and education may have also contributed to improved outcomes, as monitoring exceeded typical local provision for both chest health and postural assessments [56]. Furthermore, increased parent-therapist communication and education was highlighted as a positive aspects of this intervention study in all five qualitative interviews, in which parents noted a unique opportunity to increase their knowledge and lead in their child's chest health assessment. This aligns with wider research, in which factors of communication and education have been identified as caregiver facilitators in optimising respiratory care [57]. Such benefit may account for any carryover of improvements observed and/or reported in the follow up period. Given these findings, and the small number of participants in our study, we advocate further research into chest health monitoring and education for parent/carers, as a meaningful strategy to improve outcomes in this population.

Motor ability improved following intervention, particularly in children with higher physical functioning. This was observed clinically and echoed by parents through qualitative interview data, with one parent noting their child's active movement to be the biggest change following intervention. Findings align with other small-scale studies, supporting improvements in balance, gross motor and sitting ability following rebound therapy [25–27]. Such improvements are unlikely attributed to maturation bias, due to the lack of changes observed at baseline and the six-week intervention phase was considered too brief to expect natural gross motor development. However, despite fidelity approaches, the study acknowledges risk of assessor and measurement bias introduced through unblinded assessment, a common limitation in single case designs for cerebral palsy, as a result of limited

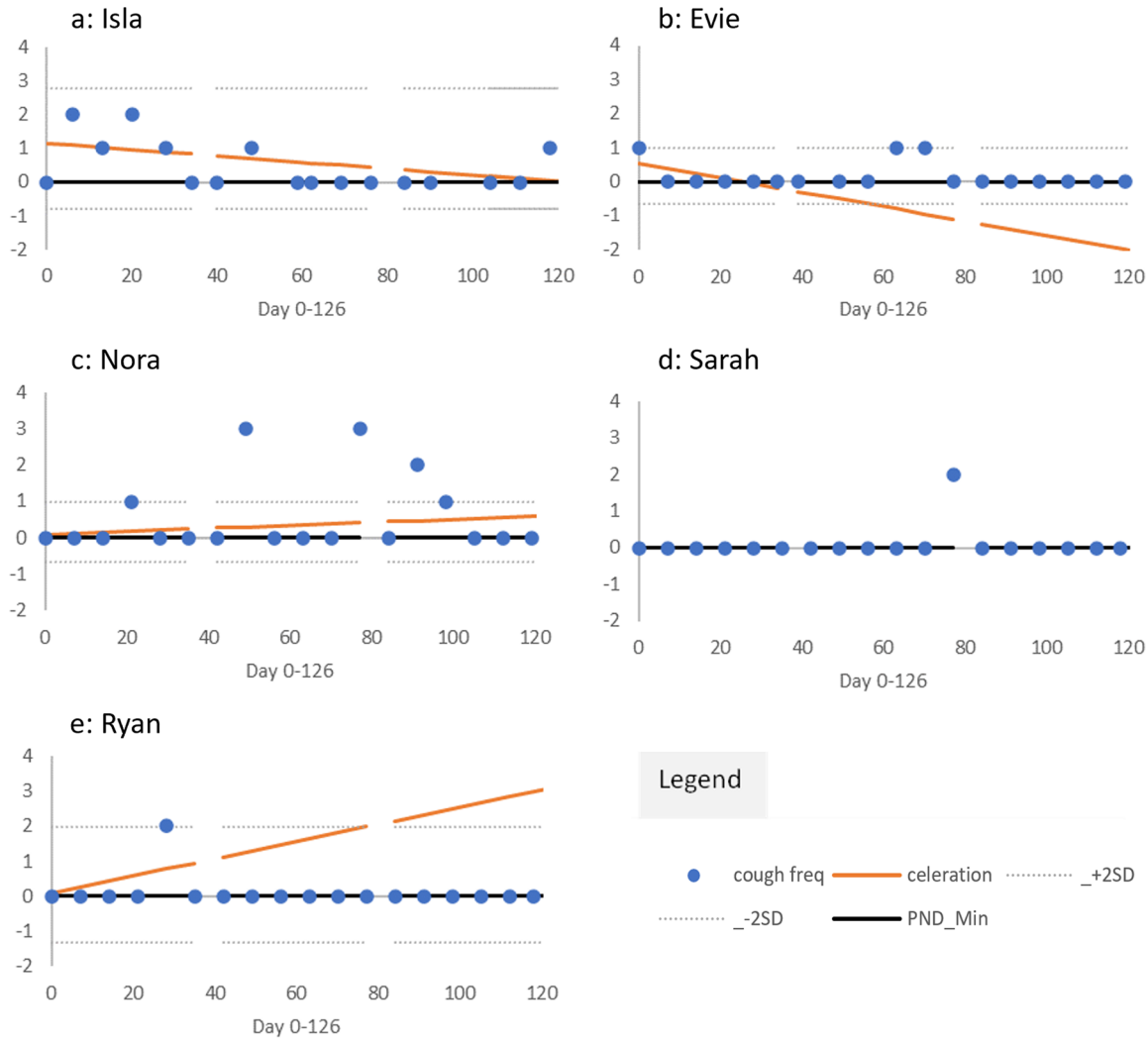

Figure 4. (a–e) Visual within-case of cough per/minute.

resources [58]. Whilst motor ability does not directly measure chest health, it impacts risk factors of chest health morbidity, such as spinal and thoracic deformity [59], and given the association between level of postural control, lung function [60] and oropharyngeal function [61], indicate potential to improve chest health outcomes indirectly.

Study findings are limited by lack of published minimally important clinical differences for the LRSQ-Neuro, CPCHILD, and Chailey Levels of Ability measures, restricting interpretation to descriptive and visual analysis [43,45,46]. Implementing half a standard deviation criterion may offer an alternative approach to identify important perceived change in health related QoL for this chronic condition in future studies [62]. Many alternative gold-standard chest health measures such as spirometry, are not feasible to perform in children at highest risk of respiratory morbidity and mortality, due to existing learning or physical impairments [63]. Therefore, a research priority is to address barriers to measuring chest health in these vulnerable children, including "what" outcome domains are important, and "how" to measure these outcomes feasibly.

Interpretation of serial weekly measures was limited by baseline instability, often due to temporary care plan changes or unrelated adverse events, such as antibiotics, oxygen post-seizure, or increased chest percussion during acute illness. While these may have affected weekly measures, the transient changes reduce likelihood of impact on summary outcomes, unless coinciding with assessment points. Two of five children were unwell at the final assessment, contracting COVID-19, likely underestimating intervention effects on motor ability, proxy-reported chest health and QoL. This underscores the challenges of research in medically complex populations, often underserved due to their condition or co-morbidities [63,64]. Given the high healthcare burden and respiratory-related mortality, the authors align with broader research initiatives, urging future studies to address these barriers through stakeholder co-design, inclusive interventions, and accessible, meaningful outcomes. However, whilst healthcare burden and respiratory-related mortality remains high in this population [2,3,6,47,65], and research interest grows [4,10,63], we urge future research to address these challenges through co-design, inclusive interventions, and consideration of accessible and meaningful outcomes [66,67].

Strengths and limitations

A strength of this study was the diversity in age and neurodisability across the five children, increasing the external validity of our findings to a wide range of children. The study procedure was co-designed with stakeholders and refined in partnership with a PCAG, contributing to the feasibility, inclusivity and acceptability of the study. This small scale, non-blinded and non-randomised

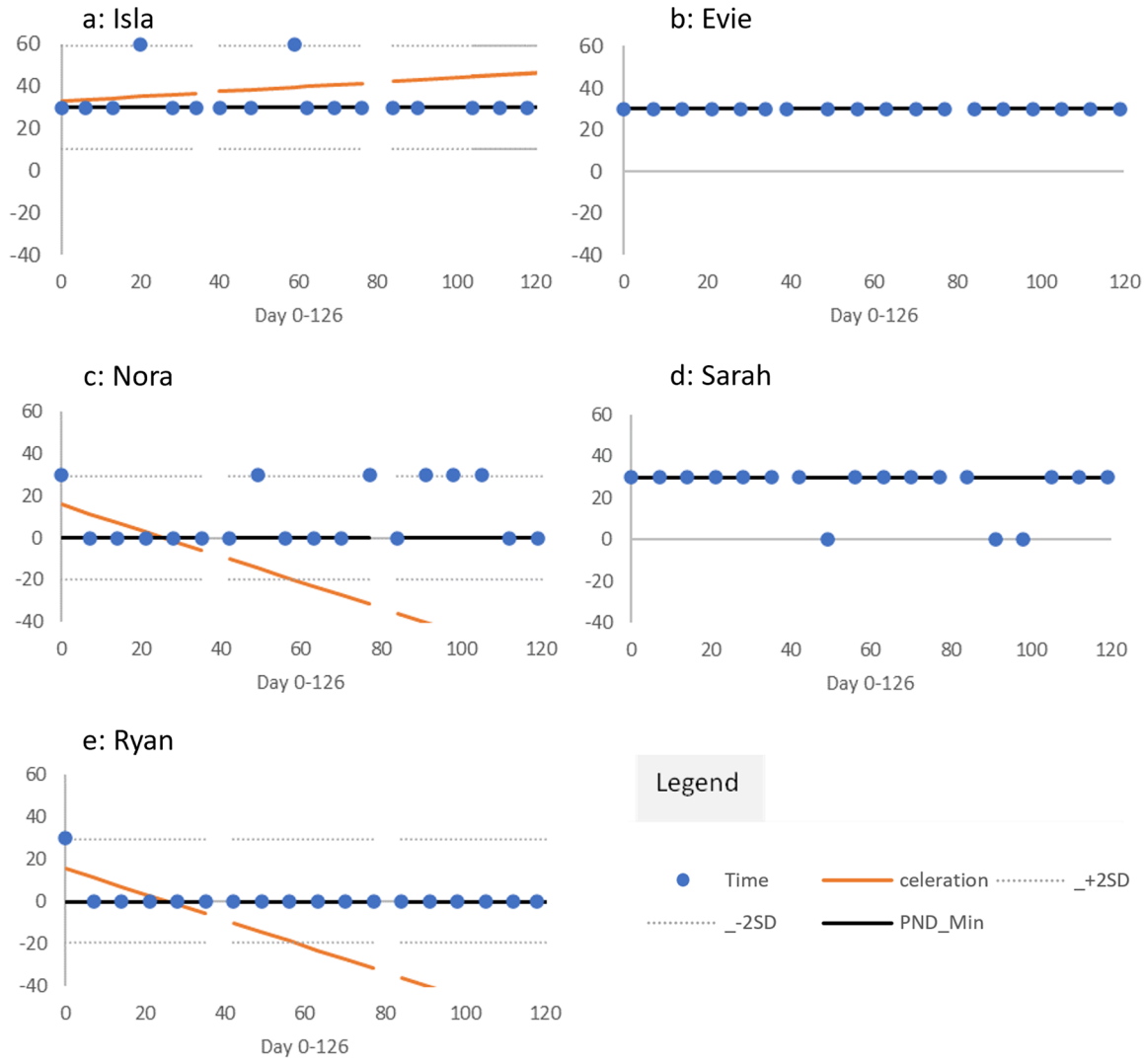

Figure 5. (a–e) Visual within-case analysis of chest care time.

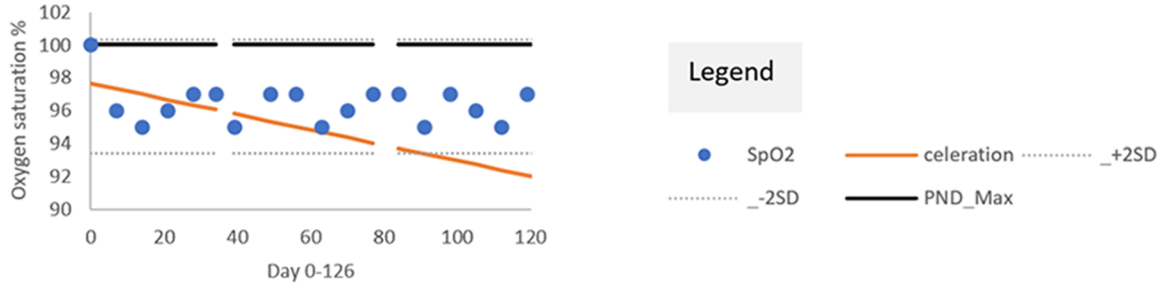

Figure 6. Visual within-case analysis of oxygen saturation.

exploratory study reveals many confounding variables, such as medical instability and changes in care plans, that may affect the overall impact of chest health. However, the contribution of qualitative data verifies and contextualises the observed and parent-reported improvements with medical complex interventions.

Future research

Future research should prioritise incrementally larger-scale study designs that consider appropriate comparators, to establish causal relationships between rebound therapy and chest health outcomes. Authors encourage research beyond examining if rebound therapy works, considering its underpinning theory, value relative to resources, interaction with real-world contexts, heterogenous population, and its wider impact, through the MRC Framework for Developing and Evaluating Complex Interventions [68]. Additionally, chest-related education and communication interventions warrant further examination, given their well-received feedback at interview, and precedence for impact in wider respiratory populations [57]. Finally, psychometric development of measurements that

are both meaningful and clinically relevant are essential to ensure future results are reliable, valid, and translate into real-world benefit [63].

Conclusion

Co-design successfully informed an inclusive, feasible intervention study for children with complex neurodisability and chest health problems. This series of single-case ABA designs provide preliminary data to support potential improvements in parent-reported chest health, QoL and observed motor ability following a six-week period of rebound therapy. However, these findings were not significant and improvements were not limited to the intervention study phase. Safety monitoring recorded variable adverse events unrelated to the intervention, highlighting the medical complexity and associated challenges to implementing research in this population of interest.

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Authors contributions

JM acted as chief investigator for this study; RKL and RR acted as co-principal investigators for each study research sites. RKL implemented all study activities, recorded data and led in writing the paper. Data were monitored and analysed by RKL, HS and JM. All authors (RKL, JM, HS, CM, RR, JM, KB, CS) were involved in the study co-design, drafting and review of the paper.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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Data sharing statement

Data supporting the results of this study can be found in Tables 2–3 and in Supplementary Information. Full de-identified data sets supporting this study will be made available by the data custodian (JM) of this study, on request.

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